REPUBLIC BUILDS
Public Works • Community Development

Standards

Stormwater Management and Design Criteria Manual

September 2023

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Drawing 30 – Diversion Dike and Swale

Drawing 50 – Straw Bale Dike

Drawing 70 – Riprap Chute (Refer to City Standard Construction Specifications for Updated Drawing)

Drawing 80 – Sediment Basin – Perforated Pipe Outlet

Drawing 90 – Sod Channel less than 15’ and greater than 15’

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Drawing 130 – Curb Opening

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Note: Additional drawing details are provided in the Standard Specifications Details for Water and Sewer Construction, related to Stormwater Infrastructure

Standard Detail #37 – Curb inlets 18” or Less

Standard Detail #38 – Curb inlets 21” or Greater

Standard Detail #39 – Top Slab Reinforcement

Standard Detail #40 – Ring and Cover for Inlet

Standard Detail #41 – Concrete Culvert Cap – Driveways

Standard Detail #42 – Riprap

SECTION 1 - GENERAL PROVISIONS

1.1 Scope

These design criteria set forth in the minimum standards for design of storm drainage facilities on public right-of-way and private property in the City of Republic.

1.2 Authority

These design criteria and standards set forth herein have been adopted by the Planning and Zoning Commission and the City Council in accordance with the procedures and authority set forth in the City of Republic.

Any development or grading begun after the date of passage of these criteria and standards which does not comply with the requirements set forth herein shall be deemed to be in violation of the requirements established herein; and shall be subject to enforcement measures and penalties set forth in City of Republic, Missouri municipal code, Section 100.220 — General Penalty.

1.3 Interpretations

Where any of the provisions contained herein may be unclear or ambiguous as they pertain to a particular site or situation, interpretations of the policies, criteria and standards set forth herein shall be made in writing by the Engineering Manager.

Such written interpretations shall be kept on file for future reference for use in similar situations and shall be incorporated in subsequent revisions for the standards, if deemed necessary for general reference.

1.4 Appeals

Where disagreements may arise over the interpretation of the requirements set forth herein, appeals may be made to the City Planner upon written request.

Information and supporting documentation for the appeal shall be submitted with the request. The City Planner shall forward the information to the Builds Administrator and the City Engineer within three (3) calendar days following receipt of the information.

1.5 Approvals and Permits Required

1.5.1 Grading Permit

Storm drainage facilities may not be constructed or altered without review and approval of the plans by the City and issuance of a Grading Permit by the City for subdivisions, commercial and other sites which may not fall under the criteria specified herein.

1.5.2 National Pollutant Discharge Elimination System (NPDES) Stormwater Permit

Provisions of the 1987 Clean Water Act require that certain stormwater discharges obtain an NPDES stormwater permit. In Missouri, these permits are administered by the Missouri Department of Natural Resources.

Federal rules for NPDES stormwater discharges are contained in 40 CFR Parts 122, 123 and 124 of the Code of Federal Regulations. State NPDES stormwater regulations are contained in 10 CSR 20-6.200 of the Code of State Regulations. Additional provisions for NPDES stormwater permits for land disturbance activities and information regarding the City of Republic General Permit for land disturbance activities are contained in Section 10 of these criteria.

1.5.2.1 Missouri Land Disturbance Permit

Effective December 8, 1999, construction sites where the area to be disturbed is one acre or more or less than one acre but part of a common plan of development will require a Missouri Land Disturbance permit.

1.5.3 USACE Section 404 Permit

1.5.3.1 General Requirement

For certain activities, which involve the discharge of dredged or fill materials into the waters of the United States a Department of the Army permit may be required as set forth in Section 404 of the Clean Water Act. Rules for 404 permits are contained in 33 CFR Parts 320 through 330 of the Code of Federal Regulations.

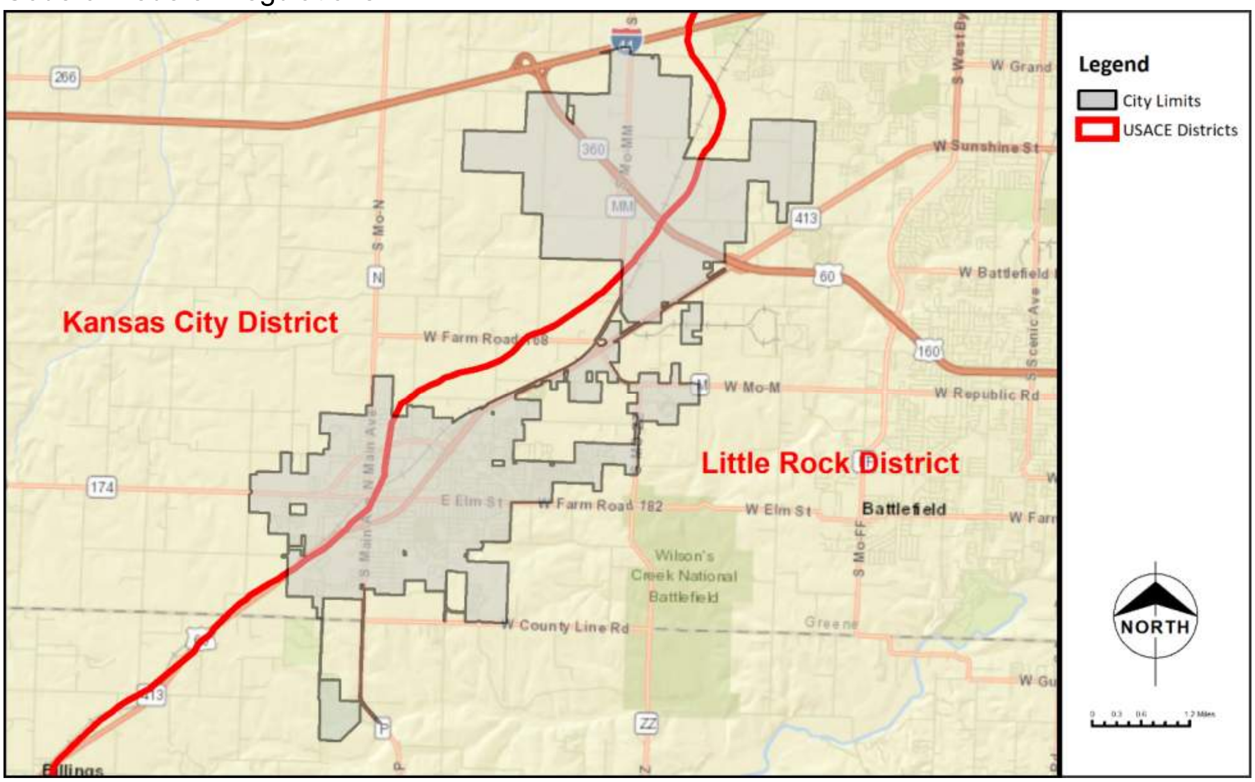


Figure 1-1: U.S. Army Corps of Engineers District Boundaries

1.5.3.2 Determination of Applicability

Determination of applicability for Section 404 requirements are made by either the Kansas City or Little Rock District office of the U. S. Army Corps of Engineers. Figure 1-1 shows the boundary of each district with respect to City limits.

Section 404 permitting requirements for the Kansas City District can be found at the following web page: https://www.nwk.usace.army.mil/Missions/Regulatory-Branch/

Section 404 permitting requirements for the Little Rock District can be found at the following web page:https://www.swl.usace.army.mil/Missions/Regulatory/Applying-for-a-Permit/

If the Army Corps of Engineers determines a 404 permit is required, the project must also be submitted to the state of Missouri for a Section 401 Water Quality Certification: Section 401 Water Quality Certification | Missouri Department of Natural Resources (mo.gov).

1.6 Coordination with Other Jurisdictions

1.6.1 Additional Design Requirements

Where proposed storm drainage facilities are located on property adjoining to other local government jurisdictions, design of storm drainage facilities shall include provisions to receive or discharge stormwater in accordance with the requirements of the adjoining jurisdiction, in addition to meeting City requirements.

1.6.2 Additional Submittal Requirements

In these cases, two (2) additional sets of plans shall be submitted and will be forwarded to the adjoining jurisdiction for review and comment.

1.6.3 Requirements for Utility Relocations

No grading or construction of storm drainage facilities may commence without prior notification of the Missouri One Call utility warning system at 1-800-DIG-RITE, as required by law.

1.7 Communications and Correspondence

Communications and correspondence regarding stormwater plan review, policies, design standards, criteria or drainage complaints shall be directed to the City Planner at the City of Republic, 213 N. Main, Republic, Missouri 65738, Phone: 417-732-3354.

1.8 Ownership and Maintenance

1.8.1 Improvements on Public Road Right-of-Way.

Storm drainage improvements on public right-of-way shall, upon acceptance of the constructed improvements, become the property of; and shall be maintained by the City of Republic.

1.8.2 Improvements on Private Property.

1.8.2.1 Maintenance Responsibility

Storm drainage improvements on private property shall be maintained by the owner of the lot upon which the improvements are located or by the Homeowners' Association for improvements located in common areas.

1.8.2.2 Drainage Easements

All such improvements, which serve to convey, detain, or retain stormwater runoff, shall be in drainage easement. The City shall have such rights of access to repair or maintain such facilities as set forth herein. If said improvements are located within private property, such as parking lots, or "common areas" the City shall have such rights of access for repair or maintenance work when required. Note that maintenance responsibilities on private property shall be as specified in Section 1.8.2.1.

The minimum easement width shall be as specified in Table 1-1.

Table 1-1. Minimum Easement Width

Stormwater Improvement System	Minimum Easement Width
42-inch diameter or less	15 feet
> 42-inch diameter	20 feet
Reinforced Concrete Box	15 feet wider than box outer wall
Open Channel (Vegetated)	Entire Channel Width + 5 feet each side
Impervious Channel (Structural)	10 feet wider than Channel (5 feet beyond the outside edge of the structure on each side)
Natural/Unimproved Channel	100-year Flood Boundary + 5 feet each side if applicable

Notes:
a. The City may require additional width to provide access to stormwater improvements.

1.8.2.3 Construction Easements

All easements required for construction, which are not included on the final plat shall be recorded and filed with the City prior to approval of the construction drawings.

SECTION 2 - PLANNING AND DESIGN

2.1 Stormwater Management Requirements

To promote protection of the general health and welfare of the citizens of the City of Republic, planning and design of stormwater management measures shall meet the following requirements:

- To work in conjunction with the City’s MS4 Stormwater Management Plan for the City of Republic.
- Prevent damage to residential dwellings and other building structures from flood waters.
- Maintain emergency vehicle access to all areas during periods of high water.
- Prevent damage to roads, bridges, utilities, and other valuable components of the City’s infrastructure from damage due to flood waters and erosion.
- Prevent degradation of surface and groundwater quality from stormwater runoff; preserve and protect quality of the environment; and promote conservation of the City's natural resources.
- Minimize floodwater and erosion damage to lawns, recreational facilities, and other outdoor improvements.
- Minimize traffic hazards from runoff conveyed in streets and roads.
- Comply with applicable State and Federal laws and regulations, not limited to National Pollutant Discharge Elimination System (NPDES) Municipal Separate Storm Sewer System (MS4) program
- Encourage innovative and cost-effective planning and design of stormwater management facilities.
- Encourage multiple purpose design of stormwater management facilities, to provide opportunities for recreational use and other benefits to the community wherever possible.
- Meet the foregoing requirements in a manner which is cost effective and which minimizes the cost of housing and development while encouraging sound development practices.
- Implement and enforce a program to address the quality of long-term stormwater runoff from new development and redevelopment projects that disturb equal to and greater than one acre, including projects less than one acre that are part of a larger common plan of development.

The standards and criteria set forth herein provide the minimum standards for planning and design of stormwater facilities. Where a particular plan or design may be found to conflict with a specific standard, the City may waive certain standard(s) in order to achieve a requirement listed.

2.2 Scenarios to be Modeled

To achieve the requirements stated above, hydrologic and hydraulic analyses must be prepared and submitted to the City to demonstrate the impacts of a project on the existing watershed and stormwater conveyance systems. To evaluate the impacts, three scenarios shall be considered for the hydrologic and hydraulic analyses required herein:

2.2.1 Case 1: Existing Conditions

Existing conditions in the drainage basin prior to development of the applicant's property.

2.2.2 Case 2: Post-Project Conditions

Existing conditions in the drainage basin with developed conditions on the applicant's property.

2.2.3 Case 3: Post-Project with Fully Developed Watershed

Fully developed conditions in the entire drainage basin.

SECTION 3 - HYDROLOGIC ANALYSES

3.1 Scope

This section sets forth the hydrologic methods and parameters to be used for computations involving the definition of runoff mass and peak rates to be accommodated by the storm drainage system. These methods are to be used for calculating runoff mass and peak rates for the design of stormwater conveyance and storage systems.

3.2 Methodology

Runoff rates to be accommodated by each element of the proposed storm drainage system shall be calculated using the criteria of this section for land use runoff factors, rainfall, and system time. The following methods of computation are to be used.

3.3 Rational Method

3.3.1 General Guidelines

The Rational Method is acceptable for drainage areas less than 100 acres when only peak flow rates are needed. However, the City reserves the right to require the use of the Unit Hydrograph method for drainage areas less than 100 acres in cases where land use in the watershed is non-homogeneous or areas of storage exist in the watershed.

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

- The rainfall intensity is uniform over the basin during the entire storm duration.
- The maximum runoff rate occurs when the rainfall lasts as long or longer than the basin time of concentration.
- Runoff response characteristics are relatively uniform over the entire basin.
- The time of concentration is the time required for the runoff from the most hydraulically remote part of the basin to reach the point of interest.

The drainage basin should be divided into sub-basins of a size where all the basic assumptions apply.

3.3.2 Rational Formula

The rational formula, when properly understood and applied, can produce satisfactory results for urban storm sewer design. The rational formula is as follows:

$$\boldsymbol{Q} = \boldsymbol{C} \times \boldsymbol{i} \times \boldsymbol{A} \qquad \text{(Equation 3.1)}$$

Where:

Q = Peak discharge in cubic feet per second.

C = Runoff coefficient which is the ratio of the maximum rate of runoff from the area to the average rate of rainfall intensity for the time of concentration.

i = Average rainfall intensity in inches per hour for a duration equal to the time of concentration.

A = Contributing watershed area in acres.

3.3.3 Precipitation

For Rational Method analysis, rainfall intensity in inches per hour must be determined from an event with a duration equivalent to the time of concentration. **Table 3-1** and **Figure 3-1** provide depth and intensity values for various rainfall durations and frequencies in the Republic, Missouri area. The City may approve use of updated precipitation data as specified in NOAA Atlas 14.

Table 3-1: Rainfall Intensity-Duration-Frequency Relationships from Rainfall Frequency Atlas of the Midwest (Huff & Angel, 1992)

	Depth of Precipitation (in)						
Duration	**1-year**	**2-year**	**5-year**	**10-year**	**25-year**	**50-year**	**100-year**
5 min	4.32	5.4	6.84	8.04	9.48	10.56	11.76
10 min	3.78	4.74	6.06	7.02	8.28	9.24	10.32
15 min	3.24	4.08	5.16	6.00	7.08	7.92	8.84
30 min	2.22	2.78	3.54	4.10	4.86	5.44	6.06
1-hour	1.41	1.77	2.25	2.61	3.08	3.45	3.84
2-hour	0.87	1.10	1.39	1.61	1.90	2.13	2.37
3-hour	0.64	0.80	1.02	1.18	1.40	1.57	1.75
6-hour	0.38	0.47	0.60	0.69	0.82	0.92	1.02
12-hour	0.22	0.27	0.35	0.40	0.48	0.53	0.59
18-hour	0.16	0.20	0.25	0.29	0.34	0.38	0.43
24-hour	0.13	0.16	0.2	0.23	0.27	0.31	0.34
48-hour	0.07	0.09	0.11	0.13	0.15	0.17	0.19
72-hour	0.05	0.06	0.08	0.09	0.11	0.12	0.14
120-hour	0.03	0.04	0.05	0.06	0.07	0.08	0.09
240-hour	0.02	0.03	0.03	0.04	0.04	0.05	0.05

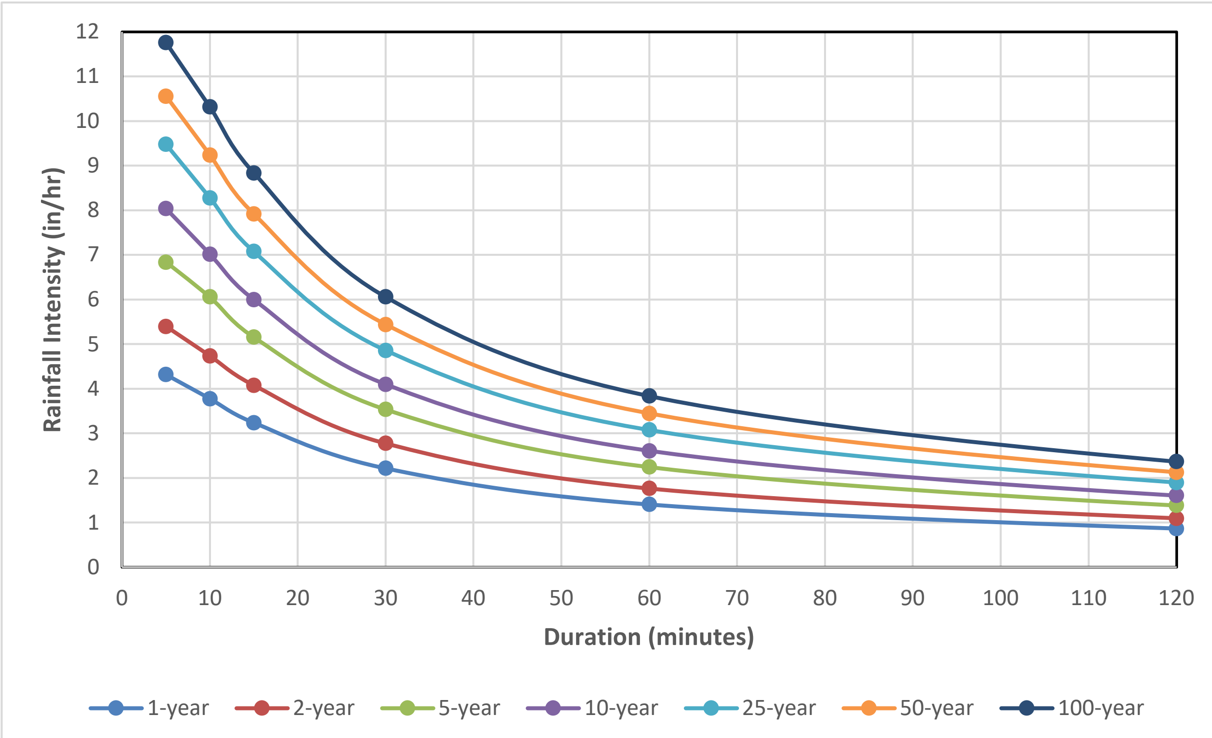


Figure 3-1: Rainfall Intensity-Duration-Frequency Relationships from Rainfall Frequency Atlas of the Midwest

3.4 SCS Unit Hydrograph Method

3.4.1 General Guidelines

The SCS Unit Hydrograph Method (Natural Resources Conservation Service, 1986) is acceptable for any size watershed and appropriate for complex watersheds and is the City's preferred method. The method to be used for all hydrologic analyses. This method shall be used with the Huff temporal rainfall distribution. The Engineer may use any computer software package that incorporates the SCS Unit Hydrograph Method for calculating runoff.

3.4.2 Study Area

The hydrologic model must include the entire drainage basin upstream of the proposed development.

The model shall be prepared in sufficient detail to ensure that peak runoff rates are reasonably accurate.

3.4.3 Precipitation

3.4.3.1 Precipitation Depths

Rainfall depths to be used with the SCS Unit Hydrograph Method shall be as shown in Table 3-2. Rainfall depths shown have been taken from *Rainfall Frequency Atlas of the Midwest* (Huff & Angel, 1992). The City may approve use of updated precipitation data as specified in NOAA Atlas 14.

Table 3-2: Rainfall Depth-Duration-Frequency Relationships from Rainfall Frequency Atlas of the Midwest

Duration	Depth of Precipitation (in)						
	1-year	2-year	5-year	10-year	25-year	50-year	100-year
5 min	0.36	0.45	0.57	0.67	0.79	0.88	0.98
10 min	0.63	0.79	1.01	1.17	1.38	1.54	1.72
15 min	0.81	1.02	1.29	1.50	1.77	1.98	2.21
30 min	1.11	1.39	1.77	2.05	2.43	2.72	3.03
1-hour	1.41	1.77	2.25	2.61	3.08	3.45	3.84
2-hour	1.74	2.19	2.78	3.22	3.80	4.26	4.74
3-hour	1.92	2.41	3.07	3.55	4.20	4.70	5.24
6-hour	2.25	2.83	3.59	4.16	4.92	5.51	6.14
12-hour	2.61	3.28	4.17	4.83	5.71	6.39	7.12
18-hour	2.82	3.54	4.50	5.22	6.17	6.90	7.69
24-hour	3.00	3.77	4.79	5.55	6.56	7.34	8.18
48-hour	3.30	4.14	5.25	6.07	7.17	8.05	8.97
72-hour	3.68	4.62	5.81	6.69	7.90	8.85	9.85
120-hour	4.16	5.21	6.50	7.45	8.70	9.68	10.77
240-hour	5.37	6.59	8.05	9.13	10.49	11.52	12.61

3.4.3.2 Rainfall Distribution

The Huff rainfall distribution (Huff & Angel, 1992) shall be used for the temporal distribution. The Huff distribution is presented in **Table 3-3** and is expressed as cumulative percentages of total duration and total rainfall accumulation. Different families of Huff rainfall distribution curves are applicable for different drainage areas. **Table 3-3** is applicable to drainage areas less than 10 square miles. For larger drainage areas, refer to the *Rainfall Frequency Atlas of the Midwest* (Huff & Angel, 1992).

Each family of curves consists of four storms (1st Quartile, 2nd Quartile, 3rd Quartile, and 4th Quartile) that correspond to the quartile within the storm event when the bulk of the rainfall occurs. Storms with durations of 6 hours or less, 6 to 12 hours, 12 to 24 hours, and greater than 24 hours tend to be associated with the first-, second-, third-, and fourth-quartile storms, respectively (City of Springfield, 2018).

Table 3-3: Huff Distribution for Drainage Areas from 0 to 10 Square Miles

Cumulative Storm Time (%)	Cumulative Storm Rainfall (%) for Given Storm Type			
	1st Quartile (Duration ≤ 6 hours)	**2nd Quartile** (6 < Duration ≤ 12 hours)	**3rd Quartile** (12 < Duration ≤ 24 hours)	**4th Quartile** (Duration > 24 hours)
0	0	0	0	0
5	16	3	3	2
10	33	8	6	5

Table 3-3: Huff Distribution for Drainage Areas from 0 to 10 Square Miles

Cumulative Storm Time (%)	Cumulative Storm Rainfall (%) for Given Storm Type			
	1st Quartile (Duration ≤ 6 hours)	**2nd Quartile** (6 < Duration ≤ 12 hours)	**3rd Quartile** (12 < Duration ≤ 24 hours)	**4th Quartile** (Duration > 24 hours)
15	43	12	9	8
20	52	16	12	10
25	60	22	15	13
30	66	29	19	16
35	71	39	23	19
40	75	51	27	22
45	79	62	32	25
50	82	70	38	28
55	84	76	45	32
60	86	81	57	35
65	88	85	70	39
70	90	88	79	45
75	92	91	85	51
80	94	93	89	59
85	96	95	92	72
90	97	97	95	84
95	98	98	97	92
100	100	100	100	100

3.4.3.3 Rainfall Duration

A critical duration analysis should be performed to determine the duration that maximizes peak runoff rates for the watershed being analyzed. A critical duration analysis should involve applying the hydrograph-based methods to events with durations ranging from 30 minutes to 24 hours to determine the duration that produces the largest peak runoff rate for the watershed.

Guidelines for the minimum recommended storm duration based on watershed size are shown in **Table 3-4**. The guidelines are intended to preclude the use of short duration events that typically do not cover the corresponding watershed uniformly. The information in **Table 3-4** should be considered as guidance for the minimum storm duration to use when calculating runoff and is not a replacement for a critical duration analysis (City of Springfield, 2018).

Table 3-4: Guidelines for Minimum Storm Duration Based on Watershed Size

Watershed Size	Minimum Recommended Duration
< 160 acres	30-minute
160 acres – < 1 sq. mi.	1-hour

Table 3-4: Guidelines for Minimum Storm Duration Based on Watershed Size

Watershed Size	Minimum Recommended Duration
1 sq. mi. – < 4 sq. mi.	2-hour
4 sq. mi. – < 8 sq. mi.	3-hour
8 sq. mi. – < 16 sq. mi.	6-hour
16 sq. mi. – < 32 sq. mi.	12-hour
> 32 sq. mi	24-hour

3.5 Runoff Curve Number Determination

3.5.1 General

The determination of the runoff Curve Number (CN) value for a watershed is a function of soil characteristics, hydrologic condition and cover, or land use. CN values for undeveloped and developed areas are provided in Table 3-5 and Table 3-6, respectively. For watersheds with multiple soil types or land uses, an area weighted CN should be calculated. When significant differences in land use or natural control points exist, the watershed should be broken into smaller drainage areas for modeling purposes.

3.5.2 Soils

Soils are classified into hydrologic soil groups (HSG) as an indicator of infiltration rate. The HSGs are A, B, C, and D, with A having the highest infiltration rate and D having the lowest (Natural Resources Conservation Service, 1986). The HSG and land cover are used in determining the CN value. The United States Department of Agriculture (USDA) makes available a Web Soil Survey website with HSG's for a specific location which can be used to estimate runoff curve numbers (Natural Resources Conservation Service, 2019):

http://websoilsurvey.sc.egov.usda.gov/App/HomePage.htm

To minimize increases in post-development runoff volume and discharge of sediment, it is important to preserve natural soil profiles, minimize total land disturbance and minimize the consolidation of in-situ soils through compaction under the weight of heavy equipment. Following these practices can provide cost savings in reduced grading, reduced infrastructure and detention and water quality treatment. For areas where the soil profile has been disturbed, the HSG should be adjusted up one level (i.e., from A to B, B to C, or C to D) unless it can be shown that the predevelopment soil profile has been reestablished through soil amendments.

Table 3-5: Runoff Curve Number Values for Undeveloped Lands

Land Use / Cover Description	Hydrologic Soils Group			
	A	B	C	D
Pasture, grassland, or range—continuous forage for grazing: Good condition (ground cover > 75% and only occasionally grazed)	39	61	74	80
Meadow—continuous grass, protected from grazing, and generally mowed for hay	30	58	71	78
Woods-grass (50%-50%) combination, orchard or tree farm Other combinations can be calculated as composite of pasture and woods, good condition	32	58	72	79
Woods, Good condition (i.e., woods are protected from grazing, and litter and brush adequately cover the soil)	30	55	70	77
Farmsteads—buildings, lanes, driveways, and surrounding lots	59	74	82	86

Notes:
1. CN for use with SCS Unit Hydrograph Method for average runoff conditions (initial abstractions = 0.2 x Maximum Runoff Retention) (Natural Resources Conservation Service, 1986).
2. Typical cover condition in Republic area is “good.” “Fair” or “poor” condition must be demonstrated by engineer prior to City approval of associated CN adjustments.

Table 3-6: Runoff Curve Number Values for Developed, Urban Areas

Land Use / Cover Description	Avg % Impervious	Hydrologic Soils Group			
		A	B	C	D
Open Space Lawns					
Good condition (grass cover > 75%)		39	61	74	80
Fair condition (grass cover 50% to 75%)		49	69	79	84
Poor condition (grass cover less than 50%)		68	79	86	89
Impervious areas:					
Paved parking lots, roofs, driveways, compacted gravel, etc. (excluding right-of-way)		98	98	98	98
Small open spaces within developments or ROW:		72	82	87	89
Streets and Roads		90	93	95	97
Paved; curbs and storm sewers (including right-of-way)		83	89	92	93
Paved; open ditches (including right-of-way)		76	85	89	81

Table 3-6: Runoff Curve Number Values for Developed, Urban Areas

Gravel (including right-of-way)		72	82	87	89
Urban Districts					
Commercial and business	85	89	92	94	95
Industrial	72	81	88	91	93
Residential districts by average lot size					
1/8 acre or less (townhouses)	65	77	85	90	92
1/4 acre	38	61	75	83	87
1/3 acre	30	57	72	81	86
1/2 acre	25	54	70	80	85
1 acre	20	51	68	79	84
2 acres	12	46	65	77	82
Newly graded areas (pervious areas only, no vegetation)		77	86	91	94

Notes:

1. CN for use with SCS Unit Hydrograph Method for average runoff conditions (initial abstractions = 0.2 x Maximum Runoff Retention) (Natural Resources Conservation Service, 1986).
2. Typical cover condition in Republic area is "good." "Fair" or "poor" condition must be demonstrated by engineer prior to City approval of associated CN adjustments.
3. This table is based on average antecedent soil moisture conditions. See Section 3.5.1 for further discussion.
4. Curve numbers provided for streets and roads are typical for residential or collector streets. Curve numbers for arterials and heavily developed areas should be calculated.
5. Curve numbers provided for urban districts are a typical composite of large areas. Curve numbers for individual sites should be calculated based on the proposed development.

3.6 Time of Concentration

Time of concentration shall be calculated using the methodologies described by the NRCS (Natural Resources Conservation Service, 1986) and as follows:

$$T_c = T_i + \sum T_t \qquad \text{(Equation 3.2)}$$

Where

T_c = time of concentration, minutes

T_i = initial, inlet or overland flow time in minutes

T_t = sum of the travel times for shallow concentrated flow and open channel flow time in minutes.

3.6.1 Initial, Inlet or Overland Flow

Initial, Inlet or Overland Flow time shall be calculated using the following equation:

$$T_i = \frac{0.007(n \times L)^{0.8}}{4.64 \times s^{0.4}} \qquad \text{(Equation 3.3)}$$

Where

n = Manning's n for sheet flow (see Table 3-7 (Natural Resources Conservation Service, 1986))

L = flow length (feet), (maximum of 300 feet)

s = slope of hydraulic grade line (land slope, ft/ft)

Table 3-7: Roughness Coefficients (Manning's n) for Sheet Flow

Surface Description	Manning's n
Smooth surfaces (concrete, asphalt, gravel or bare soil)	0.011
Fallow (no residue)	0.05
Cultivated soils:	
Residue cover less than or equal to 20%	0.06
Residue cover greater than or equal to 20%	0.17
Grass:	
Short grass prairie	0.15
Dense grasses[1]	0.24
Bermuda grass	0.41
Range (natural)	0.13
Woods[2]	
Light underbrush	0.40
Dense underbrush	0.80

Notes

[1] Includes species such as weeping lovegrass, bluegrass, buffalo grass, blue grama grass and native grass mixtures.

[2] When selecting n, consider covering to a height of about 0.1 feet. This is the only part of the plant cover that will obstruct sheet flow.

3.6.2 Shallow Concentrated Flow

Travel time for shallow concentrated flow shall be calculated in accordance with the methods following equations:

$$T_t = \frac{L}{60 \times V} \qquad \text{(Equation 3.4)}$$

Where

T_t = travel time for shallow concentrated flow (minutes)

L = Length of shallow concentrated flow path (feet) (maximum of 1,500 feet)

For flow in unpaved areas, flow velocity shall be calculated as follows:

$$V = 16.1345 \times s^{0.5} \qquad \text{(Equation 3.5)}$$

For flow in paved areas, flow velocity shall be calculated as follows:

$$V = 20.3282 \times s^{0.5} \qquad \text{(Equation 3.6)}$$

Where:

V = average velocity/ ft/s

s = slope the hydraulic grade line (watercourse slope, ft/ft)

3.6.3 Open Channel Flow

Travel time for open channel flow components shall be calculated using the following equations:

$$T_t = \frac{L}{60 \times V} \qquad \text{(Equation 3.7)}$$

Where

T_t = travel time for shallow concentrated flow (minutes)

L = Length of open channel flow (feet)

V = Velocity of open channel flow (ft/s)

Velocity shall be calculated using Manning's Equation:

$$V = \frac{1.486}{n} \times R^{2/3} \times s^{1/2} \qquad \text{(Equation 3.8)}$$

Where

n = Manning's roughness coefficient

R = hydraulic radius (feet)

s = slope of the hydraulic grade line (watercourse, ft/ft).

3.7 Model Verification

As a part of hydrologic analysis, a reasonableness check should be conducted on computed peak flow rates and runoff volumes. Reasonableness checks may include methods of calculation such as the Rational Method, the United States Geological Survey (USGS) regression equations, or other methods acceptable to the City. Other checks may include comparison of actual flood data or other flood studies that may have been conducted by the Federal Emergency Management Agency (FEMA), the U.S. Army Corps of Engineers (USACE), or the City.

SECTION 4 - STORM SEWER SYSTEMS

4.1 Storm Sewers

4.1.1 Level of Service Requirements

4.1.2 In-System Capacity

At minimum, storm sewer pipe systems shall be designed to convey the runoff from a 10-year rainfall event while meeting other requirements of this section.

4.1.2.1 Other Systems

100-year Rainfall Event: Pipes shall be designed so the total runoff for the 100-year Rainfall Event can be conveyed in both the storm sewer system and the designed overflow system. Pipe sizes shall be established so that a sufficient amount of flow is conveyed in the pipes so that overflow is contained within the easement provided as required by Section 1.8.2.

Unless otherwise approved by the City, pipes shall be designed for gravity flow, sloping downhill.

4.1.3 Overflow Systems

Each element of the storm sewer system shall include an overflow element. Overflow systems shall be designed to meet the following criteria:

4.1.3.1 Utilization of City Streets

25-year Rainfall Event: Pipes shall be designed so the total runoff for the 25-year Rainfall Event can be conveyed in both the storm sewer system and the roadway. Pipe sizes shall be established so that a sufficient amount of flow is conveyed in the pipes such that the minimum requirements for gutter spread and maximum depth of flow in the street meet the requirements of paragraph 4.3 Pavement Drainage.

100-year Rainfall Event: Pipes shall be designed so the total runoff for the 100-year Rainfall Event can be conveyed in both the storm sewer system and the roadway. Pipe sizes shall be established so that a sufficient amount of flow is conveyed in the pipes so that the minimum requirements for gutter spread and maximum depth of flow in the street meet the requirements of paragraph 4.3 Pavement Drainage.

4.1.3.2 Other Systems

100-year Rainfall Event: Pipes shall be designed so the total runoff for the 100-year Rainfall Event can be conveyed in both the storm sewer system and the designed overflow system. Pipe sizes shall be established so that a sufficient amount of flow is conveyed in the pipes so that overflow is contained within the easement provided as required by Section 1.8.2.

4.1.4 Extent of Enclosed System

The storm sewer system, beginning at the upstream end with inlets, is required when the 5-year peak flow in the street exceeds five (5) cfs or when allowable street depths are exceeded. Allowable street depths are in Section 4.3.

4.1.5 Minimum Pipe Size

The minimum pipe size for storm sewers less than or equal to 50 feet in length (measured between structure or end section) shall be fifteen inches in diameter, unless approved otherwise by the City. The City, in some instances, will review and may possibly approve the use of smaller pipe sizes for a private storm sewer system which requires a higher flushing velocity. In this case, the City may request additional calculations to be submitted along with the Storm water report to justify the approval for utilizing smaller pipe sizes.

The minimum pipe size for storm sewers greater than 50 feet in length shall be 18 inches in diameter.

4.1.6 Construction Materials

Allowable pipe materials shall be as specified in the following sections.

4.1.6.1 Reinforced Concrete

- Concrete materials shall be 4,000 psi concrete, unless otherwise approved by the City.

4.1.6.2 Reinforced Concrete Pipe

- The design of circular pipe shall conform to ASTM C76, Class III except as modified herein.
- Furnish in lengths of not less than 4'-6", except fittings, closure pieces, and specials.
- Joints shall be rubber and concrete to conform to ASTM C443. Rubber gaskets shall be O-ring cross section.
- An independent testing laboratory shall perform testing and inspection of all material except reinforcing steel. The laboratory shall be acceptable to the City.

4.1.6.3 Corrugated Polyethylene Pipe

- Pipe and fittings shall conform to ASTM F405 and F667 and shall have a circular cross-section.
- End sections shall be polyethylene flared type with toe plates.
- Joints shall be provided with neoprene or manufacturer's standard gaskets.

4.1.6.4 Acceptable Installations based on Pipe Materials

The use of a pipe material specified herein shall be as allowed in Table 4-1.

4.1.6.5 Permanent Signage on all Inlets

All new stormwater inlets shall have permanent signage that states, “No Dumping – Drains to Stream”.

Table 4-1: Allowable Installation Based on Pipe Material

Allowable Location	Corrugated Metal	Reinforced Concrete	Corrugated Polyethylene
Culverts under private driveways	✓	✓	✓
Culverts and storm sewers under paved areas		✓	
Culverts and storm sewers under unpaved areas		✓	✓

4.1.7 Vertical Alignment

4.1.7.1 Minimum Cover

The sewer grade shall be such that a minimum cover is maintained to withstand AASHTO HS-20 loading on the pipe. The minimum cover depends upon the pipe size, type and class and soil bedding condition, but shall not be less than one (1) foot from the top of pipe to the finished grade at any point along the pipe.

If the pipe encroaches on the street subgrade, approval is required.

4.1.7.2 Minimum Slope Requirements

The minimum allowable pipe slope shall be 0.5% unless otherwise approved by the City.

4.1.7.3 Requirements for Drainage Structures

Drainage structures (i.e., curb inlets, junction boxes, grate inlets, etc.) shall be required whenever there is a change in size, direction, elevation grade and slope, or where there is a junction of two (2) or more sewers. Provide a 0.2' fall within the drainage structure between invert of the upstream and downstream pipes. Provide a 0.5' fall or drop within drainage structure if pipes sharing junction box are not 180 degrees.

4.1.7.4 Structure Spacing

The maximum spacing between structures shall be based on the flow area of the conduit. Maximum spacing shall be as follows:

- Flow area 25 square feet or less: 400 feet
- Flow area more than 25 square feet: 500 feet.

4.1.7.5 Clearances for Water Mains

The Missouri Department of Natural Resources (MDNR) has established the minimum separation requirements between potable water distribution systems and potential sources of contamination such as Non-Potable Fluid Lines (Missouri Department of Natural Resources, 2013). Storm sewer systems fall under the definition of non-potable fluid lines, and the design of construction of storm sewer systems shall comply with the most recent version of the regulations. The requirements are summarized as follows:

Parallel Installation: Minimum 10 feet measured edge to edge.

Crossings: Minimum 18 inches of separation between the outside of the water main and the outside of the storm sewer. This shall be the case where the water main is either above or below the non-potable pipeline. An 18-inch separation is a structural protection measure to prevent the sewer or water main from settling and breaking the other pipe. At crossings, the full length of water pipe shall be located so both joints will be as far from the non-potable pipeline as possible but in no case less than ten feet or centered on a 20-foot pipe.

Where minimum separation requirements cannot be met, the strategy for protecting the potable water distribution system shall be in accordance with MDNR regulations and shown on the Drawings.

4.1.7.6 Clearances for Sanitary Sewers

The minimum clearance between storm sewer and sanitary sewer (for new construction), either above or below, shall be 18 inches. In addition, when an existing sanitary sewer main lies above a storm sewer or within 18 inches below, the sanitary sewer shall have a concrete encasement or be constructed of structural sewer pipe for a minimum of 10 feet on each side of the storm sewer crossing.

4.1.7.7 Siphons

Siphons or inverted siphons are not allowed in the storm sewer system.

4.1.8 Horizontal Alignment

Storm sewer alignment between manholes or other storm structures shall be straight except when approved by the City. Approved curvilinear storm sewers may be constructed by using radius pipe. The radius requirement for pipe bends is dependent upon the manufacturer's specifications.

The permitted locations for storm sewer within a street right of way are as follows:

- on centerline
- between centerline and curb
- behind the curb.

Storm sewers shall not be placed in the area within the wheel lanes of the pavement.

4.1.9 Storm Sewer Outlets

All storm sewer outlets into open channels shall be constructed with a headwall and wingwalls or a flared-end-section. Riprap or other approved material shall be provided at all outlets.

4.1.10 Hydraulics

Unless otherwise approved by the City, in-system capacity of pipes shall be based on the runoff from a 5-year rainfall event under gravity flow conditions. The flow depth throughout all pipes is to be less than the top of the pipe for the minimum design storm frequency listed above.

4.1.10.1 Gravity Flow

Calculations for gravity flow in pipes shall be done in accordance with HEC Circular No. 22, Section 7 (Federal Highway Administration, 2013).

4.1.10.2 Pressure Flow

Hydraulic design that allows the pipe to be pressurized during events equal to or less than the minimum design frequency shall be done as approved by the City. Calculations for pressure flow in pipes shall be done in accordance with HEC Circular No. 22, Section 7 (Federal Highway Administration, 2013).

4.1.10.3 Allowable Velocities

The maximum full flow velocity shall be 15 feet per second. Higher velocities may be approved by the City if the design includes adequate provisions for uplift forces, dynamic impact forces and abrasion.

The minimum velocity in a pipe based on full flow shall be 2.5 feet per second.

4.1.10.4 Hydraulic Calculations

Presented in this Section are the general procedures for hydraulic design and evaluation of storm sewers. The user is assumed to possess a basic working knowledge of storm sewer hydraulics and is encouraged to review textbooks and other technical literature available on the subject.

4.1.10.4.1 Pipe Friction Losses

Pipe friction losses shall be calculated in accordance with FHWA Hydraulic Engineering Circular No. 22, Section 7.

Pipe friction losses are to be estimated using the following equation:

$$\boldsymbol{H_f = S \times L} \qquad \text{(Equation 4.1)}$$

Where

H_f = head loss due to friction (feet)

S = friction slope from Manning's equation (feet per foot)

L = length of pipe segment (feet)

and

$$\boldsymbol{V = \frac{1.486}{n} \times R^{2/3} \times S^{1/2}} \qquad \text{(Equation 4.2)}$$

And

$$R = \frac{A}{P}$$ (Equation 4.3)

Where

V = velocity of flow (feet per second)

R = hydraulic radius (feet)

A = area of flow (square feet)

P = wetted perimeter (feet)

S = friction slope (feet per foot) A

n = Manning's roughness coefficient (Table 4-2)

Table 4-2: Pipe Roughness Coefficients

Material	**n Value**
Reinforced Concrete Culvert (pipe or box)	0.013
CMP 2-2/3 inch x ½-inch Annular Corrugations	0.024[1]
CMP 3-inch x 1-inch Annular Corrugations	0.027[1]
Structural Plate CMP 6-inch x 2-inch Annular Corrugations (5-foot diameter)	0.033
Polypropylene Pipe	0.012
PVC (Private development only)	0.012
HDPE (Private development only)	0.012

NOTES:
1. Manning's n for helically corrugated CMP may be less in certain conditions.
2. Values from City of Springfield (City of Springfield, 2018)

4.1.10.4.2 Exit Losses

Exit Losses shall be calculated in accordance with FHWA Hydraulic Engineering Circular No. 22, Section 7.

When a storm sewer is not flowing full, the sewer acts like an open channel and the hydraulic properties can be calculated using open channel.

Storm sewer outlets. When the storm sewer system discharges into an open channel, additional losses, in the form of expansions losses, occur at the outlet. For a headwall and no wing walls, the loss coefficient Ke is one (1.0). For a headwall with forty-five-degree (45°) wing walls, the loss coefficient is about one and fourteen hundredths (1.14). For a flared-end-section (which has a D2/D1 ratio of two (2) and a theta angle of around thirty degrees (30°)) the loss coefficient is approximately one- half (0.5).

4.1.10.4.3 Bend Losses

Bend Losses shall be calculated in accordance with FHWA Hydraulic Engineering Circular No. 22, Section 7.

4.1.10.4.4 Transition Losses

Transition Losses shall be calculated in accordance with FHWA Hydraulic Engineering Circular No. 22, Section 7.

4.1.10.4.5 Junction and Manhole Losses

Junction and Manhole Losses shall be calculated in accordance with FHWA Hydraulic Engineering Circular No. 22, Section 7.

A junction occurs where one (1) or more branch sewers enter a main sewer, usually at manholes. The hydraulic design of a junction is in effect the design of two (2) or more transitions, one (1) for each flow path. Allowances should be made for head loss due to the impact at junctions. The head loss at a junction for each pipe entering the junction can be calculated from:

$$H_{AH} = K_{AH} \times \frac{V_o^2}{2g} \qquad \text{(Equation 4.4)}$$

Where

V_o = the inlet velocity (feet per second)

K_{ah} = junction loss coefficient

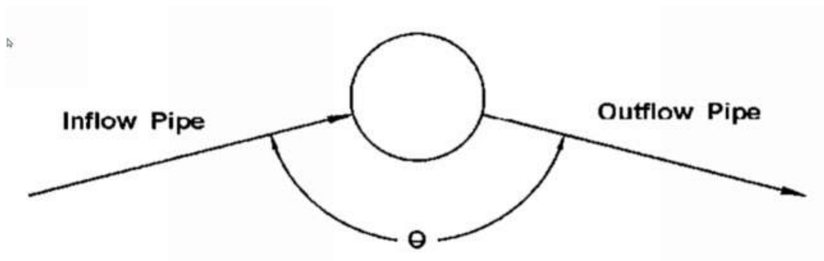
Because of the difficulty in evaluating hydraulic losses at junctions (Reference 6) due to the many complex conditions involving pipe size, geometry of the junction and flow combinations, a simplified table of loss coefficients has been prepared. Table 4-3 (Federal Highway Administration, 2013) presents the recommended energy loss coefficients for typical manhole or junction conditions encountered in the urban storm sewer system.

Table 4-3: Head Loss Coefficients for Structures

Structure Configuration	Head Loss Coefficient (K_{AH})
Inlet - straight run, square edge	0.50
Inlet – angled through 90 degrees	1.50
Access Hole – straight run	Min to 1.50
Access Hole – angled through	
Θ = 90°	1.00
Θ = 120°	0.85
Θ = 135°	1.75

Table 4-3: Head Loss Coefficients for Structures

Structure Configuration	Head Loss Coefficient (K_{AH})
Θ = 157.5°	0.45



4.2 Inlets

4.2.1 Inlet Locations

Inlets shall be provided at locations and intervals and shall have a minimum inflow capacity such that maximum flooding depths set below are not exceeded for the specified storm; at all sump locations where ponding of water is not desired and where drainage cannot be released at the ground surface.

4.2.2 Inlet Interception Capacities

Inlet capacities shall be determined in accordance with the Federal Highway Administration (FHWA) HEC-12 Manual (Federal Highway Administration, 2013).

The use of software utilizing the methods of HEC-12 is acceptable. The City allows the latest version of FHWA Hydraulic Toolbox (Federal Highway Administration, 2019). Other software shall be pre-approved for use by the City.

4.2.3 Clogging Factors

The inlet capacities determined as required in this Section must be reduced as follows, to account for partial blockage of the inlet with debris:

Table 4-4: Inlet Clogging Factors

Type if Inlet and Location	Clogging Factor
Type SS Curb Opening Inlets	
on grades	0.9
in sumps	0.8
Grated Inlets	
on grades	0.6
in sumps	0.5

Inlet lengths and/or grate areas shall be adjusted as required to account for clogging.

4.2.4 Interception and Bypass Flow

It is generally not practical for inlets on slopes to intercept 100% of the flow in gutters. Inlets must intercept sufficient flow to comply with street flooding depth requirements. Bypass flows shall be considered at each downstream inlet, until all flow has entered approved storm sewers or drainage ways.

4.2.5 Types of Inlets Allowed

4.2.5.1 Public Streets

4.2.5.1.1 Curb Opening Inlets

Type "SS" standard curb opening inlets as shown Drawing 140 shall be used for public streets with curb and gutter.

4.2.5.1.2 Grated Inlets

In general, the use of grated inlets in streets, which require adjustment when streets are repaved will not be permitted.

Where conditions are such that curb inlets cannot intercept the required rate of flow, necessary to control street flooding depth or to provide diversion of flow to detention, sedimentation, or infiltration basins, "trench inlets" with vaned grates may be specified with approval of the City.

Other types of inlets will not be permitted unless approved by the City.

4.2.5.2 Outside of Public Right-of-Way

The type of inlets specified outside of public right-of-way is left to the discretion of the designer provided the following criteria are met:

- Maximum flooding depths for the major or minor storm as set forth above are not exceeded.
- General safety requirements set forth below are met.
- All inlets shall be depressed a minimum of two (2) inches below the surrounding grade to allow proper drainage to the inlet and prevent inadvertent ponding in the area around the inlet.
- Inlets in pavements shall be provided with a concrete apron.

4.2.6 General Safety Requirements.

All inlet openings shall:

- Provide for the safety of the public from being swept into the storm drainage system; the maximum allowable opening shall not exceed six (6) inches in width.
- Be sufficiently small to prevent entry of debris which would clog the storm drainage system.

- Be sized and oriented to provide for safety of pedestrians, bicyclists, etc.

4.3 Pavement Drainage

Urban streets are a necessary part of the City drainage system. The design for the collection and conveyance of stormwater runoff is based on a reasonable frequency and degree of traffic interference. Depending on the street classification, (i.e., local, collector, primary and secondary arterial.) portions of the street may be inundated during storm events. Drainage of streets are controlled by both minor and major storm events. The minor system is provided to intercept and convey nuisance flow. Flow depths are limited for the major storm to provide access by emergency vehicles during most flood events. When the depths of flow exceed the criteria presented in this Section a storm sewer or open channel system is required.

4.3.1 General Design Requirements

Allowable flow depths: Flow in the street is permitted with allowable depths of flow as follows:

4.3.2 Local Streets

- 5-year Rainfall Event: Top of roadway crown, maximum
- 25-year Rainfall Event: Top of curb, maximum
- 100-year Rainfall Event: All flow shall be contained within the limits of the right-of-way.

4.3.3 Collector Streets

- 5-year Rainfall Event: The total maximum combined gutter spread on either side of the street shall allow a minimum 10-foot driving lane to remain open.
- 25-year Rainfall Event: Top of curb, maximum
- 100-year Rainfall Event: All flow contained within the limits of the right-of-way.

4.3.4 Arterials and Parkways

- 5-year Rainfall Event: The maximum gutter spread on either side of the street shall allow a minimum 10-foot driving lane to remain open in each direction. At total clear driving area of 20 feet shall be maintained.
- 25-year Rainfall Event: Top of curb, maximum
- 100-year Rainfall Event: All flow shall be contained within the limits of the right-of-way.

4.3.5 Cross Flow

Cross flow at intersections is permitted up to depths indicated in Table 4-5.

Table 4-5: Allowable Cross Flow Depths

Street Classification	Maximum Allowable Depth	
	5-year Storm	25-year Storm
Local	6 inches cross pan flow line	12 inches at gutter
Collector	No cross flow permitted	6 inches at gutter
Arterial or Parkway	No cross flow permitted	No cross flow permitted

4.3.6 Hydraulics

The allowable storm capacity of each street section with curb and gutter is calculated using the modified Manning's formula for both the 2-year and 25-year storm event.

$$\boldsymbol{Q = \frac{0.56}{n} \times S_x^{1.67} \times S_L^{0.5} \times T^{2.67}} \quad \text{(Equation 4.5)}$$

Where

Q = discharge in cubic feet per second

S_x = cross slope of the street in feet per foot

S_L = longitudinal slope of the street in feet per foot

T = Width of flow (spread) in feet

n = Manning's roughness coefficient

SECTION 5 - CULVERTS

5.1 Structural Design

All culverts shall be designed to withstand an HS-20 loading in accordance with the design procedures of AASHTO "Standard Specifications for Highway Bridges". The designer shall also check the construction loads and utilize the most severe loading condition. The minimum allowable cover is one (1) foot.

5.2 Design Capacity

Culverts shall be designed to pass a 25-year storm with one (1) foot of freeboard prior to overtopping the road or driveway.

5.3 Headwater

The maximum headwater for the major storm design flow shall be one and one-half (1.5) times the culvert diameter for round culverts or one and one-half (1.5) times the culvert rise dimension for shapes other than round.

5.4 Inlet and Outlet Protection

For road and driveway culverts larger than fifteen (15) inches, culverts are to be designed with protection at the inlet and outlet areas as provided in this section. Headwalls or end sections are to be located a sufficient distance from the edge of the shoulder or the back of walk to allow for a maximum slope of 3H:1V to the back of the structure. The type of outlet protection required is as follows:

Table 5-1: Minimum Requirements for Inlet and Outlet Protection

Velocity < 7 ft/sec	7 ft/sec < Velocity < 15 ft/sec	Velocity > 15 ft/sec
Minimum Riprap protection	Riprap protection or Energy Dissipater	Energy dissipater

5.5 Velocity Limitations

The maximum allowable discharge velocity is fifteen (15) feet per second.

5.6 Culvert Hydraulics

It is recommended that the procedures outlined in the publication "Hydraulic Design of Highway Culverts" (reference 4) be used for the hydraulic design of culverts. Backwater calculations demonstrating the backwater effects of the culvert may be required.

SECTION 6 - BRIDGES

6.1 Structural Design

All bridges shall be designed to withstand an HS-20 loading in accordance with the design procedures of AASHTO "Standard Specifications for Highway Bridges" (reference 13). The designer shall also check the construction loads and utilize the most severe loading condition.

6.2 Design Capacity

Bridges shall be designed to pass the 50-year storm with one (1) foot of freeboard for design areas less than 20 square miles and two (2) feet freeboard for design areas greater than or equal to 20 square miles.

6.3 Backwater

"Backwater" is defined as the rise in the water surface due to the constriction created by the bridge approach road fills. The maximum backwater for the 100-year storm design flow shall be one (1) foot.

6.4 Velocity Limitations

Discharge velocities through bridge openings shall be limited to fifteen (15) feet per second. Abutment and channel scour protection shall be provided at all bridges.

6.5 Bridge Hydraulics

All bridge hydraulics shall be evaluated using the procedures presented in the publication "Hydraulics of Bridge Waterway" (reference 14). Backwater calculations demonstrating the effects of the bridge and approach fills compared to the existing flood stages shall be submitted for all bridges.

SECTION 7 - OPEN CHANNELS

7.1 General Design Guidelines

7.1.1 Natural Channels

The hydraulic properties of natural channels vary along the channel reach and can be either controlled to the extent desired or altered to meet the given requirements. Natural channels used as part of the drainage system must be evaluated for the effects of increased peak flow, flow duration and volume of runoff due to urbanization.

7.1.2 Grass Lined Channels

Grass lined channels are the most desirable of the artificial channels. The channel storage, lower velocities and the greenbelt multiple use benefits obtained create significant advantages over other artificial channels. Unless existing development restricts the availability of right of way, channels lined with grass should be given preference over other artificial types. The minimum slope in a grass-lined channel shall be one percent (1.0%) unless a concrete low flow channel is installed.

7.1.3 Concrete Lined Channels

Concrete lined channels are sometimes required where right of way restrictions within existing development prohibit grass-lined channels. The lining must be designed to withstand the various forces and actions, which tend to overtop the bank, deteriorate the lining, erode the soil beneath the lining and erode unlined areas. The minimum slope in a concrete lined channel shall be one-half percent (0.50%).

7.1.4 Rock Lined Channels

Rock lined channels are constructed from ordinary riprap or wire enclosed riprap (gabions etc.). The rock lining permits higher design velocity than for grass lined channels. Rock linings will normally be used only for erosion control at culvert/storm sewer outlets, at sharp channel bends, at channel confluences and at locally steepened channel sections.

7.1.5 Other Lining Types

The use of fabrics and other synthetic materials for channel linings has increased over the past several years. Proposed improvements of this type will be reviewed on an individual basis as for applicability and performance.

7.2 Hydraulics

An open channel is a conduit in which water flows with a free surface. The calculations for uniform and gradually varied flow are relatively straightforward and are based upon similar assumptions (e.g., parallel streamlines). The basic equations and computational procedures are presented in this Section.

7.2.1 Uniform Flow

Open channel flow is said to be 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, the normal depth. For a channel of uniform cross section, the water surface will be parallel to the channel bottom for uniform flow.

The computation of normal depth for uniform flow shall be based upon Manning's formula as follows:

$$Q = \frac{1.486}{n} \times A \times R^{2/3} \times S^{1/2}$$ (Equation 7.1)

Where,

Q = Discharge in cubic feet per second (cfs)

n = Roughness coefficient (Table 4-2)

A = Cross sectional flow area (square feet)

R = Hydraulic radius (feet)

S = Slope of the energy grade line (EGL) (feet/foot)

For channels with a uniform cross section the EGL slope and the bottom slope are assumed to be the same.

7.2.2 Critical Flow

The design of earth or rock channels in the critical flow regime (Froude numbers from 0.9 to 1.2) is not permitted. The Froude number is defined as follows:

$$F_r = \frac{V\,T}{2gA}$$ (Equation 7.2)

Where

F = Froude number

V = Velocity in feet per second (feet/sec)

g = Acceleration of gravity (32.2 feet/sec^2)

A = Cross sectional flow area (square feet)

T = Top width of flow area (feet)

The Froude number shall be calculated for the design of all open channels.

7.2.3 Gradually Varied Flow

The most common occurrence of gradually varied flow in storm drainage is the backwater created by culverts, storm sewer inlets or channel constrictions. For these conditions the flow depth will be greater than normal depth in the channel and the water surface profile must be computed using backwater techniques.

Many computer programs are available for computation of backwater curves. The most widely used program is HEC-RAS, River Analysis System, developed by the U.S. Army Corps of

Engineers (Hydrologic Engineering Center, 2019) and is the program recommended for backwater profile computations.

7.3 Design Standards

7.3.1 Flow Velocity

Maximum flow velocities shall not exceed the following:

Table 7-1: Allowable Flow Velocity for Channels

Channel Lining Type	**Velocity** (feet/second)
Grass-lined	5
Concrete	15
Rock-line	10

7.3.2 Freeboard Requirements

- "Freeboard" is defined as the vertical distance between the computed water surface elevation for the design flow and the minimum top of bank elevation for a given cross section.
- For all channels one (1) foot minimum of freeboard is required.
- Freeboard shall be in addition to super elevation.

7.3.3 Curvature

The minimum channel centerline radius shall be three (3) times the top width of the design flow.

7.3.4 Super Elevation

Super elevation shall be calculated for all curves. An approximation of the super elevation h may be calculated from the following formula:

$$\boldsymbol{h = \frac{V^2 T}{g r}} \qquad \text{(Equation 7.3)}$$

Where,

h = super elevation (feet)

V = Velocity in (feet / second)

T = Top width of flow area (feet)

g = Acceleration of gravity (32.2 ft/sec^2)

r = radius of curvature (feet)

Freeboard shall be measured above the super elevated water surface.

7.3.5 Grass Channels

7.3.5.1 Side Slopes

Side slopes shall be three (3) (horizontal) to one (1) (vertical) or flatter. Steeper slopes may be used subject to additional erosion protection and approval from the City.

7.3.5.2 Grade Checks

For design discharges greater than fifty (50) cfs, grade checks shall be provided at a maximum of two hundred (200) feet horizontal spacing.

7.3.5.3 Channel Drops

Channel drops shall be provided as necessary to control the design velocities within acceptable limits.

Vertical drops may be used up to three (3) feet in height. Drops greater than three (3) feet shall be baffled chutes or similar structures.

7.3.5.4 Manning Roughness

Table 7-2 provides allowable maximum and minimum Manning's roughness coefficients to use for channel design (City of Springfield, 2018).

Table 7-2: Typical Manning's Roughness Coefficients for Channels

Channel Lining	Minimum	Average	Maximum
Earthen	0.020	0.025	0.030
Mowed grass	0.025	0.030	0.035
Grass-not mowed	0.030	0.035	0.040
Grass with brush/trees	0.040	0.050	0.060
Cobble bottom, grass/root side	0.030	0.040	0.050
Concrete-smooth	0.012	0.013	0.015
Concrete-rough	0.015	0.017	0.020
Riprap D_{50} 6 inches	0.032	0.035	0.038
Riprap D_{50} 9 inches	0.035	0.038	0.040
Riprap D_{50} 12 inches	0.038	0.040	0.042
Riprap D_{50} 18 inches	0.040	0.042	0.044
Riprap D_{50} 24 inches	0.042	0.044	0.047
Grouted boulders	0.025	0.032	0.040

SECTION 8 - STORMWATER DETENTION

Detention facilities are used to reduce stormwater runoff rates by storing excess runoff. The usual function of a detention facilities is to provide sufficient storage such that peak runoff rates are not increased when development occurs.

8.1 Policies for Stormwater Detention

8.1.1 Goals and Objectives

The primary goal of the City of Republic stormwater management program is the prevention of flood damage to residential, commercial, and public property and to meet the requirements of the City's MS4 Permit. In adopting this policy, City of Republic recognizes that:

- There are many areas in the City where residential flooding occurs because of inadequately sized drainage ways.

- Flooding depths and frequency will increase as development occurs upstream of these areas.

- Detention basins are considered the most effective "on-site" means which can be used to control peak runoff stormwater rates as areas develop.

- Therefore, to provide a reasonable level of flood protection to homes and businesses, while maintaining a climate favorable for development and economic growth, the City of Republic has established the following policy for design of detention facilities.

In order to ensure protection of the general health and welfare of the citizens of the City of Republic, planning and design of stormwater management measures shall meet design criteria in this section.

8.1.2 Justified Exceptions

The City may consider, upon request, a waiver of detention for sites, in which the alteration of the site is inconsequential and will not substantially increase the runoff. A justified exception will be granted for sites based on the following criteria.

- Existing sites in which the addition of impervious surface will not increase more than five thousand (5,000) square feet.

- Sites in which existing gravel, chat or stone parking lots or driveways are paved with asphalt cement or concrete surfaces. This shall not apply to parking areas or circulation routes in which vegetation has consumed the site and altered the ability to shed or absorb runoff. The City shall exercise strict discretion with respect to approving exceptions based on these criteria.

- Sites in which a change in use has occurred, that do not increase the impervious area of the site.

- Subdivisions meeting the definition of a minor subdivision or the development of individual single-family-residential homes on individual lots in existing subdivisions.

- Sites that have designed the development with use of other forms of stormwater BMPs to meet water quality standards.

A request for approval of an alternative to detention must begin with the applicant providing the City with stormwater calculations and stormwater report for the increased runoff from the development. In addition to providing calculations, the applicant must submit a request for alternative design based on the criteria established above which will also be detailed in the stormwater report. If the City determines the request is justified, the City will notify the applicant or their representative of the approval.

8.1.3 Innovation in Design

It is the desire of the City that detention facilities be designed and constructed in a manner to enhance aesthetic and environmental quality of the City as much as possible. The City of Republic therefore encourages designs, which utilize and enhance natural settings and minimize disturbance and destruction of wooded areas, natural channels and wetlands.

8.2 Stormwater Management Criteria

All sites that are developed or redeveloped with a disturbance area greater than one acre and do not meet the requirements of paragraph “Justified Exceptions” shall be designed to incorporate features for stormwater management and control, in addition to water quality criteria in this manual. This includes projects of less than one acre that are part of a larger common plan of development or sale that would disturb one acre. The Engineer shall prepare detailed hydrologic and hydraulic analyses to show that the proposed changes to the site will not create adverse conditions to either the upstream or downstream areas of the watershed and shall meet water quality criteria.

8.3 Design Criteria

8.3.1 Discharge Locations

Detention facilities shall discharge into a drainage easement or public right-of-way. Discharge locations shall not disrupt or cause damage to downstream or upstream properties. The stormwater report and plans shall provide sufficient detail of discharge locations.

8.3.2 Freeboard

1 foot of freeboard shall be provided between the maximum water surface elevation (maximum stage for a one percent (1%) annual probability event) and the minimum top of berm or wall elevation.

8.3.3 Embankment Slopes

Embankment and cut slopes steeper than 3 horizontal to 1 vertical (3H:1V) are not permitted.

8.3.4 Emergency Overflow Spillway

The overflow spillways will be required on all detention facilities, which have storage volumes of one thousand (1,000) or more cubic feet.

The overflow opening or spillway shall be designed so that the combination flow of the low flow outlet and the flow over the spillway will not exceed the total peak runoff for the improved area. The total peak runoff is to be determined from a 25-year frequency rain for drainage areas less than one (1.0) square mile and from a 100-year frequency rain for drainage areas one (1.0) square miles or greater.

As described in Section 8.4, an emergency overflow spillway may be analyzed for the one (1%) annual probability ("100-year"). If an emergency overflow spillway is needed for a facility, include a detailed summary of the overflow spillway, specifying the location, type, size and flow capacity in the Engineering Stormwater Report for Stormwater Flood Control and Water Quality specified in Section 8.5.3.

8.3.5 Special Release Rates

In certain instances, such as when the existing development conditions runoff from a watershed would exceed the capacity of the existing downstream facilities, retention basins (i.e., no outlet or with a release rate at the capacity of the downstream facilities) for the storm runoff may be required by the City.

8.3.6 Bottom Slope

Dry detention basins shall maintain a minimum bottom slope of 2 feet per hundred 100 feet (2%).

8.3.7 Trickle Channels

Detention basins may incorporate a trickle channel to concentrate and convey low flows through the basin. Trickle channels shall have a minimum slope of 0.5 foot per 100 feet (0.5%).

8.3.8 Detention in Parking Lots

8.3.8.1 Maximum Ponding Depth

The maximum allowable depth of ponding for parking lot detention is twelve (12) inches, however, the City shall reserve the right to disallow detention within a parking lot. Water quality may be compromised due to the presence of contaminants usually on parking lots and this should be taken into careful consideration when using and designing a parking lot as detention.

This design shall incorporate utilization of additional BMPs, such that water quality is met.

8.3.8.2 Percent of Total Area

Parking lot detention may not inundate more than ten percent (10%) of the total parking area.

8.3.8.3 Signage

All parking lot detention areas shall have a minimum of two (2) signs posted identifying the detention pond area. The signs shall have a minimum area of one and one-half (1.5) square feet and contain the following message:

WARNING

This area is a storm water detention pond and is subject to periodic flooding to a depth of twelve (12) inches.

The sign shall be reflective and have a minimum height of forty-eight (48) inches from the bottom of the sign to the parking space finished grade. Any suitable materials and geometry of the sign are permissible, subject to approval by the City.

8.4 Detailed Analysis

Detailed analysis shall be performed using hydrograph methodologies and reservoir routing techniques. The most common techniques are those developed by the Corps of Engineers and the Soil Conservation Service. These methods are preferred, however other proven techniques will be accepted.

Detention basins designed by detailed methods shall be designed based on multiple storm recurrence frequencies to ensure that they function properly for both frequent storms and large infrequent storms. A minimum of three (3) recurrence frequencies, the fifty percent (50%), ten percent (10%) and one percent (1%) annual probability storms (the "2-year, 10-year and 100-year" storms) must be considered.

The runoff model must include the entire drainage basin upstream of the proposed detention pond. The model shall be prepared in sufficient detail to ensure that peak runoff rates are reasonably accurate.

The runoff model shall be developed for the following cases described in Section 2 - .

Cases 1 and 2 are utilized to determine the required detention volume and the type of outlet structure to be provided and shall be analyzed for the three (3) storm recurrence frequencies required above.

The detention facility shall be designed such that peak outflow rates from the facility for Case 2 are no greater than the rates determined in Case 1 for each of the three (3) storm recurrence frequencies required.

(The storage volume provided shall not be less than the difference in total runoff volume between Case 1 and Case 2.)

Case 3 is used to determine the size of the overflow spillway. Case 3 needs only be analyzed for the one percent (1%) annual probability ("100-year").

8.5 Submittals

The following information must be submitted:

8.5.1 Analytical Methods

Information regarding analytical methods and software to be used, including:

1. Name of software to be used.
2. Type and distribution of precipitation input.
3. Method for determining precipitation losses.
4. Type of synthetic hydrograph.

5. Method for routing hydrographs.

6. Method used for reservoir routing.

8.5.2 Mapping

Map(s) showing sub-basin delineation, topography, presumed flow routes and pertinent points of interest; soil types; existing basin development conditions used in the model; fully developed conditions used in the model.

Routing diagram for the runoff model.

A summary of sub-basin characteristics used for program input.

Stage-area or stage-storage characteristics for the basin in tabular or graphic form.

Stage-discharge characteristics for the outlet structure and overflow spillway in tabular or graphic form; hydraulic data for weirs, orifices and other components of the control structure.

A printout of the input data file.

A summary printout of program output, including plots of hydrographs. (These are intended to be the printer plots generated by the software.)

8.5.3 Engineering Stormwater Report for Stormwater Flood Control and Water Quality

A supplemental stormwater report, stamped by a registered Professional Engineer licensed in the state of Missouri, that includes detailed drainage design computations, in addition to items stated in Section 8.5.1 and Section 8.5.2, must be submitted with stormwater construction plans. The stormwater report must include all details of the stormwater system including detention and water quality calculations and any other relevant hydraulic calculations required to ensure that the proposed stormwater system is designed in accordance with all City regulations. Stormwater calculations for predevelopment and post development conditions must be submitted for the 1, 10 and 100-year storm events to show that post development runoff peaks will not exceed predevelopment runoff peaks. All details of the routing procedure must be submitted with the report. At a minimum, stormwater reports should include the following sections.

8.5.3.1 Project Description and Background

Provide the development name, address and location along with any other relevant information to identify the specific location of the project site. State the type of development (i.e., Commercial Development, Residential Development, etc.), the overall size of the development, and if there are any plans for future development. Identify any and all concentrated offsite stormwater runoff crossing the development and, if so, how the offsite runoff will be conveyed through the site. Provide information on State if site contains a sinkhole or is located in a sinkhole watershed. If so, provide a Sinkhole Evaluation Report in accordance with Section 9 of this manual. State if the development is located in the FEMA floodway or 1% annual floodplain and provide name of the receiving water body. A floodplain development permit will be required to satisfy all regulatory requirements, not limited to the United States Army Corps of Engineers.

8.5.3.2 Detention Summary

Specify the impervious improvements proposed for the development and determine necessary stormwater improvements in order to meet the City's stormwater control and quality regulations.

8.5.3.2.1 Existing Detention

If an existing stormwater detention facility was previously constructed to serve a development provide necessary calculations and analysis to show that the proposed development is in conformance with the original design criteria of the existing detention facility and that existing detention can accommodate new development. Runoff from the proposed development must drain directly to the existing detention facility or drain through drainage easements and/or street right of way to the detention facility. If runoff from the proposed development exceeds the existing detention facility design criteria, additional detention must be provided in accordance with current stormwater regulations.

8.5.3.2.2 Proposed Stormwater Detention Improvements

If there is a determination through design calculations that constructing a stormwater detention facility is required as regulated by this manual, provide a description of the facility (i.e., dry, wet) along with the facility location and the maximum amount of impervious surfacing the facility is designed to handle. State the design method used to size the detention facility specified in Section 3 and provide a summary of the proposed stormwater detention facility.

In the event that an overflow spillway is required based on the regulations specified in this manual, provide a description of the spillway including location, type, size and flow capacity.

8.5.3.2.3 Water Quality Summary

Provide a description of how the proposed developments mitigate stormwater events and specify how the proposed developments will maintain stormwater quality compliance with requirements specified in Section 8.7.

8.6 Control Structures

Detention facilities designed by the simplified analysis shall be provided with obvious and effective outlet control structures. These outlet structures may include v-notch weirs or rectangular weirs, as well as pipe. Plan view and sections of the structure with adequate detail shall be included in the plans.

The design discharge (Q) for the low-flow outlet shall not exceed the existing runoff for the one-year storm. The maximum discharge shall be designed to take place under total anticipated design-head conditions. The design-head storage volume is not to be considered a part of the volume of detention required.

Sizing of a low-flow pipe shall be by inlet control.

Low-flow pipes shall not be smaller than four (4) inches in diameter to minimize maintenance and operating problems, except in parking lot and roof detention where minimum size and configuration of opening shall be designed specifically for each condition.

8.7 Detailed Submittal Plans and Drawings

At a minimum, the development shall include all stormwater related plans designed to meet items specified in the stormwater report. Submittals shall include the following:

- Overall Site Grading Plan
    - This may include phased development, in which, portions of a site will be developed prior to other areas.
    - The plans shall include all existing and proposed contours for the development.
- Erosion Control Protection Plan
- Stormwater Improvement Plans (Existing and Newly Proposed for the Development)
    - Stormwater Inlets, Drainage
    - Related stormwater structure elevations and profiles
    - Outfall Structures, overflow emergency spillways
    - Miscellaneous details for all stormwater related infrastructure
- Stormwater Pollution Prevention Plan

8.8 Water Quality Requirements

8.8.1 Purpose

This section provides requirements and standards to protect the health, safety, and welfare of the public through stormwater management that reduces the harmful effects of urban runoff on area waterways and enhances the livability of the community. The overall objective of this section focuses on the following:

- Maintain compliance with federal and state requirements under the National Pollutant Discharge Elimination System (NPDES) Municipal Separate Storm Sewer System (MS4) program. The City is regulated under this program through its MS4 permit, which mandates the City to have requirements in place to reduce the discharge of pollutants from the MS4 to the Maximum Extent Practicable (MEP) by addressing the post-construction water quality impacts of stormwater runoff from new development and redevelopment.
- Provide a basis for developing on-site design criteria which will effectively protect water quality with various treatment processes and runoff.
- Site planning and design principles incorporating Stormwater Control Measures (SCMs) and Best Management Practices (BMPs) to minimize disturbance and impervious surfaces and preserve and protect vegetation, soils, natural topography, natural channels, and karst features.

In developing this chapter, the following design manuals from other communities were referenced and adapted based on related local conditions and experiences. Designers are encouraged to consider approaches, guidelines and recommendations provided in these references in conjunction with this section.

- Greene County Missouri Design Standards for Water Quality Control Protection
- City of Springfield. (2018, April). Flood Control and Water Quality Protection Manual. Springfield, Missouri: Department of Public Works.

Outfalls specifically mentioned under the City's MS4 permit authorizes discharges to areas tributary to Dry Br., tributary to Pond Creek, and tributary to Terrell Cr. It is the responsibility of the City to maintain compliance with federal and state requirements under the National Pollutant Discharge Elimination System (NPDES) Municipal Separate Storm Sewer System (MS4) program and as result, specify the requirements and recommendations provided herein.

8.8.2 General Design Guidelines for Water Quality

Design guidelines that aid in effective stormwater quality considers the following:

8.8.2.1 In-depth Research of Proposed Site for Development

Getting to know the proposed site prior to development planning should be the first step in considering flood control and water quality. Studying the topography of a site in order to most effectively utilize natural land features in the conveyance and filtration of stormwater is a key step in developing storms.

8.8.2.2 Minimize the amount of runoff:

The amount of runoff from a development is directly related to the amount of impervious areas utilized for the conveyance of stormwater. A system utilizing impervious areas, i.e., paved drainage, curb and gutters, storm drains, in a connected system to mitigate stormwater flow greatly increases the amount of runoff and, therefore, reductions in impervious should be considered in the initial design of a development. A reduction in directly connected runoff can help decrease the likelihood of pollutants being transported to receiving waters.

8.8.2.3 Maximizing contact with vegetation.

Incorporating the use of vegetation in the conveyance of storm water through vegetative filter strips, grass swales and infiltration through soils can greatly reduce the amount of pollutants and sediments. The idea of utilizing disconnected systems is likely to reduce the runoff peak and volume if designed effectively.

8.8.2.4 Maximizing holding and settling times.

The most effective SCMs reduce both the runoff peak and volume. By reducing the rate of outflow and increasing the time of detention storage, settling of pollutants and infiltration of runoff are maximized.

8.8.2.5 Utilizing SCMs/BMPs in series where possible.

The utilization of a combination of SCMs in series can help reduce the amount of pollutants entering receiving waters. For example, conveying stormwater through first a vegetative filter strip, then to grass swales, and then to detention/ infiltration basins would help reduce the level of pollutants.

8.8.2.6 Incorporating both flood control and water quality objectives in designs.

Incorporating both flood control and water quality criteria into a single stormwater management facility is not only possible but is encouraged. Whenever practical, combining several objectives, such as water quality enhancement and flood control, maximizes the cost-effectiveness of stormwater management facilities.

8.8.3 Design Criteria

8.8.3.1 Requirements

The following requirements will apply to new developments within the City as authorized by the MS4 permit:

1. Stormwater runoff from any new development for which the total impervious area exceeds ten percent (10%) of the total land area of the development must be directed through an extended wet or dry detention basin, or other properly designed BMP, prior to discharge from the site.

2. Runoff from fueling areas and other areas having a high concentration of pollutants, such as parking lots, will be required to be directed to a sand filter or other properly designed BMP which provides filtration as well as settling.

3. The required volume for capture and treatment shall be designed as the water quality capture volume (WQCV) and shall be determined as set forth in Section 8.8.3.2.

4. Detention storage must be provided to limit the peak flow rate as set forth in Section 8.4.

8.8.3.2 Water Quality Capture Volume

Water quality BMPs shall be designed to capture the runoff from the 90th percentile rainfall for Greene County as well as to capture the first flush of pollutants from directly connected impervious areas within the proposed development. Since stormwater controls are designed for small, frequent storm events, therefore, the water quality volume (WQV) is based on the runoff from a 1-inch rainfall. The WQV must be captured using SCMs, that reduce the discharge of pollutant through runoff reduction and treatment.

The required water quality capture volume (WQCV) to be used in design of extended wet and dry detention basins and other BMPs whose design is based upon capture and treatment of stormwater, shall be the greater of the following:

1. the first one-half inch (½") of runoff from the directly connected impervious area (DCIA) in the development, or

2. the runoff resulting from total rainfall depth of one-inch (1") in twenty-four (24) hours over the entire development.

SECTION 9 - SINKHOLES AND KARST FEATURES

9.1 General

- The City of Republic is located on the Springfield Plateau of the Ozarks physiographic region. This area is underlain by Mississippian Age limestone, which is highly susceptible to solutional weathering. As a result, sinkholes, springs and caves are common.

- In many areas of the City special consideration must be given to flood hazards and potential for groundwater contamination due to the presence of sinkholes, caves, losing streams, springs and other features associated with karst geology.

- The requirements set forth herein are intended to provide specific criteria for design and construction for any site upon which sinkholes or other karst features are located.

- Interpretations of these requirements shall be made, and appeals may be made according to the procedures set forth in these Design Criteria.

9.2 Policy

In keeping with the intent of the City Development Regulations the following policy is set forth for development in areas containing sinkholes:

- Development in sinkhole areas will be based upon the following axioms:
    - Avoidance.
    - Minimization.
    - Mitigation.

Construction in sinkholes shall be avoided. Exceptions will be made only in situations where it can be conclusively demonstrated that there are no practical alternatives to such construction.

- These situations are mostly likely to arise where:
    - An underground cavity has caused a collapsed sinkhole to form, after subdivision approval or building construction.
    - A sinkhole has been altered or filled either unknowingly or prior to passage of these regulations.
    - Maintenance and operation are required for existing roads and utilities.
    - Location of existing streets or utilities would render access or utility service to a property impractical or cost prohibitive.

- In these types of cases, measures which will have minimal impact on the sinkhole or receiving water, may be proposed. Plans for minimal alteration can be approved provided it is conclusively demonstrated that the proposed plan is the minimum practical alternative.

- In these cases, potential impacts of construction on the sinkhole and receiving waters must be studied and assessed and recommendations made for mitigation of potential impacts upon surface flooding and groundwater quality before the plans can be approved. The degree and sophistication of study required will increase in proportion to the potential impacts. A remediation plan will need to be submitted for review by the City. The remediation plan will need to be stamped by a registered Professional Geotechnical Engineer licensed in the state of Missouri.

9.3 Definitions

As used in this Section, the following terms shall have these prescribed meanings:

ALTERED SINKHOLE — A sinkhole that has been filled, excavated or otherwise disturbed.

COLLAPSED SINKHOLE — A subsidence or cave-in of the ground surface caused when soil overburden can no longer be supported by underlying strata due to the presence of subsurface solution cavities.

HEAVY EQUIPMENT — Motorized equipment having a gross weight of more than six (6) tons.

LIGHT EQUIPMENT — Motorized equipment weighing six (6) tons or less.

QUALIFIED GEOLOGIST — A person who has met or exceeded the minimum geological educational requirement and who can interpret and apply geologic data principles and concepts and who can conduct field or laboratory geologic investigations (per RSMo.) and who by reason of experience and education, has an understanding of local karst geology.

QUALIFIED PROFESSIONAL GEOTECHNICAL ENGINEER — A person registered to practice engineering according to the laws of the State of Missouri and who by reason of technical education and experience has a background in the fundamentals of storm drainage and karst geology.

SINKHOLE — Any depression in the surface of the ground, with or without collapse of adjacent rock that provides a means through which surface water can come into contact with subsurface water.

Sinkhole depressions may be gradual or abrupt; they may or may not have a well-defined eye. While most sinkholes can be defined as the area within a "closed contour", some sinkholes such as those located on the sides of hills may not.

All sinkholes provide discreet points of recharge to groundwater.

SINKHOLE CLUSTER AREA — An area containing two (2) or more sinkholes located in proximity, generally interconnected by groundwater conduits.

SINKHOLE EYE — Generally, a visible opening, cavity or cave in the bottom of a sinkhole, sometimes referred to as a swallow hole.

SINKHOLE FLOODING AREA — The area inundated by runoff from a storm with an annual exceedance probability of one percent (1%) and a duration of twenty-four (24) hours.

SINKHOLE RIM — The perimeter of the sinkhole depression. The sinkhole rim will generally vary in elevation.

SINKHOLE WATERSHED — The ground surface area that provides drainage to the sinkhole. This area extends beyond the sinkhole depression and generally crosses property boundaries.

TERMINAL SINKHOLE — The lowest sinkhole in a sinkhole cluster to which any surface water overflowing from other sinkholes in the cluster will flow.

UNALTERED SINKHOLE — A sinkhole that has never been altered or disturbed.

9.4 Permits Required

9.4.1 Grading Permit

A grading permit must be obtained prior to any alteration of sinkholes associated with new subdivision construction in accordance with the City's Subdivision Regulations. Procedures and requirements for grading permits are set forth in Section 10.3.

9.4.2 Other Permits

Other permits from State or Federal agencies may be required, as outlined in Section 10.4 of these Design Criteria, depending upon the size and nature of the proposed activity.

9.5 General Plan Requirements

General requirements for grading and drainage plans are set forth in Section 8.7.

9.6 Sinkhole Evaluation

An evaluation including the following information shall be made for all sites upon which sinkholes are fully or partially located:

9.6.1 Site Plan

The site plan for the proposed development must show the following items with respect to location of proposed construction, proposed or existing property lines and existing structures:

9.6.1.1 Sinkholes

- Location and limits of the area of the sinkhole depression as determined by field surveys or other reliable sources as may be approved.
- Location of sinkholes based solely upon USGS 7-1/2 Minute Series Quadrangle Maps will not be considered sufficient unless field verified.
- Location and elevation of the sinkhole eye where visible or known.
- Topographic contours at maximum intervals of two (2) feet and spot elevations sufficient to determine the low point on the sinkhole rim and the profile of the potential overflow area.
- Minimum entry elevations of any existing structures located within the sinkhole rim.
- Elevation of any roadway located within or adjacent to the sinkhole.

9.6.1.2 Water Supply Sources

- The approximate location of public or private water supply sources such as springs or wells, as determined from information available from the City and Missouri Department of Natural Resources.

- Boundaries of any known recharge areas to wells or springs as determined from information available from the City and Missouri Department of Natural Resources.

9.6.1.3 Other Geologic Features

Location of caves, springs, faults and fracture trends, geologic mapping units based upon information from the City or other reliable sources.

9.6.1.4 Flooding Limits

Flooding limits for the sinkholes are determined as set below.

9.6.2 Drainage Area Map

A drainage area map showing the sinkhole watershed area. Where the site is in a sinkhole cluster area, this map shall be extended to include the watershed area any sinkholes located downstream of the site which may receive overflow drainage from the site.

9.6.3 Assessment of Impacts

Assessment of potential impacts on groundwater quality and proposed water quality management measures as set forth below.

9.7 Flooding Considerations

9.7.1 Minimum Flooding Analysis

- Maximum estimated flooding elevations shall be determined for each sinkhole for both pre-development and post development conditions, assuming no subsurface outflow from the sinkhole.

- Where the estimated volume of runoff exceeds the volume of the sinkhole depression, the depth, spread and path of overflow shall be estimated and shown on the map.

- The overflow volume shall be included determining the maximum estimated flooding elevations in the next downstream sinkhole. This analysis shall continue downstream until the lowest sinkhole of the sinkhole cluster is reached, or overflow reaches a surface watercourse.

- The volume of runoff considered shall be that which results from a rainstorm with an annual probability of one percent (1%) (100-year storm) and a duration of twenty-four (24) hours (eight and two-tenths (8.2) inches for Republic).

- The runoff volume shall be determined by the method set forth in Chapter 2 of the SCS TR-55 Manual (Reference).

- No further flooding analysis will be required provided that:

- The post-development flooding area of any sinkhole which receives drainage from the site is located entirely on the site.
- A drainage easement covering the post-development flooding area is provided for any off-site sinkhole or portion of a sinkhole which receives increased peak rates of runoff from the site. If the receiving sinkhole is not contiguous to the site, an easement must also be provided for the waterway that connects the site to the sinkhole.
- The minimum entry elevation of any existing structure is at least one (1) foot higher than the estimated flooding elevation from the one percent (1%) annual probability 24-hour storm.
- The flooding depth on any existing public road does not exceed the maximum depth set forth in Section 4.3 of this Manual.

9.7.2 Detailed Flooding Analysis

9.7.2.1 General Requirements

In cases where the conditions set forth above cannot be met, a detailed flooding analysis will be required if any increase in runoff volume is proposed. For detailed flooding analysis a runoff model must be made for the sinkhole watershed and reservoir routing analysis performed using hydrograph techniques as set forth in Section 3.4.

9.7.2.2 Alternative Methods

The following alternative methods may be used singly or in combination to keep flooding levels at predevelopment levels:

9.7.2.2.1 Diversion of Excess Runoff to Surface Watercourses

Where feasible, increased post-development runoff may be diverted to a surface watercourse, provided that:

- Any increase in peak runoff rate in the receiving watercourse does not create or worsen existing flooding problems downstream; and
- The diverted stormwater remains in the same surface watershed.
- Storm sewers, open channels and other appurtenances provided for diversions shall be designed in accordance with applicable sections of these Design Criteria.
- The effect of diverted water on downstream watercourses and developments and requirements for additional detention facilities prior to release of runoff to the surface watercourse shall be determined as set forth in Section 8.
- Effects of the diversion shall be shown by reservoir routing analysis. Routing of excess runoff shall be considered satisfactory when it can be demonstrated that the post-development flooding elevation in the sinkhole does not exceed the pre-development flooding elevation within reasonable tolerance (generally one-tenth (0.1) foot).

9.7.2.3 Storage of Excess Runoff within the Sinkhole Watershed

- Where feasible, detention facilities may be constructed within the sinkhole watershed or in perimeter areas of the sinkhole. However, this does not mean that detention will be permitted within the sinkhole depression. These detention facilities must be located outside the sinkhole flooding area determined for post- development conditions.

- The flooding considerations set forth in this Section will be met if it can be demonstrated that:

  - Inflow rates to the sinkhole can be reduced to a degree that, in conjunction with the observed outflow rate, the post-development flooding elevation in the sinkhole does not exceed the pre-development flooding elevation within reasonable tolerance (generally one-tenth (0.1) foot).

  - Sediment and erosion control and water quality considerations as set forth elsewhere in this Section can be satisfied.

9.8 Water Quality Considerations.

9.8.1 Requirements

Sinkholes provide direct recharge routes to groundwater. As a result, water quality in wells, caves and springs may be affected by discharge of runoff from developed areas. The Sinkhole Evaluation must consider potential impacts of the proposed construction on receiving groundwater and propose measures to mitigate such impacts. Four (4) primary factors must be considered:

- Receiving groundwater use.

- Relative groundwater contamination hazard associated with the proposed development.

- Ability to capture pollutants.

- Management measures to be provided to reduce pollutant levels.

9.8.2 Receiving Groundwater Use

The Sinkhole Evaluation Report shall identify whether the site lies within a critical area based upon information available from the City.

9.8.2.1 Dye Tracing

Where disagreements may arise over whether a site is located within a recharge area dye tracing may be required for confirmation of the destination of water discharges through a sinkhole.

9.8.2.2 Critical Areas

The following areas are classified as critically sensitive to contamination from urban runoff:

- Recharge areas of domestic water supply wells.

- Recharge areas of springs used for public or private water supply.

- Recharge areas of caves providing habitat to rare or endangered species such as the Ozark cave fish.

9.8.2.3 Sensitive Areas

All other sinkhole areas will be classified as sensitive to contamination from urban runoff.

9.8.3 Groundwater Contamination Hazard

The relative potential for groundwater contamination will be classified as low, moderate or high depending upon the type of land use, development density and amount of directly connected impervious area. The Sinkhole Evaluation shall identify whether the proposed development poses a low, moderate or high hazard to groundwater uses, as defined below:

9.8.3.1 Low hazard

The following land uses are classified as posing a relatively low hazard to groundwater contamination:

- Wooded areas and lawns.
- Parks and recreation areas.
- Residential developments on sewer, provided directly connected impervious areas discharging to the sinkhole is less than one (1) acre.
- Low density commercial and office developments provided directly connected impervious areas discharging to the sinkhole is less than one (1) acre.
- Discharge from graded areas less than one (1) acre having required sediment controls per Section 10.

9.8.3.2 Moderate Hazard

- Concentrated discharge from streets and parking lots and roofs and other directly connected impervious areas having an area greater than one (1) acre and less than five (5) acres.
- Multi-family residential developments and higher intensity office developments provided the directly connected impervious areas discharging to the sinkhole is less than five (5) acres.
- Discharge from graded areas greater than one (1) acre and less than five (5) acres having required sediment controls per Section 8.

9.8.3.3 High hazard.

- Collector and arterial streets and highways used for commercial transport of toxic materials.
- Railroads.

- Concentrated discharge from streets and parking lots and roofs and other directly connected impervious areas having an area greater than five (5) acres.
- Commercial, industrial and manufacturing areas.
- Individual wastewater treatment systems.
- Commercial feedlots or poultry operations.
- Discharge from graded areas greater than five (5) acres having required sediment controls per Section 8.

9.8.4 Capturing and Filtering Pollutants

- Most sinkholes drain a limited watershed area. For sinkholes where the surrounding drainage area is small enough that the area draining to the sinkhole flows predominantly as "sheet flow", potential impacts on water quality can be addressed by erecting silt control barriers around the sinkhole during construction and providing a vegetative buffer area around the sinkhole to filter out potential contaminants.
- When the volume of runoff into the sinkhole increases to the point where flow becomes concentrated, the degree of effort required to capture and filter out contaminants increases significantly.
- Concentrated inflow occurs naturally when the sinkhole watershed area reaches a sufficient size for watercourses leading into the sinkhole to form. Concentrated surface flows result as urbanization occurs due to construction of roads, storm sewers, drainage channels. Subsurface flows can become concentrated through utility trenches.
- The Sinkhole Evaluation shall include maps showing any existing watercourse which flows into the sinkhole and the location of any proposed concentrated stormwater discharges into the sinkhole.

9.8.5 Water Quality Management Measures

9.8.5.1 Sediment and Erosion Control.

9.8.5.1.1 Non-Concentrated Flow (Sheet Flow)

In critical areas, existing ground cover shall not be removed within thirty (30) feet of the sinkhole rim and a silt barrier shall be provided around the outer perimeter of the buffer area.

9.8.5.1.2 Concentrated flow

A sediment basin will be required at each point where concentrated flows are discharged into the sinkhole.

Sediment basins shall be designed according to the procedures set forth in Section 10.5.2.4.

9.8.5.2 Minimizing directly connected impervious areas.

- The groundwater contamination hazard category for impervious areas may be reduced by reducing the amount of Directly Connected Impervious Area. This is the area of roofs, drives, streets, parking lots, etc. which are connected via paved gutters, channels or storm sewers.

- Directly Connected Impervious Areas can be reduced by providing properly sized grass swales, vegetative filter strips or other Best Management Practices to separate paved areas.

9.8.5.3 Diversion of Runoff

- Concentrated discharges to sinkholes can be reduced to manageable levels or avoided by diverting runoff from impervious areas away from sinkholes where possible.

- Diversions shall be done in a manner that does not increase flooding hazards on downstream properties and, generally, shall not be directed out of the surface watershed in which the sinkhole is located.

9.8.5.4 Filtration Areas

- For areas having a low or moderate groundwater contamination hazard and where flow into the sinkhole occurs as sheet flow, water quality requirements can be satisfied by maintaining a permanent vegetative buffer area with a minimum width of thirty (30) feet around the sinkhole.

- Use of pesticides and fertilizers will not be permitted within the buffer area. Animal waste will not be permitted to accumulate in the buffer area.

9.8.5.5 Grassed Swales and Channels

- For areas having a low groundwater contamination hazard concentrated flows from directly connected impervious areas of less than one (1) acre may be discharged into the sinkhole through grassed swales and channels.

- Swales and channels shall be designed for non-erosive velocities and appropriate temporary erosion control measures such as sodding, or erosion control blankets provided.

9.8.5.6 Storage and Infiltration

Storage and infiltration will be required in the following cases:

- All areas having a high groundwater contamination hazard.

- Areas having a moderate groundwater contamination hazard where concentrated inflow occurs.

Storage and infiltration basins shall be designed to capture the runoff from storms up to one (1) inch and release runoff over a minimum period of twenty-four (24) hours and maximum period of forty-eight (48) hours.

Standards outlet structures for sedimentation and infiltration basins are shown in the standard drawings.

9.9 Development Requirements.

9.9.1 Stormwater Detention in Sinkholes.

Where flooding considerations and water quality considerations, as set forth in Section 10, can be met, the volume of runoff storage in sinkholes can be counted toward stormwater detention requirements, provided that proper sediment and erosion control measures are provided as set forth in Section 10.

The volume of required detention storage shall be determined as set forth in Section 8.

Excavation within the sinkhole flooding area to provide additional detention storage will not be allowed.

9.9.2 Modification of Sinkholes to Increase Outflow Rates.

Increasing outflow rates in sinkholes by excavating the sinkhole eye or installing disposal wells for diverting surface runoff to the groundwater system is prohibited, unless clear and imminent danger to the public health and safety can be demonstrated.

9.9.3 Setbacks and Use Restrictions

- No new construction of any of the following shall be permitted within thirty (30) feet of the sinkhole rim:
    - Residential, commercial or industrial structures.
    - Swimming pools.
    - Streets, highways or parking lots.
    - Storage yards for materials, vehicles and equipment.
    - Sanitary sewer lines.
- Use of pesticides and fertilizers within thirty (30) feet of the sinkhole rim is prohibited.
- Use of heavy construction equipment in unaltered sinkholes is prohibited.
- Construction of underground utilities is prohibited within the sinkhole rim.
- Recreational facilities such as hiking, jogging and bicycling trails, playgrounds, exercise courses and grass playing fields are permitted within the sinkhole area provided they are not located within the eye of the sinkhole.
- Golf courses are permitted subject to approval of a Management Plan for use of pesticides and fertilizers.
- Clearing and pruning of trees and undergrowth and limited grubbing of roots is permitted.
- Landscaping and minor gardening is permitted outside of the sinkhole eye provided erosion and sediment discharge is limited through use of minimum tillage and mulches.

- Construction of light incidental landscaping and recreational structures such as gazebos, playground equipment, etc. is permitted except in the sinkhole eye.

9.9.4 Collapsed Sinkholes

- Collapsed sinkholes may be stabilized and filled using approved techniques. A Grading Permit and a Geotechnical report and/ or mediation report all limitations in development must be issued prior to performing any construction.

- The probable cause of the collapse and potential adverse impacts of filling the collapse shall be investigated and information submitted with the Grading Permit application.

9.9.5 Altered Sinkholes

- Filling or altering of sinkholes without a Grading Permit and a Geotechnical report and/ or mediation report all limitations in development constitutes a violation of these regulations. In such cases corrective measures must be proposed within the time period specified in the Zoning Regulations for enforcement of such violations. No corrective or remedial measures shall be undertaken until the proposed remediation plan has been reviewed by the City and a Grading Permit issued.

- No Building Permits will be issued, or zoning or subdivision approvals granted, until the remedial measures specified in the Grading Permit have been completed and approved.

SECTION 10 - GRADING, SEDIMENT AND EROSION CONTROL

10.1 Goals and Objectives

The goal of the regulation is to effectively minimize erosion and discharge of sediment by application of relatively simple and cost-effective Best Management Practices. This goal can be attained by meeting the following objectives:

- Minimize the area disturbed by construction at any given time.
- Stabilize disturbed areas as soon as possible by re-establishing sod, other forms of landscaping and completing proposed structures, pavements and storm drainage systems.
- Provide for containment of sediment until areas are stabilized.
- Provide permanent erosion controls.

10.2 General Design Guidelines

The following items shall be considered in preparing a sediment and erosion control plan:

10.2.1 Temporary Versus Permanent Controls

The greatest potential for soil erosion occurs during construction. Temporary controls are those that are provided for the purpose of controlling erosion and containing sediment until construction is complete.

Temporary controls include straw or hay bale dikes, silt fences, erosion control blankets etc., which are not needed after the area is stabilized.

Permanent controls consist of riprap, concrete trickle channels, detention basins, etc., which will remain in place through the life of the development.

It is possible for the same facility to serve both a temporary and permanent purpose. The difference between temporary and permanent erosion control should be clearly recognized in preparing a sediment and erosion control plan.

10.2.2 Sheet Flow Versus Concentrated Flow

In areas where runoff occurs primarily as sheet flow, containment of sediment is relatively simple. In these areas straw or hay bales, silt fences and vegetative filter areas can be very effective.

Where concentrations of flow occur containment of sediment becomes more difficult as the rate and volume of flow increase. In these areas more sophisticated controls such as sedimentation basins must be provided.

10.2.3 Slope

Control of erosion becomes progressively more difficult as the slope of the ground increases. Areas with steeply sloping topography and cut and fill slopes must be given special consideration.

10.2.4 Soils and Geologic Setting

Area soils and the geologic setting must be considered in preparing the plan and any special considerations deemed necessary for a particular site provided.

10.2.5 Environmentally Sensitive Areas

Where construction occurs within the vicinity of permanent streams, springs, sinkholes, lakes or wetlands, special attention must be given to preventing discharge of sediment. These areas will require frequent inspections to ensure that proper mitigation measures are being implemented to hinder any water quality requirements.

10.3 Grading Permits

10.3.1 Permit Requirements

Grading permits are required for all construction sites with the following exceptions:

- Grading for single-family or duplex residences constructed in subdivisions where approved sediment and erosion controls have been constructed.
- Emergency construction required repairing or replacing roads, utilities or other items affecting the general safety and wellbeing of the public.
- For emergency construction sites which would otherwise be required to obtain a permit and for which remedial construction will take more than fourteen (14) calendar days, application for the permit must be made within three (3) calendar days from the start of construction.
- The following activities, provided that they are not located within thirty (30) feet of a spring, sinkhole, wetland or watercourse:
    - Gardening or landscaping normally associated with single- family residences that cover less than one-half (½) acre.
    - Grading and repair of existing roads or driveways.
    - Cleaning and routine maintenance of roadside ditches or utilities.
    - Utility construction where the actual trench width is two (2) feet or less.

10.3.2 Permit Procedure

The following items must be received prior to issuance of a Grading Permit:

- An approved grading, sediment and erosion control plan. The submittal and approval procedure are as follows for subdivisions, commercial and other sites.
- The sediment and erosion control plan shall be submitted for review along with the plans for the proposed improvements.
- Receipt of MDNR Land Disturbance Permit

- Grading permits for commercial, multi-family or major subdivisions will be issued by the City after the project plans have been approved.

10.3.3 Plan Requirements

Plans must be prepared by and bear the seal of an engineer registered to practice in the State of Missouri. Plan requirements are set forth in Section 8.7. Plans will not be required in the following cases:

- Grading associated solely with a single-family residence and have been accounted for in a larger development/subdivision.

- Grading or filling of less than one (1) acre if located outside of the allowable building areas and not located within twenty- five (25) feet of spring, sinkhole, wetland or watercourse. In these instances, a grading permit can be issued, providing an inspection of the site by a representative of the City does not reveal conditions that would warrant preparation of a detailed plan.

10.4 Other Permits

10.4.1 NPDES Stormwater Permit

NPDES stormwater permit. Effective October 1, 1992, construction sites where the area to be disturbed is five (5) acres or more must apply for a stormwater discharge permit from the Missouri Department of Natural Resources. Effective December 8, 1999, construction sites where the area to be disturbed is one acre or more or less than one acre but part of a common plan of development require a stormwater discharge permit from the Missouri Department of Natural Resources. Permit requirements are set forth in 10 CSR 20-6.200 of the Missouri Clean Water Laws.

10.4.2 Missouri Land Disturbance Permit

Effective December 8, 1999, construction sites where the area to be disturbed is one acre or more or less than one acre but part of a common plan of development will require a Missouri Land Disturbance permit.

10.4.3 USACE Section 404 Permit and State issued 401

"404" permit. Grading activities in streams or wetlands may require a Department of the Army Permit under Section 404 of the Clean Water Act. When a proposed development/project will take place near or in streams or wetlands, a permit or memo from the Army Corps of Engineers specifically stating, “a permit will not be required,” is required to provide to the City. If the Army Corps of Engineers determines a 404 permit is required, the project must also be submitted to the state of Missouri for a Section 401 Water Quality Certification.

10.5 Design Standards and Criteria.

10.5.1 Grading

10.5.1.1 Maximum Grades

Cut or fill slopes shall not exceed four (4) to one (1).

10.5.1.2 Maximum Height

Cut or fill slopes shall not exceed fifteen (15) feet in vertical height unless a horizontal bench area at least five (5) feet in width is provided for each fifteen (15) feet in vertical height.

10.5.1.3 Minimum Slope

Slope in grassed areas shall not be less than one percent (1%).

10.5.1.4 Construction Specifications

Construction of streets must comply with specifications set forth by the City of Republic. For all other areas, construction specifications stating requirements for stripping, materials, subgrade compaction, placement of fills, moisture and density control, preparation and maintenance of subgrade must be included or referenced on the plans or accompanying specifications submitted.

10.5.1.5 Spoil Areas

- Broken concrete, asphalt and other spoil materials may not be buried in fills within proposed building or pavement areas.
- Outside of proposed building and pavement areas, broken concrete or stone may be buried in fills, provided it is covered by a minimum of two (2) feet of earth.
- Burying of other materials in fills is prohibited.

10.5.1.6 Stockpile Areas

Location of proposed stockpile areas shall be outlined in the plans and specifications for proper drainage included.

10.5.1.7 Borrow Areas

The proposed limits of temporary borrow areas shall be outlined in the plans and a proposed operating plan described on the grading plan. Temporary slopes in borrow areas may exceed the maximums set forth above. At the time that borrow operations are completed, the area shall be graded in accordance with the criteria set forth above and reseeded.

10.5.2 Sediment Containment

10.5.2.1 Existing Vegetative Filter Area

Existing vegetative filter areas may be used where:

- Unconcentrated sheet flow occurs.
- An area of existing vegetation a minimum of twenty-five.
- (25) feet in width can be maintained between the area to be graded and a property line, watercourse, sinkhole, spring, wetland or classified lake.
- Existing ground slope is no greater than five (5) to one (1) (twenty percent (20%)).
- The existing vegetative growth is of sufficient density and in sufficiently good condition to provide for filtration of sediment.

- Vegetative filter areas are a temporary and permanent practice.

10.5.2.2 Hay/Straw Bale Dike or Silt Fence

Containment areas constructed of hay or straw bales, or silt fence may be provided in areas where:

- Unconcentrated sheet flow occurs,
- An area of existing vegetation a minimum of twenty-five (25) feet in width cannot be maintained between the area to be graded and a property line, watercourse, sinkhole, spring, wetland or classified lake,
- Existing ground slope is no greater than five (5) to one (1) (twenty percent (20%)),
- Concentrated flow from an area no greater than one (1) acre occurs and a minimum volume of one thousand (1,000) cubic feet per acre is contained behind the dike. Either cereal grain straw or hay may be used for bale dikes. Straw/hay bale dikes shall be constructed as shown in Drawing 50. Straw/hale bale dikes and silt fences are temporary practices.

10.5.2.3 Temporary containment berms.

Temporary containment berms may be provided for areas where concentrated flow from areas greater than one (1) acre and less than five (5) acres occurs. Temporary containment berms must contain a volume of one thousand (1,000) cubic feet per acre of drainage area.

- Temporary containment berms shall have a riprap outlet with a sediment filter as shown in Drawing 40 or a perforated pipe outlet as shown in Drawing 80.
- Details for temporary containment berms are shown in Drawing 30.
- Temporary containment berms and accumulated sediment may be completely removed after the tributary area is stabilized and must be removed prior to final acceptance and release of escrow.

10.5.2.4 Sedimentation Basin

10.5.2.4.1 General

Sediment basins shall be provided for all areas where concentrated flow occurs from an area of 10 or more acres disturbed at one time.

- Sediment basins shall be sized and designed, at a minimum, to treat local 2 year, 24-hour storm.
- Sediment basins shall not be constructed in any waters of the state or natural buffer zones.

Runoff shall be calculated in accordance with Section 3.

10.5.2.4.2 Sediment Basin Outfall Structures

Sediment basins shall be provided with an outflow structure consisting of:

- A flow restriction device which provides for the required detention time,
- An outfall pipe sized to carry the maximum estimated outflow rate,
- Protective structures at the pipe outlet to prevent crushing or damage of the end of the pipe,
- Protective structures to prevent blockage of the pipe with debris,
- Erosion protection at the pipe outlet. A typical outlet structure is shown in Drawing 140.

A sedimentation basin is required for each drainage area with ten or more acres disturbed at one time.

(a) The sedimentation basin shall be sized, at a minimum, to treat a local 2-year, 24-hour storm.

(b) Sediment basins shall not be constructed in any waters of the state or natural buffer zones.

(c) Discharges from dewatering activities shall be managed by appropriate controls. The SWPPP shall include a description of any anticipated dewatering methods and specific BMPs designed to treat dewatering water.

Any basin used for dewatering shall be inspected daily when discharge is occurring. The discharge shall be observed and dewatering activities shall be ceased immediately if the receiving stream is being impacted. These inspections shall be noted on a log or on the inspection report.

Outfalls examined for visual signs of erosion or sedimentation at outfalls. Excessive erosion or sedimentation may be due to BMP failure or insufficiency. Response to observations should be addressed in the inspection report.

10.5.2.4.3 Overflow Spillway

- An overflow spillway capable of discharging the peak flow rate for the four percent (4%) annual probability (25-year) storm while maintaining a minimum freeboard of one (1) foot.
- Overflow spillways may be sodded where the depth of flow at the crest is limited to no greater than six (6) inches and outlet channel velocities do not exceed five (5) feet per second for the minor (5-year) storm.
- Overflow spillways not meeting these restrictions must be constructed of riprap, concrete or other approved, non- erodible material.

10.5.3 Erosion Protection

10.5.3.1 Seeding and Mulching

10.5.3.1.1 Permanent Seeding

- Permanent seeding fertilizer and mulch shall be applied at the rates set forth in Drawing 10 or according to other specifications, which are approved with the Grading Permit.

- The City prefers that permanent seeding be performed between September first (1st) and October thirtieth (30), if possible.

- If permanent seeding cannot take place within the time frame stated above, the City's next preferred time frame would be between March first (1st) and June fifteenth (15th), with March or April being the next preferable option.

10.5.3.1.2 Mulching

Where slopes are less than four (4) to one (1), cereal grain mulch is required at the rate of one hundred (100) pounds per one thousand (1,000) square feet (four thousand five hundred (4,500) pounds per acre). Cereal grain mulch shall meet the requirements of Section 802 of the State Specifications (Reference 17) for Type 1 mulch.

Where slopes are four (4) to one (1) or greater Type 3 mulch ("hydro mulch") meeting the requirements of Section 802 of the State Specifications (Reference 17) shall be used.

10.5.3.1.3 Temporary seeding

Whenever grading operations are suspended for more than thirty (30) calendar days between permanent grass or seeding periods, all disturbed areas must be reseeded with temporary cover according to Drawing 10.

Temporary seeding season runs from May fifteenth (15th) to November fifteenth (15th).

10.5.3.1.4 Overseeding

During the winter season (November fifteenth (15th) to March first (1st)) temporary seed and mulch shall be placed in on all completed areas or areas where grading is suspended for more than thirty (30) calendar days. During this period seed, mulch and soil amendments shall be applied at the following rates:

Lime: 100% of specified quantity[1].

Fertilizer: 75% of specified quantity.

Seed: 50% of specified quantity.

Mulch: 100% of specified quantity.

Areas seeded during this period shall be reseeded and mulched during the next permanent seeding season according to seeding requirements.

10.5.3.1.5 Maintenance

Seeded areas must be maintained for one (1) year following permanent seeding.

10.5.3.2 Cut and Fill Slopes.

Cut and fill slopes shall be protected from erosion by construction of straw bale dikes, silt fences, diversion berms or swales along the top of the slope.

[1] Per Drawing 10

- Where drainage must be carried down the slopes, pipe drains, concrete flumes, riprap chutes or other impervious areas must be provided. Suitable erosion control measures such as riprap stilling basins, must be provided at the bottom of the slope.

- Diversions shall be maintained until permanent growth is firmly established on the slopes.

- Typical diversion details are shown in Drawing 30. Riprap chute details are shown in Drawing 70.

10.5.3.3 Channels and Swales

Permanent channels and swales shall be provided with a stabilized invert consisting of one of the following materials:

10.5.3.3.1 Sod

Where the average velocity of flow is five (5) feet per second or less and there is no base flow, the channel shall be lined with sod.

- For channels with a bottom width less than fifteen (15) feet, sod shall extend up the side slope to a minimum height of six (6) inches above the toe. (Drawing 90).

- Channels with a bottom width of fifteen (15) feet or greater, shall be graded as shown in Drawing 90 and a low flow area, fifteen (15) feet in width lined with sod.

- The remainder of the channel slopes shall be seeded and mulched as provided above.

10.5.3.3.2 Erosion Control Blanket

Commercial erosion control blankets may be used in lieu of sod provided that samples are submitted and approved by the City. The guaranteed maintenance period shall be one (1) year.

10.5.3.3.3 Channel Linings

In grass channels where base flow occurs, a non-erosive low-flow channel of riprap or concrete may be provided. Low flow channels shall have a minimum capacity of five (5) cubic feet per second. Other suitable non-erosive materials may be specified with approval of the City.

For channels which have an average velocity of five (5) feet per second or greater a non-erosive lining of riprap concrete or other approved material must be provided.

10.5.3.4 Storm Sewer and Culvert Outlets

Erosion protection shall be provided at storm sewer and culvert outlets. Minimum erosion protection shall consist of a concrete toe wall and non-erosive lining, meeting the City's specifications for public improvements.

- The required length of non-erosive lining will not be decreased where flared end sections or headwalls are provided unless calculations and data to support the decrease in length are submitted and approved.

- Non-erosive lining shall consist of riprap, unless otherwise specified and approved. Field stone, gabions or riprap shall extend to the point at which average channel velocity for the peak flow rate from the minor (5-year) storm has decreased to five (5) feet per second maximum.

- The length of riprap to be provided shall be as follows: (See Drawing 120)

  Average outlet velocity less than five (5) feet per second:

  L = three (3) times the pipe diameter or culvert width.

  Average outlet velocity less than five (5) to ten (10) feet per second:

  L = length determined using Drawing 120.

  Average outlet velocity greater than ten (10) feet per second:

  - Use MHTD standard energy dissipater headwall. (Reference 17)
  - The height of erosion protection shall be as shown in Drawing 120.
  - Minimum toe wall dimensions are shown in Drawing 120. Where headwalls or flared end sections are specified, toe walls must be provided at the downstream end.

10.5.3.5 Curb Openings

Where drainage has been approved by the City to flow from paved areas to grass areas through curb openings erosion protection shall be provided as shown in Drawing 130.

10.5.3.6 Ditch Checks and Drop Structures

In grass channels, grades and velocities may be controlled by ditch checks and drop structures. Riprap ditch checks may be required in natural channels where average velocity for the peak flow rate from the 5-year storm exceeds five (5) feet per second for post- development conditions.

10.5.3.7 Spillways

Erosion protection must be provided at spillways and outlet structures for detention ponds. Erosion protection shall extend to the point where flow has stabilized and average velocity in the outlet channel is five (5) feet per second or less.

10.5.4 Temporary Construction Entrance.

- A minimum of one (1) temporary construction entrance is required at each site. Additional temporary entrance may be provided if approved. The location of each construction entrance shall be shown on the plan.

- Only construction entrances designated on the sediment and erosion control plan may be used. Barricades shall be maintained, if necessary, to prevent access at other points until construction is complete.

- Construction entrances shall be constructed of crushed limestone meeting the following specifications:

- Construction entrances shall be a minimum of twenty-five (25) feet wide and fifty (50) feet long.

- The minimum thickness of crushed limestone surface shall be six (6) inches. Additional two (2) inch lifts of crushed limestone shall be added at the discretion of the County if the surface of the initial drive deteriorates or becomes too muddy to be effective.

- In locations where an existing drive or street extends at least fifty (50) feet into the site, the existing drive may be designated as the construction entrance and construction of a new gravel entrance is not required, unless job conditions warrant as set forth in the preceding paragraph.

10.5.5 Cleaning Streets

Streets both interior and adjacent to the site shall be kept clean during construction and for 1-year post-construction prior to release of security. Streets shall be swept and cleaned as necessary, after rain events, and as directed by the City.

10.5.6 Dust Control

The contractor will be required to use water trucks to water all roads and construction areas to minimize dust leaving the site when conditions warrant as determined by the City.

10.5.7 Sequencing and Scheduling

Costs of sediment and erosion control can be minimized if proper consideration is given to sequencing and scheduling construction. Any special sequencing and scheduling considerations should be noted in the grading plan. A detailed schedule must be received from the contractor at the Pre- Construction Conference

SECTION 11 - WORKS CITED

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DRAWING 10

SEED AND MULCH SPECIFICATIONS

SEEDING RATES	BROADCAST	DRILLED SODDED
Tall Fescue	30lbs/ac.	25lbs/ac. solid
Kentucky Bluegrass	3lbs/ac.	2lbs/ac. solid
Red Fescue	10lbs/ac.	7lbs/ac.
Wheat or Rye	120lbs/ac.	100lbs/ac.
Annual Ryegrass	100lbs/ac.	100lbs/ac.

SEEDING DATES:

PERENNIAL GRASSES: March 1 to May 15 or August 15 to October 15.

TEMPORARY COVER: May 15 to November 15.

OVERSEEDING: November 15 to March 1.

MULCH RATES:

Wheat Straw 100 lbs per 1,000 square feet (4,500 lbs/ac).

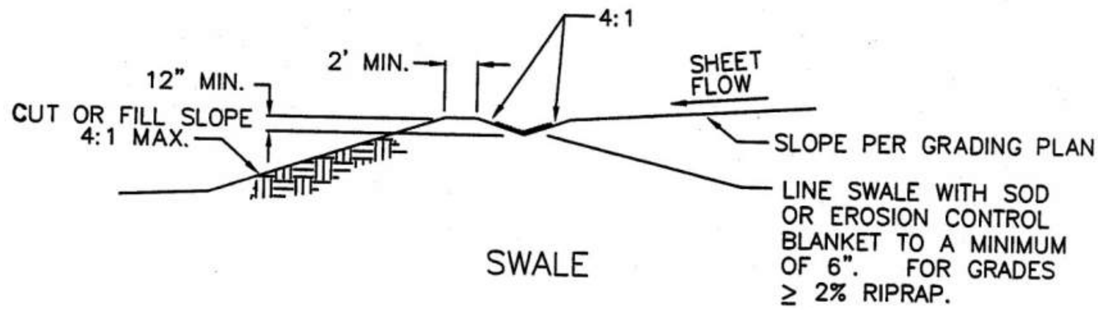
FERTILIZER RATES:

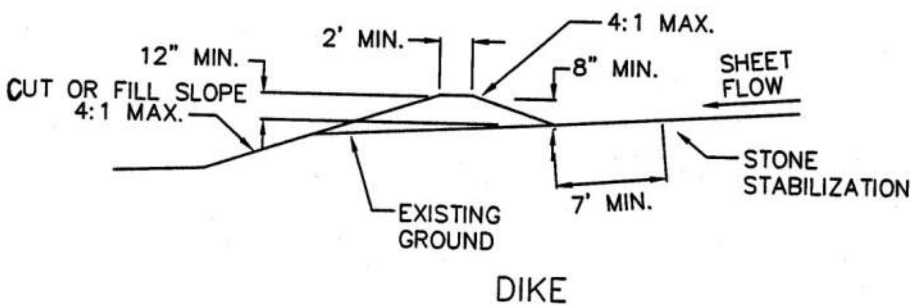
Nitrogen	90lbs/ac.
Phosphate	90lbs/ac.
Potassium	90lbs/ac.
Lime	1500lbs/ac. ENM*

* ENM – effective neutralizing material as per State evaluation of quarried rock.

DRAWING 30

DIVERSION DIKE AND SWALE





NOTES:

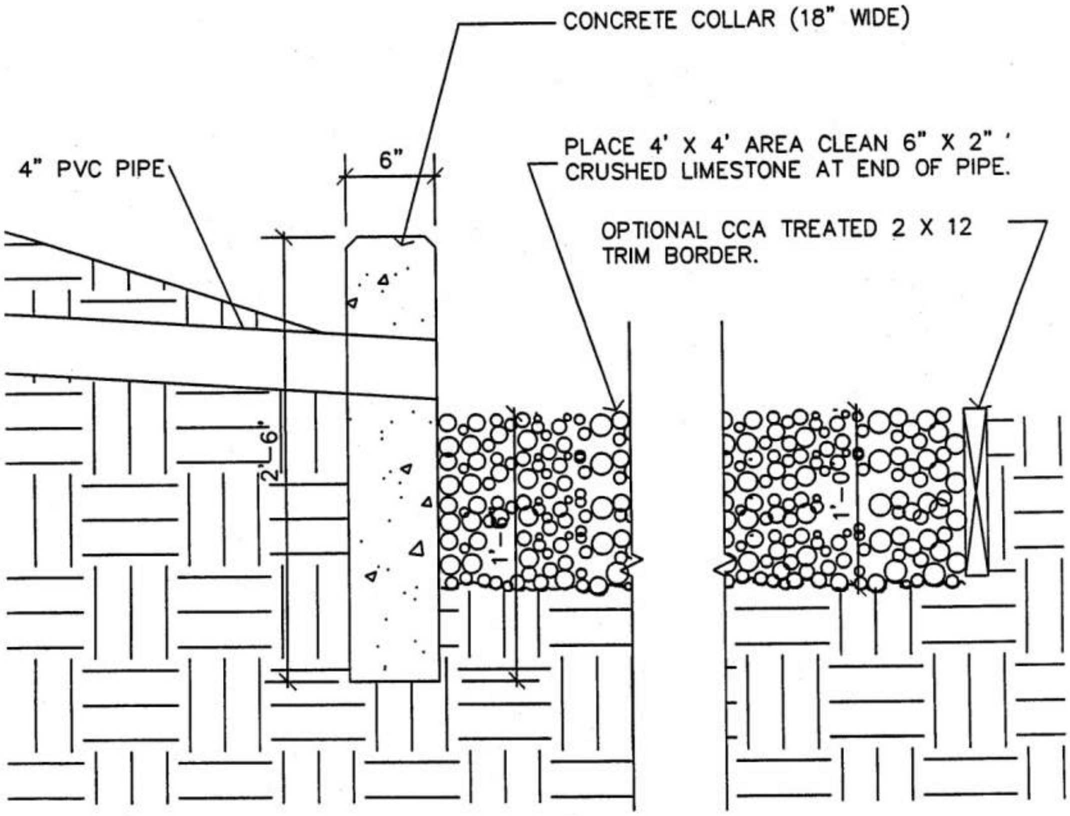
1. DIKE SHALL BE COMPACTED TO DENSITY EQUAL TO THAT SPECIFIED FOR ADJOINING AREA (90% STANDARD PROCTOR DENSITY, MINIMUM).

2. MINIMUM 1% GRADE MUST BE PROVIDED FOR SWALE OR ALONG UP SLOPE SIDE OF DIKE FOR PROPER DRAINAGE.

REFERENCE: ADAPTED FROM CITY OF AUSTIN AND CITY OF TULSA EROSION AND SEDIMENTATION CONTROL MANUALS.

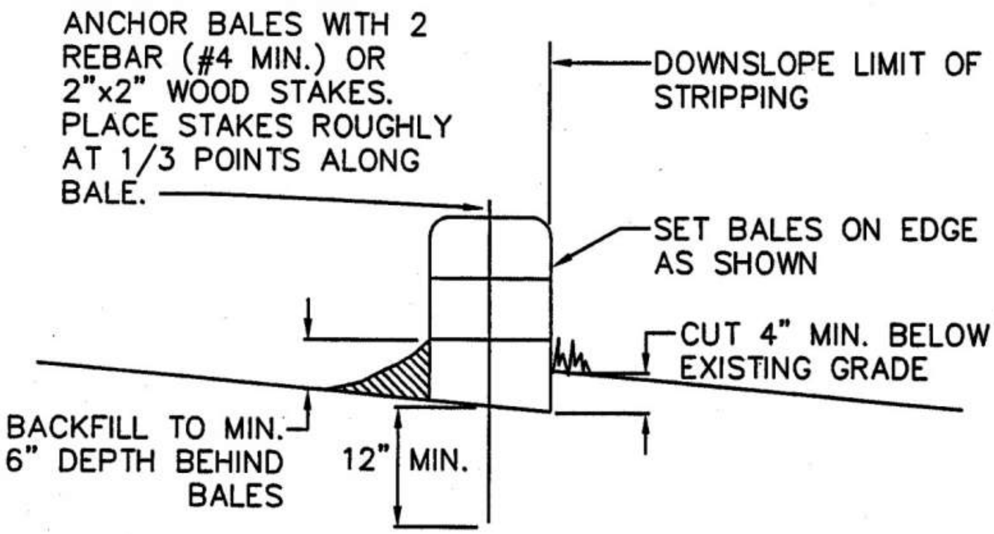
DRAWING 40

RIPRAP OUTLET SEDIMENT FILTER



DRAWING 50

STRAW BALE DIKE



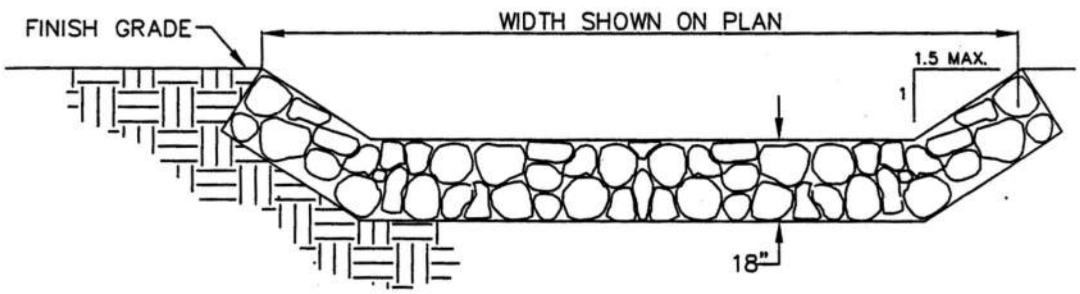
NOTES:

1. BALES SHALL BE PLACED IN A ROW WITH ENDS TIGHTLY ABUTTING THE ADJACENT BALES.
2. EACH BALE SHALL BE EMBEDDED IN THE SOIL A MINIMUM OF FOUR (4) INCHES WHERE POSSIBLE.
3. BALES SHALL BE SECURELY ANCHORED IN PLACE BY STAKES OR RE-BARS DRIVEN THROUGH THE BALES. THE FIRST STAKE IN EACH BALE SHALL BE ANGLED TOWARD PREVIOUSLY LAID BALE TO FORCE BALES TOGETHER.
4. INSPECTION SHALL BE FREQUENT AND REPAIR OR REPLACEMENT SHALL BE MADE PROMPTLY AS NEEDED BY CONTRACTOR.
5. BALES SHALL BE REMOVED WHEN THEY HAVE SERVED THEIR USEFULNESS SO AS NOT TO BLOCK OR IMPEDE STORM FLOW OR DRAINAGE.
6. ACCUMULATED SILT SHALL BE REMOVED WHEN IT REACHES A DEPTH OF SIX (6) INCHES.
7. AT EACH END OF DIKE, TURN DIKE UPSLOPE AND EXTEND UNTIL GROUND SURFACE RISES EIGHTEEN (18) INCHES.

REFERENCE: ADAPTED FROM CITY OF AUSTIN AND CITY OF TULSA EROSION AND SEDIMENTATION CONTROL MANUALS.

DRAWING 70

RIPRAP CHUTE

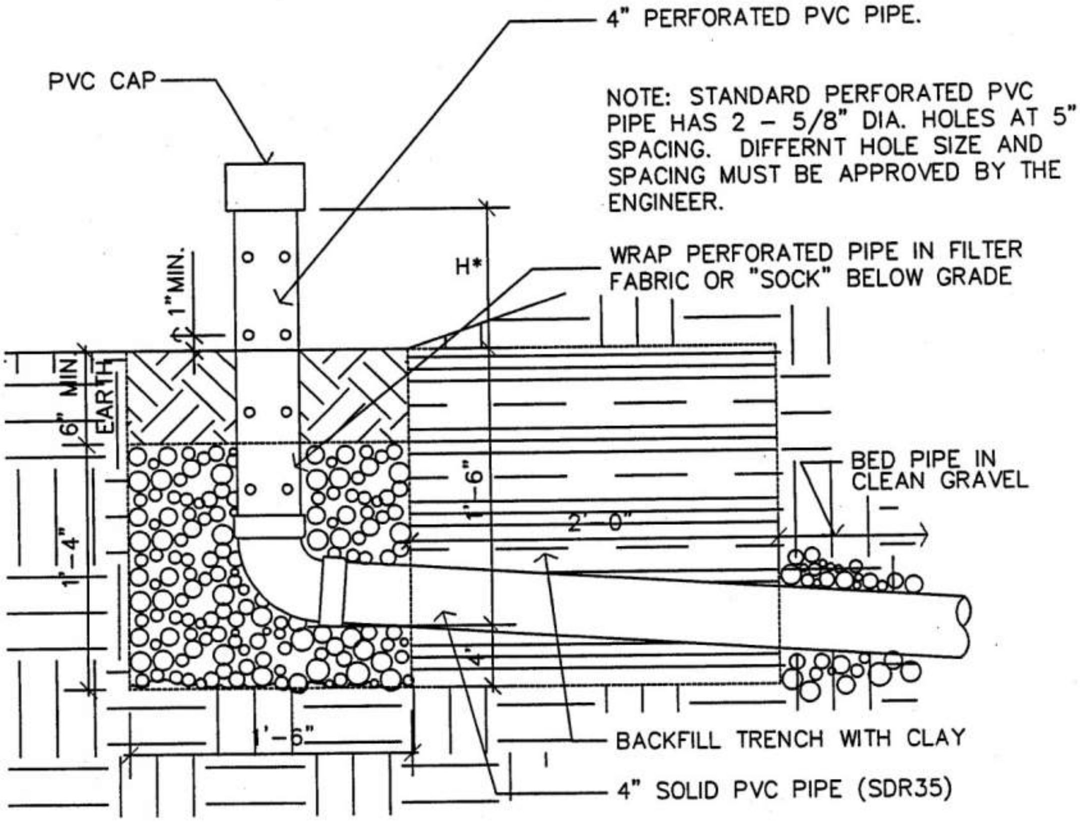


RIPRAP STONE SHALL BE GRADED AS FOLLOWS:

WEIGHT OF STONE (LBS.)	APPROXIMATE SIZE (LEAST DIMENSION)	% SMALLER BY WEIGHT
300	15.0"	100
200	13.0"	60--90
100	10.5"	30--50
50	8.5"	10--20
10	6.0"	<5

DRAWING 80

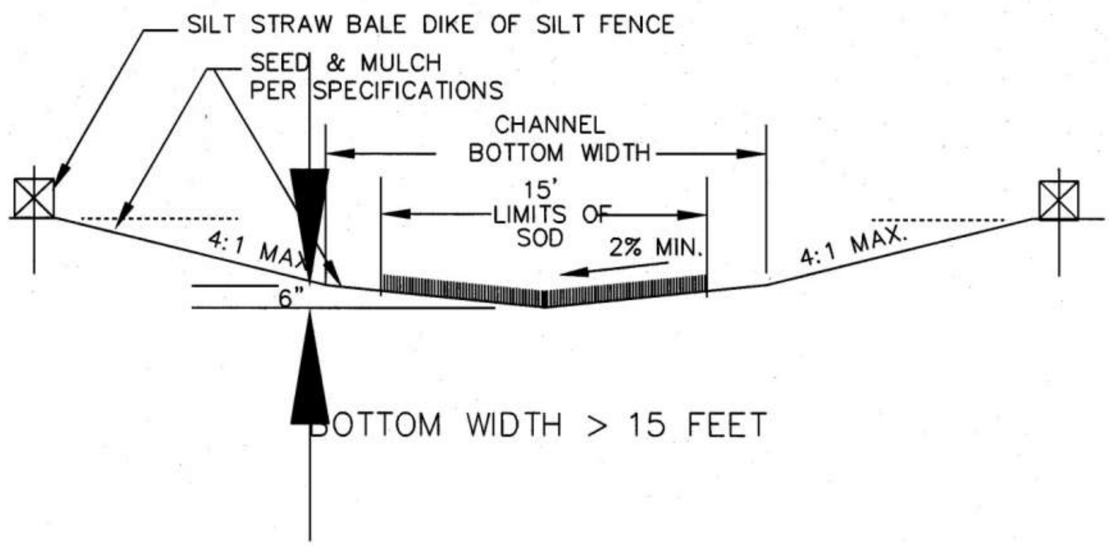
SEDIMENT BASIN--PERFORATED PIPE OUTLET

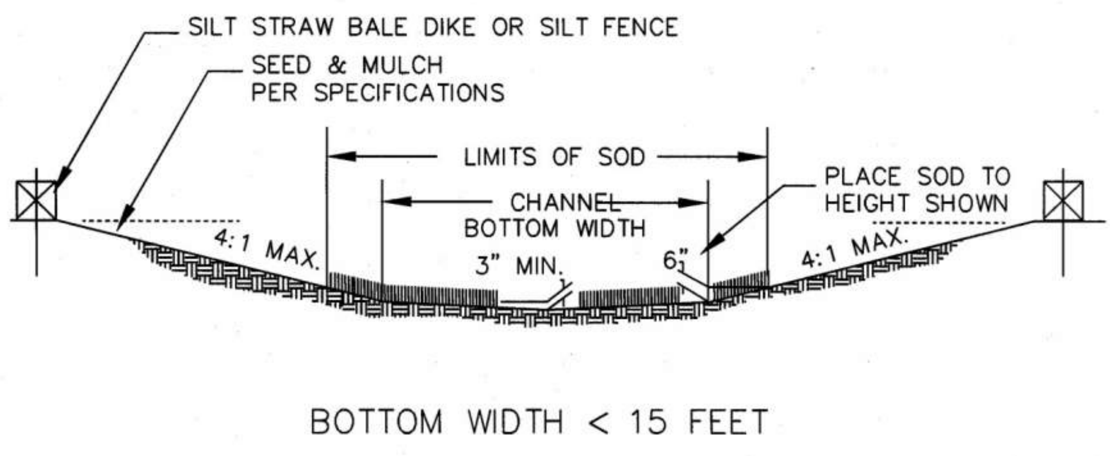


NOTE: PERFORATED RISER HEIGHT, H, TO BE SPECIFIED.

DRAWING 90

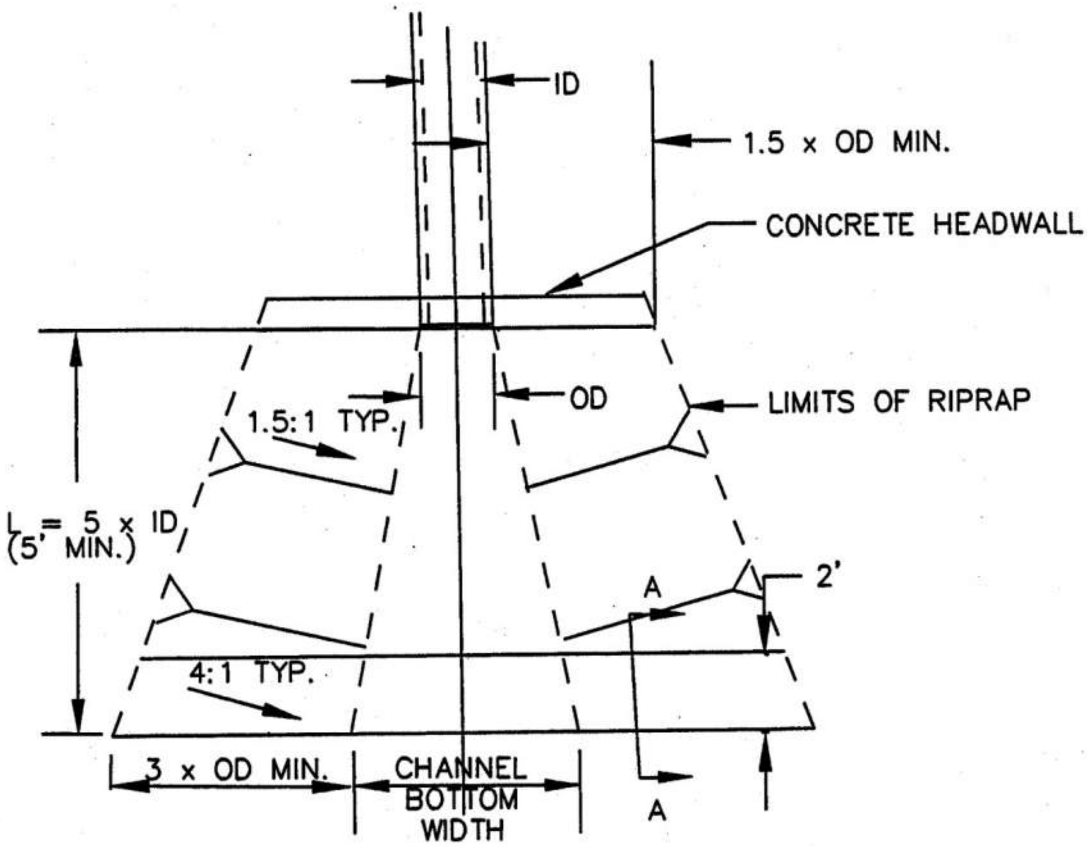
SOD CHANNEL <15' AND >15'





DRAWING 120

OUTLET EROSION PROTECTION CULVERT AND STORM SEWER OUTLETS

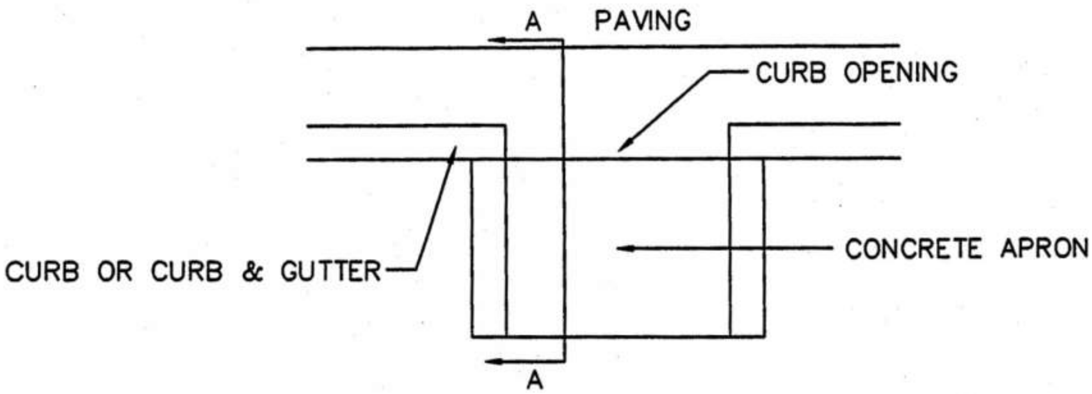


PIPE I.D. (inches)	L (feet)
12	5.0
15	6.5
18	7.5
24	10.0
30	12.5
36	15.0
42	17.5
48	20.0
54	22.5
60	25.0

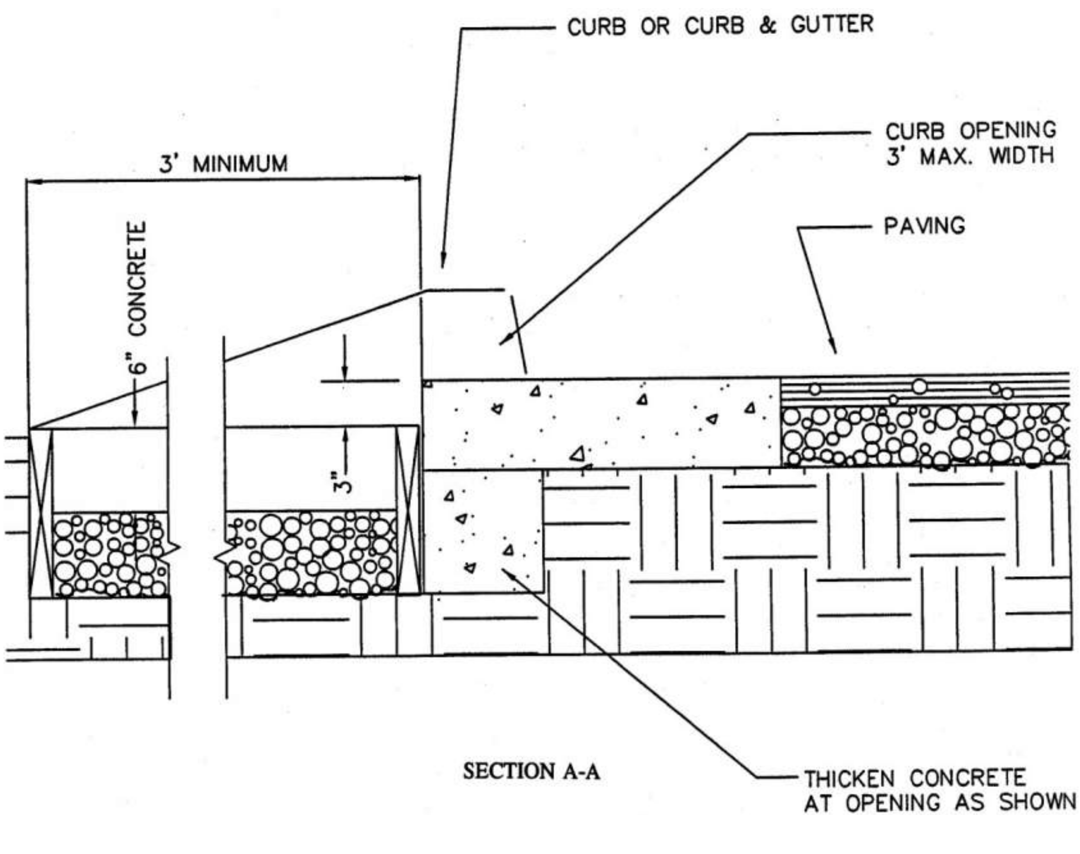
SECTION A-A
TOE WALL

DRAWING 130

CURB OPENING



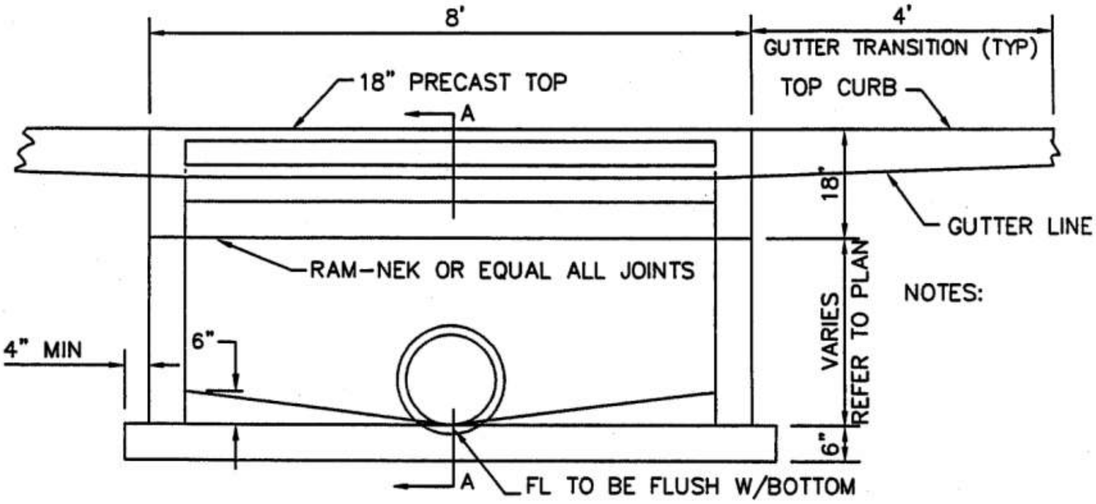
PLAN VIEW



SECTION A-A

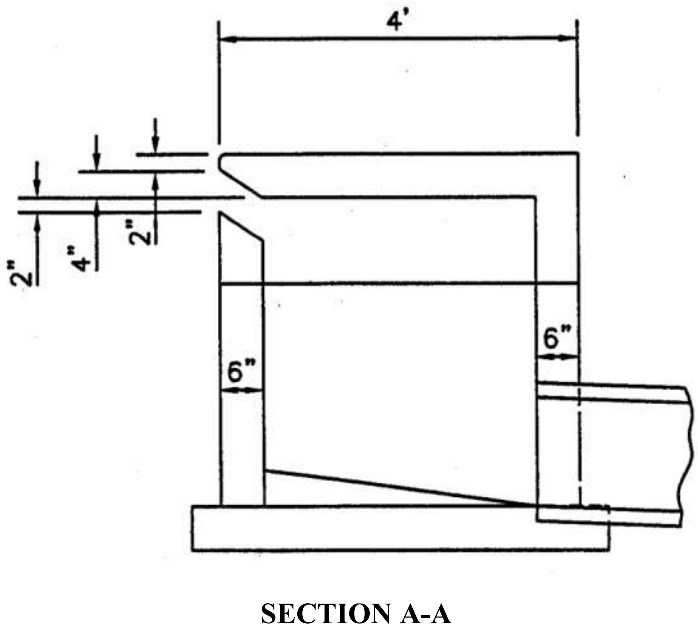
DRAWING 140

CURB INLET DETAIL



FRONT ELEVATION

1. Bottom shall be case in place.
2. Type C Ring and cover shall be provided.
3. #4 bars @ 10" ea. way in walls and slab.



SECTION A-A