Title 28

STORMWATER MANAGEMENT MANUAL

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CHAPTER 28.04
Introduction

§ 28.04.010. General index.

Each chapter of this title is numbered separately. All sections are numbered in such a way as to allow additions and deletions with ease. All figures and tables are numbered and are placed either within the text or at the end of respective sections. The figure and table numbers are bold faced in the text for their ease of finding.
(Res. 40-08 (§ 101), 3-19-08)

§ 28.04.020. Purpose and intent.

The purpose of this manual is to promote public health, safety, and general welfare and to minimize public and private losses due to flooding by adopting policies, procedures, standards, and criteria for storm drainage.

All new development and redevelopment, building permits for commercial and industrial uses, or any other proposed construction submitted for acceptance under the provisions of the Stormwater Management

Manual shall include adequate storm drainage system analysis and appropriate drainage system design. Such analysis and design shall meet or exceed the criteria set forth herein.
(Res. 40-08 (§ 102), 3-19-08)

§ 28.04.030. Amendments to this manual.

These policies, procedures, standards and criteria may be amended as new technology is developed and/or if experience gained in the use of the manual indicates a need for revision.

(a) **Mesa County.**

Amendments and revisions will be adopted by the Board of County Commissioners.

(b) **City of Grand Junction.**

Amendments and revisions may be made administratively by the City Manager or the City Manager's designee and shall have the same authority as the original document adopted by the City Council. Amendments and revisions may also be made by City Council by ordinance.

(c) **Other Jurisdictions.**

Amendments and revisions may be made by the City of Fruita, the Town of Palisade, and the Grand Junction Drainage District, in accordance with their procedures.
(Res. 40-08 (§ 103), 3-19-08)

§ 28.04.040. Purchase of a copy of the manual codified in this title.

Any party desiring to purchase a copy of the manual, provided such copies are available, may contact the City of Grand Junction Public Works Department at 970-244-1555.
(Res. 40-08 (§ 104), 3-19-08)

§ 28.04.050. Acknowledgement.

This manual was prepared by WRC Engineering, Inc., working under the direction of Mesa County. Representatives from the Cities of Grand Junction and Fruita, Town of Palisade and Grand Junction Drainage District participated and provided valuable input during the preparation of the manual.

We wish to acknowledge and thank the following individuals and organizations for their participation and contribution to the preparation of this manual:

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(Res. 40-08 (§ 105), 3-19-08)

§ 28.04.060. Updating and revisions.

This manual was prepared in accordance with existing engineering methodologies and applicable criteria at the time of publication. The field of stormwater management has experienced rapid and extensive changes in recent years. Therefore, periodic review and revision of all material contained herein is recommended.

Users of this manual are encouraged to notify Mesa County and/or local jurisdictions of any errors or omissions in this document. Comments and questions relating to the manual may also be directed to the entities listed below.

Please submit input to:

Mesa County Engineering Department
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Applicable Local Jurisdiction(s)

(Res. 40-08 (§ 106), 3-19-08)

CHAPTER 28.08
General Provisions

§ 28.08.010. Title.

This manual and design standards with all future amendments and revisions shall be known as the Stormwater Management Manual (herein referred to as the manual or SWMM).
(Res. 40-08 (§ 201), 3-19-08)

§ 28.08.020. Jurisdiction.

This manual and design standards shall apply to all new development and redevelopment within the boundaries of Mesa County, including any public lands, facilities constructed on rights-of-way, easements dedicated for public use, and to all privately owned and maintained drainage facilities, including but not limited to detention ponds, storm drains, inlets, manholes, culverts, swales, channels and water quality facilities.

(a) **Mesa County.**

Chapter 7.7 of the Mesa County Land Development Code (Code) requires that "Drainage facilities shall be designed and installed in accordance with the Mesa County Stormwater Management Manual."

(b) **City of Grand Junction.**

The City of Grand Junction Zoning and Development Code (GJMC Title 21) requires that "All proposed development must provide for on-site runoff collection and conveyance in accordance with the Stormwater Management Manual (SWMM) and applicable federal and State laws."

The City of Grand Junction adopted stormwater pollution prevention Ordinance Number 3824 (Chapter 13.28 GJMC), which requires that: "All proposed development … must provide for on-site erosion and sediment control, control of illegal discharges, and runoff collection and conveyance in accordance with the Stormwater Management Manual and applicable federal and State laws."

(c) **Other Jurisdictions.**

The City of Fruita, the Town of Palisade, and the Grand Junction Drainage District may adopt the Stormwater Management Manual in whole or in part.
(Res. 40-08 (§ 202), 3-19-08)

§ 28.08.030. Adoption authority.

(a) **Municipality.**

Powers to regulate land use activities, including drainage, are granted to a municipality under Colorado Revised Statutes as noted below:

§ 31-15-701, C.R.S. et seq. grants municipalities the power to establish, improve, and regulate such improvements as streets and sidewalks, water and water works, sewers and sewer systems, and water pollution controls. In addition, a municipality may, among other powers, deepen, widen, pipe, cover, wall, alter or change the channel or watercourses.

§ 31-25-501, C.R.S. et seq. authorizes municipalities to construct local improvements and assess the cost of the improvements wholly or in part upon property specially benefited by such improvements. By ordinance, a municipality may order construction of district sewers for storm drainage in districts called storm sewer districts. (For the City of Grand Junction, see People's Ordinance No. 33.)

§ 31-25-601, C.R.S. et seq. authorizes municipalities to establish improvement districts as taxing units for the purpose of constructing or installing public improvements.

§ 31-35-401, C.R.S. et seq. authorizes municipalities to operate, maintain, and finance water and sewage facilities for the benefit of users within and without their territorial boundaries. Sewerage facilities are defined as "any one or more of the various devices used in the collection, treatment or disposition of sewerage or industrial wastes of a liquid nature or storm, flood or surface drainage waters…."

(b) **County.**

Powers to regulate land use activities, including drainage, are granted to a county under Colorado Revised Statutes as noted below:

§ 24-67-101, C.R.S. et seq. (Planned Unit Development Act of 1972) power to encourage more efficient and innovative use of the land for public services and encourages integrated planning.

§ 29-20-101, C.R.S. et seq. (Local Government Land Use Control Enabling Act of 1974) clarifies and provides broad authority to local governments to plan for and regulate the use of land within hazardous and environmentally sensitive areas.

§ 30-20-401, C.R.S. et seq. authorizes construction, maintenance, improvements and financing of water and sewerage facilities for the County's own use and for the use of the public and private consumers and users within and without the County's territorial limit.

§ 30-20-501, C.R.S. et seq. (County Public Improvement District Act of 1968) authorizes creation of public improvement districts within any county as taxing units and for the purpose of implementing public improvements.

§ 30-20-601, C.R.S. et seq. authorizes a county by resolution to construct local improvements and to assess the costs to properties especially benefited by improvements.

§ 30-28-101, C.R.S. et seq. provides the County with planning authority, such as development of master plans and adoption of such plans by resolution; creation of a regional planning commission; and regulation of development density.

§ 30-30-101, C.R.S. et seq. (control of stream flow) provides power to remove any obstruction to the channel of any natural stream which causes a flood hazard and provides a right of access to any such natural stream.

§§ 37-20-101 and 37-33-101, C.R.S. et seq. authorizes the owner of agricultural lands susceptible to drainage problems from the same general system to petition the Board of County Commissioners to set up a drainage district.

(Res. 40-08 (§ 203), 3-19-08)

§ 28.08.040. Enforcement responsibility.

(a) **Mesa County.**

The Director or an authorized representative is responsible for enforcing the provisions of this manual.

(b) **City of Grand Junction.**

The City Manager or the City Manager's designee is responsible for enforcing the provisions of this manual.

(c) **Other Jurisdictions.**

Contact the City of Fruita, the Town of Palisade, or the Grand Junction Drainage District for information.

(Res. 40-08 (§ 204), 3-19-08)

§ 28.08.050. Review and acceptance.

All drainage submittals will be reviewed for general compliance with this manual. An acceptance does not relieve the owner, engineer, or designer from responsibility of ensuring that the calculations, plans, specifications, construction, and record drawings comply with this manual.

Adequate time must be allocated in development planning to permit a complete review. The intent of this manual is to more clearly define the requirements and reduce the time and effort required to develop an acceptable drainage design.

(a) **Mesa County.**

Acceptance of final drainage report and drainage facility construction plans shall be valid for two years. Documents with approvals more than two years old may require revision prior to development to comply with the provisions of the manual in effect at that time. Amendments to this manual will apply to all drainage reports submitted after the effective date of the amendment. Final drainage reports are exempt from an amendment provided they are submitted for approval within 60 days after the effective date of an amendment.

(b) **City of Grand Junction.**

Drainage submittals shall contain all information required by this manual but the review process will be in accordance with the City's Submittal Standards for Improvements and Development (SSID) and the Zoning and Development Code (GJMC Title 21).

(c) **Other Jurisdictions.**

Contact the City of Fruita, the Town of Palisade, or the Grand Junction Drainage District for information.

(Res. 40-08 (§ 205), 3-19-08)

§ 28.08.060. Interpretation.

In the interpretation and application of the provisions of the manual, the following shall govern:

(a) **Minimum Standards.**

This manual shall be regarded as the minimum requirements for analysis and design of storm drainage facilities. Special site conditions or mitigation for potential impacts from new development or redevelopment may result in more stringent standards.

(b) **Higher Standards.**

For Mesa County if provisions of the code, any law, ordinance, resolution, rule, or regulation contains restrictions covering the same subject matter, the more stringent standards or requirements shall govern. For the City of Grand Junction if provisions of the Zoning and Development Code (GJMC Title 21), any law, ordinance, resolution, rule, or regulation contains restrictions covering the same subject matter, the more stringent standards or requirements shall govern.

(c) **Flexibility.**

There may on occasion be need for site-specific application and interpretation of this manual. The Director in Mesa County or the City Manager or the City Manager's designee in the City of Grand Junction may deviate from the requirements of this manual; provided, that the approved plan is compatible with surrounding in-place improvements and is sufficiently protective. The burden of responsibility shall be on the applicant to show that the requested deviation/variance from standards does not create a public hazard.

(d) **Abrogation.**

This manual shall not abrogate or annul any permits or approved drainage reports, construction plans, easements, or covenants issued before the effective date of this manual.

(Res. 40-08 (§ 206), 3-19-08)

§ 28.08.070. Deviation/variance procedures.

(a) Deviations/variances from specific standards, procedures, or criteria in this manual may only be requested for:

(1) Unusual situations where strict compliance with the manual may not protect the public health and safety; or

(2) Unusual situations which require additional analysis outside the scope of the manual for which the additional analysis shows that strict compliance with the manual may not protect the public health and safety; or

(3) Unusual hydrologic and/or hydraulic conditions which cannot be adequately addressed by strict compliance with the manual.

(b) **Mesa County.**

A variance from the technical provision of this manual may be granted by the Director. All requests for variances shall be submitted in writing (normally with the drainage report, see Chapter 28.12 GJMC), shall state the provision for which the variance is requested, and shall provide evidence, data or other information in support of the request. The Director will review and rule on the request and provide his findings in writing.

(c) **City of Grand Junction.**

A deviation from any requirement of this manual may be granted by the City Manager or the City Manager's designee. A request for deviation shall be submitted in writing as a separate letter attached to the drainage report. The request shall state the provision for which the deviation is requested and shall provide supporting evidence, data, or other appropriate information. The City Manager or the City Manager's designee shall review and rule on the request and provide the findings in writing.

(d) **Other Jurisdictions.**

Contact the City of Fruita, the Town of Palisade, or the Grand Junction Drainage District for information.

(Res. 40-08 (§ 207), 3-19-08)

§ 28.08.080. Acronyms.

The following acronyms are used within the context of this manual:

BMP	Best Management Practice
CAP	Corrugated Aluminum Pipe
CAPA	Corrugated Aluminum Pipe Arch
CMP	Corrugated Metal Pipe
CMPA	Corrugated Metal Pipe Arch
CDOT	Colorado Department of Transportation
CDPHE	Colorado Department of Public Health and Environment
CDPS	Colorado Discharge Permit System
CRS	Colorado Revised Statutes
CSP	Corrugated Steel Pipe
CSPA	Corrugated Steel Pipe Arch
CSWMP	Construction Stormwater Management Plan
CWA	Clean Water Act
CWCB	Colorado Water Conservation Board
EC	Erosion Control
ECP	Erosion Control Plan
EGL	Energy Grade Line
EPA	Environmental Protection Agency
FEMA	Federal Emergency Management Agency
GIS	Geographic Information System
HDS	Hydraulic Design Series
HEC	Hydrologic Engineering Center or Hydraulic Engineering Circular (FHWA)

HERCP	Horizontal Elliptical Reinforced Concrete Pipe
HGL	Hydraulic Grade Line
MS4	Municipal Separate Storm Sewer System
NAVD	North American Vertical Datum
NFIP	National Flood Insurance Program
NOAA	National Oceanic and Atmospheric Administration
NRCS	Natural Resource Conservation Services, formerly the SCS
NPDES	National Pollutant Discharge Elimination System
NWS	National Weather Service
PE	Professional Engineer licensed by the State of Colorado
PMF	Probable Maximum Flood
PVC	Polyvinyl Chloride
RCBC	Reinforced Concrete Box Culvert
RCP	Reinforced Concrete Pipe
ROW	Right-of-Way
SCS	Soil Conservation Service
SPP	Structural Plate Pipe
SSID	Submittal Standards for Improvements and Development (City of Grand Junction)
SWMM	Stormwater Management Manual
SWMP	Stormwater Management Plan (either the construction SWMP or the final drainage report containing post-construction BMPs)
TAC	Technical Advisory Committee
TRC	Technical Review Committee
UDFCD	Urban Drainage and Flood Control District (Denver, Colorado)
USACE	United States Army Corps of Engineers
USBR	United States Bureau of Reclamation
USDCM	Urban Storm Drainage Criteria Manual, prepared by the Urban Drainage and Flood Control District in three volumes
USGS	United States Geological Survey
WQCD	Water Quality Control Division of the Colorado Department of Public Health and Environment
WQCV	Water Quality Capture Volume

(Res. 40-08 (§ 208), 3-19-08)

§ 28.08.090. Definitions.

Applicant means a qualified agent, individual or firm acting on behalf of the owner of property requesting approval of plans for new development and redevelopment.

Authority or *Drainage Authority*. Mesa County, the Cities of Grand Junction and Fruita, the Town of Palisade, and the Grand Junction Drainage District have contracted through intergovernmental agreements (IGA) to form the 5-2-1 Drainage Authority (Authority), under Colorado Revised Statutes, specifically § 29-1-204.2, C.R.S.

Best management practices means schedules of activities, prohibitions of practices, maintenance procedures, and other management practices to prevent or reduce the pollution of State waters. BMPs also include treatment requirements, operating procedures and practices to control site runoff, spillage or leaks, sludge or waste disposal, or drainage from raw material storage.

CDPS permit means a permit issued by the State of Colorado under Part 5 of the Colorado Water Quality Control Act that authorizes the discharge of pollutants to waters of the State, whether the permit is applicable to a person, group or area.

Channel means a natural or artificial low-lying area with a definite bed and banks, which confines and conveys continuous or periodic flows of water. (Mesa County Land Development Code Section 12.1 and GJMC § 21.10.020, Terms defined.)

Clean Water Act means Federal Act of 1977, 33 U.S.C. Section 466 et seq. as amended.

Colorado Water Quality Control Act means Title 25, Article 8, C.R.S.

Commercial means any business, trade, industry or other activity engaged in profit.

Construction activity includes clearing, grubbing, filling, grading, and excavation. Does not include routine maintenance performed by public agencies, private parties, or their agents to maintain original line and grade, hydraulic capacity, or original purpose of the facility. Also see *Land disturbance*. [(Adapted from CDPS General Permit No. COR-030000 @ Part I A(2)(a)]

Construction site means any location where construction or construction related activity occurs.

Construction stormwater management plan means a specific individual construction plan that describes the BMPs to be implemented at a site to prevent or reduce the discharge of pollutants during construction activities.

Director means the Mesa County Planning Director or designee when referring to a Mesa County official, but the City Manager or his designee when referring to a City of Grand Junction official.

Discharge means the addition or release of any pollutant, stormwater, subsurface, groundwater or any substance whatsoever to the storm drainage system.

Downstream refers to locations which are hydraulically lower in elevation than the location at which the comparison is being made. *Downstream* may include locations outside of the stream, channel, pipe, etc., such as sheet flow, which often meanders in several directions.

Drainageway means any natural or artificial (manmade) channel which provides a course for water flowing either continuously or intermittently to downstream areas.

Final stabilization means when all soil disturbing activities at the site have been completed, and uniform vegetative cover has been established with a density of at least 70 percent of pre-disturbance levels, or equivalent permanent, physical erosion reduction methods have been employed. For purposes of the construction SWMP, establishment of a vegetative cover capable of providing erosion control equivalent to pre-existing conditions at the site will be considered final stabilization.

Flood means a temporary rise in a watercourse, flow, or stage, that results in water overtopping its banks and inundating areas adjacent to the channel. (Mesa County Land Development Code Section 12.1; see also GJMC § 21.10.020, Terms defined.)

Grand Valley means the portion of Mesa County whose boundary is approximated by the 5,000-foot elevation contour and extends west of the community of Mack, along the north eastern edge of the Colorado National Monument, south of Whitewater, to the east of Palisade, and along the face of the Bookcliffs to the north.

Land disturbance means a manmade change in the existing cover or topography of the land, including grading, excavation, filling, building, paving, and other activities that may result in or contribute to soil erosion or sedimentation in the discharge of pollutants.

Local facility means a detention and/or water quality facility that has been sized based on the area and imperviousness of the watershed that includes all the development that drains to the facility, but is not publicly owned and maintained. Also see *Regional facility* and *On-site facility*.

Local jurisdiction, within the context of the SWMM, means Mesa County, City of Grand Junction or Fruita, Town of Palisade, or the Grand Junction Drainage Authority.

Major drainage system means a stormwater facility, such as a channel, large conduit, detention or retention, which receives storm runoff from a watershed generally 160 acres in size or larger.

Municipal separate storm sewer system (MS4) means a conveyance or the system of conveyances, including roads with drainage systems, municipal streets, curbs, gutters, ditches, drainage inlets, catch basins, pipes, tunnels, culverts, channels, detention basins and ponds owned and operated by a municipality or county and designed or used for collecting or conveying stormwater that is not a combined sewer or used for collecting or conveying sanitary sewage.

New development and redevelopment. For Mesa County definition, refer to the Mesa County Land Development Code. For the City of Grand Junction definition, refer to GJMC Title 21, Zoning and Development. For the City of Fruita, Town of Palisade and the Grand Junction Drainage District definitions, refer to the applicable development codes.

NPDES means the National Pollutant Discharge Elimination System under Section 402 of the Clean Water Act.

On-site facility means a local facility that is contained within and only serves the development in question and not other developments.

Outfall drainage system means the drainage system typically consisting of swales, curb and gutter, storm drains, and sometimes small open channels that discharge to a major drainage system. Also called “local drainage system.”

Owner means a person having dominant and/or servient interest in property, having sufficient interest to convey property, and/or having possessory interest in property. The term *owner* also includes the owner’s agent.

Part of a larger common plan of development or sale means a contiguous area where multiple separate and distinct construction activities will take place at different times on different schedules under one plan. An example would be a commercial development with multiple separate buildings constructed over the course of multiple construction schedules.

Pollutant means dredged spoil, dirt, slurry, solid waste, incinerator residue, sewage, sewage sludge, garbage, trash, chemical waste, biological nutrient, biological material, radioactive material, heat, wrecked or discarded equipment, rock, sand, or any industrial, municipal, or agricultural waste. [§ 25-8-103(15), C.R.S.]

Pollution means the alteration of the physical, thermal, chemical, or biological quality of, or the contamination of any water that renders the water harmful, detrimental, or injurious to humans, animal life, plant life, property or public health, safety or welfare, or impairs the usefulness or the public enjoyment of the water for any lawful or reasonable purpose.

Post-construction stormwater management plan means the final drainage report, in accordance with GJMC § 28.12.060 through 28.12.110, final drainage report, which includes a combination of structural and/or nonstructural BMPs, further described in Chapter 28.64 GJMC, Post-Construction Stormwater Management, that reduce the discharge of pollutants after construction is complete.

Pre-developed or *pre-existing* means conditions that existed as of the adoption date of this manual.

Private drainage system means all privately owned ground, surfaces, structures or systems, excluding the MS4, that contribute to or convey stormwater including but not limited to roofs, gutters, downspouts, lawns, driveways, pavement, roads, streets, curbs, gutters, inlets, drains, catch basins, pipes, tunnels, culverts, channels, detention basins, ponds, draws, swales, streams and any ground surfaces.

Public improvement means any improvement, facility or service together with its associated public site, right-of-way or easement necessary to provide transportation, drainage, public private utilities, parks or recreational, energy or similar essential services. (Mesa County Land Development Code Section 12.1.)

Qualified erosion control specialist means a qualified person, as defined by GJMC § 13.28.010, with specialized training, education, or experience in the field of erosion control methods, planning, and inspection.

Recurrence Interval. The recurrence interval corresponds to the statistical return period of an event of the same intensity (e.g., a 100-year recurrence interval flood has a one percent chance to occur each year, which does not mean that it will occur every 100 years).

Regional facility means a detention and/or water quality facility that is publicly owned and maintained and serves all properties within the tributary watershed.

Sediment means soil, mud, dirt, gravel and rocks that have been disturbed, eroded and/or transported naturally by water, wind or gravity and/or mechanically by any person, vehicle or equipment.

Significant materials include but are not limited to: raw materials; fuels; materials such as metallic products; hazardous substances designated under Section 101(14) of CERCLA; any chemical the facility is required to report pursuant to Section 313 of Title III of SARA; fertilizers; pesticides; and waste products such as ashes, slag and sludge that have the potential to be released with stormwater discharge.

Storm drainage system means all surfaces, structures and systems that contribute to or convey stormwater including private drainage systems and the MS4, and any nonmunicipal drain or pipe, channel or other conveyance, including natural and artificial (manmade) washes and ditches for conveying water, groundwater, drainage water or unpolluted water from any source, excluding sewage and industrial wastes, to waters of the State and United States.

Storm water or *stormwater.* Within the context of the Stormwater Management Manual, stormwater, whether one or two words, shall mean surface runoff resulting from precipitation.

Stormwater construction permit means the permit issued by the CDPHE called the general permit for stormwater discharges associated with construction activities. Mesa County or the City of Grand Junction will also issue a stormwater construction permit for land disturbances related to new development.

Stormwater management plan. Within the context of the Stormwater Management Manual, a stormwater management plan (SWMP) means the construction SWMP (CSWMP) and/or the post-construction SWMP.

Stream channel means the area of the floodplain which carries the normal flow of the watercourse. (Mesa County Land Development Code Section 12.1).

Urbanized area means the area identified by the Colorado Department of Public Health and Environment based on the 2000 census and called the urban area of Mesa County. Within the context of the SWMM, urban area also includes the Redlands within the urban growth boundary of the County.

Water quality capture volume means the minimum storage volume, based on the eightieth percentile event, which is retained and released over a specified period of time, depending on the specific structural BMP and is based on the time it takes to fully drain the brim-full volume contained in storage.

Water quality outlet means a structure designed to release the water quality capture volume over the specified period of time for the specific BMP.

Waters of the State means any groundwater, percolating or otherwise, lakes, bays, ponds, impounding reservoirs, springs, rivers, streams, creeks, estuaries, marshes, inlets, canals, wells, watercourses, drainage systems, and irrigation systems; all sources of water such as snow, ice, and glaciers; and all other bodies or accumulations of water, surface and underground, natural or artificial, navigable or nonnavigable, and including beds and banks of all watercourses and bodies of surface water, public or private, located wholly or partly within or bordering upon this State and within the jurisdiction of this State.

Watershed master plan means the Grand Valley Stormwater Management Master Plan or other stormwater master plans approved by the Drainage Authority representing applicable municipalities and Mesa County.

Wetland means any area that is inundated or saturated by surface or groundwater at a frequency and duration sufficient to support, under normal circumstances, a prevalence of vegetation typically adapted to the saturated soil conditions. Wetlands generally include swamps, marshes, bogs and similar areas.
(Res. 40-08 (§ 209), 3-19-08)

CHAPTER 28.12
Drainage Planning Submittal Requirements

§ 28.12.010. Review process.

All development within the jurisdiction of this manual shall submit drainage reports, construction drawings/specifications, and record drawing information for review and approval in accordance with the requirements of this chapter. The City of Fruita, the Town of Palisade, or the Grand Junction Drainage District may alter the requirements of this chapter, in accordance with their guidance documents. Figure 28.12.010 provides a flow chart of the general review process.

(a) **Mesa County.**

The County will review reports and plans for completeness of the submittal to the Planning Department. The County will provide written or oral review comments of the submittal. The County will make every effort to effect a complete review and comment within a reasonable period; however, the County cannot approve reports or plans by default.

The applicant or his designated representative is required to attend a pre-application conference to review processing steps in accordance with the Mesa County Land Development Code (Code Section 3.1.6). The applicant shall consult with the Director or representative for general information regarding land development regulations, required procedures, possible drainage problems and deviations/variances, and specific submittal requirements. As a minimum, a conceptual and final drainage report will be required, unless modified at the pre-application conference.

(b) **City of Grand Junction.**

The City shall review and approve drainage reports and construction plans in accordance with Submittal Standards for Improvements and Development (SSID), Zoning and Development Code (GJMC Title 21), and the pollution prevention stormwater ordinance.

(c) **Other Jurisdictions.**

Refer to requirements of the City of Fruita, the Town of Palisade or the Grand Junction Drainage District for specific information regarding review and acceptance of drainage reports and plans.

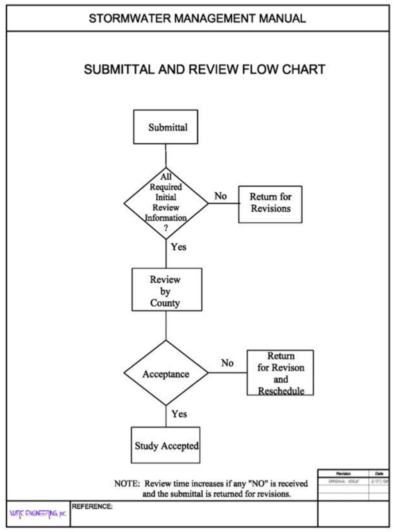


FIGURE 28.12.010

(Res. 40-08 (§ 300), 3-19-08)

§ 28.12.020. Submittal requirements.

A conceptual/preliminary and final drainage report is required for all new development and redevelopment, except as otherwise determined at the pre-application conference. The number of report copies to be submitted will be determined at the pre-application conference. One copy will be returned to the applicant or his representative with comments.

All submitted reports shall be clearly and cleanly reproduced. Copies of charts, tables, nomographs, calculations, or any other referenced material shall be legible. Washed out, blurred or unreadable portions of the report are unacceptable and may warrant resubmittal of the report. The submittal shall include a declaration of the type of report submitted (i.e., conceptual/preliminary or final).

Table 28.12.020 shall be used to determine the adequacy of the submittal, in addition to those requirements identified at the pre-application meeting, which may alter the checklist. Incomplete or absent information may result in the report being rejected for review. Revision dates must be included on all re-submittals.

All development and redevelopment must provide construction site best management practices (see Chapter 28.6 GJMC), on-site detention (see Chapter 28.56 GJMC), and post-construction BMPs (see Chapter 28.64 GJMC), unless otherwise modified at the pre-application conference.

Table 28.12.020: Stormwater Management Manual Drainage Report Checklist

Instructions:

1. Applicant to identify with a check-mark if information is provided with report. If applicant believes information is not required, indicate with “n/a” and attach separate sheet with explanation.
2. The reviewer will determine if information labeled “n/a” is required and whether information must be submitted.
3. Those items noted with an asterisk are not typically required for conceptual/ preliminary report. Applicant shall confirm this with local jurisdiction.

Table 28.12.020: Stormwater Management Manual Drainage Report Checklist

4. Submit three copies of report and include copy of check list bound with report.

TITLE PAGE

A. Type of report (conceptual/preliminary or final drainage report).

B. Project name.

C. Preparer name, firm, address, number, and date.

D. Professional Engineer's seal of preparer.

E. Certifications (see GJMC § 28.12.070).

I. INTRODUCTION

A. Background

______ 1. Identify report preparer and purpose.

______ 2. Identify date of letter with previous County comments.

B. Project Location

______ 1. Identify Township, Range, and Section.

______ 2. Identify adjacent street and subdivision names.

______ 3. Reference to General Location Map.

C. Property Description

______ 1. Identify area in acres of entire contiguous ownership.

______ 2. Describe existing ground cover, vegetation, soils, topography and slopes.

______ 3. Describe existing drainage facilities, such as channels, detention areas, or structures.

______ 4. Describe existing irrigation facilities, such as ditches, headgates, or diversions.

______ 5. Identify proposed types of land use and encumbrances.

D. Previous Investigations

______ 1. Identify drainage master plans that include the project area, including floodplain studies.

______ 2. Identify drainage reports for adjacent development.

II. DRAINAGE SYSTEM DESCRIPTION

A. Existing Drainage Conditions

______ 1. Describe existing topography and provide map with contours extending a minimum of 100 feet beyond property limits.

______ 2. Identify major drainageway or outfall drainageway and describe map showing location of proposed development within the drainageways.

Table 28.12.020: Stormwater Management Manual Drainage Report Checklist

______________ 3. Identify pre-developed drainage patterns and describe map showing predeveloped sub-basins and concentrated discharge locations. Provide calculations of pre-developed peak flows entering and leaving the site.

B. Master Drainage Plan

______________ 1. Describe location of the project relative to a previously prepared master drainage plan, including drainage plans prepared for adjacent development.

C. Off-Site Tributary Area

______________ 1. Identify all off-site drainage basins that are tributary to the project.

______________ 2. Identify assumptions regarding existing and future land use and effects of off-site detention on peak flows.

D. Proposed Drainage System Description

______________ 1. Identify how off-site stormwater is collected and conveyed through the site and ultimately to the receiving water(s).

______________ 2. Identify sub-basins and describe, in general terms, how on-site stormwater is collected and conveyed through the site for each location where stormwater is discharged from the site.

_____________* 3. Describe detention volumes, release rates and pool elevations.

_____________* 4. Identify the difference in elevation between pond invert and the groundwater table.

______________ 5. Describe how stormwater is discharged from the site, including both concentrated and dispersed discharges and rates.

______________ 6. Describe stormwater quality facilities.

_____________* 7. Describe maintenance access aspects of design.

_____________* 8. Describe easements and tracts for drainage purposes, including limitation on use.

E. Drainage Facility Maintenance

_____________* 1. Identify responsible parties for maintenance of each drainage and water quality facility.

_____________* 2. Identify general maintenance activities and schedules.

III. DRAINAGE ANALYSIS AND DESIGN CRITERIA

A. Regulations

______________ 1. Identify that analysis and design was prepared in accordance with the provisions of this manual.

______________ 2. Identify other regulations or criteria which have been used to prepare analysis and design.

B. Development Criteria

Table 28.12.020: Stormwater Management Manual Drainage Report Checklist

______________ 1. Identify drainage constraints placed on the project, such as by a major drainage study, floodplain study or other drainage reports relevant to the project.

______________ 2. Identify drainage constraints placed on the project, such as from major street alignments, utilities, existing structures, and other developments.

C. Hydrologic Criteria

(If manual was followed without deviation, then a statement to that effect is all that is required. Otherwise provide the following information where the criteria used deviates from this manual.)

______________ 1. Identify developed storm runoff peak flows and volumes and how they were determined, including rainfall intensity or design storm.

______________ 2. Identify which storm events were used for minor and major flood analysis and design.

______________ 3. Identify how and why any other deviations from this manual occurred.

D. Hydraulic Criteria

(If manual was followed without deviation, then a statement to that effect is all that is required. Otherwise provide the following information where the criteria used deviates from this manual.)

____________* 1. Identify type(s) of streets within and adjacent to development and source for allowable street capacity.

____________* 2. Identify which type(s) of storm inlets were analyzed or designed and source for allowable capacity.

____________* 3. Identify which type of storm sewers which were analyzed or designed and Manning's n-values used.

____________* 4. Identify which method was used to determine detention volume requirements and how allowable release rates were determined.

____________* 5. Identify how the capacity of open channels and culverts were determined.

____________* 6. Identify any special analysis or design requirements not contained with this manual.

______________ 7. Identify how and why any other deviations from this manual occurred.

E. Variance from Criteria

______________ 1. Identify any provisions of this manual for which a variance is requested.

______________ 2. Identify pre-existing conditions which cause the variance request.

***IV. POST-CONSTRUCTION STORMWATER MANAGEMENT. See Chapter 28.64 GJMC for requirements.**

Table 28.12.020: Stormwater Management Manual Drainage Report Checklist

Note: This section of the final drainage report identifies additional information required by Mesa County's, City of Grand Junction's, and Town of Palisade's, permit for stormwater discharges associated with municipal separate storm sewer systems (MS4s), Permit No. COR-090000. The final drainage plan and the construction SWMP (see Chapter 28.6 GJMC) meets the requirements of the MS4s permit. In general, this section identifies permanent BMP practices to control the discharge of pollutants after construction is complete.

*A. Stormwater Quality Control Measures

___________* 1. Describe the post-construction BMPs to control discharge of pollutants from the project site.

___________* 2. If compensating detention is provided, discuss practices to address water quality from area not tributary to detention area.

___________* 3. If underground detention is proposed, discuss how water quality facilities will be provided on the surface.

___________ 4. If proprietary BMPs are proposed, provide the justification and sizing requirements (see GJMC § 28.64.040).

*B. Calculations

___________ 1. Provide methods and calculations for WQCV, sediment storage, and water quality outlet structure.

V. CONCLUSIONS

A. Compliance with Manual

___________ Compliance with manual and other approved documents, such as drainage plans and floodplain studies.

B. Design Effectiveness

___________ Effectiveness of drainage design to control impacts of storm runoff.

C. Areas in Flood Hazard Zone

___________ Meet requirements of Floodplain Regulations: Mesa County Land Development Code, Section 7.13; GJMC § 21.07.010.

D. Variances from Manual

___________ Applicant shall identify any requested variances and provide basis for approving variance. If no variances are requested, applicant shall state that none are requested.

VI. REFERENCES

___________ Provide a reference list of all criteria, master plans, drainage reports, and technical information used.

TABLES

___________ Include copy of all tables prepared for report.

FIGURES

___________ A. General Location Map (See GJMC § 28.12.080(a))

Table 28.12.020: Stormwater Management Manual Drainage Report Checklist

______________	B.	Floodplain Information
______________	C.	Drainage Plan (See GJMC § 28.12.080(b))
______________	D.	Other pertinent figures.
	APPENDICES	
	A.	DESIGN CHARTS
______________	1.	Provide copy of all design charts (i.e., tables, figures, charts from other criteria) used for the report.
	B.	HYDROLOGIC CALCULATIONS (see Chapters 28.24 and 28.28 GJMC)
______________	1.	Land use assumptions for off-site runoff calculations.
______________	2.	Time of concentration and runoff coefficients for pre-existing and post development conditions.
______________	3.	Pre-developed hydrologic computations.
______________	4.	Developed conditions hydrologic computations.
	C.	HYDRAULIC CALCULATIONS
______________	1.	Capacity of existing channels, streets, storm sewers, inlets, culverts and other facilities.
______________	2.	Calculations for existing storm sewer and open channel.
______________	3.	Irrigation ditch flows and ditch system capacity.
____________*	4.	Detention pond design (see Chapter 28.56 GJMC for requirements).
____________*	a.	Storage volume, release rates, and pool elevations for 10-year and 100-year storm.
*____________	b.	Outlet structure dimensions, orifice diameter, weir lengths, pipe headwater and other data.
____________*	c.	Outlet velocity and energy dissipation requirements.
____________*	d.	Routing of outlet flows and emergency spillway flows.
____________*	5.	Street capacity calculations, if data in manual not used (see Chapter 28.44 GJMC).
____________*	6.	Storm inlet capacity calculations, if data in manual not used (see Chapter 28.44 GJMC).
____________*	7.	Storm sewer capacity calculations, if data in manual not used (see Chapter 28.44 GJMC).
____________*	8.	Channel capacity calculations, if data in manual not used (see Chapter 28.32 GJMC).
____________*	9.	Culvert capacity calculations (see Chapter 28.48 GJMC).
____________*	10.	Other hydraulic structure calculations (see Chapter 28.36 GJMC).
	D.	STORMWATER QUALITY CALCULATIONS
______________	1.	Water quality capture volume (WQCV).

Table 28.12.020: Stormwater Management Manual Drainage Report Checklist

____________*	2.	Storage volume for sediment volume and pool elevations for WQCV.
____________*	3.	Outlet calculations for required area per row, diameter of individual holes, number of holes per row, and number of holes per column.
_____________		**CERTIFICATION – PROFESSIONAL ENGINEER'S SEAL AND SIGNATURE ACKNOWLEDGEMENTS**
		Drainage Report checklist was prepared by: ____________________________________

(Res. 40-08 (§ 301), 3-19-08)

§ 28.12.030. Conceptual/preliminary drainage report.

The purpose of the conceptual/preliminary drainage report is to:

(a) Identify drainage conditions prior to proposed development, including designated floodplain boundaries (see Table 28.12.020).

(b) Identify existing and potential drainage problems, which may occur on site or off site because of the development.

(c) Identify proposed solutions to drainage problems, including location of detention storage and water quality requirements, in sufficient detail to verify technical feasibility.

Text shall be typed on eight-and-one-half-inch by 11-inch paper. All pages, including appendices, shall be numbered in a fashion that identifies the report (e.g., PDR-#). Text, tables, figures, charts, calculations, and appendices shall be bound to form a formal report. Drawings shall be included in a pocket attached with the report, but shall not be smaller than 11 inches by 17 inches or larger than 24 inches by 36 inches in size. The report shall include a cover letter presenting the conceptual/preliminary design for review and shall be stamped and signed by an engineer licensed in Colorado.

(Res. 40-08 (§ 302), 3-19-08)

§ 28.12.040. Conceptual/preliminary report contents.

The conceptual/preliminary drainage report shall contain general information regarding the proposed drainage facilities for the development. For instance, only identify that a channel or storm drain is proposed for conveyance, and not the size, slope, velocity or other more detailed information. Also, it is only required to identify the location and type of detention (i.e., drainage and water quality), and not the volumes or release rates; however, post-development flow rates shall be calculated and submitted with the preliminary report.

The report shall be prepared in accordance with the outline provided as part of the checklist in Table 28.12.020 (see also GJMC § 28.12.130). Grading and erosion control information are not required. The checklist must be completed by the applicant and included with the drainage report. The checklist will be used to determine the completeness of the report. If information provided is lacking or incomplete, the information may be required prior to further review. It is understood that information in the conceptual/ preliminary drainage report is subject to change. More detail can be required if necessary due to the complexity of a development.
(Res. 40-08 (§ 302.1), 3-19-08)

§ 28.12.050. Conceptual/preliminary report drawing contents.

(a) **General Location Map.**

A map (eight and one-half inches by 11 inches) shall be provided in sufficient detail at a scale not larger than one inch equals 1,000 feet and included with the report. The map shall identify:

(1) Drainage flows entering and leaving the development and general drainage patterns within the development.

(2) Path of all drainage from the upper end of any off-site basins to the defined major drainageways (see Chapter 28.16 GJMC, Drainage Policy).

(3) Major construction (i.e., development, irrigation ditches, existing detention facilities, culverts, and storm drains) along the entire path of drainage.

(4) All major basins. Topographic contours are optional.

(b) **Conceptual/Preliminary Drainage Plan.**

Map(s) of the proposed development at a scale of one inch equals 20 feet to one inch equals 200 feet on a 24-inch by 36-inch drawing shall be included. The plan shall show the following:

(1) Existing and (if available) proposed contours at five-foot maximum intervals. The contours shall extend beyond the property boundaries the distance necessary to show how the development interacts hydraulically with the surrounding area, but no less than 50 feet. Mesa County contours are acceptable provided they are representative of actual field conditions.

(2) All existing drainage facilities. If existing (pre-development) conditions cannot be adequately addressed on the proposed drainage plan, then a separate existing conditions drainage plan shall be prepared and included with the submittal document.

(3) Approximate flooding limits based on available information.

(4) Conceptual major drainage facilities including detention basins, storm drains, swales, riprap, and outlet structures in the detail consistent with the proposed development plan.

(5) Major drainage boundaries and sub-boundaries.

(6) Any off-site feature influencing development, including both upstream and downstream structures.

(7) Proposed flow directions entering, within, and exiting the development and, if available, proposed contours. Identify the drainage path from the development to the nearest MS4 facility or major drainageway.

(8) Existing and proposed irrigation facilities.

(9) Legend to define map symbols.

(10) Title block in lower right corner.

(11) All elevations shall be NAVD 1988.

(Res. 40-08 (§ 302.2), 3-19-08)

§ 28.12.060. Final drainage report.

The purpose of the final drainage report is to:

(a) Identify drainage conditions prior to proposed development, including floodplain boundaries.

(b) Identify existing and potential drainage problems, which may occur on site or off site because of the development.

(c) Investigate or refine conceptual solutions to drainage problems, including detention storage and water quality requirements, in sufficient detail to verify their technical feasibility.

(d) Present final design and details for drainage facilities discussed in the conceptual/preliminary drainage report.

(e) Identify post-construction BMPs to control the discharge of pollutants in stormwater to the maximum extent practicable.

Text shall be typed on eight-and-one-half-inch by 11-inch paper. All pages, including appendices, shall be numbered in a fashion that identifies the report (e.g., FDR-#). Text, tables, figures, charts, calculations, and appendices shall be bound to form a formal report. Drawings shall be 24 inches by 36 inches and included in a pocket attached with the report. The report shall include a cover letter presenting final design for review and shall be stamped and signed by an engineer licensed in Colorado.

(Res. 40-08 (§ 303), 3-19-08)

§ 28.12.070. Final report contents.

The final drainage report shall provide final details of proposed drainage facilities, including grading, erosion control, and water quality enhancement, and is to be submitted along with construction documents (see GJMC § 28.12.130).

The final drainage report shall be prepared by an engineer registered in Colorado in accordance with the outline provided as part of the checklist in Table 28.12.020 (see also GJMC § 28.12.130). The checklist must be completed by the applicant and included with the drainage report. The checklist will be used to determine the completeness of the report. If information provided is lacking or incomplete, the information may be required prior to further review.

The report shall contain the following certifications:

I hereby certify that this *Final Drainage Report* (plan) for the design of (Name of Development) was prepared by me (or under my direct supervision) in accordance with the provisions of the *Stormwater Management Manual* for the owners thereof. I understand that the (local jurisdiction) does not and will not assume liability for drainage facilities designed by others.

____
Registered Professional Engineer
State of Colorado No._________
(Affix Seal)

I, (Name of Developer) hereby certify that the drainage facilities for (Name of Development) shall be constructed according to the design presented in this report. I understand that the (local jurisdiction) does not and will not assume liability for the drainage facilities designed and/or certified by my engineer. I understand that the (local jurisdiction) reviews drainage plans but cannot, on behalf of (Name of Development), guarantee that final drainage design review will absolve (Name of Developer) and/or their successors and/or assigns of future liability for improper design. I further understand that approval of the Final Plat and/or Final Development Plan does not imply approval of my engineer's drainage design.

____
Name of Developer

________________________ ____________________
Authorized Signature Date

(Res. 40-08 (§ 303.1), 3-19-08)

§ 28.12.080. Final report drawing contents.

(a) **General Location Map.**

An eight-and-one-half-inch by 11-inch map shall be provided in sufficient detail at a scale not larger than one inch equals 1,000 feet and included with the report. The map shall identify:

(1) Drainage flows entering and leaving the development and general drainage patterns.

(2) Path of all drainage from the upper end of any off-site basins to the defined major drainageways (see Chapter 28.16 GJMC, Drainage Policy).

(3) Major construction (i.e., development, irrigation ditches, existing detention facilities, culverts, and storm drains) along the entire path of drainage.

(4) All major basins. Topographic contours are optional.

(b) **Final Drainage Plan.**

Map(s) of the proposed development at a scale of one inch equals 20 feet to one inch equals 200 feet on a 24-inch by 36-inch drawing shall be included. The plan shall show the following:

(1) Existing and proposed contours at two-foot maximum intervals. The contours shall be based on a USGS datum and extend a minimum of 50 feet beyond property lines, or further if required to show how the development interacts with the surrounding area.

(2) Location of benchmarks, which must be one of the following:

(i) Mesa County monumentation, including GIS reference points;

(ii) USGS NAVD 1988;

(iii) City of Grand Junction; or

(iv) Colorado Department of Transportation.

(3) Property lines and easements with purposes noted.

(4) Existing street names and proposed streets, indicating names, right-of-way width, flowline

width, curb type, sidewalk, and approximate slopes.

(5) All existing drainage boundaries and peak flows entering and within the exiting development. Existing facilities such as irrigation and roadside ditches, drainageways, culverts, and detention sites. Include pertinent characteristics, such as location, size, shape, slope, and material. A separate existing conditions drainage plan shall be prepared and included with the submittal document that details the pre-development conditions listed in this line item.

(6) Any off-site feature influencing development, including both upstream and downstream structures.

(7) Proposed drainage boundaries and sub-boundaries.

(8) Proposed type of street flow (i.e., vertical or combination curb and gutter), roadside ditches, gutter slope, and flow directions, and cross-pans.

(9) Proposed storm drains and open drainageways, including inlets, manholes, culverts, and other appurtenances, including erosion/riprap protection.

(10) Proposed outfall point for runoff from the developed area and facilities to convey flows to the final outfall point without damage to downstream properties.

(11) Routing and accumulation and flows at various critical points for the initial storm runoff listed on the drawing.

(12) Volumes and release rates for detention storage facilities and information on outlet works.

(13) Location and elevations of all existing floodplains affecting the property.

(14) Location and elevations of all existing and proposed utilities affected by or affecting the drainage design.

(15) Routing of off-site drainage flow through the development.

(16) Definition of flow path leaving the development through the downstream properties ending at a major drainageway.

(17) Legend to define map symbols (see Table 28.12.080 for symbol criteria).

(18) Title block in lower right hand corner.

(19) Identify each post-construction BMP including the WQCV provided or other bases for sizing BMPs.

(20) All elevations shall be NAVD 1988.

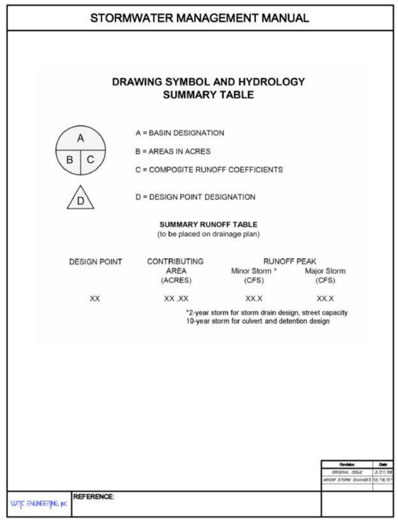


TABLE 28.12.080

(Res. 40-08 (§ 303.2), 3-19-08)

§ 28.12.090. Construction plans.

(a) **Mesa County.**

The final construction plans and final drainage report must be submitted for acceptance to the Director at least 20 working days prior to the consideration of the plat before the County Commissioners. Before final subdivision plats and site plans can be submitted to County Commissioners for approval, the following conditions must be met:

(1) Drainage reports and/or construction plans must be accepted by the Director without conditions;

(2) All required easements and licenses with the County must be approved by the Director and the County Attorney, and the appropriate title insurance provided; and

(3) Easements and other agency approvals must be fully executed and copies provided to the County.

Acceptance of the final construction plans and final drainage report are required prior to issuance of a permit.

Construction plans shall be prepared in accordance with sound engineering principles, this manual and the Mesa County Land Development Code for subdivision designs. Construction documents shall include geometric, dimensional, structural, foundation, bedding, hydraulic, landscaping, and other details as needed to construct the storm drainage facility. The approved final drainage plan shall be included as part of the construction document for all facilities affected by the drainage plan. Construction plans shall be signed by a registered professional engineer as being in accordance with the County approved drainage report, drawings, and this manual. Requirements for construction plans are outlined in the checklist in Table 28.12.090.

(b) **City of Grand Junction.**

Refer to the Submittal Standards for Improvements and Development for specific requirements for construction plans.

(c) **Other Jurisdictions.**

Refer to requirements of the City of Fruita, Town of Palisade or the Grand Junction Drainage District for construction plans.

Table 28.12.090: Stormwater Management Manual Drainage Plan Checklist

Instructions:

1. Applicant to identify with a check-mark if information is provided. If applicant believes information is not required, indicate with "n/a."
2. County will determine if information labeled "n/a" is required and whether information must be submitted.

I. EXISTING FACILITIES

____________	A.	Contours at two-foot intervals, based on USGS datum. Contours to extend at least 50 feet past property line.
____________	B.	Location and elevation of USGS benchmarks or benchmarks referenced to USGS.
____________	C.	Property lines.
____________	D.	Drainage easements.
____________	E.	Street names.
____________	F.	Major and minor channels and floodplains.
____________	G.	A historic drainage plan including historic basin boundaries and flow paths.

II. PROPOSED FACILITIES

____________	A.	Contours at two-foot intervals, based on USGS datum.
____________	B.	Property lines.
____________	C.	Drainage easements.
____________	D.	Street names and grades.

Table 28.12.090: Stormwater Management Manual Drainage Plan Checklist

_____________ E. Right-of-way and easement.

_____________ F. Finished floor elevations for protection from major storm runoff.

_____________ G. Detention pond information:

_____________ 1. Location of each detention pond with site at 1" = 50' scale or larger with two-foot contour intervals.

_____________ 2. Inlet and outlet structure, and trickle channel design details.

_____________ 3. Details of emergency spillway and channel.

_____________ 4. Landscape information, including side slopes, vegetation and planting requirements.

_____________ 5. Details of water quality outlet structure.

H. Channel information:

_____________ 1. Profiles with existing and proposed grades.

_____________ 2. Cross-sections on 100-foot stations showing existing and proposed topography and required rights-of-way.

_____________ 3. Locations and size of all existing and proposed structures.

_____________ 4. Locations and profiles of adjacent utilities.

_____________ 5. Typical channel section and lining details.

I. Storm sewer information:

_____________ 1. Alignment and location of manholes, inlets, and outlet structures.

_____________ 2. Profile of invert and pipe crown.

_____________ 3. Invert elevations at manholes and inlets.

_____________ 4. Lengths and grades between manholes and inlets.

_____________ 5. Locations and elevations of utilities adjacent to and crossing storm sewer.

_____________ 6. Easement and other O&M access geometry.

_____________ 7. Outlet details, such as end sections, headwall and wingwalls, erosion control, and vegetation.

_____________ J. Street cross-sections with design 100-year flood depth.

_____________ K. Other drainage related structures and facilities, including underdrains and sump pump discharge lines.

_____________ L. Other permanent BMP measures to control pollutant discharges to the County’s MS4 system.

III. HYDRAULIC AND HYDROLOGIC INFORMATION

_____________ A. Routing and accumulative runoff peaks at upstream and downstream ends of the site and at various critical points on-site for initial and major storms. Inflow and outflow from each sub-basin shall be shown for both initial and major storms.

Table 28.12.090: Stormwater Management Manual Drainage Plan Checklist

_____________ B. Street cross-sections showing 100-year flood levels.

_____________ C. Major and minor channels and floodplains.

_____________ D. Detention pond data:

_____________ 1. Release rates for 10- and 100-year storm events.

_____________ 2. Required and provided volumes for 10- and 100-year storm events.

_____________ 3. Design depths for 10- and 100-year storm events.

_____________ 4. Water quality capture volume and pool elevation.

E. Channel data:

_____________ 1. Water surface profiles.

_____________ 2. Representative 100-year flow velocity and Froude number.

F. Storm sewer data:

_____________ 1. Profile of water surface for design flow rate.

_____________ 2. Peak flows for design flow, two-year and 100-year storm events.

IV. STANDARD NOTES

_____________ A. No building, structure, or fill will be placed in the detention areas and no changes or alterations affecting the hydraulic characteristics of the detention areas will be made without the approval of the County.

_____________ B. Maintenance and operation of the detention and water quality areas is the responsibility of property owner. If owner fails in this responsibility, the County has the right to enter the property, maintain the detention areas, and be reimbursed for costs incurred.

_____________ C. Detention pond volumes, all drainage appurtenances, and basin boundaries shall be verified. As-built drawings shall be prepared by a registered professional engineer prior to issuance of certificate of occupancy for any structure within the development.

D. Permission to reproduce these plans is hereby given to Mesa County for County purposes associated with plan review, approval, permitting, inspection and construction of work.

_____________ **V. PROFESSIONAL ENGINEER'S SEAL AND SIGNATURE**

VI. OTHER

_____________ A. Horizontal and vertical control information and ties to existing and proposed features.

ACKNOWLEDGEMENTS

Drainage Plan checklist was prepared by: ___________________

(Res. 40-08 (§ 303.3), 3-19-08)

§ 28.12.100. Post-construction BMPs.

Mesa County, the City of Grand Junction, the Grand Junction Drainage District, and the Town of Palisade, who are members of the Drainage Authority, have obtained permits to discharge stormwater under the Colorado Discharge Permit System (permit numbers COR-090031, COR-090077, COR-090006, and COR-090005, respectively). The terms and conditions of the permits set forth minimum requirements for stormwater management programs including construction site stormwater runoff control and post-construction stormwater management for new development and redevelopment to reduce pollutants in all stormwater runoff to the MS4.

These permit conditions are the basis for requirements identified in Chapter 28.64 GJMC. The final drainage report shall identify and include design bases, calculations, and construction details for post-construction BMPs, in accordance with requirements of Chapter 28.64 GJMC.
(Res. 40-08 (§ 303.4), 3-19-08)

§ 28.12.110. Construction SWMP.

The permit conditions described in GJMC § 28.12.100 are the basis for requirements identified in Chapter 28.6 GJMC. The construction SWMP requirements, which are described in Chapter 28.6 GJMC, meet the conditions of the permit. The construction SWMP is a separate document from the final drainage report, must be prepared and certified by a qualified erosion control specialist, and is generally submitted for approval after the final drainage report. Contact local jurisdiction for exact timing of submittal.
(Res. 40-08 (§ 303.5), 3-19-08)

§ 28.12.120. Record drawings and acceptances.

(a) **Mesa County.**

(1) **Record Drawings.**

(i) Record drawings for all improvements are to be submitted to the County. Drawings shall be submitted in electronic format, along with mylar (minimum three mil.) reproducible copy and paper prints. Drawings shall include appropriate seals and signatures in accordance with current State law, with the request for probationary acceptance of public improvements or prior to requesting a certificate of occupancy for commercial, industrial or multifamily residential building sites. Certification of the record drawings is required as follows:

(A) **Registered Professional Engineer (PE).**

A registered PE in the State of Colorado shall certify, based on survey from a registered land surveyor, the as-built detention pond volumes and surface areas at the design depths, outlet structure sizes and elevations, storm drain sizes and invert elevations at inlets, manholes, and discharge location, and representative open channel cross-sections, and dimensions of all the drainage structures.

(B) **Registered Professional Engineer.**

The responsible design engineer shall state that "to the best of my knowledge, belief, and opinion, the drainage facilities were constructed in accordance with the design intent of the approved drainage report and construction drawings."

(ii) The Director will compare the certified record drawing information with the construction drawings to ensure that:

(A) The record drawing information demonstrates that the construction is in compliance with the design intent.

(B) The record drawings are certified by a professional engineer licensed in Colorado.

(2) **Probationary Acceptance.**

All public storm drainage facilities shall be guaranteed by the developer to the County for a minimum 18-month warranty period (with the exception of drains over 20 feet deep, which shall require a two-year warranty period or other special cases).

The developer is responsible for routine maintenance, any workmanship defects, and for removal and cleanup of construction debris, dirt and mud in the system during the warranty period.

(3) **Acceptances.**

(i) For newly constructed public drainage improvements, the County may consent to a reduction of the improvements guarantee provided by the developer when the drainage improvements are granted probationary acceptance.

(ii) For new commercial, industrial and residential building sites, the drainage portion of the certificate of occupancy shall be accepted when the record drawings are determined by the County to comply with the above criteria.

(b) **City of Grand Junction.**

Refer to the Submittal Standards for Improvements and Development (SSID) for specific requirements regarding record drawings and acceptance.

(c) **Other Jurisdictions.**

Refer to requirements of the City of Fruita, Town of Palisade or the Grand Junction Drainage District regarding record drawings and acceptance.

(Res. 40-08 (§ 304), 3-19-08)

§ 28.12.130. Submittal checklist.

(a) **Mesa County.**

To aid the designer and reviewer, a summary of the required certifications and approvals is presented below.

ITEM	CERTIFICATION REQUIRED	COUNTY ACCEPTANCE REQUIRED
Conceptual Drainage Report	Engineer	No
Final Drainage Report	Engineer and Developer	Yes

ITEM	CERTIFICATION REQUIRED	COUNTY ACCEPTANCE REQUIRED
Construction Drawings	Engineer	Yes
Construction SWMP (see Chapter 28.6 GJMC)	Qualified EC Specialist	Yes
Record Drawings	Engineer	Yes

Checklists for conceptual/preliminary and final drainage reports, and for construction plans, are provided in Table 28.12.020 and Table 28.12.090. These checklists contain recommended report outline and contents for all drainage reports. A copy of the completed checklist shall be bound with the conceptual/preliminary and final drainage report.

The applicant is to identify with a "✓" if information is provided with the appropriate submittal. If applicant believes information is not required, indicate with "n/a." The County will review the submittal to determine if information is required and whether information must be submitted. Due to the nature of a conceptual/preliminary report, not all information listed in the outline/checklist may be required for a conceptual/preliminary drainage report, such as those items listed with an asterisk (*). If the applicant is uncertain if information is required, the applicant is encouraged to contact the County.

(b) **City of Grand Junction.**

The submittal checklist for the City of Grand Junction follows the same steps and procedures set forth for Mesa County presented in subsection (a) of this section. In addition the designer and reviewer are to refer to the Submittal Standards for Improvements and Development (SSID) for specific requirements regarding checklist requirements.

(c) **Other Jurisdictions.**

Refer to requirements of the City of Fruita, Town of Palisade or the Grand Junction Drainage District regarding checklist requirements.

(Res. 40-08 (§ 305), 3-19-08)

CHAPTER 28.16
Drainage Policy

§ 28.16.010. Introduction.

Presented in this chapter of the manual are policies that govern development of specific standards and criteria for the design, evaluation, and construction of drainage facilities. These policies are based on industry standards for stormwater management that have evolved through experience gained. Policy statements are indicated by ***bold italic*** text to distinguish them from background information, which is presented to assist with decisions regarding special circumstances that may arise during development.
(Res. 40-08 (§ 401), 3-19-08)

§ 28.16.020. Basic principles.

(a) **Jurisdictional Cooperation.**

Mesa County, the Cities of Grand Junction and Fruita, the Town of Palisade, and the Grand Junction Drainage District have contracted through intergovernmental agreements (IGA) to form the 5-2-1 Drainage Authority (Authority), under Colorado Revised Statutes, specifically § 29-1-204.2, C.R.S. The stated purpose of the Authority is to pursue unified stormwater management planning that meets the requirements of the Colorado Water Quality Control Act (§ 25-8-101, C.R.S. et seq.) and the Federal Water Pollution Control Act, as amended (33 U.S.C. 1251 et seq.) for the discharge of stormwater associated with municipal separate storm sewer systems.

The Drainage Authority was created to pursue a jurisdictionally unified effort to promote integrated, comprehensive, regional stormwater management planning, while recognizing local requirements may have minor differences in policies, standards and criteria presented in this manual.

(b) **Drainage Planning and Required Space.**

All new development and redevelopment shall provide storm drainage planning that includes allocation of space for drainage facilities, construction and maintenance, and dedication of rights-of-way and/or easements.

(c) **Multi-Purpose Resource.**

Stormwater runoff is an integral part of Mesa County's and the City of Grand Junction's water resources and may have potential for beneficial uses, such as groundwater recharge, recreation, and wildlife habitat. These uses, however, must be compatible with adjacent land uses and applicable State water laws.

Stormwater runoff shall be considered an integral part of Mesa County's water resources.

(d) **Water Rights.**

A drainage design must be planned and constructed with recognition given to adjudicated water rights and applicable water laws.

The existence of adjudicated water rights and all applicable State laws related thereto shall be recognized in stormwater management plans.

(e) **Drainage Analysis Tributary Area.**

Stormwater runoff will follow pathways established by physical boundaries and not political or property boundaries. Therefore:

Any drainage analysis must consider all tributary area and the potential for future land use changes within the tributary area.

(Res. 40-08 (§ 402), 3-19-08)

§ 28.16.030. Regional and local planning.

(a) **Reasonable Use Rule.**

The *reasonable use rule* is defined for drainage planning purposes as permitting the use of an economic and hydraulically efficient drainage system which is demonstrated not to adversely impact downstream properties within reason. This reasonable use of drainage therefore allows development to occur while preserving the rights of adjacent property owners.

Stormwater discharges from new development and redevelopment shall be:

(1) Discharged to downstream properties within the pre-developed drainage path and in a manner and quantity and quality that approximates pre-developed conditions. If developed stormwater discharges occur in a more concentrated manner, then additional measures are required to protect downstream properties.

(2) Limited to pre-developed rates, unless downstream drainage facilities can accommodate increased flow rates from development and permission/easements are granted.

(Res. 40-08 (§ 403.1), 3-19-08)

§ 28.16.040. Regional master planning.

It is the intent of Mesa County and the other cooperating governmental entities to develop, adopt, and use Watershed Master Plans to identify stormwater requirements. Once adopted, these plans will be reviewed and updated regularly. When Watershed Master Plans are not available, then requirements in the Stormwater Management Manual will govern.

(Res. 40-08 (§ 403.2), 3-19-08)

§ 28.16.050. Drainage improvements.

Drainage facilities are categorized as part of either the major drainage system or the outfall system. Recommended public improvements to major drainage and outfall drainage systems are defined in Watershed Master Plans, if they exist. If a Master Plan does not exist, other information will be used to determine the scope of public improvements.

All new development and redevelopment shall participate in drainage improvements as set forth below:

(a) Outfall Drainage System.

(1) Design and construct that portion of the outfall drainage system, as defined by the approved final drainage report (Chapter 28.12 GJMC).

(2) If the outfall system is defined in a Watershed Master Plan, and traverses the development, the developer shall design and construct that portion of the outfall system within the development, in accordance with this manual.

(3) If the outfall system defined in a Watershed Master Plan does not traverse the development, but is required to convey stormwater from the development to the major drainageway, the developer shall design and construct that portion of the outfall system within the development, in accordance with this manual. The local jurisdiction may participate in the connection of the outfall to the major drainageway at their sole discretion.

(b) Major Drainage System.

(1) If new development (i.e., the placement of fill or structures) encroaches into a 100-year floodplain (whether mapped or not), the developer will be required to construct improvements as described in the Watershed Master Plan. If a Watershed Master Plan is not available, the developer shall have prepared a channel stabilization analysis, under the guidance of the local jurisdiction, to identify required improvements and shall implement the mitigation plan.

(2) Additional improvements to protect health, safety, and welfare may be required by the local jurisdiction if new development is within the vicinity of a 100-year floodplain, whether mapped or not. The developer may be required to participate in a channel stabilization analysis, under the guidance of the local jurisdiction, and may be required to participate in the implementation of the mitigation plan. For the purpose of this policy, "vicinity" shall mean any portion of the property that lies within a setback area defined by a slope of 10 feet horizontal to one foot vertical (10:1) from the channel invert to the point where the slope daylights.

(Res. 40-08 (§ 403.3), 3-19-08)

§ 28.16.060. Drainage fee calculation.

Fees may be collected by the local jurisdiction and used by the local jurisdiction solely for the planning, design and construction of drainage improvements to the outfall drainage system and major drainage systems.

When drainage fees are assessed for new development and redevelopment, the drainage fee will be determined based on the following equation:

$$\text{Drainage Fee} = B(CD - CH)A^{0.7} \quad (28.16\text{-}1)$$

where:	B	=	Fee constant (U.S. dollars, see local jurisdiction for value)
	CD	=	100-year runoff coefficient (expressed as a decimal) based on developed land use conditions
	CH	=	100-year runoff coefficient (expressed as a decimal) based on pre-developed land use conditions
	A	=	Area of development (acres)

(Res. 40-08 (§ 403.4), 3-19-08)

§ 28.16.070. Proposed drainage improvements.

All investigations, reports, and construction plans prepared for drainage improvements shall be submitted for review and acceptance before construction of said improvements, and shall be consistent with this Stormwater Management Manual and Watershed Master Plans.
(Res. 40-08 (§ 403.5), 3-19-08)

§ 28.16.080. Floodplain management.

Floodplains within Mesa County, Grand Junction, Fruita and Palisade shall be regulated in accordance with the provisions of the applicable land development/use code.
(Res. 40-08 (§ 403.6), 3-19-08)

§ 28.16.090. Storm runoff detention.

Since urban development can increase the rate, volume, duration, and frequency of stormwater runoff, measures must be implemented to avoid harm to downstream properties. Detention is considered a viable method to reduce development impacts and drainage costs. Temporarily detaining storm runoff can significantly reduce downstream flood hazards as well as reduce pipe and channel sizes in developed areas. Temporary storage also provides for sediment and debris collection which helps to maintain water quality in downstream channels and streams. However, detention may not be necessary where downstream drainage facilities have adequate capacity to convey runoff from fully developed upstream areas without negatively impacting downstream properties.

(a) **Detention Requirements.**

(1) ***On-site detention storage is required for all new development or redevelopment to limit 10-year peak stormwater discharges to the 10-year storm runoff based on pre-developed conditions. In addition to the 10-year detention, detention of the 100-year storm event and release at pre-developed rates will be required, if the capacity of the downstream drainage system will be exceeded. With local jurisdiction approval, detention may be considered for off-site flows draining to a site. See Chapter 28.56 GJMC for details.***

(2) ***A fee in lieu of detention may be required in lieu of on-site detention that is not required (see GJMC § 28.56.050 through 28.56.070). Granting fee in lieu of detention does not exempt the development from providing post-construction BMPs.***

(b) **Detention Exemption.**

At the sole discretion of the local jurisdiction, exemptions to on-site detention may be granted for the following conditions. Note that in all cases, post-construction BMPs are required:

(1) A development which discharges to a regional drainage facility is exempt provided the regional facility is completed in accordance with a Watershed Master Plan, the regional facility was designed to include runoff from the proposed development, and there is adequate conveyance capacity for the drainage system from the development to the regional facility.

(2) A development lying within the limits of a Watershed Master Plan which explicitly exempts on-site detention for development.

(3) A development which discharges to a local detention facility is exempt provided the local

detention is completed in accordance with the final drainage plan for the development and was designed to include runoff from the proposed development.

(4) A development which discharges to an outfall drainage system that has adequate conveyance capacity for the 100-year flood from a fully developed watershed.

(5) When it can be demonstrated that the peak flows from the development will not increase the peak flows from the watershed for storm events up to the 100-year flood. The burden of proof is on the developer to demonstrate this condition.

A fee in lieu of detention may be required in lieu of on-site detention that is not required.

(Res. 40-08 (§ 403.7), 3-19-08)

§ 28.16.100. Storm runoff retention.

Storm runoff retention or over-detention may be used when downstream drainage facilities lack adequate conveyance capacity or are essentially nonexistent and construction of an outfall drainage system is impractical.

Retention or over-detention may be used in those instances where there are severe limitations on the downstream conveyance capacity or where there is essentially no outfall or drainage system to convey storm runoff from the development. The acceptability of retention will be determined on a case-by-case basis.
(Res. 40-08 (§ 403.8), 3-19-08)

§ 28.16.110. Stormwater quality.

Studies by the Environmental Protection Agency (EPA) and others have shown that land disturbances due to construction activities and the resulting development decrease the quality of storm runoff. The CDPS stormwater discharge permit requires that construction activities and new development be controlled to minimize the discharge of pollutants to the maximum extent practicable. As such, it is recognized that construction sediment and erosion control, stream stabilization, and permanent best management practices (BMPs) are necessary to protect the quality of the waters of the State.

All significant development and redevelopment disturbing more than one acre within the urban areas of Mesa County shown on Figure 28.16.110 shall implement:

(a) Sediment and erosion control measures during construction activities;

(b) Stream stabilization measures for the major drainageways;

(c) Post-construction best management practices to control the discharge of pollutants to the municipal separate stormwater system (MS4).

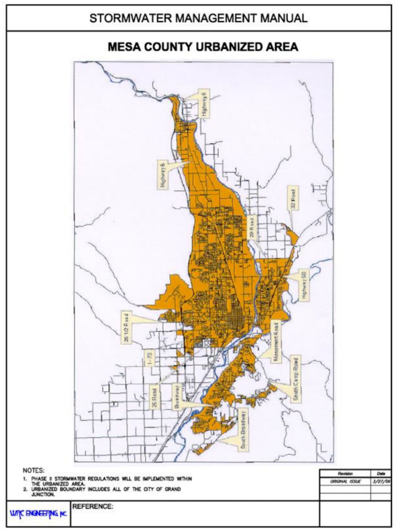


FIGURE 28.16.110

(Res. 40-08 (§ 403.9), 3-19-08)

§ 28.16.120. Drainage facilities maintenance.

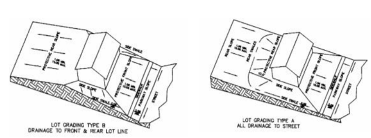
An important part of all storm drainage facilities is continued maintenance of the facilities to ensure they will function as designed. Maintenance of drainage facilities includes a number of routine tasks, such as removal of debris and sediment, and nonroutine tasks, such as restoring damaged structures.

All drainage facilities will be maintained to preserve their function, and shall:

(a) ***Be designed to minimize and facilitate maintenance.***

(b) ***Include access to the entire drainage facility by dedication of rights-of-way, easements and tracts of land specifically for drainage purposes. Tracts or easement dedications shall prohibit uses and the construction of permanent improvements that restrict or block access. Specifically, detention and retention basins in subdivisions shall be located in tracts owned by the property owners' association with an easement granted to the local jurisdiction. Basins for individual sites require neither a tract nor an easement but do require a maintenance agreement.***

(c) ***Be incorporated in the lot grading for residential development in conformance with FHA lot grading Type A (all drainage to street) or Type B (drainage to front and rear lot line). Typical FHA three dimension Type A and Type B grading plans are shown below:***



(d) Be maintained by the property owner, the developer and/or a homeowners' association. Should the property owner fail to adequately maintain drainage facilities, the right is reserved to enter the property, upon proper notice, for the purpose of performing drainage maintenance. All maintenance costs shall be assessed against the owner(s) of the property.

(e) Include v-pans (two-foot minimum width) or storm sewer systems with an inlet in each yard when the grading plan creates backyard swales (regardless of swale slope). These must be installed prior to curb and gutter installation. Check with local municipality to confirm this requirement.

(Res. 40-08 (§ 403.10), 3-19-08)

§ 28.16.130. Watershed transfer of storm runoff.

Drainage law recognizes the inequity of transferring the burden of managing storm drainage from one location or property to another. Liability questions also arise when the historic drainage continuum is altered. The diversion of storm runoff from one basin to another shall be avoided unless specific and prudent reasons justify and dictate such a transfer.

Stormwater diversion may be investigated during development of Watershed Master Plans and may be shown, in some instances, to be a viable option to address drainage and flooding problems. Tests for reasonableness of the potential transfer include:

(a) Determine where the runoff would go if the diversion system were to fail. If the flow stays in the historic basin, then the diversion may be reasonable.

(b) Determine if the downstream channel to which the drainage flows are being transferred is adequate to handle increased flows. If the channel has capacity, the diversion may be reasonable.

(c) Check condition where diversion fails during the major flood. If the downstream natural channel would have adequate capacity without adverse effects, the diversion may be reasonable.

(d) Determine if there would be any adverse water quality impact in either drainageway. If there is little or no impact, the diversion may be reasonable.

The development process can and will significantly alter the historic or natural drainage paths. When these alterations result in development outfall system that discharges back into the natural drainageway at or near the historic location, then the alterations (i.e., intra-basin transfer) are generally acceptable. However, when the subdivision outfall system does not return to the historic drainageway, an inter-basin transfer may result.

Inter-basin transfer as a drainage solution for new development is prohibited, unless allowed as a deviation/variance to this manual (see Chapter 28.08 GJMC) or as part of the Watershed Master Plan. During development of Watershed Master Plans where retrofit facilities are evaluated, inter-basin transfer may be a viable alternative in certain instances and will be reviewed on a case-by-case basis.

(Res. 40-08 (§ 403.11), 3-19-08)

§ 28.16.140. Technical criteria – Stormwater management technology.

All storm drainage facilities shall be planned and designed in accordance with this manual. Criteria in this manual may be revised or amended as new technology is developed and/or experience gained in the

use of these criteria. Exemptions to criteria and standards may be approved on a case-by-case basis.

Construction of any drainage facility not initiated within a two-year period from the time of construction plan approval must be reevaluated for approval and must receive re-approval.
(Res. 40-08 (§ 404.1), 3-19-08)

§ 28.16.150. Technical criteria – Design storm events.

All new development and redevelopment shall plan for, design and construct drainage facilities to convey storm runoff from the minor storm and major storm events. Emergency overflow paths for drainage may be required for storms greater than the 100-year flood event as evaluated on a case-by-case basis.

Analysis and design of all drainage improvements for new development and significant redevelopment shall be based on projected future land use conditions, in accordance with local jurisdictional requirements and plans, except as may be modified by adopted Watershed Master Plans.

Culverts for local categorized streets may be designed for a flood more frequent than the 100-year, subject to the following conditions:

(a) ***The overtopping of the roadway during the 100-year event is limited to depths no greater than one foot and the downstream embankment is protected from erosion during overtopping.***

(b) ***The culvert must pass the 10-year flood with a minimum of one foot of freeboard from the water surface to the lowest point in the roadway.***

(c) ***The water surface elevation during the 100-year flood shall not cause additional flooding of adjacent properties and shall be compliant with local floodplain regulations.***

All drainage systems shall be sized without accounting for peak flow reductions from on-site or local detention unless noted otherwise in the tables below. When required to size best management practices, the mean annual storm event shall be used.

A summary of requirements and design storms for the different types of stormwater facilities is presented in the following table.

STREETS	
Minor Storm	***Design Requirements***
2-year	***Flow depth ≤ 0.5 feet at gutter flow line***
	Flow depth ≤ top of curb
	Flow velocity ≤ 8.0 feet per second
Major Storm	***Design Requirements***
100-year	***Flow depth ≤ 1.0 foot at gutter flow line***
	Flow velocity ≤ 8.0 feet per second
	Freeboard ≥ 1.0 foot at all finished floor elevations

STORM DRAIN SYSTEMS	
Minor Storm	***Design Requirements***
2-year*	***Flow velocity between 2.5 and 15 feet per second***
	EGL must remain below manhole rims and inlet throats
Major Storm	***Design Requirements***
100-year*	***Flow velocity between 2.5 and 15 feet per second***
	EGL must remain below manhole rims and inlet throats
****These flow rates will be whatever the street inlets cumulatively accept during the two-year and 100-year storm events.***	

CULVERTS	
Minor Storm	***Design Requirements for Roadways with right-of-way ≤ 80 feet***
10-year †	***Freeboard ≥ 1.0 foot at lowest point of drive lane(s)***
	Approval of local jurisdiction to use minor storm design
Major Storm	***Design Requirements for Roadways with right-of-way ≤ 80 feet***
100-year †	***Overtopping ≤ 1.0 foot at crown of roadway***
	No additional flooding of adjacent properties
	Comply with all floodplain regulations
	Freeboard ≥ 1.0 foot at all finished floor elevations
	Design Requirements for Roadways with right-of-way ≥ 80 feet
	Flow depth ≤ 0.0 feet at crown of roadway
	Freeboard ≥ 1.0 foot at all finished floor elevations
†Design of culverts may consider the effects of detention.	

DETENTION/WATER QUALITY	
Water Quality	***Design Requirements***
WQCV	***Design is per Volume 3 of the USDCM (see Chapter 28.8 GJMC)***
Detention	
Minor Storm	***Design Requirements***
10-year	***Design volume is the detention volume plus the WQCV***
	Allowable release rates apply
Major Storm	***Design Requirements***
100-year	***Design volume is the detention volume (do not add WQCV)***

DETENTION/WATER QUALITY	
	Allowable release rates apply

(Res. 40-08 (§ 404.2), 3-19-08)

§ 28.16.160. Technical criteria – Storm runoff determination.

Storm runoff peaks and volumes for the design and evaluation of storm drainage facilities shall be determined using statistical analysis of recorded stream gage data, the rational method, or synthetic rainfall runoff models.
(Res. 40-08 (§ 404.3), 3-19-08)

§ 28.16.170. Technical criteria – Streets.

Streets and street rights-of-way may be used to convey storm runoff from the minor and major events, subject to limitations set forth in this manual.

Storm runoff is permitted to cross street crowns at intersections, subject to limitations set forth in this manual.

Storm runoff is permitted to cross street crowns at culverts and bridges, subject to limitations set forth in this manual.
(Res. 40-08 (§ 404.4), 3-19-08)

§ 28.16.180. Technical criteria – Flood proofing.

Flood proofing can be defined as those measures which reduce the potential for flood damages to properties within a floodplain. Measures can range from elevating structures to intentional flooding of noncritical building spaces (i.e., basement) to minimize structural damages.

Flood proofing is permitted in accordance with the provisions of the Mesa County Land Development Code. For other jurisdictions, contact the specific jurisdiction for specific guidance.
(Res. 40-08 (§ 404.5), 3-19-08)

§ 28.16.190. Technical criteria – Alluvial fans.

Alluvial fans, consisting of sand and fine sediment, are subject to radical changes in shape, direction, depth, and flow carrying capacity during storm events. These changes increase the potential flood hazards of developing on alluvial fan areas.

Additional analysis and specialized design is required for any development located within an active alluvial fan. Requirements for analysis and design will be determined on a case-by-case basis.
(Res. 40-08 (§ 404.6), 3-19-08)

§ 28.16.200. Irrigation facilities.

Irrigation conveyance facilities and reservoirs in the Mesa County area have historically intercepted the storm runoff from the rural and agricultural watersheds, generally without major problems. With urbanization of the watersheds, however, the storm runoff has increased in rate, quantity and frequency, as well as changing water quality. In developed areas, the irrigation facilities can no longer be utilized indiscriminately to convey storm runoff. New developments and redevelopment are prohibited from using

irrigation facilities to convey storm runoff, except as described below.
(Res. 40-08 (§ 405), 3-19-08)

§ 28.16.210. Irrigation facilities – Watershed analysis.

Drainage analysis and design shall be based on the assumption that an irrigation conveyance facility does not intercept storm runoff from the upper watershed and that the upper watershed is tributary to the watershed downstream of the irrigation conveyance facility, unless such irrigation conveyance facility has been designed to accommodate storm runoff and is part of an adopted Watershed Master Plan.
(Res. 40-08 (§ 405.1), 3-19-08)

§ 28.16.220. Irrigation facilities – Discharge to irrigation conveyance facility.

Storm runoff shall be directed into pre-developed drainageways downstream of the irrigation conveyance facility. Storm runoff shall not be discharged into an irrigation conveyance facility, except as required by water rights law or the discharge is part of an adopted Watershed Master Plan or negotiated with an irrigation company.

Where irrigation ditches will serve as the outfall for a detention facility, the ditch water surface elevation shall be determined for the maximum irrigation flow of the ditch, and the stormwater surface elevation shall be determined for the combination of the maximum irrigation flow and the 100-year stormwater discharge of the detention facility.
(Res. 40-08 (§ 405.2), 3-19-08)

§ 28.16.230. Irrigation facilities – Irrigation reservoirs.

New development is restricted to areas outside of:

(a) ***The reservoir's high water line created by the design flood for the emergency spillway.***

(b) ***The high water line created by the breach of a dam (except high hazard classified dams which have passed inspection by the State Engineer's Office in accordance with § 37-87-105, C.R.S. et seq.). For dams without the breach high waterline identified, the developer shall analyze and define the high waterline resulting from such a breach.***

(c) ***Existing or potential future emergency spillway paths, beginning at the dam and proceeding to the point where the flood water returns to the natural drainage course.***

(Res. 40-08 (§ 405.3), 3-19-08)

§ 28.16.240. Preservation of natural drainageways.

Natural drainageways are considered an important environmental feature that contributes to the image and livability of a community. Their value includes the ability to convey floodwater, to provide opportunities for trails and open space corridors, and to maintain natural vegetation and wildlife habitat to the greatest degree possible.

Preservation of natural drainageways, based on developed land use hydrology, is encouraged. Development of property shall not adversely affect any natural drainage facility or natural watercourse, and shall be subject to the following provisions:

(a) ***Drainageways shall remain in as near a natural state as is practicable. All proposed modification to the natural drainageway shall be subject to approval.***

(b) ***When the flow rates, velocities, side slopes or other characteristics indicate a potential negative impact to the natural drainageway, the impact shall be mitigated in accordance with criteria set forth in this manual.***

(Res. 40-08 (§ 406), 3-19-08)

CHAPTER 28.20
(Reserved)

CHAPTER 28.24
Rainfall

§ 28.24.010. Introduction.

Presented in this chapter are design rainfall data for the mean annual, minor, and major storm events. These data are used to determine storm runoff peak flows and volumes in conjunction with the runoff models described in Chapter 28.28 GJMC. All hydrologic analyses within the jurisdiction of this manual shall utilize the rainfall data presented herein for calculating storm runoff.
(Res. 40-08 (§ 601), 3-19-08)

§ 28.24.020. Data sources.

Rainfall data is presented for three areas within Mesa County, the Grand Valley, as approximately defined by the area below 5,000 feet in elevation, area outside the Grand Valley, and the Leach Creek/Horizon Drive watersheds.

(a) **Rainfall Data – Grand Valley Area.**

The rainfall data for the Grand Valley was obtained from the Henz Meteorological Services report prepared for Mesa County (Henz, 1992), which included a detailed analysis of the gage at Walker Field. Tables, figures, and equations are provided for point rainfall, intensity, and storm distributions for various storm recurrence intervals.

(b) **Rainfall Data – Outside Grand Valley.**

For the area outside of the Grand Valley, rainfall data published by the National Oceanic and Atmospheric Administration (NOAA) in the NOAA Atlas 2, “Precipitation – Frequency Atlas of the Western United States, Volume III – Colorado” (NOAA, 1973) is recommended to develop point rainfall values, storm intensities, and distributions for the remainder of Mesa County. Procedures to obtain and interpret the data are provided herein.

(c) **Rainfall Data – Both Areas.**

In the case where a watershed includes both areas (or areas outside of Mesa County), it is recommended that both sets of rainfall data be used to generate peak runoff rates and volumes, depending on which area the sub-watershed lies within. In addition, if point rainfall values from NOAA Atlas 2 vary throughout the watershed by more than 10 percent, the rainfall values used for analysis should also vary depending on where the sub-watershed lies.

(d) **Rainfall Data – Leach Creek/Horizon Drive Watershed.**

For projects within the Leach Creek/Horizon Drive watershed (see Figure 28.24.020), the depth-duration-frequency data approved by FEMA (FEMA October 1, 2002) are recommended because these data were used for floodplain analysis and for design purposes. However, since the FEMA-approved data did not include all durations and frequencies, and since the Henz data are similar, the Henz data was used to supplement the FEMA data.

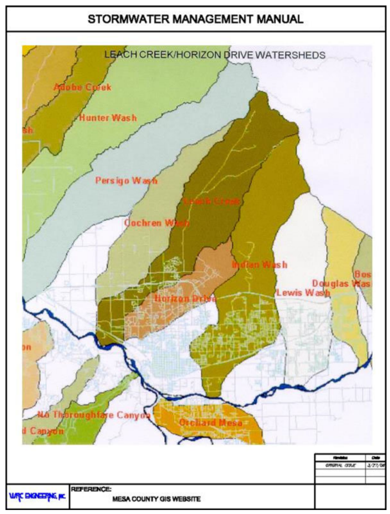
(e) **Mean Annual Precipitation.**

Mean annual precipitation and mean annual storm events for design of water quality BMPs were obtained from Driscoll (Driscoll et al., November 1989). *Analysis of Storm Event Characteristics for Selected Rainfall Gages Throughout the United States,* EPA 8919148B 1100). These values are based on recording gage number 3488 and can be used throughout Mesa County.

(f) **Probable Maximum Precipitation.**

In cases where probable maximum precipitation analyses are required, methodology outlined in a publication by NOAA and the USACE entitled "Hydrometeorological Report No. 49, Probable Maximum Precipitation Estimates, Colorado River and Great Basin Drainages" (NOAA and USACE, 1977) is recommended.

Figure 28.24.020: Leach Creek/Horizon Drive Watersheds



(Res. 40-08 (§ 601.1), 3-19-08)

§ 28.24.030. Comparison to NOAA Atlas 14.

The National Weather Service (NWS) has updated the precipitation-frequency atlas for the semiarid, southwestern region of the United States (including the Mesa County area) from NOAA Atlas 2 to NOAA Atlas 14. A comparison was made for the 100- and two-year storms for durations of six- and 24-hour between NOAA Atlas 2 and NOAA Atlas 14.

The comparison shows that NOAA Atlas 14 is generally lower than NOAA Atlas 2 (i.e., from four to 16 percent in the Grand Valley and from zero to 46 percent in the mountains). NOAA Atlas 14 does appear to be more consistent with the data developed by Henz for the Grand Valley area. However, since NOAA Atlas 14 has not been accepted by the Colorado Water Conservation Board, precipitation values for areas outside of the Grand Valley were not obtained from NOAA Atlas 14, but were obtained from NOAA Atlas 2. When preparing Watershed Master Plans, the County will evaluate whether NOAA Atlas 14 values are more appropriate and may decide to use NOAA Atlas 14. For new developments and redevelopment, rainfall/runoff relationships shall be in accordance with GJMC § 28.24.020.
(Res. 40-08 (§ 601.2), 3-19-08)

§ 28.24.040. Rainfall analysis – Rainfall depth – Duration – Frequency.

For areas within the Grand Valley, point precipitation values are provided in Table 28.24.040(a) for various recurrence interval storms. These data were used to develop intensity-duration-frequency values and are used in developing storm distributions.

Table 28.24.040(a): Point Rainfall Values for the Grand Valley Area

Storm Duration	Precipitation Depth (inches)					
	2-year Recurrence	5-year Recurrence	10-year Recurrence	25-year Recurrence	50-year Recurrence	100-year Recurrence
5-min	0.1	0.14	0.18	0.25	0.31	0.39
10-min	0.15	0.22	0.28	0.38	0.48	0.6
15-min	0.19	0.28	0.36	0.48	0.61	0.76
30-min	0.27	0.39	0.5	0.67	0.85	1.06
1-hr	0.34	0.49	0.63	0.85	1.07	1.34
2-hr	0.42	0.58	0.72	0.94	1.15	1.4
3-hr	0.47	0.63	0.77	0.99	1.19	1.44
6-hr	0.55	0.73	0.87	1.1	1.31	1.56
12-hr	0.55	0.83	0.98	1.22	1.44	1.69
24-hr	0.7	0.93	1.12	1.42	1.69	2.01

For the area outside of the Grand Valley, the NOAA Atlas 2 Rainfall Depth-Duration-Frequency Maps are reproduced for the Mesa County area in Figures 28.24.040(a) through (l). Maps are presented for the six- and 24-hour durations for the two-, five-, 10-, 25-, 50-, and 100-year recurrence intervals. Depending on the location of the project, point rainfall values are read from these figures, converted to other storm durations, and used to generate intensity-duration-frequency curves and design storms, following procedures described below.

For the areas within the Leach Creek/Horizon Drive watershed, point precipitation values are provided in Table 28.24.040(b) for various frequencies and durations.

Table 28.24.040(b): Point Rainfall Values for the Leach Creek/Horizon Drive Watershed

Storm Duration	Precipitation Depth (inches)					
	2-year Recurrence	5-year Recurrence	10-year Recurrence	25-year Recurrence	50-year Recurrence	100-year Recurrence
5-min	0.1	0.14	0.18	0.25	0.31	0.39
10-min	0.15	0.22	0.28	0.38	0.48	0.6
15-min	0.19	0.28	0.36	0.48	0.61	0.76
30-min	0.27	0.39	0.5	0.67	0.85	1.06

Table 28.24.040(b): Point Rainfall Values for the Leach Creek/Horizon Drive Watershed						
Storm Duration	**Precipitation Depth (inches)**					
	2-year Recurrence	**5-year Recurrence**	**10-year Recurrence**	**25-year Recurrence**	**50-year Recurrence**	**100-year Recurrence**
1-hr	*0.29*	*0.41*	*0.52*	0.85	*0.86*	*1.07*
2-hr	0.42	0.58	0.72	0.94	1.15	1.4
3-hr	*0.46*	*0.63*	*0.78*	0.99	*1.24*	*1.52*
6-hr	*0.55*	*0.72*	*0.86*	1.1	*1.28*	*1.52*
12-hr	*0.67*	*0.85*	*0.99*	1.22	*1.39*	*1.61*
24-hr	*0.79*	*1.01*	*1.19*	1.42	*1.71*	*1.99*

NOTE: The *italicized* values are the actual FEMA-approved data. The remaining data was obtained from Table 28.24.040(a).

Figure 28.24.040(a): Rainfall Depth-Duration-Frequency: 2-Year, 6-Hour

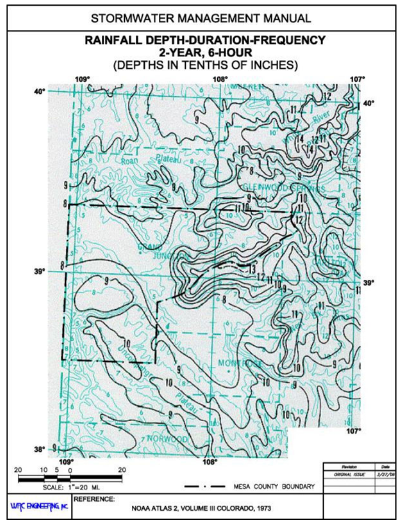


Figure 28.24.040(b): Rainfall Depth-Duration-Frequency: 5-Year, 6-Hour

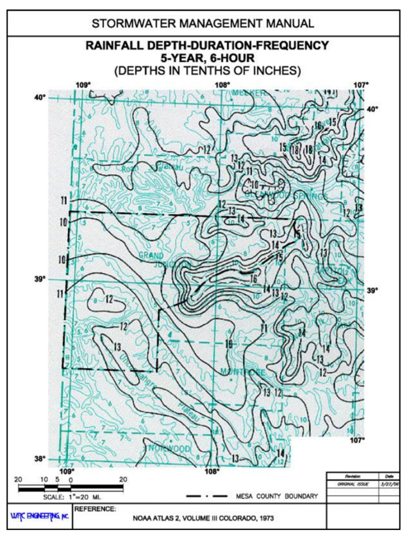


Figure 28.24.040(c): Rainfall Depth-Duration-Frequency: 10-Year, 6-Hour

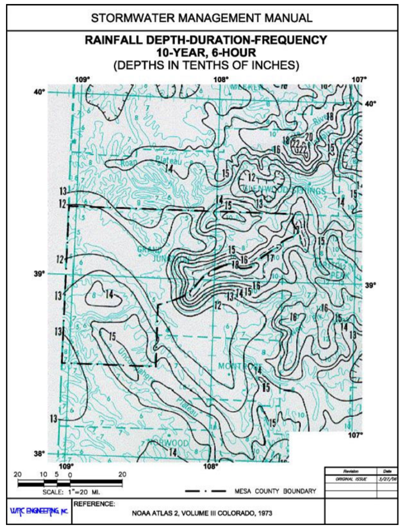


Figure 28.24.040(d): Rainfall Depth-Duration-Frequency: 25-Year, 6-Hour

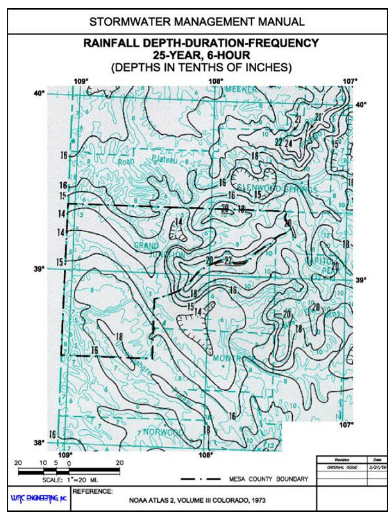


Figure 28.24.040(e): Rainfall Depth-Duration-Frequency: 50-Year, 6-Hour

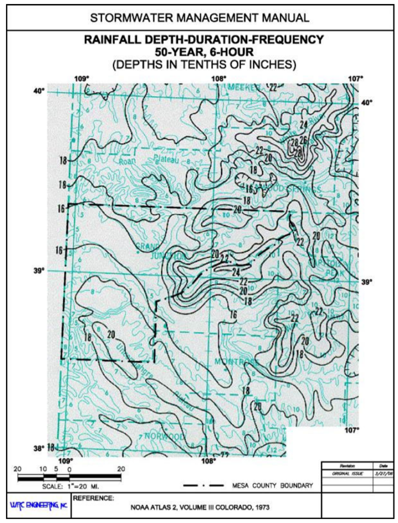


Figure 28.24.040(f): Rainfall Depth-Duration-Frequency: 100-Year, 6-Hour

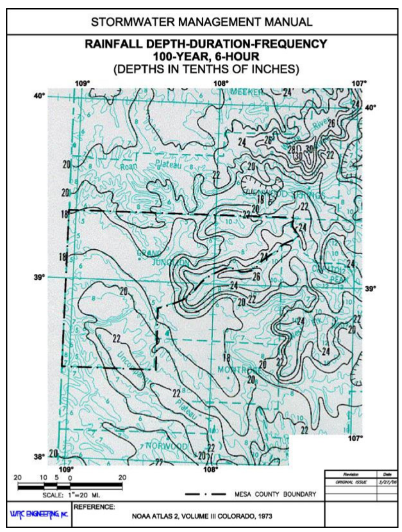


Figure 28.24.040(g): Rainfall Depth-Duration-Frequency: 2-Year, 24-Hour

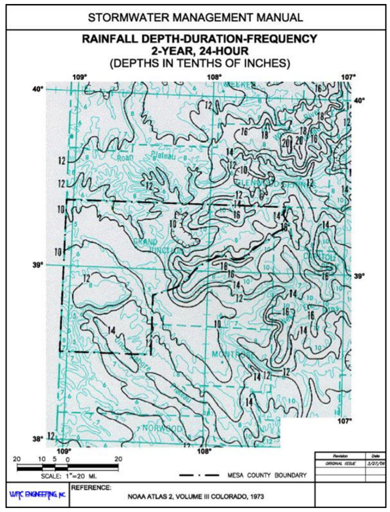


Figure 28.24.040(h): Rainfall Depth-Duration-Frequency: 5-Year, 24-Hour

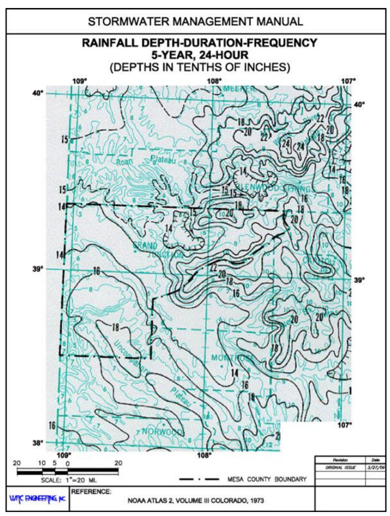


Figure 28.24.040(i): Rainfall Depth-Duration-Frequency: 10-Year, 24-Hour

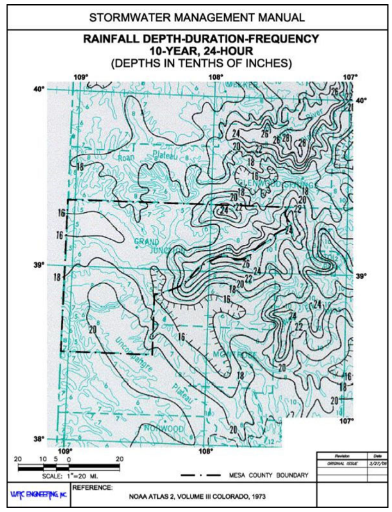


Figure 28.24.040(j): Rainfall Depth-Duration-Frequency: 25-Year, 24-Hour

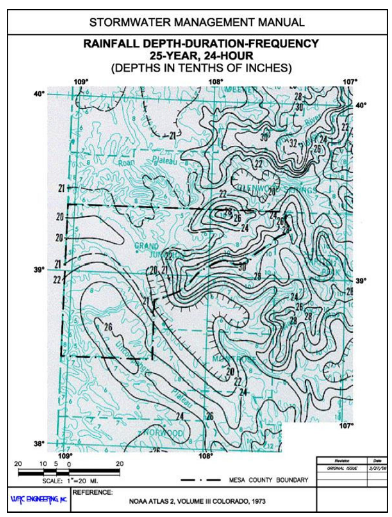


Figure 28.24.040(k): Rainfall Depth-Duration-Frequency: 50-Year, 24-Hour

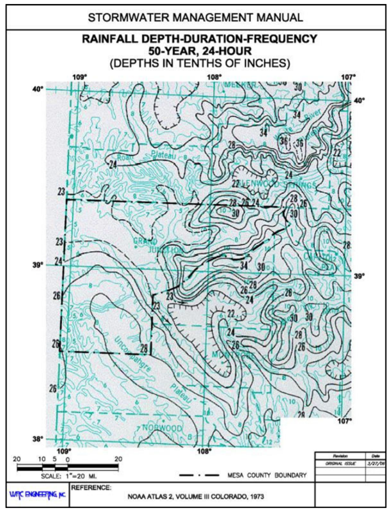
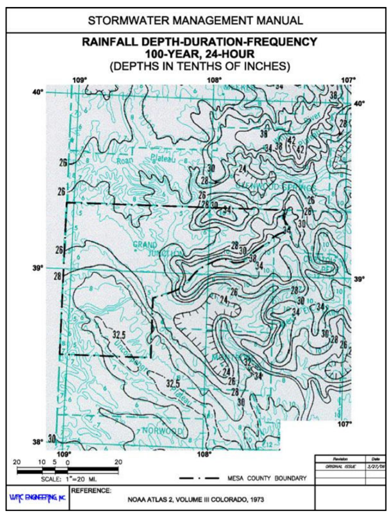


Figure 28.24.040(l): Rainfall Depth-Duration-Frequency: 100-Year, 24-Hour



(Res. 40-08 (§ 602.1), 3-19-08)

§ 28.24.050. Rainfall analysis – Rainfall depths for durations from one to six hours and less than one hour.

For areas within Grand Valley, point rainfall values for different storm durations are obtained from Table 28.24.040(a).

For areas outside the Grand Valley, the rainfall values are determined using procedures recommended in NOAA Atlas 2 and summarized below:

(a) **Step 1.**

Read and record the point rainfall values for the six- and the 24-hour durations obtained from Figures

28.24.040(a) through (l) for the two- and 100-year recurrence intervals at the desired location(s) within Mesa County.

(b) **Step 2.**

Calculate the two-year, one-hour and 100-year, one-hour rainfall amounts using the following equations:

$$Y2 = 0.011 + 0.942 [(x1) (x1 / x2)] \quad (28.24\text{-}1)$$

$$Y100 = 0.494 + 0.755 [(x3) (x3 / x4)] \quad (28.24\text{-}2)$$

Where:

Y2 = 2-yr, 1-hr estimated value (in)

Y100 = 100-yr, 1-hr estimated value (in)

x1 = 2-yr, 6-hr value (in)

x2 = 2-yr, 24-hr value (in)

x3 = 100-yr, 6-hr value from (in)

x4 = 100-yr, 24-hr value from (in)

(c) **Step 3.**

Plot the two- and 100-year, one-hour rainfall (Y2 and Y100) values on Figure 28.24.050 and draw a straight line connecting these points. The one-hour point rainfall values for the five-, 10-, 25-, and 50-year storm events are then read from the graph.

(d) **Step 4.**

Calculate the two- and three-hour duration rainfall for the various recurrence intervals using the following equations:

$$P2\text{-}hr = 0.341\ P6\text{-}hr + 0.659\ P1\text{-}hr \quad (28.24\text{-}3)$$

$$P3\text{-}hr = 0.569\ P6\text{-}hr + 0.431\ P1\text{-}hr \quad (28.24\text{-}4)$$

Where:

P 2-hr = 2-hr ‘x’-yr estimated value (in)

P 3-hr = 3-hr ‘x’-yr estimated value (in)

P 1-hr = 1-hr ‘x’-yr previously determined (in)

P 6-hr = 6-hr ‘x’-yr previously determined (in)

(e) **Step 5.**

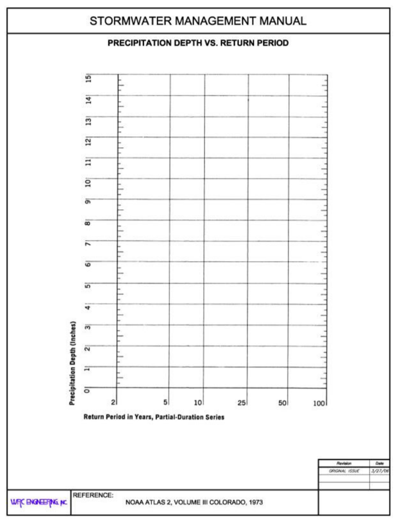
Calculate the point rainfall values for durations less than one hour by multiplying the one-hour precipitation depths by the factors listed in Table 28.24.050:

Table 28.24.050: Factors for Durations of Less Than One Hour					
Duration (min)	5	10	15	30	60
Ratio to 1 hour	0.29	0.45	0.57	0.79	1

The results from the steps above will result in a table of point rainfall values for the project area, similar to Table 28.24.040(a). These data can then be adjusted for the size of the watershed if needed (see GJMC § 28.24.070) and used to develop intensity-duration-frequency curves (see GJMC § 28.24.080) design storm (see GJMC § 28.24.090).

For areas within the Leach Creek/Horizon Drive watershed, point rainfall values for different storm durations are obtained from Table 28.24.040(b).

Figure 28.24.050: Precipitation Depth Versus Return Period



(Res. 40-08 (§ 602.2), 3-19-08)

§ 28.24.060. Rainfall analysis – Mean annual precipitation and storm events.

For analysis and design of water quality BMPs, the mean annual precipitation and storm events are used, which are summarized below:

Table 28.24.060: Mean Storm Statistics		
	Average	**Coefficient of Variation**
Annual Statistics		
No. of Storms	25	0.27
Precipitation (in/year)	6.76	0.35

Table 28.24.060: Mean Storm Statistics

	Average	Coefficient of Variation
Independent Storm Events		
Duration (hr)	9.4	0.73
Intensity (in/hr)	0.044	1.15
Volume (in)	0.28	0.7
Interval (hr)	370	1.21

Note that the coefficient of variation is defined as the ratio of the standard deviation to the mean.
(Res. 40-08 (§ 602.3), 3-19-08)

§ 28.24.070. Depth-area reduction factors.

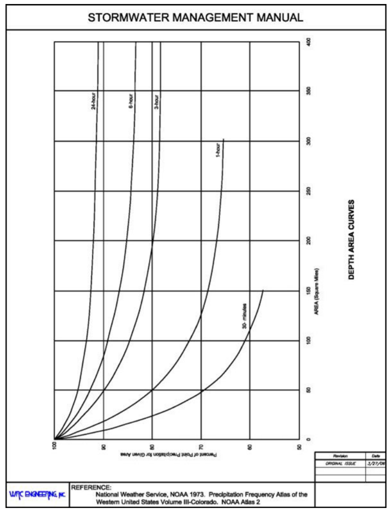
The area adjustment to the point rainfall values described below applies to both the Grand Valley area and areas outside of the Grand Valley. In general, watersheds of less than 10 square miles do not require adjustment.

The NOAA Atlas 2 precipitation depths are related to rainfall frequency at an isolated point. Storms, however, cause rainfall to occur over extensive areas simultaneously, with more intense rainfall typically occurring near the center of the storm. Standard precipitation analysis methods require adjusting point precipitation depths downward to estimate the average depth of rainfall over the entire storm area. This is normally performed using depth-area reduction curves relating to a point precipitation reduction factor to storm area and duration.

The depth-area reduction factors used for rainfall analysis in the Mesa County area are provided in Figure 28.24.070.

For areas greater than 200 square miles, the ability of the thunderstorm generating mechanisms (i.e., available moisture, strong convective currents, etc.) to sustain a thunderstorm much greater than 200 square miles in diameter is greatly reduced. Therefore, only a portion of an entire drainage basin could be subject to precipitation from the thunderstorm event. Analysis of this effect on runoff peaks and volumes is complicated by the necessity to determine the “storm centering” which produces the greatest peak flow and/or volume at the selected design point. In order to obtain a consistent method of analysis for these areas, the designer shall consult with the director to determine the appropriate method of analysis and design rainfall area reduction factors for the specific location and basin under study.

Figure 28.24.070: Depth-Area Curves



(Res. 40-08 (§ 603), 3-19-08)

§ 28.24.080. Intensity-duration-frequency curves for rational method.

For areas within the Grand Valley Area, rainfall intensities as a function of storm duration and recurrence interval are provided in Table 28.24.080 and Figure 28.24.080. These data were derived from the investigation by Henz Meteorological Services (Henz 1992).

Table 28.24.080: Intensity-Duration-Frequency Data for Grand Valley						
	Precipitation Intensity – Grand Valley Area (inches/hour)					
Storm Duration	2-Year Recurrence	5-Year Recurrence	10-Year Recurrence	25-Year Recurrence	50-Year Recurrence	100-Year Recurrence
5	1.2	1.68	2.16	3	3.72	4.68
10	0.9	1.32	1.68	2.28	2.88	3.6
15	0.76	1.12	1.44	1.92	2.44	3.04
30	0.54	0.78	1	1.34	1.7	2.12
60	0.34	0.49	0.63	0.85	1.07	1.34

Intensity values for any time of concentration up to 60 minutes can also be determined from the following equation (Froehlich 1995):

$$Ix = a*P1/(10+Tc)^{b}$$

Where:

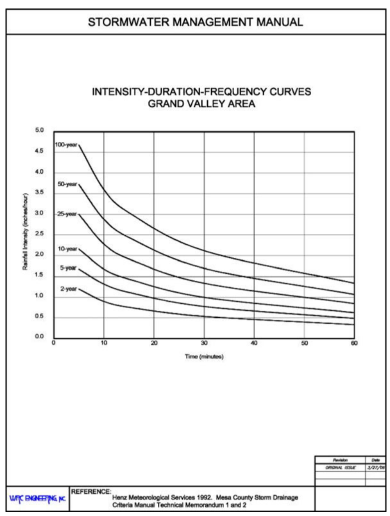
Ix	=	Intensity for recurrence interval "x," in/hour
P1	=	Point rainfall value for one-hour duration (see Table 28.24.040(a)) (inches)
Tc	=	Time of concentration, minutes
a, b	=	coefficients, a = 28.9, b = 0.786 for all of Mesa County

Using the coefficients above, this equation will generally match the values in Table 28.24.040(a) to within two percent. Whereas the coefficients have not been verified for areas outside the Grand Valley, since the equation is based on the same ratios provided in Table 28.24.040(b), the results will be comparable.

For areas outside of the Grand Valley, first determine the two- and 24-hour point rainfall values for the desired storm recurrence intervals, then determine the one-hour point rainfall value, as described in GJMC § 28.24.050. Finally, use the above equation to compute the intensity at any time of concentration and for all storm recurrence intervals.

For areas within the Leach Creek/Horizon Drive watershed, determine the two- and 24-hour point rainfall from Table 28.24.040(b), and then follow the procedures described above.

Figure 28.24.080: Intensity-Duration-Frequency Curves – Grand Valley Area



(Res. 40-08 (§ 604), 3-19-08)

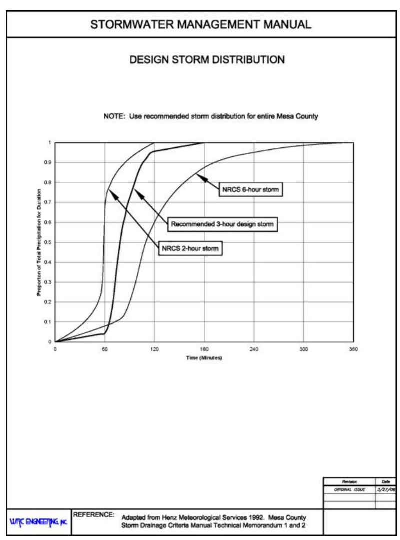
§ 28.24.090. Design storms.

For hydrograph analysis, the recommended minimum design storm duration is three-hour (Henz 1992). Approximately 90 percent of the three-hour total rainfall is distributed within the second hour of the storm, in accordance with recommendations of Henz (Henz 1992). The remaining 10 percent of the storm total is divided equally between the first and third hour.

An example of this distribution is provided in Table 28.24.090 and on Figure 28.24.090, which also compares the recommended design storm to the NRCS two- and six-hour distributions. As can be seen from the figure, the recommended storm is more severe in that 90 percent of the total precipitation occurs in a one-hour period compared to 80 percent for the NRCS two-hour and a little more than 50 percent for the NRCS six-hour event.

Table 28.24.090: Design Rainfall Distribution					
Duration (minutes)	Cumulative Proportion of 3-Hour Precipitation	Duration (minutes)	Cumulative Proportion of 3-Hour Precipitation	Duration (minutes)	Cumulative Proportion of 3-Hour Precipitation
5	0.004	65	0.089	125	0.96
10	0.007	70	0.199	130	0.964
15	0.011	75	0.391	135	0.967
20	0.015	80	0.546	140	0.971
25	0.018	85	0.642	145	0.974
30	0.022	90	0.728	150	0.978
35	0.026	95	0.792	155	0.982
40	0.029	100	0.847	160	0.985
45	0.033	105	0.892	165	0.989
50	0.036	110	0.929	170	0.993
55	0.04	115	0.947	175	0.996
60	0.044	120	0.956	180	1

Figure 28.24.090: Design Storm Distribution



(Res. 40-08 (§ 605), 3-19-08)

CHAPTER 28.28
Storm Runoff

§ 28.28.010. Introduction.

For the area within the jurisdiction of this manual, two deterministic hydrological models can be used to estimate storm runoff, rational formula and the SCS unit hydrograph method. The techniques for these methods are presented in this chapter.

The rational and SCS unit hydrograph methods require the user to determine watershed characteristics (i.e., area, length, slope, imperviousness, etc.) and the characteristic response time for the watershed (time of concentration). The SCS unit hydrograph method also requires calculation of the precipitation losses. Procedures for these parameters are presented first, followed by specific requirements for each method.

For certain circumstances, where adequate recorded stream flow data are available and the watershed area is large (greater than 10 square miles), a statistical analysis may be required to predict the storm runoff peaks or for calibration of deterministic models.
(Res. 40-08 (§ 701), 3-19-08)

§ 28.28.020. Watershed characteristics.

The watershed characteristics needed for the runoff computation methods include the watershed area, the various flow path lengths, slopes, and surface conditions (i.e., overland, grassed channel, gutter), soil infiltration rates, and land use or imperviousness.

(a) **Physical Features.**

Watershed boundaries and areas can be determined from topographic maps, but a field investigation is recommended to verify boundaries. Land use and flow path characteristics can be obtained from zoning maps, aerial photographs, field investigations, or detailed topographic maps. Soil characteristics can be determined from NRCS (formerly SCS) soil reports for Mesa County.

(b) **Watershed Imperviousness.**

Imperviousness, Imp, is a basic characteristic that is a direct measure of the watershed’s potential to produce storm runoff in terms of peak rates and total runoff volume. It is also a predictive indicator of watershed response to urbanization and the subsequent impact on stream stabilization and water quality.

Imperviousness is used in the rational method to derive the runoff coefficient and can be used in the SCS unit hydrograph method to derive runoff curve number. Imperviousness is typically determined in one of two ways, either by identification of watershed surface conditions (i.e., natural ground versus hard surfaces) and direct computation or by characterization of the land uses (i.e., undeveloped, residential, commercial, industrial) which have typical values of imperviousness.

Recommended impervious values for surface conditions and for typical land use types are provided in Table 28.28.020. The more precise approach is to divide the watershed into pervious and impervious surfaces and then compute the overall imperviousness directly, which is the required method for determining imperviousness for new development. This approach can be used when aerial photographs or detailed development plans (i.e., for planned unit developments) are available, or field investigations of existing conditions are performed.

When this information is not available or for projecting watershed imperviousness for future land uses, then typical imperviousness values from Table 28.28.020 are used. For single-family residential development when the housing density (i.e., units per acre) and the size and type of housing (i.e., ranch, split level, and two-story) can be determined, then the use of Figures 28.28.020(a), 28.28.020(b) and 28.28.020(c) is recommended. These figures are indicative of the existing development trend to place larger houses, including driveways, walks, patios, and outbuildings, on smaller lots. However, imperviousness values have also been found to be representative of older developments with small lots where additional impervious surfaces were added over time.

Note that in undeveloped areas that are to remain undeveloped, two percent imperviousness may be used for all areas that have soil and vegetative cover. However, these undeveloped areas often have significant geological features such as rock outcroppings that must be accounted for by calculating a composite imperviousness for these basins. Rock outcroppings are typically assigned an imperviousness of 100 percent for these calculations.

STORMWATER MANAGEMENT MANUAL

RECOMMENDED IMPERVIOUSNESS VALUES

Land Use or Surface Characteristic	Percentage Imperviousness
Business	
Commercial Areas	85
Neighborhood Areas	70
Residential	
Single Family	(see figures)
Multi-unit (detached)	60
Multi-unit (attached)	75
Half-acre lot or larger	(see figures)
Apartments	80
Industrial	
Light industrial	80
Heavy industrial	90
Parks, cemeteries	5
Playgrounds	10
Schools	50
Railroad yards	15
Undeveloped Areas	
Historic flow analysis	2
Greenbelts, agriculture	2
Off-site flow analysis (when land use not defined)	45
Streets	
Paved (concrete/asphalt)	100
Gravel	40
Drives and walks	90
Roofs	90
Lawns (all soils)	0

NOTES:
1. The imperviousness values are representative of land uses shown and are for future development projections only. Impervious values for existing land uses may vary.
2. For areas that will not be developed, 2% imperviousness is an appropriate assumption where soil and vegetative cover are present. Areas with geological features, including significant rock outcroppings, need to be accounted for. See GJMC 26.28.020(b).

Revision	Date
ORIGINAL ISSUE	3/27/06
CHANGED BUS. VALUES	12/6/07
ADDED NOTE 2	1/25/08

WRC ENGINEERING INC.

REFERENCE:
UDFCD 2001. Urban Storm Drainage Criteria Manual, Volume 1 (revised)

TABLE 28.28.020

Figure 28.28.020(a): Watershed Imperviousness, Single-Family Residential Ranch Style House

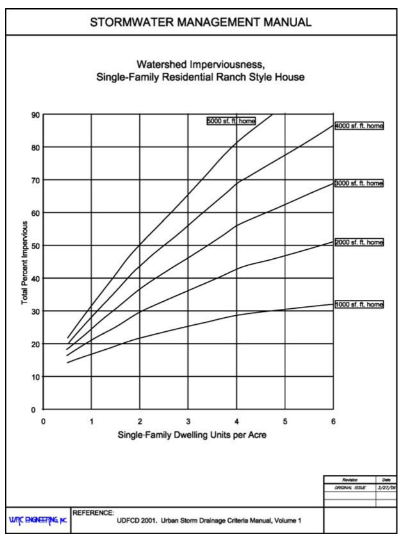


Figure 28.28.020(b): Watershed Imperviousness, Single-Family Residential Split Level House

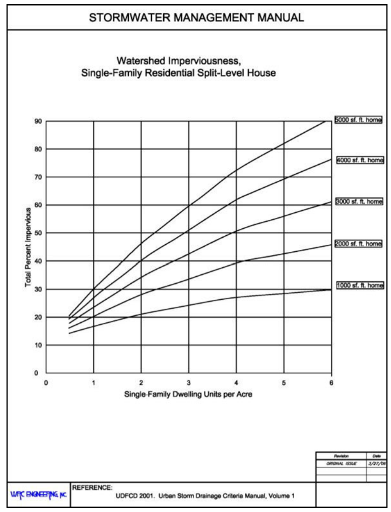
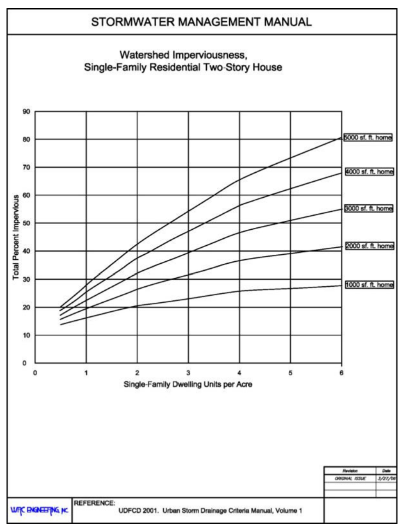


Figure 28.28.020(c): Watershed Imperviousness, Single-Family Residential Two-Story House



(Res. 40-08 (§ 702), 3-19-08)

§ 28.28.030. Time of concentration.

The time of concentration, tc, is the time required for runoff to flow from the most remote part of the watershed area to the point of interest. For the rational formula, the time of concentration is calculated so that the average rainfall rate for a corresponding duration can be determined from the rainfall intensity-duration-frequency curves. For the SCS unit hydrograph methods, the time of concentration is used to determine the time-to-peak, tp, of the unit hydrograph and subsequently, the peak runoff.

For consistency between runoff analyses, the time of concentration equations presented in this chapter shall be used for all small watershed (less than 1.0 square miles) runoff calculations. For large watershed calculations, the watershed lag equation for the SCS unit hydrograph method is recommended (see GJMC

§ 28.28.110(c)).

Time of concentration consists of an initial time or overland flow time, ti, plus travel time, tt, which is in a combined form. In both urban and nonurban environments, the initial or overland flow is assumed to occur as sheet flow and as a function of surface type and slope, with an upper limit on the distance which this type of flow can occur.
(Res. 40-08 (§ 703), 3-19-08)

§ 28.28.040. Nonurbanized watersheds.

For nonurban areas, the travel time occurs in a combined form, such as a small swale, channel, or wash. In urban areas, the travel time occurs in a combined form, such as in the storm drain, paved gutter, roadside drainage ditch, or drainage channel. Travel time can be estimated from the hydraulic properties of the storm drain, gutter, swale, ditch, or wash. Initial time, on the other hand, will vary with surface slope, depression storage, surface cover, antecedent rainfall, and infiltration capacity of the soil, as well as distance of surface flow.

The time of concentration for both urban and nonurban areas is calculated as follows:

$$tc = ti + tt \qquad (28.28\text{-}1)$$

Where:

tc	=	Time of concentration (min)
ti	=	Initial, inlet, or overland flow time (min)
tt	=	Travel time in the ditch, channel, gutter, storm drain, etc. (min)

Standard Form No. 2 has been developed to organize the calculation of tc.

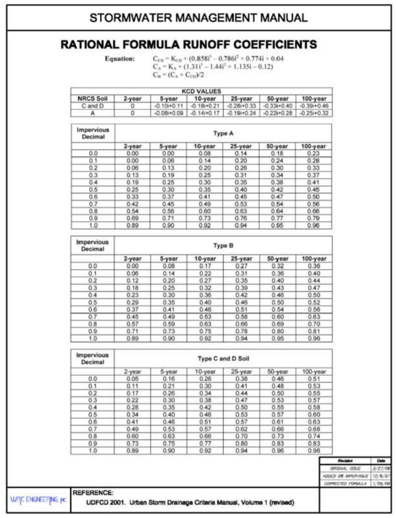
The initial or overland flow time, ti, may be calculated using the following equation:

$$ti = 1.8\,(1.1 - K)\,Lo^{1/2} / S^{1/3} \qquad (28.28\text{-}2)$$

Where:

ti	=	Initial or overland flow time (min)
K	=	Flow resistance coefficient
Lo	=	Length of overland flow (feet, 300-foot maximum)
S	=	Average watershed slope (percent)

Equation 28.28-2 was originally developed by the Federal Aviation Administration (FAA, 1970) for use with the rational formula method. However, the equation is also valid for computation of the initial or overland flow time for the SCS unit hydrograph method. The five-year runoff coefficient, C5, presented in Table 28.28.040(a) is recommended for the flow resistance coefficient, K.



STORMWATER MANAGEMENT MANUAL

RATIONAL FORMULA RUNOFF COEFFICIENTS

Equation:
$$C_{CD} = K_{CD} + (0.858i^3 - 0.786i^2 + 0.774i + 0.04$$
$$C_A = K_A + (1.31i^3 - 1.44i^2 + 1.135i - 0.12)$$
$$C_B = (C_A + C_{CD})/2$$

KCD VALUES						
NRCS Soil	2-year	5-year	10-year	25-year	50-year	100-year
C and D	0	-0.10i+0.11	-0.18i+0.21	-0.28i+0.33	-0.33i+0.40	-0.39i+0.46
A	0	-0.08i+0.09	-0.14i+0.17	-0.19i+0.24	-0.22i+0.28	-0.25i+0.32

Impervious Decimal	Type A					
	2-year	5-year	10-year	25-year	50-year	100-year
0.0	0.00	0.00	0.08	0.14	0.18	0.23
0.1	0.00	0.06	0.14	0.20	0.24	0.28
0.2	0.06	0.13	0.20	0.26	0.30	0.33
0.3	0.13	0.19	0.25	0.31	0.34	0.37
0.4	0.19	0.25	0.30	0.35	0.38	0.41
0.5	0.25	0.30	0.35	0.40	0.42	0.45
0.6	0.33	0.37	0.41	0.45	0.47	0.50
0.7	0.42	0.45	0.49	0.53	0.54	0.56
0.8	0.54	0.56	0.60	0.63	0.64	0.66
0.9	0.69	0.71	0.73	0.76	0.77	0.79
1.0	0.89	0.90	0.92	0.94	0.95	0.96

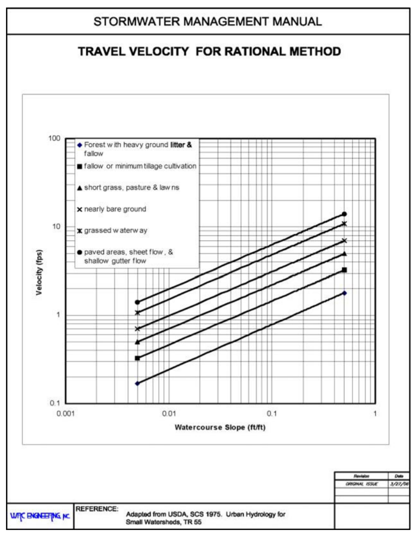
Impervious Decimal	Type B					
	2-year	5-year	10-year	25-year	50-year	100-year
0.0	0.00	0.08	0.17	0.27	0.32	0.36
0.1	0.06	0.14	0.22	0.31	0.36	0.40
0.2	0.12	0.20	0.27	0.35	0.40	0.44
0.3	0.18	0.25	0.32	0.39	0.43	0.47
0.4	0.23	0.30	0.36	0.42	0.46	0.50
0.5	0.29	0.35	0.40	0.46	0.50	0.52
0.6	0.37	0.41	0.46	0.51	0.54	0.56
0.7	0.45	0.49	0.53	0.58	0.60	0.63
0.8	0.57	0.59	0.63	0.66	0.69	0.70
0.9	0.71	0.73	0.75	0.78	0.80	0.81
1.0	0.89	0.90	0.92	0.94	0.95	0.96

Impervious Decimal	Type C and D Soil					
	2-year	5-year	10-year	25-year	50-year	100-year
0.0	0.05	0.16	0.26	0.38	0.46	0.51
0.1	0.11	0.21	0.30	0.41	0.48	0.53
0.2	0.17	0.26	0.34	0.44	0.50	0.55
0.3	0.22	0.30	0.38	0.47	0.53	0.57
0.4	0.28	0.35	0.42	0.50	0.55	0.58
0.5	0.34	0.40	0.46	0.53	0.57	0.60
0.6	0.41	0.46	0.51	0.57	0.61	0.63
0.7	0.49	0.53	0.57	0.62	0.66	0.68
0.8	0.60	0.63	0.66	0.70	0.73	0.74
0.9	0.73	0.75	0.77	0.80	0.83	0.83
1.0	0.89	0.90	0.92	0.94	0.96	0.96

REFERENCE:
UDFCD 2001. Urban Storm Drainage Criteria Manual, Volume 1 (revised)

TABLE 28.28.040(a)

Figure 28.28.040: Travel Velocity for Rational Method



The overland flow length, Lo, is generally defined as the length over which the flow characteristics appear as sheet flow or very shallow flow in broad, grassed swales. Changes in land slope, surface characteristics, and small drainage ditches or gullies will tend to force the overland flow into a combined flow condition, which results in higher flow velocities and shorter travel times. Therefore, the initial flow time is limited to the time to travel a distance of 300 feet.

For watersheds longer than 300 feet, the travel time, tt, must be added to the overland flow time. Travel time can be calculated using Manning's equation and the hydraulic properties of the storm drain, gutter, swale, ditch, or channel or can be approximated from Equation 28.28-3 and Figure 28.28.040:

$$V = Cv\ Sw^{0.5} \quad (28.28\text{-}3)$$

Where:

V	=	Velocity, fps
Sw	=	Watercourse slope, ft./ft.
Cv	=	Conveyance coefficient

Table 28.28.040(b): Travel Time Conveyance Coefficients	
Land Surface	**Conveyance Coefficient Cv**
Heavy meadow	2.5
Tillage/field	5
Short pasture and lawns	7
Nearly bare ground	10
Grassed waterways	15
Paved areas and shallow swales	20

The time of concentration is then the sum of the initial flow time ti and the travel time tt. The minimum recommended tc for nonurban watersheds is 10 minutes.
(Res. 40-08 (§ 703.1), 3-19-08)

§ 28.28.050. Urbanized watersheds.

Overland flow in urbanized watersheds can occur from the back of the lot to the street, in parking lots, in greenbelt areas, or within park areas and can be calculated using the procedure described in GJMC § 28.28.030. Travel time, tt, to the first design point or inlet is often determined based on the conveyance coefficient for paved areas and shallow swales, but can be estimated using Manning's equation.

The time of concentration for the first design point in an urbanized watershed using this procedure should not exceed the time of concentration calculated using Equation 28.28-4, which was developed using rainfall/runoff data collected in urbanized regions (USDCM, 1969).

$$tc = L / 180 + 10 \quad (28.28\text{-}4)$$

Where:

tc	=	Time of concentration at the first design point (min.)
L	=	Watershed length (ft.)

Equation 28.28-4 may result in a lesser time of concentration at the first design point and thus would govern in an urbanized watershed. The recommended minimum tc to the first urban design point is five minutes. For subsequent design points, the time of concentration is calculated by accumulating the travel

times in downstream reaches.
(Res. 40-08 (§ 703.2), 3-19-08)

§ 28.28.060. Precipitation losses.

Two methods for calculating precipitation losses are presented below, the SCS curve number and the Green-Ampt methods, both of which can be used for the SCS unit hydrograph method.

Land surface interception, depression storage and infiltration are referred to as precipitation losses. Interception and depression storage represent the surface storage of water by trees or grass, in local depressions in the ground surface, in cracks and crevices in parking lots or roofs, or in a surface area where water is not free to move as overland flow. Infiltration represents the movement of water through the soil beneath the land surface.

Three important factors should be noted about precipitation loss computations. First, precipitation which does not contribute to the runoff process is considered to be lost from the system. Second, the equations used to compute the losses do not provide for soil moisture or surface storage recovery (i.e., contribute to surface runoff); therefore, the calculated amount of runoff is conservatively high. Finally, precipitation losses are considered to be uniformly distributed over an entire sub-watershed.
(Res. 40-08 (§ 704), 3-19-08)

§ 28.28.070. SCS curve number method.

The National Resources Conservation Service (NRCS, formerly SCS), U.S. Department of Agriculture, has instituted a soil classification system for use in soil survey maps across the country. Based on experimentation and experience, the agency has been able to relate the watershed characteristics of soil groups to a curve number, CN (SCS, 1985). The NRCS provides information relating soil group type to the curve number as a function of soil cover, land use type and antecedent moisture conditions, which can be determined from the soil name.

Precipitation loss is calculated based on supplied values of CN and IA, which are related to a total runoff depth for a storm by the following relationships:

$$Q = (P - IA)^2 / ((P - IA) + S) \qquad (28.28\text{-}5)$$

$$S = (1{,}000 / CN) - 10 \qquad (28.28\text{-}6)$$

$$IA = 0.2\ S \qquad (28.28\text{-}7)$$

Where:

Q	=	Accumulated excess (in.)
P	=	Accumulated rainfall depth (in.)
IA	=	Initial abstraction (in.)
S	=	Currently available soil moisture storage deficit (in.)
CN	=	SCS curve number

Note that initial abstraction, IA, (i.e., soil surface storage capacity) is based on empirical evidence established by the NRCS, and is the default value in HEC-1 Program (HEC, 1988).

Since the SCS method results in total excess for a storm, the incremental excess (the difference between rainfall and precipitation loss) for a time period is computed as the difference between the accumulated excess at the end of the current period and the accumulated excess at the end of the previous period.
(Res. 40-08 (§ 704.1), 3-19-08)

§ 28.28.080. CN determination.

The SCS curve number method uses a soil cover curve number (CN) for computing excess precipitation. The curve number CN is related to hydrologic soil group (A, B, C, or D), land use, treatment class (cover), and antecedent moisture condition.

The soil group is determined from published soil maps for the area, which correlates each soil name with the soil group. Land use and treatment class are determined during field visits or from aerial photographs. Procedures for determining land use and treatment class are found in Chapter 8 of National Engineering Handbook, Section 4 (SCS, 1985). Antecedent moisture condition of the watershed is explained as follows:

The amount of rainfall in a period of five to 30 days preceding a particular storm is referred to as antecedent rainfall, and the resulting condition of the watershed in regard to potential runoff is referred to as an antecedent moisture condition. In general, higher amounts of antecedent rainfall result in greater amounts of runoff from a given storm. The effects of infiltration and evapotranspiration during the antecedent period are also important, as they may increase or lessen the effect of antecedent rainfall. Because of the difficulties of determining antecedent storm conditions from data normally available, the conditions are reduced to three cases, AMC-I, AMC-II and AMC-III. For the Mesa County area, an AMC-II condition is recommended for determining storm runoff.

Having determined the soil group, land use and treatment class and the antecedent moisture condition, CN values can be determined from Table 28.28.080, which is reproduced from Table 2-2 in TR-55 (SCS, 1986).

When land uses shown in Table 28.28.080 are not applicable or when more detailed land use information is available, CN values can be calculated directly from imperviousness estimates using the following equation.

$$CN = 98*Imp + X*(1-Imp) \qquad (28.28\text{-}8)$$

Where:

Imp = Imperviousness as a decimal

X = Adjustment factor based on NRCS Soil Type

NRCS Soil Type	Adjustment Factor
A	39
B	61
C	74
D	80

Note that Equation 28.28-8 was derived from the data plotted on Figure 2-3 in TR-55 (SCS 1986) and applies when impervious surfaces are connected. Adjustment for disconnected impervious surfaces can be made using Figure 2-4 in TR-55. This adjustment is not required as the connected impervious surface assumption will result in conservatively high CN values.

STORMWATER MANAGEMENT MANUAL

RUNOFF CURVE NUMBERS

Land Use or Surface Characteristic	Average Imperv. (%)	Runoff Curve Number Soil Complex			
		A	B	C	D
Business					
Commercial Areas	85	89	92	94	95
Neighborhood Areas	70	80	87	91	93
Residential					
Single Family (note 1)	(note 1)				
Multi-unit (detached)	60	74	83	88	91
Multi-unit (attached)	75	83	89	92	94
Apartments	80	86	91	93	94
Industrial					
Light	80	86	91	93	94
Heavy	90	92	94	96	96
Parks, cemeteries	5	42	63	75	81
Playgrounds	10	45	65	76	82
Schools	50	69	80	86	89
Railroad yards	15	48	67	78	83
Irrigated Areas					
Lawns, parks, golf course	0	39	61	74	80
Agriculture	0	39	61	74	80
Undeveloped Areas					
Pre-development conditions	2	40	62	74	80
Greenbelts, agriculture	2	40	62	74	80
Off-site analysis when land use Unknown	45	66	78	85	88
Outcrops	70	80	87		94
Streets/Roads					
Paved	100	98	98	98	98
Gravel	40	63	76	84	87
Drives/Walks	90	92	94	96	96
Roofs	90	92	94	96	96

Revision	Date
ORIGINAL ISSUE	3/27/08

WRC ENGINEERING, INC.

REFERENCE: SCS TECHNICAL RELEASE NO. 55 (1986)

TABLE 28.28.080

(Res. 40-08 (§ 704.2), 3-19-08)

§ 28.28.090. Green and Ampt method.

The Green-Ampt method models infiltration by combining an unsaturated flow form of Darcy's law with requirements of mass conservation. The Green-Ampt method involves the simulation of rainfall loss as a two-phase process. The first phase of rainfall loss is called initial abstraction (IA) or surface retention loss, which involves vegetation interception, evaporation, and surface depression storage. Typical surface retention loss values are shown in Table 28.28.090(a).

Table 28.28.090(a): Surface – Retention Loss	
Land Use and/or Surface Cover	**Surface Retention Loss, IA (inches)**
Natural	
Desert and rangeland, flat slope	0.35
Desert hillslopes	0.15
Mountain with vegetated surface	0.25
Developed (residential/commercial)	
Lawn and turf	0.2
Desert landscape	0.1
Pavement	0.05
Agricultural, tilled fields and irrigated pasture	0.5

The second phase of the rainfall loss process is infiltration of rainfall into the soil. The infiltration is assumed to begin after the surface retention loss is completely satisfied. Excess precipitation is computed using the Green-Ampt equations after the initial loss is satisfied. Required parameters are then the hydraulic conductivity of the soil at saturation, volumetric moisture deficit at the beginning of rainfall, and wetting front capillary action.

Typical values for Green-Ampt parameters were obtained from the *Drainage Design Manual for Maricopa County Hydrology* (Maricopa County 2003 (draft)), available at:

http://www.fcd.maricopa.gov/Resources/HydrologyManual.asp.

(a) **Soil Hydraulic Conductivity.**

The soil hydraulic conductivity is based on soil texture classification. Typical values for different soil type are listed in Table 28.28.090(b). For watershed areas of sub-watersheds consisting of several different soil textures, a composite value for Green-Ampt parameters should be used.

Table 28.28.090(b): Soil Hydraulic Conductivity Values (for bare ground)

Soil Texture Classification	Hydrologic Soils Group	Soil Hydraulic Conductivity (in/hr)
Loamy-sand and sand	A	1.2
Sandy-loam	B	0.4
Loam	B	0.25
Silty-loam	C	0.15
Sandy clay-loam	C	0.06
Clay-loam	D	0.04
Silty clay-loam	D	0.04
Sandy-clay	D	0.02
Silty-clay	D	0.02
Clay	D	0.01

Hydraulic conductivity is affected by several factors besides soil texture, including soil crusting, tillage, ground cover, and canopy cover and should be adjusted. Ground cover, such as grass, litter, and gravel, will generally increase the infiltration rate over that of bare ground conditions. Canopy cover, such as from trees, brush, and tall grasses, also increases the bare ground infiltration rate. A simplified procedure for adjusting bare ground hydraulic conductivity to account for vegetation cover is provided in Equation 28.28-9:

$$Ck = (Vc-10)/90 + 1.0 \qquad (28.28\text{-}9)$$

Where:

Ck	=	Hydraulic conductivity ratio to bare ground conductivity
Vc	=	Vegetated cover as a percentage

(b) **Volumetric Soil Moisture Deficit.**

The soil moisture deficit is a volumetric measure of the soil moisture-storage capacity that is available at the start of the rainfall. The volumetric moisture deficit is a function of the effective porosity of the soil and its value is in the range of near zero to the effective porosity. If the soil is saturated at the start of rainfall, then the moisture deficit equals zero. If the soil is devoid of moisture at the start of rainfall, then the moisture deficit is essentially the effective porosity of the soil.

Three conditions for soil moisture deficit have been defined for use based on the antecedent soil moisture condition that could be expected to exist at the start of the design rainfall. These three conditions are:

(1) "Dry" for antecedent soil moisture near the vegetation wilting point;

(2) "Normal" for antecedent soil moisture condition near field capacity due to previous precipitation or land irrigation; and

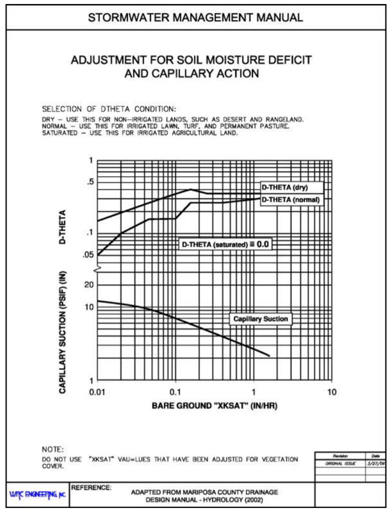
(3) "Saturated" for antecedent soil moisture near effective saturation due to recent precipitation or land irrigation.

Typical volumetric soil moisture deficit values for the above three defined conditions may be taken from Figure 28.28.090. For Mesa County, the recommended condition is "normal," which is consistent with antecedent moisture condition II.

(c) **Wetting Front Capillary Action.**

This parameter is relatively insensitive to ground cover, and is a function of the average bare soil type hydraulic conductivity. Typical values may be taken from Figure 28.28.090.

Figure 28.28.090: Adjustment for Soil Moisture Deficit and Capillary Action



(Res. 40-08 (§ 704.3), 3-19-08)

§ 28.28.100. Rational formula method.

For watersheds that are not complex and have small watershed areas, the design storm runoff may be analyzed using the rational formula method. This method is widely used due to its simplicity and level of general acceptance. The rational formula method, when properly applied in a consistent manner, results in drainage facilities sizes that adequately convey storm runoff with minimal consequences.

(a) **Methodology.**

The rational method is based on the formula:

$$Q = CIA \qquad (28.28\text{-}10)$$

Where:

Q	=	Maximum rate of runoff in cubic feet per second (cfs)
C	=	Runoff coefficient
I	=	Average intensity of rainfall in inches per hour
A	=	Contributing watershed area in acres

(b) **Assumptions.**

The basic assumptions made when applying the rational formula method are as follows:

(1) The computed maximum rate of runoff to the design point is a function of the average rainfall rate during the time of concentration to that point.

(2) The maximum rate of rainfall occurs during the time of concentration, and the design rainfall

depth during the time of concentration is converted to the average rainfall intensity for the time of concentration.

(3) The maximum runoff rate occurs when the entire area is contributing flow.

(c) **Limitations on Methodology.**

The rational formula method adequately estimates the peak rate of runoff from a rainstorm in a given watershed, but does not provide information on the full hydrograph and only approximates the runoff volume.

Typical design procedures assume that all of the design flow is collected at the design point and that there is no carry-over water running overland to the next design point. The problem becomes one of routing the surface and subsurface hydrographs which have been separated by the storm drain system. In general, this sophistication is not warranted and a conservative assumption is made that the entire routing occurs through the storm drain system when the system is present.

Because of the limitations of the rational method, the following guidelines on its application are provided:

(1) The individual sub-watershed sizes should not be greater than 20 acres.

(2) The aggregate of all sub-watershed areas should not be greater than 160 acres.

(3) The sub-watersheds should be reasonably homogeneous for existing and for projected land use.

(d) **Rainfall Intensity.**

The rainfall 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. Development of rainfall intensities for the rational method is described in Chapter 28.24 GJMC.

(e) **Runoff Coefficient.**

The runoff coefficient, C, represents the integrated effects of infiltration, evaporation, retention, flow routing, and interception, all of which affect the time distribution and peak rate of runoff. Determination of the coefficient requires judgment and understanding on the part of the engineer.

The first step is to determine the composite imperviousness of the watershed using recommended values in Table 28.28.020. Once the imperviousness is determined, recommended C values for various recurrence interval storms are determined from Table 28.28.090 or can be calculated using the following equations:

$$CCD = KCD + (0.858*i^3 - 0.786*i^2 + 0.774*i + 0.04) \quad (28.28\text{-}11)$$

$$CA = KA + (1.31*i^3 - 1.44*i^2 + 1.135*i - 0.12) \quad (28.28\text{-}12)$$

$$CB = (CA + CCD)/2 \quad (28.28\text{-}13)$$

Where:

CCD	=	Runoff coefficient for C and D soils*
CA	=	Runoff coefficient for A soils*
CB	=	Runoff coefficient for B soils*
i	=	Imperviousness as a decimal
KCD	=	Coefficient adjustment for C and D soils
KA	=	Coefficient adjustment for A soils

* If C is not greater than or equal to zero, it should be set to zero.

Table 28.28.100: Adjustment Factors for Runoff Coefficient Equations (values of KA and KCD based on rainfall intensity (i) in inches/hour)

NRCS Soil	2-year	5-year	10-year	25-year	50-year	100-year
C and D	0	-0.10i+0.11	-0.18i+0.21	-0.28i+0.33	-0.33i+0.40	-0.39i+0.46
A	0	-0.08i+0.09	-0.14i+0.17	-0.19i+0.24	-0.22i+0.28	-0.25i+0.32

Composite imperviousness is computed on the basis of the percentage of different types of surfaces or land uses in the watershed area. This procedure is often applied to typical sample blocks as a guide to selection of reasonable values of the coefficient for an entire area.

The equations for runoff coefficients as a function of imperviousness and recurrence interval were obtained from the *Urban Storm Drainage Criteria Manual* by the Urban Drainage and Flood Control District (UDFCD 2001), which can be obtained in .pdf format on the following website:

http://www.udfcd.org/

(f) **Application of the Rational Formula Method.**

The first step in applying the rational formula method is to obtain a topographic map and define the boundaries of all the relevant watersheds. Watersheds to be defined include all watersheds tributary (i.e., off-site areas) to the area of study and sub-watersheds in the study area. A field check is recommended and field surveys may be required in some cases. At this stage of planning, the possibility for the diversion of watershed runoff should be identified.

The major storm watershed does not always coincide with the minor storm watershed. This is often the case in urban areas where a low flow will stay within the gutter and follow the lowest grade, but when a large flow occurs, the flow will be sufficiently deep or flowing with a high velocity such that part of the runoff will overflow street crown and flow into a new sub-watershed.

(g) **Major Storm Analysis.**

When analyzing the major runoff occurring on an area that has a storm drain system sized for the minor storm, care must be used when applying the rational formula method. Normal application of the rational formula method assumes that all of the runoff is collected by the storm drain. For the minor storm design, the time of concentration is dependent upon the flow time in the drain. However, during the major storm runoff, the drains will probably be at capacity and could not carry the additional water flowing to the inlets. This additional water then flows overland past the inlets, generally at a lower velocity than the flow in the storm drains.

If a separate time of concentration analysis is made for the pipe flow and surface flow, a time lag between the surface flow peak and the pipe flow peak will occur. This lag, in effect, will allow the pipe to carry a larger portion of the major storm runoff than would be predicted using the minor storm time of concentration. The basis for this increased benefit is that the excess water from one inlet will flow to the next inlet downhill, using the overland route. If that inlet is also at capacity, the water will often continue on until capacity is available in the storm drain. The analysis of this aspect of the interaction between the storm drain system and the major storm runoff is complex. The simplified and conservative approach of using the minor storm time of concentration for all frequency analyses is acceptable for the Mesa County area.

(Res. 40-08 (§ 705), 3-19-08)

§ 28.28.110. SCS unit hydrograph method.

The SCS unit hydrograph was derived from a large number of natural unit hydrographs from watersheds varying widely in size and geographic location.

(a) **Methodology.**

The SCS unit hydrograph method, which uses the unit hydrograph theory as a basis for runoff computations, computes a hydrograph for a unit amount of rainfall excess applied uniformly over a sub-watershed for a given unit of time (or unit duration). The rainfall excess hydrographs are then transformed to a sub-watershed hydrograph by superimposing each excess hydrograph lagged by the unit duration.

The shape of the SCS unit hydrograph is based on studies of various natural unit hydrographs. The basic governing parameters of this curvilinear hydrograph are as follows:

(1) The time-to-peak, Tp, of the unit hydrograph approximately equals 0.2 times the time-of-base, Tb.

(2) The point of inflection of the falling leg of the unit hydrograph approximately equals 1.7 times Tp.

(b) **Assumptions.**

The basic assumptions made when applying the SCS unit hydrograph method (and all other unit hydrograph methods) are as follows:

(1) The effects of all physical characteristics of a given watershed are reflected in the shape of the storm runoff hydrograph for that watershed.

(2) At a given point on a stream, discharge ordinates of different unit graphs of the same unit time of rainfall excess are mutually proportional to respective volumes.

(3) A hydrograph of storm discharge that would result from a series of bursts of excess rain or from continuous excess rain of variable intensity may be constructed from a series of overlapping unit graphs each resulting from a single increment of excess rain of unit duration.

(c) **Lag Time.**

Input data for the SCS dimensionless unit hydrograph method (SCS, 1985) consists of a single parameter, TLAG, which is equal to the lag (in hours) between the center of mass of rainfall excess and the peak of the unit hydrograph.

For small watersheds (less than one square mile) in the Mesa County area, the lag time is related to the time of concentration, tc, by the following empirical relationship:

$$TLAG = 0.6\ tc \qquad (28.28\text{-}14)$$

Where:

TLAG	=	The time (hours) between the center of mass of the rainfall excess and the peak of the unit hydrograph.
tc	=	The time of concentration (minutes, see GJMC § 28.28.030 through 28.28.050).

For large watersheds (greater than one square mile), the lag time (and tc) is generally governed mostly by the concentrated flow travel time, not the initial overland flow time. In addition, as the watershed gets increasingly larger, the average flow velocity (and associated travel time) becomes more difficult to estimate. Therefore, for these watersheds, the following lag equation is recommended for use in computing TLAG:

$$TLAG = 22.1\ Kn\ (L\ Lc\ /\ S^{0.5})^{0.33} \qquad (28.28\text{-}15)$$

Where:

Kn	=	Manning’s roughness factor for the watershed channels
L	=	Length of longest watercourse (miles)
Lc	=	Watercourse length from the outflow point to a point on the channel nearest the centroid of the watershed (miles)
S	=	Average slope of the longest watercourse (feet per mile)

This lag equation is based on the United States Bureau of Reclamation’s (USBR) analysis of the above parameters for several watersheds in the Southwest desert, Great Basin, and Colorado Plateau area (USBR, 1989). This equation was developed by converting the USBR’s S-graph lag equation to a dimensionless unit hydrograph lag equation.

For watersheds 1.0 square miles in size, it is recommended that the method which results in the shortest TLAG value be used to be conservative.

(d) **Roughness Factor.**

For consistency, recommended roughness factors, Kn, used in the lag time calculation are presented in Table 28.28.110. These factors are based on roughness factor analysis by the USACE (1982) and USBR (1989) as compared to the typical watershed channels found in the Mesa County area. The reader is referred to these documents for further discussion on selection of a proper roughness factor.

For multiple land uses within a watershed, composite roughness factors should be determined.

Table 28.28.110: Lag Equation Roughness Factors		
Land Use	**Imperviousness %**	**Kn**
Commercial, industrial, office and business	70 – 85	0.05
Residential		
Rural	10 – 15	0.08
Low density	20 – 25	0.07
Medium and high density	30 – 65	0.05
Irrigated grass, golf courses, parks and cemeteries	0 – 5	0.1
Undeveloped areas:		
Rock outcroppings		0.04
Irrigated agriculture		0.1
Rangelands:		
Grass lands		0.08
Grass and shrubs		0.09
Shrub and brush		0.1
Forest, evergreen		0.15

(e) **Unit Storm Duration.**

The minimum unit duration, Δt, is dependent on the time of concentration of a given watershed. As a general rule, the unit storm duration, Δt, should be no greater than $T_c/3$. For small watersheds (i.e., less than one square mile), the recommended duration is five minutes. For larger watersheds, larger unit durations may be used, but should not exceed 15 minutes.

(f) **Sub-Watershed Sizing.**

The determination of the peak rate of runoff at a given design point is affected by the number of sub-watersheds within a larger watershed. Typically, the more discrete the analysis of a given watershed (more sub-watersheds), the more representative the resulting peak flow is of actual runoff conditions. The improved predictive capability of multiple sub-watersheds is due to better homogeneity of the sub-watershed characteristics, as compared to analysis of the watershed with no sub-watersheds. Recommended guidelines are:

(1) For watersheds up to 100 acres in size, the maximum sub-watershed size should be approximately 20 acres.

(2) For watersheds over 100 acres in size, increasingly larger sub-watersheds may be used as long as the land use and surface characteristics within each sub-watershed are homogeneous. In addition, the sub-watershed sizing should be consistent with the level of detail needed to determine peak flow rates at various design points within a given watershed.

(Res. 40-08 (§ 706), 3-19-08)

§ 28.28.120. Channel routing of hydrographs.

Whenever a large or a nonhomogeneous watershed is being investigated, the watershed should be divided into smaller and more homogeneous sub-watersheds. The storm hydrograph for each sub-watershed is then routed through the channel and combined with individual sub-watershed hydrographs to develop a storm hydrograph for the entire watershed. For hydrograph routing, the Muskingum, kinematic wave, and Muskingum-Cunge methods are recommended for use in the Mesa County area.

The kinematic wave method is recommended when the watershed has well defined channels. The Muskingum-Cunge method is recommended for poorly defined channels that have cross-sections that can be determined from detailed topography or from a cross-section survey, otherwise the Muskingum method is recommended.

(a) **Muskingum Method.**

The Muskingum method estimates some channel storage effects and, as a result, the storm hydrograph shape is modified in translation along a channel reach. The basic equation for the Muskingum method as described by HEC-1 (HEC, 1988) is as follows:

$$O2 = (C1 - C2)I1 + (1 C1)O1 + C2I2 \quad (28.28\text{-}16)$$

Where:

O2	=	Outflow from the reach at the end of the unit time increment (beginning of the next time increment)
O1	=	Outflow from the reach at the beginning of the time increment
I1	=	Inflow into the reach at the beginning of the time increment
I2	=	Inflow into the reach at the end of the time increment
C1, C2	=	Coefficients defined in Equations 28.28-17 and 28.28-18, respectively

And

$$C1 = (2\Delta t)/[2K(1-X)] + \Delta t \quad (28.28\text{-}17)$$

$$C2 = (\Delta t-2KX)/[2K(1-X)] + \Delta t \quad (28.28\text{-}18)$$

$$K = L/(3{,}600V) \quad (28.28\text{-}19)$$

Where:

K	=	Muskingum storage time constant in hours
L	=	Channel reach length in feet
V	=	Translation velocity in fps
Δt	=	Unit time increment in hours
X	=	Muskingum weighting factor

The velocity used in Equation 28.28-19 is the wave velocity, which can be estimated for various channel shapes as a function of average velocity, V, for steady uniform flow using Manning's equation. The approximate wave velocities for different channel shapes are provided below:

Wave Velocities for Muskingum Method	
Channel Shape	**Wave Velocity**
Wide rectangular	5/8 V
Triangular	4/3 V
Wide parabolic	11/9 V

Where V is the velocity from application of the Manning's equation.

The weighting factor (X) in the Muskingum routing method accounts for the peak flow reduction caused by channel routing. The weighting factor generally varies from 0.0 to 0.5, with 0.0 representing a reservoir type peak reduction and 0.5 representing no peak reduction.

Weighting Factors for Muskingum Method	
Channel Condition	**Weighting Factor "X"**
Some storage in over bank but few obstructions (i.e., alluvial fans)	0.15
Overbanks with severe obstruction	0.1

The reader is referred to the USBR Flood Hydrology Manual (USBR, 1989) for further discussion on the selection of an appropriate Muskingum weighting factor (X).

The storage constant (K) in the Muskingum routing method accounts for the peak flow translation along a channel reach. This constant is therefore directly related to the reach length and the mean channel flow velocity as shown in Equation 28.28-19. An estimate of the mean channel flow velocity may be obtained using Manning's formula with the hydraulic radius estimated as being equal to the flow depth. The flow depth (and thus channel flow velocity) is estimated based on the channel cross-sectional shape and the design discharge for the selected flood frequency.

The routing procedure may be repeated for several sub-reaches so the total travel time through the reach is equal to K. To ensure the method's computational stability and the accuracy of computed hydrograph, the routing reach should be chosen so that:

$$1/[2(1-X)] \leq K/(\Delta T \cdot NSTPS) \leq 1/(2X) \qquad (28.28\text{-}20)$$

Where ΔT is the time increment in hours.

(b) **Kinematic Wave Method.**

In the kinematic wave interpretation of the equations of motion, it is assumed that the bed slope and water surface slope are equal and acceleration effects are negligible.

Thus flow at any point in the channel can be computed from Manning's formula:

$$Q = (1.486/n)\ R^{2/3}\ So^{1/2}\ A \qquad (28.28\text{-}21)$$

Where:

Q	=	Flow rate, cfs
R	=	Hydraulic radius, ft.
So	=	Channel bed slope, ft./ft.
A	=	Cross-sectional area, square feet
n	=	Manning's resistance factor

Equation 28.28-21 can be simplified to:

$$Q = \alpha A^{m} \qquad (28.28\text{-}22)$$

Where α and m are related to flow geometry and surface roughness. This is the form of the equation used to route hydrographs through channels.

The kinematic wave method in HEC-1 does not allow for explicit separation of main channel and overbank areas. Therefore, a flood wave routed by the kinematic wave technique through a channel reach is translated, but does not attenuate (although a small degree of attenuation is introduced by the finite difference solution). Consequently, the kinematic wave routing technique is most appropriate in channels where flood wave attenuation is not significant, as is typically the case in urban areas. Otherwise, flood wave attenuation can be modeled empirically by using the Muskingum method or other applicable storage routing techniques.

(c) **Muskingum-Cunge Method.**

The Muskingum-Cunge routing method is similar to the Muskingum method, but is a physically based method whose parameters are determined from actual channel characteristics. Because it does not require calibration to streamflow data, it is suited for use in ungaged watersheds. One limitation to the use of Muskingum-Cunge routing is that this method does not account for backwater and storage in the channel.

Muskingum-Cunge routing is based on wave diffusion theory and is nonlinear in nature. In Muskingum-Cunge routing, the amount of diffusion is matched to physical diffusion determined using physical channel characteristics. This is compared to Muskingum routing which uses the X parameter to control diffusion without any relation to physical channel characteristics. Additional detail about the theory behind the Muskingum-Cunge routing method is presented in the HEC-1 User's Manual (HEC, 1990).

Data required for use with HEC-1 include representative channel cross-section, reach length, Manning's roughness coefficients for main channel and overbanks, and channel bed slope.

The representative channel cross-sections are not limited to the standard prismatic shapes required for kinematic wave routing so eight-point cross-sections can be used to define the channel and overbanks as with normal-depth storage routing.

The results obtained using Muskingum-Cunge routing in HEC-1 should be checked for reasonableness. The increments of time and distance selected internally by HEC-1 and used in the finite-difference computation can affect the accuracy of the results.

(Res. 40-08 (§ 707), 3-19-08)

§ 28.28.130. Reservoir routing of hydrographs.

Storm runoff detention is required for new development (GJMC § 28.16.090) and therefore detention reservoirs will be required (see Chapter 28.56 GJMC). In some instances, the sizing of the detention storage will be based upon hydrograph storage routing techniques rather than direct calculation of volume and discharge requirements. The modified Puls methodology for reservoir routing, which is computerized in the HEC-1 and other programs, is recommended.

The procedure for the original Puls method was developed in 1928 by L.G. Puls of the United States Army Corps of Engineers (USACE). The method was modified in 1949 by the USBR simplifying the computational and graphic requirements. The method is also referred to as the storage indication or Goodrich Reservoir routing method. The differences, if any, are mainly in the form of the equation and means of initializing the routing. The procedures presented herein were obtained from Hydrology for Engineers (Linsley, 1975).

The principle of mass continuity for a channel reach can be expressed by the equation:

$$(I-D)\Delta t = \Delta S \qquad (28.28\text{-}23)$$

I is the inflow rate, D is the discharge rate, Δt is the time interval, and ΔS is the change in storage. If the average rate of flow during a given time period is equal to the average of the flows at the beginning and end of the period, the equation can be expressed as follows:

$$(I1 + I2)\ \Delta t / 2 - (D1 + D2)\ \Delta t / 2 = S2 - S1 \qquad (28.28\text{-}24)$$

Where the subscripts 1 and 2 refer to the beginning and end of time period t. Rearranging the equation gives the following form used for the modified Puls method:

$$I1 + I2 + (2S1 / \Delta t - D1) = (2S2 / \Delta t + D2) \qquad (28.28\text{-}25)$$

(Res. 40-08 (§ 708), 3-19-08)

CHAPTER 28.32
Open Channels

§ 28.32.010. Introduction.

Presented in this chapter are the technical criteria and design standards for hydraulic evaluation and design of open channels (natural and artificial). Open channel flow can be extremely complex, and often entire textbooks are devoted to the subject. Discussions and hydraulic standards are provided for different channel types that are most likely to be found in Mesa County.

The ultimate responsibility for the design of a safe and stable channel rests with the professional design engineer. A good understanding of the site conditions is vital to the production of a stable channel design. The information presented in this chapter must be considered to be the minimum standards upon which channel evaluation and design shall be based. Additional analysis that goes beyond the scope of this manual may be necessary for unique or unusual channel conditions. For additional information, the users of this manual are encouraged to refer to other textbooks and technical publications addressing this subject.
(Res. 40-08 (§ 801), 3-19-08)

§ 28.32.020. Parameters and terms commonly used in open channel analysis and design.

Several terms and parameters are used and must be understood when analyzing open channel flows. These are described below.

Area (A). The area always means the cross-sectional area of the flow, and is measured perpendicular to the direction of flow.

Critical depth (dc). This refers to the depth of flow under critical flow conditions.

Critical flow. This refers to flow at critical depth or velocity, where the specific energy is a minimum for a given discharge. Critical flow is very unstable.

Critical slope. This refers to the slope which, for a given cross-section and flow rate, results in critical flow.

Critical velocity. This refers to the velocity of flow under critical flow conditions.

Depth (d). If not specified otherwise, depth of flow refers to the maximum depth of water in the cross-section.

Energy grade line (EGL). The grade line of the water surface profile plus the velocity head, or the specific energy line.

Froude number (Fr). This is a dimensionless number, equal to the ratio of the velocity of flow to the velocity of very small gravity waves, the latter being equal to the square root of the product of the acceleration of gravity and the flow depth, or:

$$Fr = \frac{V}{\left(\frac{gA}{T}\right)^{0.5}} = \frac{V}{(gDh)^{0.5}} \quad (28.32\text{-}1)$$

Where:

$Fr<1.0$, flow is subcritical;

$Fr = 1.0$, flow is critical; and

$Fr>1.0$, flow is supercritical

V = velocity (fps)

A = cross-sectional area of flow (sf)

T = top width of flow (ft.)

Dh = hydraulic depth (ft.)

Gradually varied flow. Varied flow in which the depth does not change abruptly over a comparatively short distance.

Hydraulic depth (Dh). The hydraulic depth is the ratio of area in flow to the width of the channel at the fluid surface, or Dh=A/T.

Hydraulic grade line (HGL). In an open channel, the hydraulic grade line is the profile of the free water surface.

Hydraulic gradient (Hg). The slope of the hydraulic grade line is the profile of the free water surface.

Hydraulic radius (Rh). The hydraulic radius is the cross-sectional area of flow divided by the wetted perimeter, or Rh=A/Pw.

Normal depth. When the flow depth is constant along a channel reach; that is, when neither the flow depth nor velocity is changing, the depth is said to be normal.

Slope (S). Slope may refer to the channel bed, the hydraulic grade line, or energy grade line.

Surface spread (T). The surface spread is the width at the top of the flow, measured perpendicular to the flow direction.

Uniform flow. Uniform flow occurs when flow has a constant water area, depth, discharge, and average velocity through a reach of channel.

Wetted perimeter (Pw). The wetted perimeter is the portion of the perimeter of a flow conveyance facility that is in contact with the flowing water.
(Res. 40-08 (§ 802), 3-19-08)

§ 28.32.030. General open channel flow.

Any water flow that is conveyed in such a manner that top surface is exposed to the atmosphere is defined as open channel flow. This type of flow occurs in all channel types described in GJCM 28.32.100 including canals, ditches, drainage channels, culverts, and pipes under partially full flow conditions. The hydraulics of an open channel can be very complex, encompassing many different flow conditions from steady-state uniform flow to unsteady, rapidly varying flow. Most of the problems in stormwater drainage involve uniform, gradually varying or rapidly varying flow states. Examples of these flow conditions are illustrated in Figure 28.32.030. Steady uniform flow is most commonly treated flow in open channel hydraulics, in which the depth of flow remains constant over the time interval studied. The calculations for uniform and gradually varying flow are relatively straightforward and are based upon similar assumptions (e.g., parallel streamlines). Rapidly varying flow computations (e.g., hydraulic jumps and flow over spillways), however, can be very complex, and the solutions are generally empirical in nature.

Presented in this chapter are the basic equations and computational procedures for uniform, gradually varying and rapidly varying flow. The user is encouraged to review the many hydraulics textbooks written on this subject.

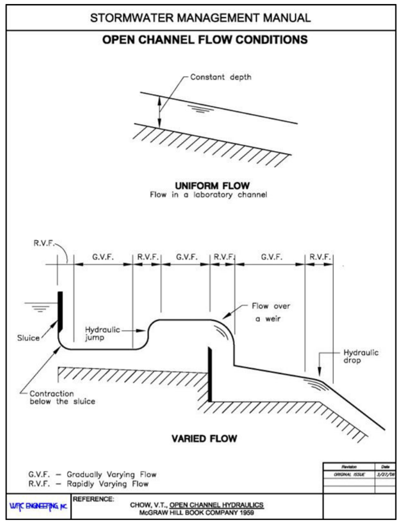


FIGURE 28.32.030

(Res. 40-08 (§ 803), 3-19-08)

§ 28.32.040. Uniform flow computation.

Open-channel flow is uniform if the depth of flow is the same at every section of the channel. For a given channel geometry, roughness, discharge and slope, there is only one possible depth for maintaining uniform flow. This depth is referred to as the "normal depth." For uniform flow within a prismatic channel (i.e., uniform cross-section), the water surface will be parallel to the channel bottom. While uniform flow rarely occurs in nature and is difficult to achieve in a laboratory, a uniform-flow approximation is generally adequate for planning and design purposes.

The computation of uniform flow and normal depth shall be based upon the Manning or uniform flow equation:

$$Q = \frac{1.49}{n} A^{5/3} P^{-2/3} \sqrt{S} = \frac{1.49}{n} A R^{2/3} \sqrt{S} \quad (28.32\text{-}2)$$

Where:

Q	=	flow rate ($ft.^3/s$)
n	=	Manning roughness coefficient
A	=	area ($ft.^2$)
P	=	wetted perimeter (ft.)

R	=	hydraulic radius, R = A/P (ft.)
S	=	slope of the energy grade line (ft./ft.)

For prismatic channels, the energy grade line (EGL), hydraulic grade line (HGL), and the bottom can be assumed parallel for uniform, normal depth flow conditions.

The variables dependent on channel cross-section geometry (i.e., area and hydraulic radius) can be lumped together as the conveyance (K) of the channel. This simplifies the uniform flow equation to the following expression:

$$Q = K\sqrt{S} \qquad (28.32\text{-}3)$$

Table 28.32.040(a) presents equations for calculating many of the parameters required for hydraulic analysis of different uniform channel sections.

Tables 28.32.040(b), 28.32.040(c), 28.32.040(d), and 28.32.040(e) provide a list of Manning roughness coefficient values for many types of conditions that may occur in Mesa County. The uniform flow equation and its constituent parameters are readily computed using handheld calculators and personal computers.

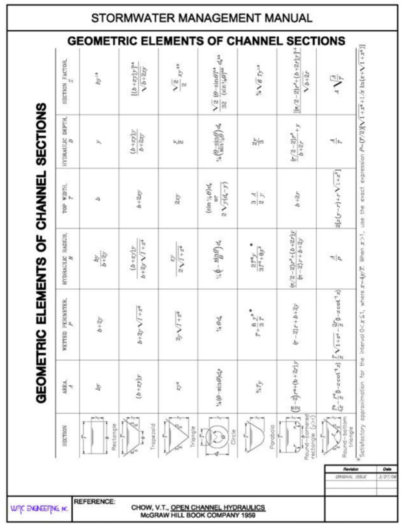


TABLE 28.32.040(a)

STORMWATER MANAGEMENT MANUAL

TYPICAL ROUGHNESS COEFFICIENTS FOR OPEN CHANNELS

TYPE OF CHANNEL AND DESCRIPTION	MINIMUM	NORMAL	MAXIMUM
EXCAVATED OR DREDGED			
a. Earth, straight and uniform			
1. Clean, recently completed	0.016	0.018	0.020
2. Clean, after weathering	0.018	0.022	0.025
3. Gravel, uniform section, clean	0.022	0.025	0.030
4. With short grass, few weeds	0.022	0.027	0.033
b. Earth, winding and sluggish			
1. No vegetation	0.023	0.025	0.030
2. Grass, some weeds	0.025	0.030	0.033
3. Dense weeds or aquatic plans in deep channels	0.030	0.035	0.040
4. Earth bottom and rubble sides	0.028	0.030	0.035
5. Stony bottom and weedy banks	0.025	0.035	0.040
6. Cobble bottom and clean sides	0.030	0.040	0.050
c. Dragline-excavated or dredged			
1. No vegetation	0.025	0.028	0.033
2. Light brush on banks	0.035	0.050	0.060
d. Rock cuts			
1. Smooth and uniform	0.025	0.035	0.040
2. Jagged and irregular	0.035	0.040	0.050
e. Channels not maintained, weeds and brush			
1. Dense weeds, high as flow depth	0.050	0.080	0.120
2. Clean bottom, brush on sides	0.040	0.050	0.080
3. Same as above, but highest state of flow	0.045	0.070	0.110
4. Dense brush, high state	0.080	0.100	0.140

REFERENCE: CHOW, V.T., OPEN CHANNEL HYDRAULICS
McGRAW HILL BOOK COMPANY 1959

TABLE 28.32.040(b)

STORMWATER MANAGEMENT MANUAL

TYPICAL ROUGHNESS COEFFECIENTS FOR OPEN CHANNELS

TYPE OF CHANNEL & DESCRIPTION	MINIMUM	NORMAL	MAXIMUM
Brass, smooth	0.009	0.010	0.013
Steel:			
Lockbar and welded	0.010	0.012	0.014
Riveted and spiral	0.013	0.016	0.017
Cast Iron:			
Coated	0.010	0.013	0.014
Uncoated	0.011	0.014	0.016
Wrought Iron:			
Black	0.012	0.014	0.015
Galvanized	0.013	0.016	0.017
Corrugated Metal:			
Sub-drain	0.017	0.019	0.021
Storm Drain	0.021	0.024	0.030
Lucite	0.008	0.009	0.010
Glass	0.009	0.010	0.013
Cement:			
Neat, surface	0.010	0.011	0.013
Mortar	0.011	0.013	0.015
Concrete:			
Culvert, straight and free of debris	0.010	0.011	0.013
Culvert with bends, connections, and some debris	0.011	0.013	0.014
Finished	0.011	0.012	0.014
Sewer with manholes, inlet, etc., straight	0.013	0.015	0.017
Unfinished, steel form	0.012	0.013	0.014
Unfinished, smooth wood form	0.012	0.014	0.016
Unfinished, rough wood form	0.015	0.017	0.020
Wood:			
Stave	0.010	0.012	0.014
Laminated, treated	0.015	0.017	0.020
Clay:			
Common drainage tile	0.011	0.013	0.017
Vitrified sewer	0.011	0.014	0.017
Vitrified sewer with manholes, inlet, etc.	0.013	0.015	0.017
Vitrified subdrain with open joint	0.014	0.016	0.018
Brickwork:			
Glazed	0.011	0.013	0.015
Lined with cement mortar	0.012	0.015	0.017
Sanitary sewers coated with sewage slime with bends and connections	0.012	0.013	0.016
Paved invert, sewer, smooth bottom	0.016	0.019	0.020
Rubble masonry, cemented	0.018	0.025	0.030

Revision	Date
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REFERENCE: CHOW, V.T., OPEN CHANNEL HYDRAULICS McGRAW HILL BOOK COMPANY 1959

TABLE 28.32.040(c)

STORMWATER MANAGEMENT MANUAL

TYPICAL ROUGHNESS COEFFICIENTS FOR OPEN CHANNELS

TYPE OF CHANNEL AND DESCRIPTION	MINIMUM	NORMAL	MAXIMUM
LINED OR BUILT-UP CHANNELS			
a. CONCRETE			
1. TROWEL FINISH	0.011	0.013	0.015
2. FLOAT FINISH	0.013	0.015	0.016
3. GUNITE, GOOD SECTION	0.016	0.019	0.023
4. GUNITE, WAVY SECTION	0.018	0.022	0.023
b. CONCRETE BOTTOM FLOAT FINISHED WITH SIDE OF			
1. DRESSED STONE IN MORTAR	0.015	0.017	0.020
2. RANSOM STONE IN MORTAR	0.017	0.020	0.024
3. DRY RUBBLE OR RIPRAP	0.020	0.030	0.035
c. GRAVEL BOTTOM WITH SIDES OF			
1. FORMED CONCRETE	0.017	0.020	0.025
2. RANDOM STONE IN MORTAR	0.020	0.023	0.026
3. DRY RUBBLE OR RIPRAP	0.023	0.033	0.036
d. ASPHALT			
1. SMOOTH	0.013	0.013	--
2. ROUGH	0.016	0.016	--
e. GRASSED	0.030	0.040	0.050

Revision	Date
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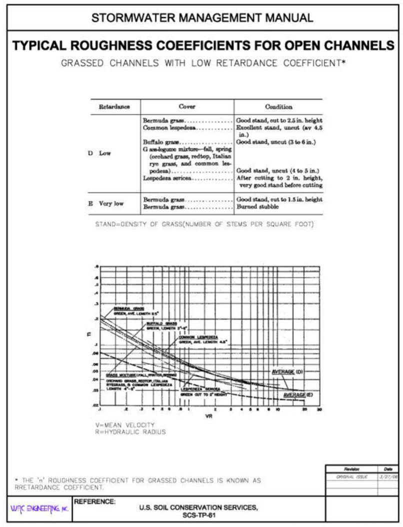
WRC ENGINEERING INC.

REFERENCE: CHOW, V.T., OPEN CHANNEL HYDRAULICS McGRAW HILL BOOK COMPANY 1959

TABLE 28.32.040(d)



STORMWATER MANAGEMENT MANUAL

TYPICAL ROUGHNESS COEEFICIENTS FOR OPEN CHANNELS

GRASSED CHANNELS WITH LOW RETARDANCE COEFFICIENT*

Retardance	Cover	Condition
D Low	Bermuda grass	Good stand, cut to 2.5 in. height
	Common lespedeza	Excellent stand, uncut (av 4.5 in.)
	Buffalo grass	Good stand, uncut (3 to 6 in.)
	G ass-legume mixture—fall, spring (orchard grass, redtop, Italian rye grass, and common lespedeza)	Good stand, uncut (4 to 5 in.)
	Lespedeza sericea	After cutting to 2 in. height, very good stand before cutting
E Very low	Bermuda grass	Good stand, cut to 1.5 in. height
	Bermuda grass	Burned stubble

STAND=DENSITY OF GRASS(NUMBER OF STEMS PER SQUARE FOOT)

V=MEAN VELOCITY
R=HYDRAULIC RADIUS

* THE 'n' ROUGHNESS COEFFICIENT FOR GRASSED CHANNELS IS KNOWN AS RRETARDANCE COEFFICIENT.

Revision	Date
ORIGINAL ISSUE	3/27/06

WRC ENGINEERING INC.

REFERENCE: U.S. SOIL CONSERVATION SERVICES, SCS-TP-61

TABLE 28.32.040(e)

(a) **Gradually Varying Flow.**

The most common occurrence of gradually varying flow in storm drainage is the backwater created by culverts, storm drain inlets, or channel constrictions. For these conditions, the flow depth will be greater than normal depth in the channel, and the water surface profile (a.k.a. "backwater curve") is computed using either the direct-step or standard step method.

(1) **Direct-Step Method.**

The direct-step method is best suited to the analysis of open prismatic channels. Water surface profiles in simple prismatic channels can be computed manually. Chow (1959) presents the basic method for applying the direct-step analysis. The direct-step method is also available in many handheld and personal computer programs. The most general and widely used programs are the U.S. Army Corps of Engineers' *HEC-2 Water Surface Profiles* and *HEC-RAS River Analysis System*. The design engineer may use these programs or proprietary computer software to compute water surface profiles for channel and floodplain analyses.

(2) **Standard-Step Method.**

The standard-step method is required for the analysis of irregular or nonuniform cross-sections. Because the standard-step method involves a more tedious iterative process, this manual recommends that design engineers use computer programs such as HEC-RAS to accomplish these calculations.

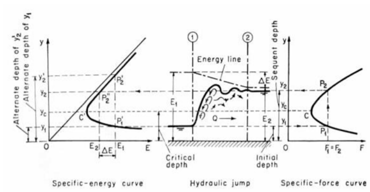


Figure 28.32.040: Specific Energy Curve

(b) **Rapidly Varying Flow.**

Rapidly varying flow is characterized by very pronounced curvature of the water surface profile. The change in water surface profile may become so abrupt as to result in a state of high turbulence. Calculation methods for gradually varying flow (e.g., direct-step and standard-step methods) do not apply for rapidly varying flow. There are mathematical solutions to some specific cases of rapidly varying flow, but the solutions to most rapidly varying flow problems rely on empirical data.

The most common occurrence of rapidly varying flow in storm drainage applications involves weirs, orifices, hydraulic jumps, nonprismatic channel sections (transitions, culverts and bridges), and nonlinear channel alignments (bends). Each of these flow conditions requires detailed calculations to properly identify the flow capacities and depths of flow in the given section. The design engineer must be cognizant of the design requirements for rapidly varying flow conditions and shall include all necessary calculations as part of the design submittal documents. The design engineer is referred to the hydraulic references for the proper calculation methods to use in the design of drainage facilities with rapidly varying flow facilities.

(Res. 40-08 (§ 803.1), 3-19-08)

§ 28.32.050. Critical flow computation.

(a) The critical flow through a channel is characterized by several important conditions regarding the relationship between the flow, specific energy, and slope of a particular hydraulic cross-section (Figure 28.32.040). Critical state is characterized by the following conditions:

(1) The specific energy ($E=y+v^2/2g$) is at a minimum for a given discharge (Q).

(2) The discharge (Q) is a maximum for a given specific energy (E).

(3) The specific force is a minimum for a given discharge (Q).

(4) The velocity head ($v^2/2g$) is equal to half the hydraulic depth (D/2) in a channel of small slope.

(5) The Froude number (Fr) is equal to 1.0.

(b) Typically, channels must not be designed to flow at or near critical state ($0.80<Fr<1.2$). If the critical state of uniform flow exists throughout an entire reach, the channel flow is critical and the channel slope is at critical slope (Sc). A slope less than Sc will cause subcritical flow. A slope steeper than Sc will cause supercritical flow. A flow at or near the critical state is unstable. Factors creating minor changes in specific energy, such as channel debris or minor variation in roughness, will cause a major change in depth.

(c) The criteria of minimum specific energy for critical flow results in the definition of the Froude number (Fr) as follows:

$$Fr = \frac{v}{\sqrt{gD}} \quad (28.32\text{-}4)$$

Where:

Fr	=	Froude number (dimensionless)
v	=	velocity (ft./s)
g	=	gravitational acceleration (32.2 ft./s^2)
A	=	channel flow area (ft.^{2})
T	=	top width of flow area (ft.)
D	=	hydraulic depth, D=A/T (ft.)

(d) The critical depth in a given trapezoidal channel section with a known flow rate can be determined using the following method:

(1) **Step 1.**

Compute the section factor (Z).

$$Z = \frac{Q}{\sqrt{g}} \quad (28.32\text{-}5)$$

Where:

Z	=	section factor
Q	=	flow rate (cfs)
g	=	gravitational acceleration (32.2 ft./s^2)

(2) **Step 2.**

Determine the critical depth in the channel (dc) from Figure 28.32.050, using appropriate values for the section factor (Z), the channel bottom width (b), and the channel side slope (z).

For other prismatic channel shapes, Equation 28.32-5 determines the critical depth using the section factors provided in Table 28.32.040(a).

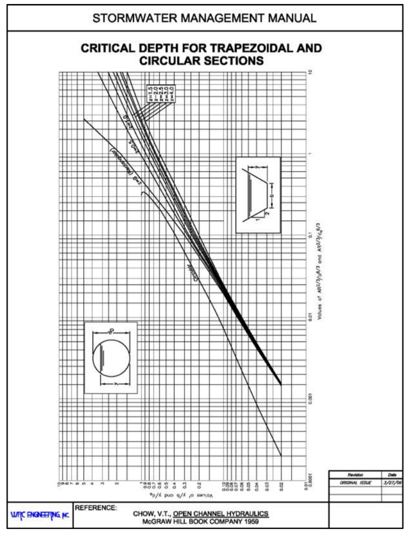


FIGURE 28.32.050

(Res. 40-08 (§ 803.2), 3-19-08)

§ 28.32.060. Design procedures – Subcritical flow.

All open channels shall be designed with the limits as stated in GJMC § 28.32.140 through 28.32.330. The following design procedures shall be used when the design runoff in the channel is flowing in a subcritical condition (Fr<1.0).

(a) Transitions. Subcritical transitions occur when transitioning one subcritical channel section to another subcritical channel section (expansion or contraction), or when a subcritical channel section is steepened to create a supercritical flow condition downstream (e.g., a sloping spillway entrance).

Figure 28.32.060 presents a number of typical subcritical transition sections. The warped transition section, although most efficient, shall only be used in extreme cases where minimum loss of energy is required since the section is very difficult and costly to construct. Conversely, the square-ended transition shall only be used when either a straight-line transition or a cylinder-quadrant transition cannot be used due to topographic constraints or utility conflicts.

(b) **Contractions.**

The energy loss created by a contracting section may be calculated using the following equation:

$$H_t = K_{tc}\left(\frac{V_2^2}{2g} - \frac{V_1^2}{2g}\right) \qquad (28.32\text{-}6)$$

Where:

Ht	=	energy loss (ft.);
Ktc	=	contraction transition coefficient
V1	=	upstream velocity (ft./s); and
V2	=	downstream velocity (ft./s); and
g	=	gravitational acceleration (32.2 ft./s^2)

Figure 28.32.060 shows contraction loss coefficient (Ktc) values for the typical open-channel transition section.

(c) **Expansions.**

The energy loss created by an expanding transition section may be calculated using the following equation:

$$H_t = K_{te}\left(\frac{V_1^2}{2g} - \frac{V_2^2}{2g}\right) \quad (28.32\text{-}7)$$

Figure 28.32.060 also shows expansion loss coefficients (Ktc) values for typical open-channel transition sections.

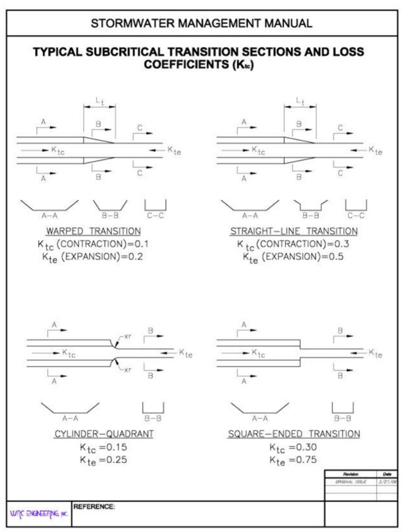


FIGURE 28.32.060

(d) **Transition Length.**

The length of the transition section shall be long enough to keep the streamlines smooth and nearly parallel throughout the expanding (contracting) section. Experimental data and performance of existing structures have been used to estimate the minimum transition length necessary to maintain the stated flow conditions. Based on this information, guidelines for the minimum length of the transition section are as follows:

$$Lt \geq 0.5Lc\ (\Delta Tw) \quad (28.32\text{-}8)$$

Where:

Lt	=	minimum transition length (feet);
Lc	=	length coefficient (dimensionless); and
ΔTw	=	difference in the top width of the normal water surface upstream and downstream of the transition (feet).

Table 28.32.060 below summarizes the transition length coefficients for subcritical flow conditions. These transition length guidelines are not applicable to cylinder-quadrant or square-ended transitions.

For flow approach velocities of 12 ft./sec. or less, the transition length coefficient (Lc) shall be 4.5. This represents a 4.5L:1W expansion or contraction, or about a 12.5-degree divergence from the channel centerline. For flow approach velocities of more than 12 feet/second, the transition length coefficient (Lc) shall be 10. This represents a 10L:1W expansion or contraction, or about a 5.75-degree divergence from the channel centerline.

Table 28.32.060: Transition Length Coefficients for Subcritical Open Channels	
Flow Approach Velocity (v) (ft/s)	**Transition Length Coefficient (Lc)**
= 12	4.5
> 12	10

(Res. 40-08 (§ 803.3), 3-19-08)

§ 28.32.070. Design procedures – Supercritical flow.

Mesa County and the City of Grand Junction do not encourage supercritical channels, which typically are concrete-lined. The information presented herein is for completeness and in anticipation that analysis of a supercritical channel may be necessary in the future. All supercritical channels shall be designed within the limits as stated in GJMC § 28.32.140 through 28.32.330. The following design procedures shall be used when channels are designed to flow in a supercritical condition (Fr>1.0).

Supercritical flow can become unstable in response to relatively minor disturbances to the channel cross-section; even small obstruction can sometimes cause a hydraulic jump. Good design practice is to test supercritical flow stability during events smaller than the design flow by evaluating flows of specific more frequent storm events (e.g., 10-year, two-year, etc.), or testing successive fractions (e.g., one-half, one-quarter, and further if necessary) of the design flow. Also, the designer shall test for small variations in n-value as well. However, only calculations for the full design flow are required to be submitted for review.

(a) **Transitions.**

The design of supercritical flow transitions is more complicated than subcritical transition design due to the potential damaging effects of the oblique jump created by the transition. The oblique jump results in cross waves and higher flow depths that can cause damage if not properly accounted for in the design. Supercritical transitions can be avoided by designing a hydraulic jump, which must also be carefully designed to assure the jump will remain where the jump is designed to occur. Hydraulic jumps shall be designed to take place only within concrete-lined portions of the channel, such as energy dissipation or drop structures.

(b) **Contractions.**

igure 28.32.070(a) presents an example of a supercritical contracting transition, with upstream flow contracted from width b1 to b3 and a wall diffraction angle of θ. The oblique jump occurs at the points A and B where the diffraction angles start. Wave fronts generated by the oblique jumps on both sides propagate toward the centerline with a wave angle ß1. Since the flow pattern is symmetric, the centerline acts as if there was a solid wall that causes a subsequent oblique jump and generates a backward wave front toward the wall with another angle ß2. These continuous oblique jumps result in turbulent fluctuations in the water surface.

To minimize the turbulence, the first two wave fronts are designed to meet at the center and then end at the exit of the contraction. Using the contraction geometry, the length of the transition shall be as follows:

$$LT = \frac{b1 - b3}{2\tan\theta} \qquad (28.32\text{-}9)$$

Where:

LT	=	transition length (ft.);
b1	=	upstream top width of flow (ft.);
b3	=	downstream top width of flow (ft.);
θ	=	wall angle as related to the channel centerline (degrees).

Using the continuity principle,

$$\frac{b_1}{b_3} = \left(\frac{y3}{y1}\right)^{3/2}\left(\frac{F_{R_3}}{F_{R_1}}\right) \qquad (28.32\text{-}10)$$

Where:

y1	=	upstream depth of flow (ft.)
y3	=	downstream depth of flow (ft.)
Fr1	=	upstream Froude number
Fr3	=	downstream Froude number

Also, by the continuity and momentum principles, the following relationship between the Froude number, wave angle, and wall angle is:

$$\tan\theta = \frac{\tan\beta_1\left[\left(1+8F_{R1}^2\sin^2\beta_1\right)^{1/2}-3\right]}{2\tan^2\beta_1+\left(1+8F_{R1}^2\sin^2\beta_1\right)^{1/2}-1} \qquad (28.32\text{-}11)$$

Where:

ß1	=	Initial wave angle (degrees)

By trial and error, this design procedure can be used to determine the transition length and wall angle. Figure 28.32.070(b) offers a faster solution than trial and error using Equation 28.32-10 and Equation 28.32-11 (above). Figure 28.32.070(b) can also be used to determine the wave angle (ß), or may be used with the equations to determine the required downstream depth or width parameter if a certain transition length is desired or required.

To minimize the length of the transition section, the ratio of downstream and upstream flow depths should generally be greater than 2.0 and less than 3.0 (2.0<y3/y1<3.0). The downstream Froude number should generally be greater than 1.7 to help avoid undulating hydraulic jumps downstream. For further discussion on oblique jumps and supercritical contractions, refer to Chow (1959).

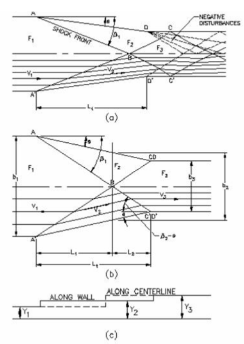


Figure 28.32.070(a): Supercritical Contraction Transition and Angle Definitions

(c) **Expansions.**

A properly designed expansion transition expands the flow boundaries at approximately the same rate as the natural flow expansion. Based on experimental and analytical data results, the minimum length of a supercritical expansion shall be as follows:

$$L_t \geq 1.5\,(\Delta W)\,F_r \qquad (28.32\text{-}12)$$

Where:

Lt	=	minimum transition length (ft.);
ΔW	=	difference in the top width of the normal water surface upstream and downstream of the transition
Fr	=	Upstream Froude number

(d) **Transition Curves.**

A transition curve may be used to reduce the required amount of freeboard or radius of curvature in a rectangular channel. The length of the transition curve measured along the channel centerline shall be determined as follows:

$$L_c = 2D = 0.32\frac{WV}{\sqrt{y}} \quad (28.32\text{-}13)$$

Where:

Lc	=	length of transition curve (ft.);
D	=	distance from the start of curve to point of first maximum superelevation (ft.). Typically D=3Lw; see description of how to apply superelevation allowance in GJMC § 28.32.080;
W	=	top width of design water surface (ft.);
V	=	mean design velocity (ft./s); and
y	=	depth of design flow (ft.).

The radius of the transition curves shall be twice the radius of the main bend. Transition curves shall be located both upstream and downstream of the main bend.

(e) **Slug Flow and Roll Waves.**

Steep channels with significantly rapid flows (Fr>2.0) are prone to developing pulsating flow profiles, often called slug flows or roll waves. These standing waves can cause flow to exceed freeboard limits and possible damage to the channel lining. The design engineer may resolve pulsating flow issues either by adjusting the channel slope to prevent the development of these waves or providing additional freeboard to account for the height of the standing waves.

Theoretically, slug flow will not occur when the Froude number is less than 2.0. To avoid slug flow when the Froude number is greater than 2.0, the channel slope shall be as follows:

$$S \leq \frac{12}{RE} \quad (28.32\text{-}14)$$

Where:

S	=	channel slope (feet per feet);
RE	=	Reynolds Number, $RE = \frac{uR}{v}$
u	=	mean design velocity (feet per second);
R	=	hydraulic radius (feet); and

v = kinematic viscosity of water (ft^2/s).

More detailed discussion of pulsating flow is beyond the scope of this manual. Several references, including Chow (1959) and Clark County (2000), provide further discussion of this topic. The Los Angeles County Flood Control District (1982) has developed nomographs for determining the appropriate freeboard allowance for roll wave height based on empirical research at the California Institute of Technology (Brock, 1967).

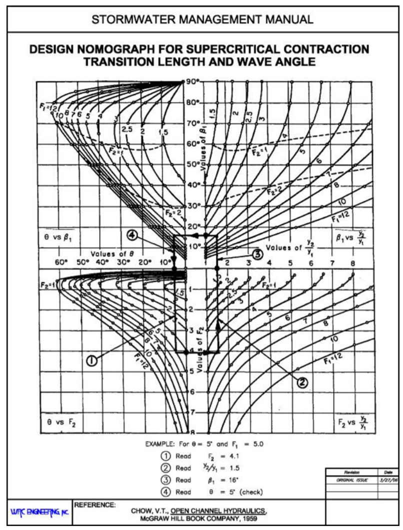


FIGURE 28.32.070(b)

(Res. 40-08 (§ 803.4), 3-19-08)

§ 28.32.080. Design procedures – Superelevation.

Superelevation is the transverse rise in water surface that occurs around a channel bend, measured between the theoretical water surface at the centerline of a channel and the water surface elevation on the outside of the bend. Superelevation in bends shall be estimated from the following equation:

$$\Delta y = \frac{CV^2W}{rg} \qquad (28.32\text{-}15)$$

Where:

r	=	radius of curvature at centerline of channel (ft.);
C	=	curvature coefficient (see Table 28.32.080);
Δy	=	rise in water surface between design water surface at centerline of channel and outside water surface elevation (ft.);
W	=	top width at the design water surface at channel centerline (ft.);
V	=	mean channel velocity (ft./s); and

g = gravitational acceleration (ft./s^2).

The curvature coefficient C shall be 0.5 for subcritical flow conditions. For supercritical flow conditions, the curvature coefficient shall be 1.0 for all trapezoidal channels and for rectangular channels without transition curves, and 0.5 for rectangular channels with transition curves. Table 28.32.080 provides superelevation curvature coefficients for various flow regimes, cross-section shapes, and types of curves.

Bends in supercritical channels create cross-waves and superelevated flow in the bend section as well as further downstream from the bend. In order to minimize these disturbances, best design practice is to design the channel radius of curvature to limit the superelevation of the water surface to 2.0 feet or less. This can be accomplished by modifying Equation 28.32-15 to determine the allowable radius of curvature of a channel for a given superelevation value.

Table 28.32.080: Superelevation Curvature Coefficients

Flow Type	Cross-Section	Type of Curve	Curvature C
Subcritical	Rectangular	No Transition	0.5
Subcritical	Trapezoidal	No Transition	0.5
Supercritical	Rectangular	No Transition	1
Supercritical	Trapezoidal	No Transition	1
Supercritical	Rectangular	with Spiral Transition	0.5
Supercritical	Trapezoidal	with Spiral Transition	1
Supercritical	Rectangular	with Spiral Banked Transition	0.5

Source: Corps EM 1110-2-1601 (July 1991)

(Res. 40-08 (§ 803.5), 3-19-08)

§ 28.32.090. Transitions.

(a) Channel transitions occur in open channel design whenever there is a change in channel slope or shape and at junctions with other open channels or storm sewers. The goal of a good transition design is to minimize the loss of energy as well as minimize surface disturbances from cross-waves and turbulence. Special cases of transitions where excess energy is dissipated by design are drop structures and hydraulic jumps. Channel drop structures are discussed in GJMC § 28.32.340(d)(2).

(b) Transitions in open channels are generally designed for the following four flow conditions.

(1) Subcritical flow to subcritical flow.

(2) Subcritical flow to supercritical flow.

(3) Supercritical flow to subcritical flow (hydraulic jump).

(4) Supercritical flow to supercritical flow.

(c) For definition purposes, the conditions in subsections (b)(1) and (2) of this section will be considered as subcritical transitions and are later discussed in GJMC § 28.32.110 through 28.32.130. The conditions in subsections (b)(3) and (4) of this section will be considered as supercritical transitions and are later discussed in GJMC § 28.32.110 through 28.32.130.

(Res. 40-08 (§ 803.6), 3-19-08)

§ 28.32.100. Types of open channels and their selection.

Open channels can be categorized as either natural or engineered (artificial). Natural channels include all watercourses that are carved and shaped by the erosion and sediment transport process. Engineered channels are those constructed by human efforts. Open channels can be separated into six different types:

(a) **Natural Channels.**

Watercourses are carved and shaped by natural erosion processes before urbanization occurs. As the channel's tributary watershed urbanizes, natural channels often experience erosion and may need grade control checks and localized bank protection to stabilize.

Natural channels are also strongly influenced by urbanization in the watershed, which significantly alters the hydrology and therefore, the geometry of the natural channels. If the watershed imperviousness exceeds around 10 percent, it is likely that channel geometry will be altered such that a natural channel is no longer viable and mitigation measures will be required, such as bank and bed stabilization measures.

(b) **Grass-Lined Channels.**

Among various types of constructed or modified drainageways, grass-lined channels are most desirable. They provide channel storage, lower velocities, groundwater recharge, and various multiple-use benefits. Low-flow areas may need to be concrete, rock-lined, or otherwise reinforced with vegetation to minimize erosion and maintenance problems.

(c) **Wetland Vegetation Bottom Channels.**

A subset of grass-lined channels that are designed to encourage the development of wetlands or certain types of riparian vegetation in the channel bottom. These channels offer potential benefits that may include wildlife habitat, groundwater recharge and water quality enhancement. In low-flow areas, the banks may need supplemental reinforcement to protect against undermining.

(d) **Concrete-Lined Channels.**

Concrete-lined channels are high velocity artificial drainageways that are not encouraged. However, in retrofit situations where existing flooding problems need to be solved and where right-of-way is limited, concrete channels may offer advantages over other types of open drainageways. Special attention shall be taken to provide safety measures (i.e., fence) around the concrete-lined channels.

(e) **Riprap-Lined Channels.**

Riprap-lined channels offer a compromise between a grass-lined channel and a concrete-lined channel. They can reduce right-of-way needs as compared to grass-lined channels and avoid the higher costs of concrete-lined channels. Riprap-lined channels are not encouraged.

(f) **Other Lined Channels.**

A variety of artificial channel liners are on the market, all intended to protect the channel walls and bottom from erosion at higher velocities. These include gabion, interlocked concrete blocks, concrete revetment mats formed by injecting concrete into double layer fabric forms, and various types of synthetic fiber liners. As with rock and concrete liners, all of these types are best considered for helping to solve existing urban flooding problems and are not recommended for new developments. Each type of liner has to be scrutinized for its merits, applicability, how it meets other community needs, its long-term integrity, and maintenance needs and costs. Channels lined with artificial materials are not permitted in new development areas of Mesa County, including the City of Grand Junction, except by variance to or deviation from these criteria.

(g) **Selection of Channel Type.**

Mesa County and the City of Grand Junction do not have a preference for any particular channel-lining system, as long as it is properly evaluated on its merits. Each type of channel must be evaluated for its longevity, integrity, maintenance requirements and costs, and general suitability for community needs, among other factors. Selection of a channel type that is most appropriate for the conditions that exist at a project site shall be based on a multi-disciplinary evaluation, which may include hydraulic, structural, environmental, sociological, maintenance, economic, and regulatory factors.

(Res. 40-08 (§ 804), 3-19-08)

§ 28.32.110. Natural channel systems.

(a) In general, a natural channel system continually changes its position and shape as a result of hydraulic forces acting on its bed and banks. These changes may be slow or rapid and may result from natural environmental changes or from changes caused by human activities. When a natural channel is modified locally, the change frequently causes alteration in channel characteristics both upstream and downstream. The response of a natural channel to human-induced changes often occurs in spite of attempts to control the natural channel environment.

(b) Natural and human-induced changes in natural channels frequently set in motion responses that can be propagated for long distances. In spite of the complexity of these responses, all natural channels are governed by the same basic forces but to varying degrees. It is necessary that a natural channel system design be based on adequate knowledge of:

(1) Geologic factors, including soil conditions;

(2) Hydrologic factors, including possible changes in flow and runoff, and the hydrologic effects of changes in land use;

(3) Geometric characteristics of the stream, including the probable geometric alterations that developments will impose on the channel;

(4) Hydraulic characteristics such as depth, slope, velocity of streams, sediment transport, and the changes that may be expected in these characteristics over space and time; and

(5) Ecological/biological changes that will result from physical changes that may in turn induce or modify physical changes.

(c) Effects of development in natural channels, flood control measures, and constructed channel structures have proven the need for considering the immediate, delayed, and far-reaching effects of alterations imposed on natural channel systems. Variables affecting natural channels are numerous and interrelated. Their nature is such that, unlike rigid-boundary hydraulic problems, it is not possible to isolate and study the role of each individual variable. Because of the complexity of the processes occurring in natural flows that influence the erosion and deposition of material, a detached analytical approach to the problem may be difficult and time consuming. Most relationships describing natural channel processes have been derived empirically. The major factors affecting natural channel geometry are:

(1) Stream discharge;

(2) Sediment load;

(3) Longitudinal slope;

(4) Characteristics of bed and bank material;

(5) Bank and bed resistance to flow;

(6) Vegetation or lack thereof;

(7) Geology, including type of sediment; and

(8) Constructed improvements.

(Res. 40-08 (§ 805), 3-19-08)

§ 28.32.120. Channel morphology.

(a) When seeking to utilize or modify a natural channel, an understanding of the mechanism of its morphology is important. Without incorporating a thorough understanding of the geomorphic conditions of the stream and the watershed, alterations to channels or to their watersheds can lead to unexpected instabilities, bring about unwanted erosion or aggradation, and cause significant damage to fluvial systems.

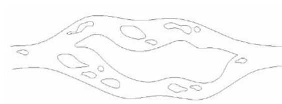
The morphology of a stream is a result of the variables that determine the quantity of water and sediment it carries, including the geology, soils and vegetation of the stream and watershed, the hydrology and dominant discharge of the system, and the slope of the stream. The following is a short discussion of some fundamentals of fluvial geomorphology. The users of this manual are encouraged to review the related textbooks and other technical literatures on the subject for more detailed discussions. The following is a partial list of some of the related publications:

- Dave Rosgen, illustrated by Hilton Lee Silvey, Applied River Morphology, 1996.
- Lane, E.W., 14957. A study of the shape of channels formed by natural streams flossing in erodible material: M.R., D. Sediment Series No. 9, U.S. Army Engineer Division, Missouri River, Corps of Engineers, Omaha, NE.
- Ritter, Dale F., 1986. Process Geomorphology. Wm C. Brown Publishers, Dubuque, Iowa.
- Simons Li and Associates, 1982. Engineering Analysis of Fluvial Systems.

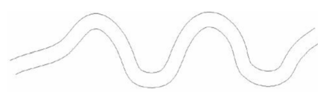
(b) There are three general principles governing the geomorphology of a natural stream system. First, riverine systems are dynamic. Erosion and aggradation can occur over a relatively short period of time (as sudden as one storm event) and can result from unstable conditions brought about by changing hydrologic or sediment-supply conditions (either natural or human induced). However, because all systems are dynamic, normal progression of a stream is not always a result or a symptom of instability. Second, the responses resulting from changes to a channel or its watershed are complex. Morphologic responses can be anticipated but cannot always be quantitatively predicted, even by the most experienced engineers. Additionally, short reaches of streams cannot be looked at individually; a change to a short stretch or even to a single area of the stream can cause unwanted or unexpected alterations upstream or downstream of the change. Third, most geomorphic boundaries within a riverine system can be classified as thresholds. Gradual changes to a channel or its watershed will not always bring about gradual responses. Instead, gradual changes may build up to a threshold so that a small-scale occurrence, such as a moderately large flood, will seemingly cause a catastrophic result. (Simons Li and Associates, 1982)

(c) Natural streams can be classified generally into three prevailing patterns. These patterns, straight, meandering and braided, are characteristics of the responses of a system to its prevailing discharge and load.

Braided Channel



Meandering Channel



Straight Channel

(d) Straight and meandering streams are two manifestations of similar dynamics. The thalwegs in both shift from bank to bank and sediment deposition and erosion within the channel bottom establish a series of riffles and pools. Straight channels have relatively straight banks; meandering streams have sinuous banks. Straight channels are fairly rare; most natural channels have some degree of sinuosity. Although meandering and straight streams can be in quasi-equilibrium, their thalwegs, meanders and riffle-pool sequences migrate in predictable patterns if left untouched. Braided systems, unlike meandering and straight, do not have a single trunk; they have a network of branches and series of islands. The single branches usually meander to some degree. Braided channels convey low to medium flows in the series of branches; large flows intermingle into a single floodplain. Meandering and straight systems are generally more stable than braided. Braided channels tend to carve new channels and deposit islands at a relatively fast pace and be horizontally unstable. The divisions between the three classifications are imprecise and relatively indistinct. A given stream can have reaches of each classification, and given reaches can include characteristics of one or more pattern. (Ritter, 1986)

(e) Any change to a variable of a natural stream system, such as the slope or dominant discharge, can change the morphology and/or the existing stream pattern according to the three principles outlined above. These changes can be somewhat predicted; much work has been done to establish relationships between the variables and characteristics of natural streams. Two general relationships for predicting morphological responses to changes in riverine variables are as follows:

$$Q \cong \frac{b, d, \lambda}{S} \qquad (28.32\text{-}16)$$

and

$$Qs \cong \frac{b, \lambda, \lambda}{d, P} \quad \text{(SLA, 1982)} \qquad (28.32\text{-}17)$$

Where:

Q	=	Average discharge
Qs	=	Sediment supply
b	=	Channel width
d	=	Channel depth
λ	=	Meander wavelength
S	=	Bed slope
P	=	Sinuosity

(f) An increase in mean annual discharge will generally cause an increase in channel depth, width, and meander wavelength and a decrease in bed slope. An increase in sediment supply will generally cause an increase in channel width, meander wavelength and bed slope and a decrease in sinuosity and channel width. Because the average flow rate is usually directly related to sediment supply, these relationships can become complex when both flow and sediment supply increase or flow increases and sediment supply decreases, or vice versa. Additionally, changes to one or more channel morphology characteristics can cause changes to other characteristics. An increase in slope can cause a decrease in channel depth or a decrease in meander wavelength. Further complicating these relationships are variables such as the average grain-size and type of sediment, the percentage of sediment carried as bed load, and the geology of the valley, all which can affect the responses of the stream and contribute to unexpected or seemingly counterintuitive results.

(g) A general relationship between slope, mean annual discharge and the tendency of a system to be meandering or braided has been established by Lane (1957). They found that if a stream's $SQ^{1/4}$ is less than or equal to 0.0017, it tends to be meandering. If $SQ^{1/4}$ is greater than or equal to 0.01, systems tend toward a braided pattern. Streams that have $SQ^{1/4}$ between 0.0017 and 0.01 are in an intermediate zone and can be either braided or meandering with a greater tendency to respond to flow and slope alterations with a change in river pattern. These relationships are complicated and not absolute.

(h) Some specific examples of man-induced changes to the natural stream/river systems that could cause undesired responses by channel morphology are as follows:

(1) **Change in Flow.**

As demonstrated in the above relationships, a decrease in flow due to diversion or reservoir routing change can cause a decrease in channel width, depth, and sinuosity and an increase in slope; an increase in flow due to development can have the opposite effect. In addition to these changes, the corresponding decrease or increase of average stage of the main stem of a river can have significant effects on the streams' tributaries. If the average stage decreases, the tributaries' energy slopes will increase, increasing the ability of the tributary to transport sediment, which can cause degradation of its channel, commonly referred to as headcutting. Similarly, an increase in stage in the main stem can lead to aggradation within its tributaries. Both of these scenarios can do serious damage to the tributary channel and increase its horizontal instability. Headcutting can cause bank destabilization and failure. Aggradation can cause increased flooding potential and rerouting of the channel.

(2) **Channelization.**

The channelization of a natural stream to allow increased conveyance often straightens channels and cuts off meanders, causing an increase in slope through the improved stretch. This can increase velocities and degradation through the stretch and then decrease slopes and increase aggradation downstream of the stretch. The increase in slope and average discharge can also cause a meandering system to tend toward a braided configuration that can lead to further horizontal and vertical instabilities. In addition, by lowering the average stage, channelization will affect the stream's tributary channels in the same manner as the first example.

(3) **Construction of Dams.**

The construction of both large- and small-scale dams can have far-reaching effects on a stream system. Without a design approach that will allow frequent flows to travel through the dam unadulterated, some suspended sediment and most bed load will be deposited upstream of the dam. This will decrease slopes and change channel configuration upstream and release clear water and potentially cause scour and degradation in the downstream reach.

(4) **Construction of Bridges and Culverts.**

The construction of bridges and culverts, in addition to the well-documented local scour issues, can cause more regional channel morphology problems. An undersized bridge or culvert can decrease velocity and increase average stage upstream of the bridge, causing deposition and affecting the tributaries' channels. Scour around the bridges can cause an increase in sediment supply in the channel, leading to deposition downstream.

(i) There are many additional examples of morphological problems that can be caused by manmade changes on a natural stream system. Any substantial modification to a natural channel system shall be evaluated carefully to determine the potential adverse impacts on the stream system both upstream and downstream of the proposed modification.

(Res. 40-08 (§ 805.1), 3-19-08)

§ 28.32.130. Channel restoration.

The practice of channel restoration is becoming more common in the United States as the negative effects of urbanization, channelization, and other hydraulic "improvements" have taken their toll on the sediment balance, channel stability, biological habitats, and the aesthetic and recreational benefits of the impacted rivers and streams.

Although it may not be feasible to restore a disturbed stream/river system back to its original condition, channel restoration projects can help expedite the natural channel recovering process and help to recreate an environment that closely resembles the original configuration of the stream system. Channel/river restoration projects typically involve reconnection of the floodplain back to its channel, establishment of wetland areas around the channel, restoration of meanders, point-bars and riffle-pool sequences, and recreation of the chemical and biological complexity that exists in the natural channel system. Benching, allowing for a low-flow meandering channel with terraced banks above the low-flow channel, is a popular technique that allows for expansive riparian plant and wildlife habitat, recreation opportunities, and unique flood control options. Channel restoration usually involves a significant degree of both planting and seeding native, wetland, and self-sustainable vegetations within the channel and along the banks.

A design team comprised of hydraulic engineers, fluvial geomorphologists, biologists and botanists who are highly knowledgeable of the system should be involved in the channel restoration design process. Furthermore, due to the advantage of irregular alignments and channel cross-sections, the construction phase shall be carefully managed and overseen to ensure that the design is fully incorporated into the final improvement.
(Res. 40-08 (§ 805.2), 3-19-08)

§ 28.32.140. General design criteria for improved open channels.

GJMC § 28.32.140 through 28.32.260 present general design standards that apply to all improved channels. GJMC § 28.32.270 provides specific design criteria for natural and alluvial bed channels. GJMC § 28.32.280 through 28.32.320 provide specific design criteria for fixed-bed type channels that include: grass-lined channels, wetland bottom channels, riprap-lined channels, concrete-lined channels, and channels with other types of linings.

Depending on the local conditions, the specific requirements for a particular type channel may be more strict than the general criteria outlined in this chapter. In addition, unique and unusual site conditions may require additional design analysis be performed to verify the suitability of the proposed channel design for the project site.
(Res. 40-08 (§ 806), 3-19-08)

§ 28.32.150. Channel type selection.

Six general different types of open channels were presented in GJMC § 28.32.100. In general, the use of concrete-lined and riprap-lined channels is discouraged. The selection of a channel type was presented in general terms in GJMC § 28.32.100(g). The following multi-disciplinary factors shall be used if selecting the channel that is most suitable for a specific site:

(a) **Hydraulic Factors.**

(1) Slope of thalweg.

(2) Right-of-way.

(3) Capacity needed.

(4) Basin sediment yield.

(5) Topography.

(6) Ability to drain adjacent lands.

(b) **Structural Factors.**

(1) Cost.

(2) Availability of material.

(3) Areas for wasting excess excavated material.

(4) Seepage and uplift forces.

(5) Shear stresses.

(6) Pressures and pressure fluctuations.

(7) Momentum transfer.

(c) **Environmental Factors.**

(1) Neighborhood character.

(2) Neighborhood aesthetic requirements.

(3) Need for new green areas.

(4) Street and traffic patterns.

(5) Municipal or county policies.

(6) Wetland mitigation.

(7) Wildlife habitat.

(8) Water quality enhancement.

(d) **Sociological Factors.**

(1) Neighborhood social patterns.

(2) Neighborhood children population.

(3) Pedestrian traffic.

(4) Recreational needs.

(e) **Maintenance Factors.**

(1) Life expectancy.

(2) Repair and reconstruction needs.

(3) Maintainability.

(4) Proven performance.

(5) Accessibility.

(f) **Regulatory Factors.**

(1) Federal regulations.

(2) State regulations.

(3) Local regulations.

(Res. 40-08 (§ 806.1), 3-19-08)

§ 28.32.160. Hydraulic capacity.

All new open channels shall be designed, at a minimum, to safely confine and convey the runoff from the 100-year design event.
(Res. 40-08 (§ 806.2), 3-19-08)

§ 28.32.170. Manning roughness coefficient.

Selection of an appropriate channel roughness value for a given channel section is important for the hydraulic capacity analysis and design of open channel. The roughness value can vary significantly depending on the channel type and configuration, density and type of vegetation, depth of flows, and other hydraulic properties.

Tables 28.32.040(b), 28.32.040(c), 28.32.040(d) and 28.32.040(e) show recommended values for the Manning roughness coefficient for various channel types and conditions. Manning roughness coefficients for riprap channels shall be computed based on the criteria outlined in GJMC § 28.32.040.
(Res. 40-08 (§ 806.3), 3-19-08)

§ 28.32.180. Uniform flow.

Open channel drainage systems shall be designed assuming uniform flow conditions. GJMC § 28.32.040 presents the uniform flow equation and methods for calculating uniform flow.
(Res. 40-08 (§ 806.4), 3-19-08)

§ 28.32.190. Vertical and horizontal alignment.

Open channels shall have a minimum longitudinal gradient of 0.5 percent whenever practical. Flatter grades may be approved with prior consultation with Mesa County or applicable governing agencies. Open channels with grades flatter than 0.5 percent shall have provisions for the drainage of nuisance low flows.

Horizontal alignment changes of two degrees or less may be accomplished without the use of a circular curve for subcritical flow designs (Fr<1.0, see GJMC § 28.32.060). Curves must be used for supercritical flow designs (Fr>1.0), no matter the degree of change in horizontal alignment. Curved channel alignments shall have superelevated banks in accordance with GJMC § 28.32.080.

Spiral transition curves shall be used upstream and downstream of curves for supercritical channel designs with reverse curves or horizontal alignments with consecutive circular curves. Spiral curves may also be used to reduce required superelevation allowances and cross-wave disturbances.
(Res. 40-08 (§ 806.5), 3-19-08)

§ 28.32.200. Maximum permissible velocity.

The design of open channels shall be governed by maximum permissible velocity. This design method assumes that a given channel section will remain stable up to a maximum permissible velocity; provided, that the channel is designed in accordance with the standards presented in this manual. Table 28.32.200 presents the maximum permissible velocities for several types of natural, improved, unlined, and lined channels.

Regardless of these maximum permissible velocities, the channel section shall be designed to remain stable at the final design flow rate and velocity. The design flow may not always be based on the highest flow velocity. Therefore, best practice is to confirm channel section stability during events smaller than the design flow. This may be accomplished by evaluating flows of specific more frequent storm events (e.g., 10-year, two-year, etc.), or testing successive fractions (e.g., one-half, one-quarter, and further if necessary) of the design flow. However, only calculations for the full design flow are required to be submitted for review.

Additional geotechnical and geomorphologic investigation and analyses may be required for natural channels or improved unlined channels to verify that the channel will remain stable based on the maximum design velocities.