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CITY OF GREAT FALLS
MONTANA

STORM DRAINAGE DESIGN MANUAL

June 1990

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STORM DRAINAGE DESIGN CRITERIA

SECTION 1. DRAINAGE POLICY

1.1 Purpose and Scope

This manual presents technical criteria to be used in the analysis and design of drainage systems within the City limits of Great Falls, Montana and its Urban Growth Area. All subdivision plats, planned unit developments or any other proposed construction must include an adequate plan for storm drainage. This plan must be based on a thorough analysis, using this manual as a guide.

Prior to any phase of construction, approval of the drainage plan is required by the Director of Public Works of the City of Great Falls.

The Director of Public Works reserves the right in the City's best interests to issue and enforce more stringent criteria should adverse conditions exist. Occasions may arise where the minimum standards are inappropriate. In these cases, a variance to these criteria may be considered. All designs varying from the criteria shall obtain written approval of the variance prior to final approval of plans.

1.2 Storm Drain Master Plan

On April 18, 1989, the City Commission enacted Ordinance 13.24 which adopted the storm drain master plan and created a storm drainage utility. The master plan establishes a formal policy to manage and control the detrimental aspects of storm drainage that affect the City of Great Falls.

The master plan provides a system analysis for those basins that are located in part or entirely within the City Limits. If a conflict should arise between Ordinance 13.24 or any other City code and the criteria set forth in this manual, the City codes shall govern.

The storm drainage design criteria shall be periodically reviewed and revised or amended if appropriate.

1.3 General Design Criteria

The runoff analysis for a particular area shall be based on the land use classification for that area. Contributing runoff from upstream areas shall be based on the projected land use and topographic characteristics of those areas. All runoff calculations shall be consistent with the master drainage plan for the area.

Natural topographic features shall govern the system design and the location of easements. In developed and undeveloped areas, average land slopes may be utilized in runoff computations. Wherever existing drainage patterns and slopes are defined, these shall be used. The drainage facilities so designed must be able to handle the design flows with no erosion damage.

The streets may be used to carry a portion of the storm runoff. The amount of runoff in the street shall not exceed the limits established in Section 4.3 "Street Conveyance Systems".

Natural drainageways are to be used whenever feasible. Alteration to natural drainage patterns will be approved if a thorough investigation and analysis shows no hazard or liability.

The planning and design of the drainage system shall not simply transfer the problem from one location to another or create a more hazardous condition downstream. Although improvements may not have to be made upstream or downstream of a subdivision, provisions shall be made in every development to comply with the criteria set forth in this manual.

All drainage improvements shall be natural in appearance and blend aesthetically with the surroundings.

Easements shall be provided for all drainage and flood control facilities to be maintained by the City. The minimum width shall be 20 feet where facilities are underground and 10 feet for vehicle access to facilities.

SECTION 2. DOCUMENTATION

2.1 Submission of a Drainage Plan

Anyone applying for any of the following permits and/or approvals shall submit a drainage plan prepared by a professional engineer licensed in the State of Montana.

a. Major subdivision plat approval.

b. Minor subdivision plat approval.

c. Zone change applications to accommodate multi-family, business or industrial uses.

d. Conditional Use Permits.

e. Building permits or site development where an impervious surface is being placed on more than 15,000 ~~7,500~~ square feet within the property, or where development is in a critical area as determined by the City Engineer.

f. Planned Unit Development (PUD).

g. Parking lot landscape approval where more than ~~7,500~~ 15,000 square feet of pavement and/or concrete area is proposed.

Construction work shall not begin until final approval of the drainage plan is obtained.

The same plan submitted during one permit/approval process may be subsequently submitted with further required applications, if appropriate. The plan shall be supplemented with such additional information as may be requested by the Director of Public Works.

The plan requirement established in this section will apply except when it is demonstrated to the satisfaction of the Director of Public Works that the proposed activity or development:

a. Will not adversely impact the water quality conditions of any affected receiving bodies of water, and,

b. Will not alter the surface discharge location, alter drainage patterns, increase the discharge, nor cause any other adverse effects in the drainage area.

2.2 Drainage Plan Requirements

The data required in a drainage plan submittal shall include, but not necessarily be limited to, the data described herein. The drainage plan shall adhere to all the design criteria and standards and other requirements contained in the City of Great Falls Storm Drainage Master Plan and to the requirements of the Uniform Building Code.

2.2.1 Building and Use Permits

The applications for zone change to accommodate multi-family, business or industrial uses, conditional use permits, building permits, or site development where more than ~~7,500~~ 15,000. square feet of impervious surface is being placed within the property, or where development is in a critical area as determined by the City Engineer shall contain the following:

1. A scaled topographic plan of the site showing all existing and finished ground contours, structures and drainage patterns.

2. The limits of the impervious surfaces shall be clearly identified on the plan.

3. Land use of lots adjacent to the proposed site shall be identified on the plan.

4. All streets and avenues adjacent to the site shall be shown on site plan.

5. A north arrow shall be shown.

6. Design calculations showing the estimated storm runoff for the appropriate design storm, the location of the runoff, and its impact on the nearest City storm drain inlet. Design calculations shall be neat and orderly, and in full compliance with all design criteria and standards.

7. Most developments will be required to detain runoff.Calculations supporting the detention basin size shall be submitted for review.

2.2.2 Subdivisions and Planned Unit Development

The drainage plans to accompany major and minor subdivision plat, zoning change applications for multiple family, business and industrial usage and for Planned Unit Development (PUD) shall contain engineering drawings and a drainage report. The engineering drawings shall be incorporated with the utility plans and accompanied by a drainage report containing the information described herein.

2.2.2.1 Engineering Drawings

The drawing shall be made on a reproducible medium and shall be signed and sealed by a licensed professional engineer.

The drawing shall contain the following information:

- The name of the subdivision or project.
- The date of preparation, the scale and symbol designating true north.
- The boundary lines of the subdivision or project, right-of-way lines of streets, easements and other rights-of-way, detention ponds, watercourses, and lot lines with accurate bearings and distances.
- Designations of all streets and other rights-of-way including dimensions and names of such streets.
- The location and dimensions of any easements.

- The boundary lines of all floodways and floodplains.
- Existing and proposed contours at two foot intervals.
- The location, size and type of all storm sewers.
- The location, size and type of all inlets, valley gutters, manholes, and other storm sewer appurtenances.
- Profile views for all subsurface drainage facilities showing their size, slope, lengths, cover and relationship with existing utilities.
- The location, size and type of all culverts including box culverts, and of all open channels.
- The location, size and type of all existing utilities.
- The location, size and type of permanent erosion and sedimentation control measures.
- Cross-sectional views of all open channels, trickle channels, spillway structures, etc. These views should include applicable water surface elevations such as the 100-year and 5-year storm depth.
- Flow line elevations should be shown for spillways, inlets and outlets of all storm sewers and culverts, and storm sewer outlets.
- Detention ponds should show capacity, discharge and high water level.
- Water surface profiles for applicable 100-year and 5-year storms for all open channels.

2.2.2.2 Drainage Reports

The supplemental drainage report shall contain the information and calculations supporting the design of the storm drainage system detailed in the engineering drawings. Such information and calculations shall be presented in a neat and orderly fashion to facilitate review.

The report shall include an analysis of the area under consideration in reference to the land use, historical and developed conditions, existing topography, contributing runoff from upstream areas, control easements or features, permanent erosion and sedimentation control measures and facilities, and continuity with the existing drainage patterns and the storm drainage master plan. Natural drainageways are to be used whenever possible.

The report shall contain the hydrologic analysis including areas, storm frequencies, rainfall intensities, runoff coefficients, times of concentration, adjustments for infrequent storms, and all runoff computations.

Calculations of street flows for both initial and major storms shall be provided with regard to street encroachments, theoretical capacities and allowable gutter flows. The report shall include the calculations for sizing of storm sewer systems, including inlets, culverts and open channels.

For any detention facility design, the supplemental drainage report shall include a soils analysis and water table elevations. All calculations, mass diagrams, and/or hydrographs required to size the detention facility and determine its discharge shall also be included. Calculations for specific detention times shall be provided if required by the City Engineer. See Section 5.1 for specific design criteria.

All drainage reports shall include a cover letter indicating the date, the name of the project or subdivision, the engineer designing the system, a statement of compliance with the Storm Drainage Design Criteria, and shall be stamped and signed by a Montana licensed professional engineer.

2.3 Appeals Process

The purpose of this criteria is to set forth rules and regulations which provide some assurance that the health, safety, welfare and property of the City and citizens will be safeguarded and protected through the proper control and drainage of storm and surface water; and further, to assure that there will be uniformity in performance with respect to design and construction of all drainage facilities. Consequently, any time that it can be shown that an alternate design analysis or procedure will provide performance equal to or better than the suggested methods of design analysis, said alternate may be submitted to the Director of Public Works for his review and approval. If the decision is negative, it may be appealed to the City Commission.

SECTION 3. HYDROLOGY AND HYDRAULIC DESIGN STANDARDS

3.1 General Design Storms

All drainage systems have to take into consideration two separate and distinct drainage problems. The first is the initial storm which recurs at fairly regular intervals and is to be based on a 5-year storm, depending on land use. The second is the major storm which is based on an infrequent 100-year storm.

3.1.1 Initial Storm Provisions

The planning objectives for the recurring storms are to minimize inconvenience, to protect against recurring minor damage and to reduce maintenance costs in order to create an orderly drainage system at a reasonable cost for the urban resident.

3.1.2 Major Storm Provisions

The planning objectives of the major storm are to eliminate substantial property damage or loss of life. The correlation between the initial and major storm system shall be analyzed to insure a well coordinated drainage system.

3.2 Analysis Methodology

The methods presented in this section will be used in the determination and/or verification of runoff at specific design points in the drainage system. Runoff from the drainage areas above the area being developed shall be computed using the existing conditions for a major storm. For subdivided land, the runoff shall be computed on the basis of all the land being fully developed regardless of the status of construction of the improvements to serve the subdivision and of the buildings to be placed on the individual lots. The runoff shall also be computed for the initial storm assuming the upstream area to be fully developed in accordance with the land use classification. The conveyance systems for the proposed development shall be designed in accordance with Tables 5 and 6, to carry whichever flow is greater.

In general, the rational method may be used on smaller areas, and the SWMM method will be required to analyze larger areas. Drainage system proposed for construction shall provide the minimum protection as determined by the methodology used.

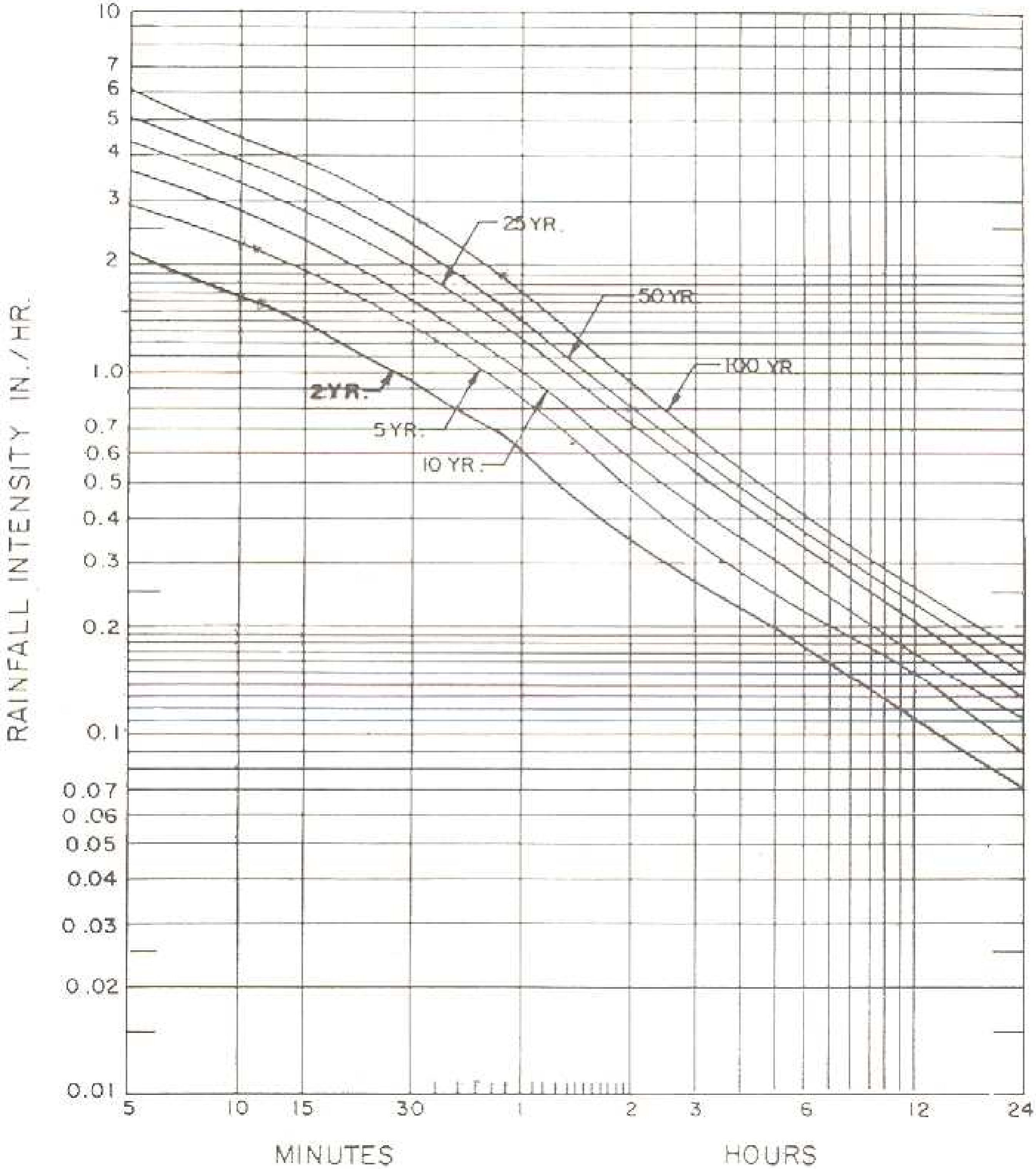
3.3 Rational Method

The rational method may be used where drainage plans are required for minor subdivision plats, zone change applications, conditional use permits and building permits. The rational method may be used on major subdivisions and planned unit developments, provided they have a total acreage of less than 10 acres or have a time of concentration of one hour or less for the upstream drainage basin including the proposed development.

The rational method shall utilize the equation $Q = CIA$. Q is the flow in cubic feet per second; C is the coefficient of runoff; I is the storm intensity with a duration corresponding to the time of concentration for the water shed; and A is the area of the water shed in acres.

3.4 Rainfall Intensity

The applicable design storm intensity shall be selected from



RAINFALL INTENSITY DURATION CURVES

FIGURE 1

Figure 1 for appropriate time of concentration and recurrence interval. These curves were developed from data compiled by the National Oceanic & Atmosphere Administration at the Great Falls International Airport, and recorded in the Precipitation-Frequency Atlas of the Western United States (NOAA Atlas 2).

3.5 Time of Concentration

The time of concentration represents the time interval required for storm drainage from all areas in the drainage basin to reach the design point. The time of concentration represents a summation of one or more of the following elements:

1. Overland flow time across sod or earth.
2. Overland flow time across concrete or pavement.
3. Flow time in gutters or open ditches.
4. Flow time in pipes or other conduits.

In general, the assumption will be made that the largest flow will occur when the water from the furthest point in the drainage basin reaches the design point. This assumption is not always correct. In special cases where the time of concentration to the most distant part of the drainage basin may be disproportionate to the effective size of the drainage basin, the time of concentration shall be adjusted to reflect the majority of the area. This is a matter of judgement and is subject to review and approval of the City staff.

The time of concentration for overland flow shall be determined from Figure 2.

Time of Concentration

In order to use the Rainfall Intensity Duration Curve, the time of concentration must be known. This can be determined either by the following equation or the "Overland Time of Flow Curves" from the Urban Storm Drainage Criteria Manual, included in this report (See Figure 3-2).

$$Tc = \frac{1.87\,(1.1 - CC_f)\,D^{1/2}}{S^{1/3}}$$

Where Tc = Time of Concentration, minutes
- S = Slope of Basin, %
- C = Rational Method Runoff Coefficient
- D = Length of Basin, feet
- C_f = Frequency Adjustment Factor

Time of concentration calculations should reflect channel and storm sewer velocities as well as overland flow times.

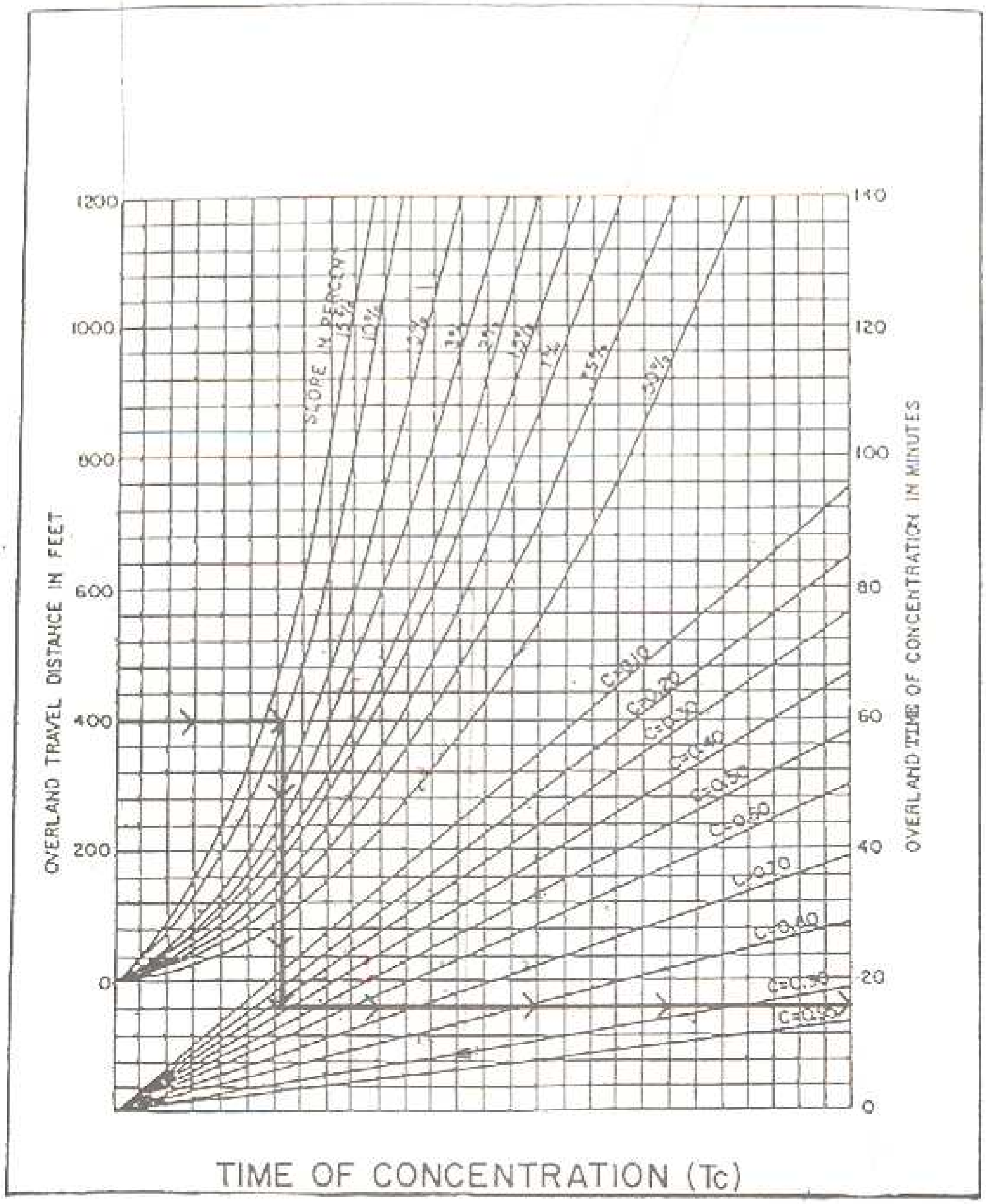


FIGURE 2

3.6 Coefficient of Runoff

The coefficient of runoff represents the percentage of total rainfall that will run off a site during a storm.

The coefficient of runoff is affected by the shape of the basin, ground slope, antecedent precipitation, ground conditions (frozen or unfrozen, saturated or unsaturated), and type of soil (seepage rate). The coefficient of runoff varies with time during a storm since surface storage and adsorption decreases as the duration and total amount of rainfall increases. The design storm will often be preceded by a longer term, less intense storm that reduces available surface storage and the potential adsorption rate.

For simplicity, the design coefficients listed in Table 1 shall be utilized for analysis. The coefficients assume some antecedent precipitation, but not a major storm. Steep slopes tend to reduce the time available for percolation and the amount of available surface storage. As such, runoff coefficients shown vary with the slope of the water shed. For basins with a variation in slope, separate coefficients will be used.

3.7 Adjustment for Infrequent Storms

The preceding variables are based on the recurring storm, that is, a 5-year storm. For storms with higher intensities, an adjustment of the runoff coefficient is required because of the lessening amount of infiltration, depression retention and other losses that have a proportionally smaller effect on storm runoff.

TABLE 1

RUNOFF COEFFICIENTS

LAND USE	RUNOFF COEFFICIENTS LAND SLOPE 5% or Less	LAND SLOPE Greater than 5%
Parks - turfed		
Soils--clays, loams, rock	0.2	0.3
Soils--sand, gravel	0.15	0.2
Agriculture		
Soils--clays, loam, rock	0.15	0.3
Soils--sand, gravel	0.1	0.2
Vacant lots	0.2	0.3
Railroad yards	0.4	0.5
Single family residential	0.4	0.5
Single family mobile homes	0.4	0.5
Multiple family residential - Impervious area less than 50%	0.5	0.6
Mobile home trailer courts	0.5	0.6
Churches	0.5	0.6
Multiple family residential - Impervious area greater than 50%	0.65	0.75
Boarding and rooming houses	0.65	0.75
Small hotel & motel - less than 10 units	0.65	0.75
Hotel & motel - larger than 10 units	0.9	0.95
Industrial (impervious area less than 70% of the lot)	0.65	0.75
General business - impervious area less than 70% of lot)	0.65	0.75
Public Buildings (Government Services)	0.9	0.95
Schools	0.65	0.75
Industrial - (impervious area greater than 70% of lot)	0.9	0.95
General business - (impervious areas greater than 50%)	0.9	0.95
Parking lots	0.9	0.95

RATIONAL METHOD FREQUENCY ADJUSTMENT FACTORS

Storm Return Period (years)	Frequency Factor C_f
2 to 10	1.00
11 to 25	1.10
26 to 50	1.20
51 to 100	1.25

Note: The product of C times C_f shall not exceed 1.00.

3.8 SWMM Method

The SWMM program shall be used for any drainage plan and will be required for major subdivisions and planned unit developments containing 10 acres or more or having a time of concentration of one hour or greater. Development of the storm drainage runoff data using the SWMM-3 computer model requires the services of a professional engineer trained in the use of this computer model. Only those individuals knowledgeable in storm drainage computer modeling shall be retained to evaluate the data required herein.

The SWMM analysis will utilize SWMM-3 Micro computer model or acceptable updates. The analysis will follow the prescribed methodology contained in the computer model. This section provides limits on variables to be used in the model.

The "Runoff Module" of SWMM-3 shall be used for all areas in Great Falls larger than 10 acres. This module is used to determine pipe sizes based on design storm rainfall hydrographs, soil conditions, land use and topography. The program also determines the total runoff produced by a storm for detention basin design.

All SWMM-3 analyses for the Great Falls areas shall use the following data:

Table 2, Design Storm Rainfall Distribution, gives the rainfall intensities in inches/hour for the 2-year, 5-year, 10-year or 100-year design storm as required for the area being evaluated.

Evaporation Data: The following rates shall be used:

January	0	July	0.26
February	0	August	0.23
March	0	September	0.15
April	0.15	October	0.10
May	0.19	November	0
June	0.21	December	0

For subcatchment Areas (areas that discharge flow into the system), the area, width and slope of each sub-basin shall be determined.

The Manning Roughness Factors to be used for each subcatchment are as follows:

Asphalt and concrete	0.017
Short pasture grass	0.025
Tall pasture grass	0.030
Scattered brush and heavy weeds	0.035
Light brush and trees	0.040
Mature field crops in cultivated areas	0.030
Pipe: concrete	0.013

Other parameters in the SWMM program require a degree of judgement. Some parameters drastically affect the results, while others do not significantly affect the flow computed by the SWMM program. The following input parameters have a large affect on the computer output and therefore need to be carefully analyzed. The following input data should be used.

TABLE 2

DESIGN STORM RAINFALL DISTRIBUTION

(2 YR. - 2 HR. STORM)

5-MINUTE TIME INCREMENT	RAINFALL INCHES/5 MIN.	RAINFALL INTENSITY INCHES/HR.
1	0.003	0.04
2	0.020	0.24
3	0.183	2.20
4	0.092	1.10
5	0.071	0.85
6	0.057	0.68
7	0.045	0.54
8	0.037	0.44
9	0.028	0.34
10	0.023	0.28
11	0.018	0.22
12	0.017	0.20
13	0.016	0.19
14	0.015	0.18
15	0.014	0.17
16	0.013	0.16
17	0.012	0.14
18	0.011	0.13
19	0.010	0.12
20	0.009	0.11
21	0.008	0.10
22	0.007	0.08
23	0.006	0.07
24	0.005	0.06
TOTAL:	0.720 inches	

(10 YR. - 2 HR. STORM)

5 MINUTE TIME INCREMENT	RAINFALL INCHES	RAINFALL INTENSITY INCHES/HR.
1	0.004	0.05
2	0.028	0.34
3	0.308	3.70
4	0.159	1.91
5	0.121	1.45
6	0.083	1.00
7	0.074	0.89
8	0.060	0.72
9	0.050	0.60
10	0.042	0.50
11	0.034	0.41
12	0.031	0.37
13	0.028	0.34
14	0.025	0.30
15	0.021	0.25
16	0.019	0.23
17	0.017	0.20
18	0.015	0.18
19	0.013	0.16
20	0.011	0.13
21	0.009	0.11
22	0.007	0.08
23	0.006	0.07
24	0.005	0.06
TOTAL:	1.170 Inches	

(5 YR. - 2 HR. STORM)

1	0.003	0.04
2	0.014	0.17
3	0.242	2.90
4	0.125	1.50
5	0.099	1.19
6	0.081	0.97
7	0.063	0.76
8	0.051	0.61
9	0.041	0.49
10	0.035	0.42
11	0.030	0.36
12	0.027	0.32
13	0.023	0.28
14	0.020	0.24
15	0.019	0.23
16	0.017	0.20
17	0.016	0.19
18	0.014	0.17
19	0.012	0.14
20	0.011	0.13
21	0.009	0.11
22	0.007	0.08
23	0.006	0.07
24	0.005	0.06
TOTAL:	0.970 inches	

(100 YR. - 2 HR. STORM)

1	0.007	0.08
2	0.020	0.24
3	0.508	6.10
4	0.242	2.90
5	0.201	2.41
6	0.165	1.98
7	0.131	1.57
8	0.108	1.30
9	0.084	1.01
10	0.070	0.84
11	0.059	0.71
12	0.049	0.59
13	0.043	0.52
14	0.037	0.44
15	0.031	0.37
16	0.027	0.32
17	0.023	0.28
18	0.021	0.25
19	0.020	0.24
20	0.019	0.23
21	0.018	0.22
22	0.017	0.20
23	0.016	0.19
24	0.015	0.18
TOTAL:	1.931 Inches	

3.8.1 Percent of Impervious Area with Zero Detention (SWMM)

The percent of impervious area with zero detention indicates the area that will result in immediate runoff of the storm drainage. For all types of land use classifications, 25 percent of the land shall be considered impervious and to have zero detention.

3.8.2 Percent of Impervious Area in Basin (SWMM)

The percent of area in a basin that will not allow water to percolate into the ground may be calculated from aerial photos or by lot sizes, land use and other data regarding the individual lot development. In residential areas, runoff from roofs that flows onto the lawn and infiltrates into the lawn area will not be included in the impervious area. Roofs or portions of roofs that discharge runoff onto a driveway, sidewalk or other impervious surface that drains to the street shall be included as an impervious surface. The impervious areas on a residential lot shall include sidewalks and driveways. Each area should be analyzed on a case by case basis. Typical rates are as follows:

Congested residential area - 31%
Open residential area - 29%
Empty lot with paved street - 10%

3.8.3 Depression Storage (SWMM)

Depression storage is the volume that must be filled before runoff discharges from the area of influence of the depression. For impervious areas, the depression storage shall be 0.033 inch of depth, and for pervious areas, shall be 0.10 inches.

3.9 Infiltration Equation Parameters (SWMM)

Horton's equation (Horton 1940) for prediction of infiltration capacity into the soil as a function of time shall be used as the infiltration model. The three parameters in the Horton equation are the initial value or maximum infiltration capacity, the ultimate value or minimum infiltration capacity and the decay coefficient.

The initial infiltration capacity for Great Falls varies with the type of soil. Refer to Table 3 for recommended values for soils that vary from a clay to a sandy soil.

TABLE 3

INITIAL SOIL INFILTRATION CAPACITY

Sandy Soil	1.67 in/hr.
Loam Soil	1.00 in/hr.
Clay Loam Soil	0.75 in/hr.
Clay Soil	0.20 in/hr.

The final infiltration capacity parameter for the Horton equation depends on the hydrologic soil group of the area. The U.S. Soil Conservation Service (SCS) maps of the Great Falls area shall be used to find the hydrologic soil groups, and then determine the final infiltration capacity from Table 4.

Use a decay rate of infiltration for the Horton equation equal to 0.00115.

TABLE 4

FINAL SOIL INFILTRATION CAPACITY

Hydrologic Soil Group	(in/hr.)
A. Sands & Gravels	0.45 - 0.30
B. Moderately Fine to Coarse	0.30 - 0.15
C. Moderately Fine to Fine	0.15 - 0.05
D. Clay Soils	0.05 - 0

SECTION 4. STORM DRAINAGE CONVEYANCE SYSTEMS

The criteria and procedures found in this section establish the basis of design for the various types of improvements and facilities required to carry runoff throughout each drainage basin. Runoff from both the initial and major storms shall be analyzed and checked for compliance with this criteria. Runoff calculations shall be submitted for approval, with Criteria sections of this manual being referenced. Streets, curbs and gutters, inlets, underground piping, manholes, open channels and related appurtenances shall conform to City construction standards.

4.1 Overland Flow

Overland flow is defined as the storm drainage that flows off the land in sheet fashion prior to accumulating in a drainageway. Drainageways may be either natural depressions or man-made. In general, overland flow will only be permitted within individual private lots or land parcels, natural drainageways, and in swales or small ditches (less than 2 feet deep). Storm drainage will not be diverted from one private lot to another unless appropriate easements are executed. Overland flow on residential streets will be restricted to a maximum total length of 600 feet before being controlled by a storm drainage conveyance system.

4.2 Open Channels

Channels should be designed to avoid flows at critical depth or supercritical flows. All open channels shall be designed to carry the major storm runoff (100-year recurrence interval) with allowance for flow being carried by other types of conveyance systems. The use of open channels shall generally be limited to undeveloped areas that can conform to the requirements of the hydraulics, topography and right-of-way limitations.

4.2.1 Unlined Channels

Channel side slopes shall be a maximum of 4:1. Any slopes steeper than 4:1 are not permitted unless approved stabilization is used.

The maximum channel depth of flow shall be 4.0 feet. The critical depth shall be determined for both the major and initial storms in order to insure that supercritical flows do not occur. The minimum amount of freeboard shall be 1.0 feet or additional capacity for 1/3 of the design flow, whichever is less.

Channel slopes shall be constructed so that flow velocities do not exceed 7.5 feet per second during the major storm nor less than 2.0 feet per second for the initial storm. Drop structures may be used to control the grade in order to meet these limits.

Curved, unlined channels shall not have a radius less than 100 feet. Slope protection shall be provided if the velocity of the major storm exceeds 5.0 feet per second.

4.2.2 Lined Channels

Where conditions for unlined channels cannot be met, open channels shall be lined.

If supercritical flow is unavoidable, all concrete channel sections shall be continuously reinforced, both longitudinally and laterally.

A minimum of 0.5 feet of freeboard shall be incorporated into major channels. Small channels shall have either 0.5 feet of freeboard or additional capacity of approximately one-third (1/3) of the design flow, whichever is smaller. The design of lined channels on bends or curves shall take into consideration the centrifugal and gravitational forces on the flow within the channel section.

All lined channels shall be protected from hydrostatic uplift forces by the use of either drain piping, weep holes or appropriate footings. The concrete shall be finished, as close as possible, to the degree of roughness used in the design channel. Lined channels must have the bottom sloped so that the flow is channelized towards the center line of the channel.

When lined channels with high velocity flows enter unlined channels with subcritical flow, a structure for the purpose of reducing velocity and dissipating energy shall be required.

A combination of channel stabilization measures may be utilized if acceptable hydraulic conditions exist, subject to approval by the City Engineer. Concrete, gabions, slope mattresses, riprap and other approved measures can be used. Gabions, slope mattresses and riprap smaller than 12 inches shall either be buried on maintainable slopes (4 to 1) or grouted to prevent vandalism.

4.3 Street Conveyance Systems

Streets shall be designed as an integral part of the storm drainage conveyance system. The allowable flow in the streets shall be less for the initial storm than for a major storm.

4.3.1 Street Layout

Subdivisions shall be laid out such that there is a street generally following the bottom of the natural drainageway. This street is to be designed to supplement other conveyance systems to carry the major storm runoff. The natural drainageway may be dedicated as publicly owned land in the form of a park. Structures shall not be built in the drainage path. Buildings on private lots adjacent to the natural drainageway shall be flood-proofed to a point at least two feet above the projected flow depth generated by the major storm.

T-intersections shall not be permitted except under the following conditions:

1. The slope of the street that is terminating in the intersection must be less than 2 percent for the last 100 feet to the intersection centerlines.
2. The street running through the intersection shall have a slope greater than the terminating street.
3. The total depth of gutter flow on the terminating street during the 100-year storm must be at or below the intersecting street crown. A storm sewer conveyance system shall be constructed if needed to meet this condition.

Standard intersections (four streets converging) shall meet the following conditions:

1. The grades of the streets sloping into the intersection shall be less than 2 percent for the last 100 feet and preferably 150 feet to the intersection centerlines.

2. Install storm drain inlets on street of least grade and bring water around corner from steeper grade.

3. Install valley gutters at all residential intersections where gutter flow is to continue straight through the intersection.

4.3.2 Design Flow Criteria

The following sections set forth the minimum design criteria for the runoff in urban streets.

The minimum gutter grade shall be 0.4 percent. In areas where the AASHTO classification system for soils is A-6 or A-7, a minimum gutter grade shall be 0.6 percent and 6" of compacted gravel shall be placed under the gutter. The maximum gutter grade shall be such that the average flow velocity should not exceed ten (10) feet per second.

The minimum cross-slope on all streets shall be 2.0 percent and may vary from 2.0 to 4.0 percent. The street and gutter section having the most restrictive capacity shall be used for design.

4.3.2.1 Initial Storms

The determination of the street runoff carrying capacity shall be based on the following procedure:

- Compute the theoretical flow conditions for pavement encroachment.
- Apply a reduction factor to the theoretical flow rate to take into account field conditions.

In order to calculate the allowable flow rate, the theoretical capacity shall be multiplied by a reduction factor. These factors are determined by the curve in Figure 3 entitled "Reduction Factor for Allowable Gutter Capacity".

The encroachment of gutter flow on the street for the initial storm runoff shall not exceed the specifications set forth in Table 5. A storm drainage system shall begin where the encroachment reaches the limits found in this table.

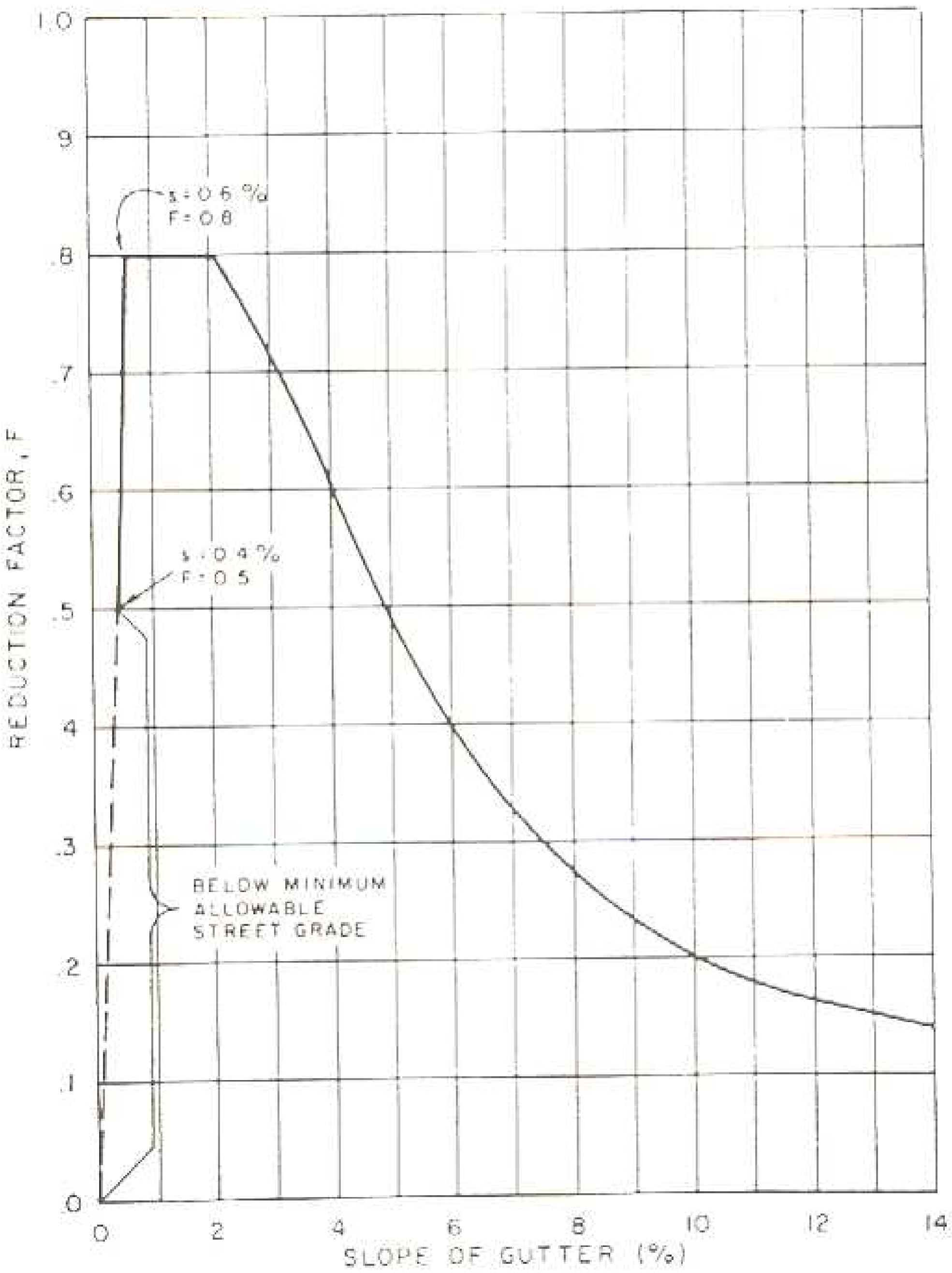
TABLE 5

INITIAL STORM - STREET RUNOFF ENCROACHMENT

Street Classification	Maximum Encroachment
Local (includes residential, alleys, marginal access)	No curb-topping.* Flow may spread to crown of street
Collector	No curb-topping.* Flow spread must leave at least one lane width free of water
Major Arterial	No curb-topping.* Flow spread must leave at least 1/2 of roadway width free of water in each direction

*Where no curbing exists, encroachment shall not extend over property lines.

Once the allowable pavement encroachment has been established, theoretical gutter capacity shall be computed using the following revised Manning's equation for flow in shallow triangular channels:



REDUCTION FACTOR FOR ALLOWABLE GUTTER CAPACITY
Apply reduction factor for applicable slope to the theoretical gutter capacity to obtain allowable gutter capacity.

(From: U.S. Dept. of Commerce, Bureau of Public Roads, 1965)

FIGURE 3

$$Q = 0.56 \frac{Z}{n} S^{1/2} y^{8/3}$$

Where Q = Theoretical Gutter Capacity, cfs
y = Depth of Flow at Face of Gutter, feet
n = Roughness Coefficient
S = Channel Slope, feet/feet
Z = Reciprocal of Cross Slope, feet/feet

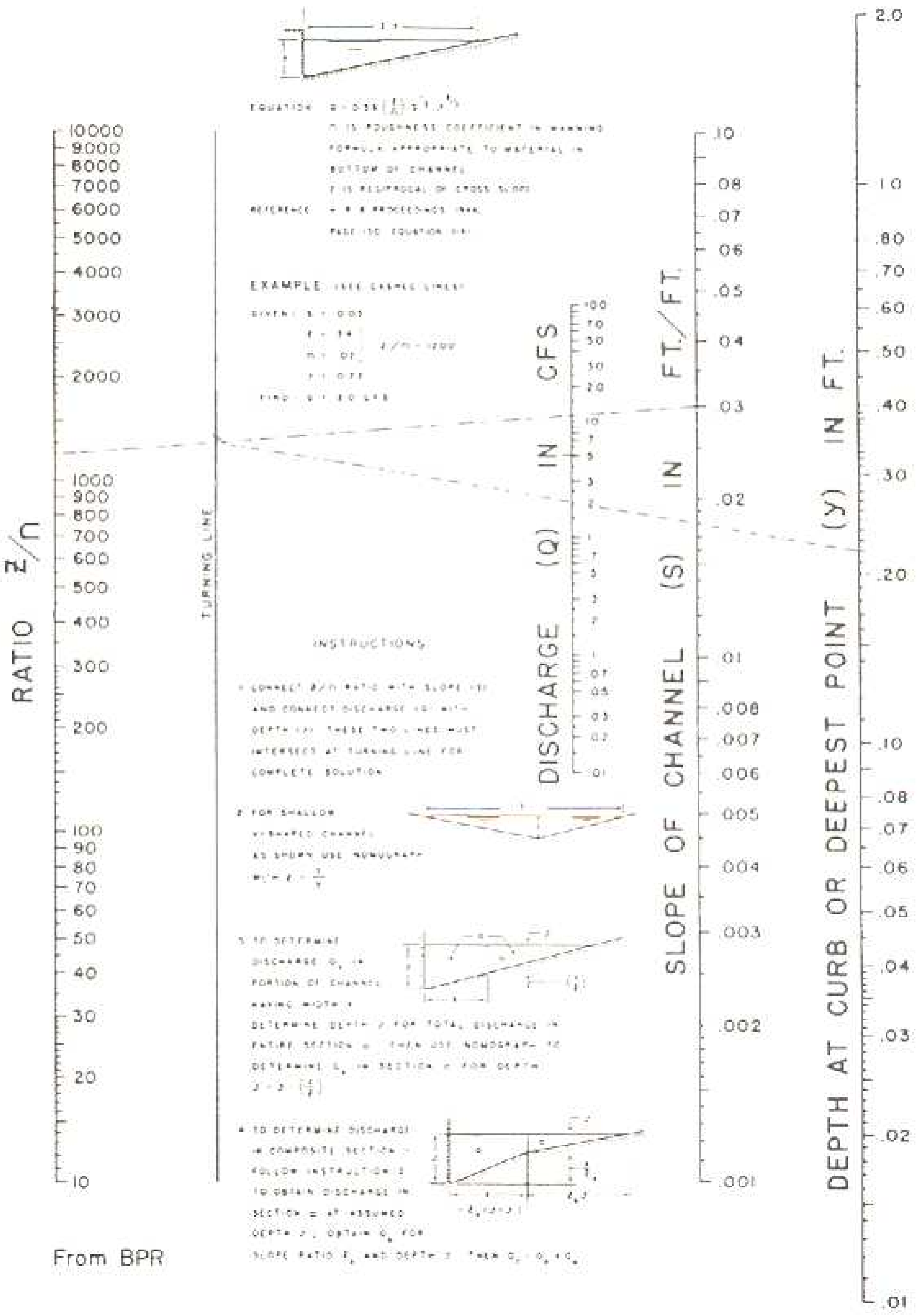
A nomograph based on the previous equation has been developed and is included in Figure 4. The graph is applicable for all gutter configurations. An "n" value of 0.016 shall be used for all calculations involving street runoff.

4.3.2.2 Major Storms

The determination of the allowable street flow due to the major storm shall be based on the following criteria:

- Theoretical capacity based on allowable depth and inundated area.
- Reduced allowable flow due to velocity conditions.

Table 6 sets forth the allowable street inundation for the major storm runoff.



NOMOGRAPH FOR FLOW IN TRIANGULAR GUTTERS
(From U.S. Dept. of Commerce, Bureau of Public Roads, 1965)

FIGURE 4

TABLE 6

MAJOR STORM - STREET RUNOFF ENCROACHMENT

Street Classification	Maximum Encroachment
Local (includes places, alleys, marginal access & collector)	Residential dwellings, public, commercial and industrial buildings shall not be inundated at the ground line unless buildings are flood-proofed. The depth of water over the crown shall not exceed 6 inches.
Arterial and Major Arterial	Residential dwellings, public, commercial and industrial buildings shall not be inundated at the ground line unless buildings are flood-proofed. Depth of water at the street crown shall not exceed 6 inches to allow operation of emergency vehicles. The depth of water over the gutter flowline shall not exceed 18 inches. In some cases, the 18 inch depth over the gutter flowline is more restrictive than the 6 inch depth over the street crown. For these conditions, the most restrictive of the two criteria shall govern.

Manning's equation shall be used to calculate the theoretical runoff-carrying capacity based on the allowable street inundation. The equation will be as follows:

$$Q = \frac{1.486}{n} R^{2/3} S^{1/2} A$$

Where Q = Capacity, cfs
n = Roughness Coefficient
R = Hydraulic Radius, A/P
S = Slope, feet/feet
A = Area, feet

An "n" value of 0.016 shall be used.

The theoretical capacity must be reduced in order to obtain the actual flow rate allowable. The procedures and criteria are identical to those found in Section 4.3.2.1, "Initial Storms".

Table 7 is the criteria to be used for allowable cross street flow. Both the theoretical and allowable cross street flow shall be determined by the methods described in the preceding sections, depending upon which design storm is being considered. However, the gutter slope variable should be replaced with the cross street water surface slope.

TABLE 7

ALLOWABLE CROSS STREET FLOW

Street Classification	Initial Design Runoff	Major Design Runoff
Local (includes places, alleys, marginal access)	6 inch depth in crosspan	18 inch depth above gutter flowline
Collector	Where crosspans allowed, depth of flow shall not exceed 6 inches	18 inch depth above gutter flowline
Major Arterial	None	6 inches or less over crown

4.4 Storm Sewer Conveyance Systems

The term storm sewer shall be defined as an underground system designed to transport storm drainage runoff to major drainageways. This includes inlets, conduits, manholes and all appurtenances.

A storm sewer system shall be deemed necessary in new subdivisions whenever street capacities to carry design storm runoff are exceeded. This includes both the initial storm and major storm runoff.

The placement of storm inlets shall be determined by a thorough analysis of the drainage area and streets involved, in accordance with the provisions of this Section.

Capacities of storm sewers shall be computed using Manning's equation unless designed for pressure flow and the hydraulic gradient shall be calculated for each storm sewer system.

Storm sewers with pressure flows shall be designed to withstand the forces of such pressure in accordance with the appropriate standards.

4.4.1 Drainage Facilities at Intersections

<u>4.4.1.1 Storm Sewer Inlets</u>

Storm inlets shall be installed where sump (low-spot) conditions exist or street runoff-carrying capacities are exceeded.

The storm sewer inlets being placed in City streets shall be design so the encroachment of gutter flow on the intersection does not exceed the specified encroachment for that street and design storm as described in Tables 5 and 6. The inlets shall be similar to a Neenah Foundry Company R-3067 combination curb inlet frame, grate and curb box. To eliminate large debris from entering the curb-opening, a 5/8 inch diameter smooth rod threaded on each end shall be installed horizontally centered across the face of the curb opening.

All curb openings shall be installed with the opening at least 2 inches below the flow line elevation. The minimum transition length shall be 3 feet 6 inches as shown on the standard details previously listed.

The theoretical capacity of inlets and grates in sags or on grade shall be determined from manufacturers' or industry design charts or procedures. Hydrologic Engineering Circular No. 12, (HEC 12), <u>Drainage of Highway Pavements</u>, is recommended as a reference.

4.4.1.2 Drop Inlet Culverts

When sufficient grade is available, a drop inlet culvert may be used to transport runoff under a street when a storm sewer system is not justified. The culvert must be designed to handle sufficient runoff so that the encroachment of runoff on the intersection is limited to that allowed for the street.

4.4.1.3 Valley Gutters

Where storm sewers are not justified, valley gutters may be installed to transport runoff across local streets. The minimum grade of the valley gutter shall be 0.5% at the flow line. No valley gutters are allowed on arterial or collector streets except in extreme cases when approved by the City Engineer.

4.4.2 Storm Sewer Pipe, Materials, Size and Roughness Coefficient

The materials shall conform to Section 02610-C, "Storm Drain Materials", of the MPWSS.

Concrete pipe shall be used underneath street pavement sections within the right-of-way. Other approved pipe materials may be used for construction in open space areas.

The minimum allowable pipe diameter shall be 15 inches for main trunks and laterals. The minimum inside dimension shall be no less than 12 inches for elliptical and arch pipe. The conduit shall be of sufficient structural strength to withstand the AASHTO HS-20-44 loading. Conduits shall be designed to withstand anticipated loads in accordance with standard industry design procedure (D Crack Analysis for Concrete and PVC).

The roughness coefficients, "n", for closed conduits that are to be used in Manning's equation shall be the accepted standard for the pipe material being proposed.

The average flow velocity in any conduit should not be less than 2.5 feet per second for the initial storm.

4.4.3 Manholes

Manholes shall conform to standard drawing No. 02722-2 of the MPWSS.

Manholes shall be placed wherever there is a change in size, abrupt change in direction, elevation or slope, where there is a junction of two or more systems or laterals, or to conform to the maximum distance shown in Table 8.

TABLE 8

MAXIMUM MANHOLE SPACING

Vertical Pipe Dimensions (inches)	Maximum Allowable Distance Between Manholes and/or Cleanouts
15 to 36	400 feet
36 to 60	500 feet
60 and larger	600 feet

The interior diameter of all "straight through" storm sewer manholes is specified in Table 9.

TABLE 9

MANHOLE BARREL DIAMETER

Horizontal Pipe Dimensions (inches)	Minimum Barrel Diameter (feet)
15 to 24	4
27 to 42	5
Larger than 42	6

4.4.4 Culvert Design Criteria

The design of culverts shall be equal or equivalent to the procedures set forth in the following publications:

- Hydraulic Charts for the Selection of Highway Culverts, Hydraulic Engineering Circular No. 5, December, 1965.
- Capacity Charts for the Hydraulic Design of Highway Culverts, Hydraulic Engineering Circular No. 10, March, 1965.

The size, shape and type of culvert crossings shall be based on the calculated flow quantities as well as existing topographic conditions. Soil tests shall be taken at the culvert site and evaluated based on the criteria listed in Section 4.4.2, "Pipe Materials". All culvert designs and types are subject to approval by the City Engineer prior to installation.

The structural design of culverts shall conform to those methods and criteria recommended by the manufacturer for that culvert type and for the conditions found at the installation site. However, the minimum standards set forth in the current American Association of State Highway and Transportation Officials (AASHTO) Standard Specifications for Highway Bridges shall be adhered to.

All culvert installations (except under major arterials) shall be designed to carry the initial storm with an overflow capacity for the major storm. The amount of overflow for major arterials shall not exceed 6" over the crown of the street for a major storm.

Culvert design shall be based on the runoff quantities for the appropriate design storm and shall include inlet and outlet structure design.

All inlet structures shall be designed to minimize entrance losses. All culverts shall be fitted with flared end sections, headwalls, wingwalls or other approved methods of entrance loss minimization. Projecting ends are not permitted.

For large structures or where groundwater is a problem, the design shall include necessary provisions to resist hydrostatic uplift forces that could result in failure of the structure.

All culvert designs shall include an analysis that determines whether inlet or outlet control conditions govern for both major and minor storm runoff. Additional outlet control may be required should conditions exist that would possibly be damaging to surrounding facilities.

Culvert slopes shall be designed so that neither silting or excessive velocities resulting in scour can occur.

Ponding above culvert entrances will not be allowed if such ponding will cause property or roadway damage, culvert clogging, saturation of fills, detrimental upstream deposits of debris, or inundate or any other structure. All tailwater and headwater conditions shall be designed to meet the above criteria. The limitations in Table 10 may be used as a guide in alleviating some of the problems due to ponded water. The HW/D ratios listed in Table 10 are to be applied to culverts at street crossings and should not be applied in the case of an outlet from a detention facility.

TABLE 10

MAXIMUM HEADWATER/DIAMETER RATIOS (HW/D)

Storm Frequency	HW/D
10 year	< 1.0
100 year	< 1.5

SECTION 5. RUNOFF CONTROL MEASURES

The storm runoff shall not be released from a proposed development at a rate greater than that for the initial storm (5-year design storm) for the land use classification of the area. The amount of runoff to be detained on-site shall be as a minimum, the difference between the major storm (100-year) and the initial storm (5-year) based on full development in accordance with the land use. In areas with existing flooding problems, as identified in the Master Plan or otherwise, additional detention up to the difference between the 100-year developed and 2-year undeveloped runoffs may be required. Detention shall be for the runoff generated on the property being developed. If adequate outfall capacity is available to a major drainageway, a lesser amount of detention may be allowed.

The City encourages innovative measures to limit the maximum runoff from any proposed development. Such strategies may include any of the following:

1. Retention with disposal through seepage into the groundwater, evaporation into the atmosphere and/or plant uptake through transpiration.
2. Increase the time of concentration by lengthening the overland flow path, terracing or flattening of slopes.
3. Roof detention.
4. Roughening surfaces or utilizing filter berms.
5. Underground storage.
6. Other new or innovative methods.

Any requests for the use of innovative approaches would need to be accompanied by appropriate design computations. It would be necessary to demonstrate that the methods would not create public nuisances or have an adverse environmental impact.

TABLE 11

HOURLY PRECIPITATION DISTRIBUTIONS FOR 24-HOUR DURATION EVENTS FOR USE IN DETENTION BASIN DESIGN

(Based on NWS Records from 1898-1989 and NOAA Atlas 2)

DESIGN STORMS

HOUR #	2YR-24HR	5YR-24HR	10YR-24HR	25YR-24HR	50YR-24HR	100YR-24HR
1	.01	.03	.02	.02	.03	.01
2	.01	.08	.08	.08	.21	.11
3	.02	.04	.02	.10	.23	.18
4	.05	.07	.09	.06	.10	.12
5	.07	.01	.18	.12	.06	.06
6	.06	.16	.16	.14	.07	.08
7	.02	.18	.17	.13	.13	.15
8	.06	.25	.13	.21	.20	.22
9	.09	.22	.15	.16	.11	.13
10	.04	.33	.24	.18	.02	.03
11	.13	.14	.16	.14	.08	.14
12	.18	.19	.12	.24	.12	.12
13	.20	.11	.15	.16	.17	.19
14	.15	.02	.13	.30	.09	.11
15	.13	.04	.11	.18	.35	.34
16	.09	.05	.20	.20	.17	.16
17	.08	.05	.12	.14	.06	.20
18	.04	.04	.13	.19	.15	.75
19	.06	.03	.07	.11	.50	.55
20	.05	.06	.05	.20	.70	.15
21	.02	.02	.03	.06	.06	.06
22	.05	.03	.04	.04	.01	.08
23	.06	.01	.06	.03	.02	.09
24	.03	.04	.01	.01	.01	.02
TOTAL PRECIP	1.70"	2.22"	2.62"	3.20"	3.65"	4.05"

For any release from an area greater than that from the initial design storm, a detailed analysis of the downstream conditions shall be made to show that no adverse affects will occur. The analysis shall include any and all information required by the City, and all calculations pertaining to the analysis shall be submitted for review. These would include the volume of peak discharge and the capacity of the downstream conveyance systems.

5.1 Detention Storage

For the design of improvements within a development, the detention storage will be considered an integral part of the storm drainage conveyance system. The amount of storage would therefore impact the sizing of open channels, subsurface conveyance systems and the street layout requirements. To discharge runoff in excess of the design storm would require demonstration that the downstream storm drainage conveyance system within the basin had adequate capacity to carry the flow that would be discharged from the new development. The amount of runoff to be detained on-site shall, as a minimum, be the difference between the runoff from the major design storm and from the initial design storm. The time of concentration (T_c) used to compute detention shall be for the entire drainage basin located above the point of discharge from the proposed development. Both a 2 hour and a 24 hour storm shall be considered. The design shall be based on the storm that provides the larger amount of runoff.

The design of the various types of detention facilities shall conform to the following standards.

5.1.1 Roof Storage

1. Roofs shall be structurally designed by a Registered Engineer for the added loads.

2. Roof membranes, flashing and penetrations shall be designed for the maximum possible water depth.

3. The impact of snow melt and ice shall be considered.

4. The impact of improperly maintained drains and outlets shall be considered.

5. Roof scuppers shall provide emergency relief if drains fail, as per the building code requirements.

5.1.2 Parking Lot Storage

1. The maximum allowable design depth in parking lots is 1.5 feet.

2. Storm drain inlets with orifice flow controls shall be designed in conformance with the construction standards.

3. Regular maintenance shall be provided by the property owner.

4. Signs shall be posted warning the public that the parking lot is a storm drainage detention area.

5.1.3 Parks and Other Public Areas

1. Maximum water depth of the detention basin shall be limited to 3 feet.

2. Side slopes shall not be steeper than 4:1 unless the area is fenced.

3. Inlets shall be designed such that all sediment (sand and gravel) larger than 0.20 inches is trapped on a concrete slab that can be cleaned with a front-end loader.

4. Outlet structures shall be equipped with debris racks to remove all debris greater than 4 inches in width.

5. Outlets shall be designed with a baffle system to prevent oil and floating debris from discharging to the downstream storm drain system.

6. Basins shall be designed such that flows from extreme storms can safely overflow the basin without causing failure of the basin.

7. The basin area shall be seeded to grass. The grass shall be either lawn grass or dryland grass as appropriate for the area.

5.2 Detention Credit

Credit against monthly storm drain bills shall be allowed for developments that detain <u>more</u> than the difference between the 100-year and 5-year developed runoffs. The credit shall be based on the amount of reduction of the 5-year developed peak flow. If the detention reduced the 5-year peak flow 50% for example, the charge per square foot of lot shall be reduced 50% as well. Methods used for computation of peak flows shall be in compliance with this manual.

5.3 Maintenance

Ease of maintenance shall be a paramount consideration in the design and construction of all detention basins. Basins located on private land shall be maintained by the landowner, but subject to inspection by the City. If the basin is not being properly maintained, the City will notify the landowner of the deficiencies. If the landowner does not perform the required maintenance, the City can impose fines in accordance with the City Ordinances. The City can also perform the maintenance and charge the landowner the cost of said work.

SECTION 6. EROSION AND SEDIMENTATION CONTROL

6.1 General Requirements

The construction of all of the storm drainage conveyance systems including street improvements shall include provisions to control accelerated erosion and the resulting degradation of the air and water quality and sedimentation on property, streets, drainage ditches, storm drain pipes and related appurtenances. Accelerated erosion is defined as the removal of the surface of the land through the combined action of man's activities and the natural processes at a rate greater than what would occur because of the natural process alone.

All earthmoving or any construction activity which disturbs the natural ground shall be conducted in such a way as to prevent accelerated erosion and the resulting sedimentation. Prior to beginning construction, a plan shall be submitted which describes the measures and facilities that are to be used to control accelerated erosion and sedimentation. The drainage plan required under Section 2, Documentation, shall include the provisions for permanent control measures and facilities for long term protection of each area being developed.

Any person engaging in earthmoving activities within the City shall obtain a permit prior to commencement of the activity, except that permits will not be required:

1. Where earthmoving activities involve plowing or tilling for agricultural purposes.

2. Where an erosion and sedimentation control plan has been developed for an earthmoving activity by the U.S.D.A. Soil Conservation Service.

3. Where the affected area is less than one acre.

Applications shall be submitted by the person undertaking the activity. In the case of land development, the application shall be submitted by the land developer rather than the contractor or agent. All applications shall include an erosion and sedimentation control plan and be accompanied by a $50.00 processing fee.

Failure by any party to respond within ten (10) days to written notice by the City of an erosion problem with a stabilization plan shall be considered a misdemeanor and carry the penalties as allowed by the O.CC.G.F.

6.2 Control Measures

Limiting exposed areas. All earthmoving activities shall be planned in such a manner as to minimize the areal extent of disturbed land.

Surface water diversion. All surface water shall be diverted away from the project area.

Velocity control. All permanent facilities for the conveyance of water around, through or from the project area shall be designed or contain facilities to limit the velocity of flow in the facilities to less than 1.5 feet per second.

Stabilization. All slopes, channels, ditches or any disturbed area shall be stabilized as soon as possible after the final grade or final earthmoving has been completed.

Interim stabilization. Where it is not possible to permanently stabilize a disturbed area immediately after the final earthmoving has been completed or where the activity ceases for more than 20 days, interim stabilization measures shall be implemented promptly. Examples of interim stabilization techniques are illustrated in Figures 5 and 6 on the following pages.

Collection of runoff. All runoff from a project area shall be collected and diverted to facilities for removal of sediment.

Solids separation. Runoff from a project area shall not be discharged into flowing creeks; streams or rivers; or lakes, all of which are considered waters of the State, without first taking steps to remove sediment from the runoff.

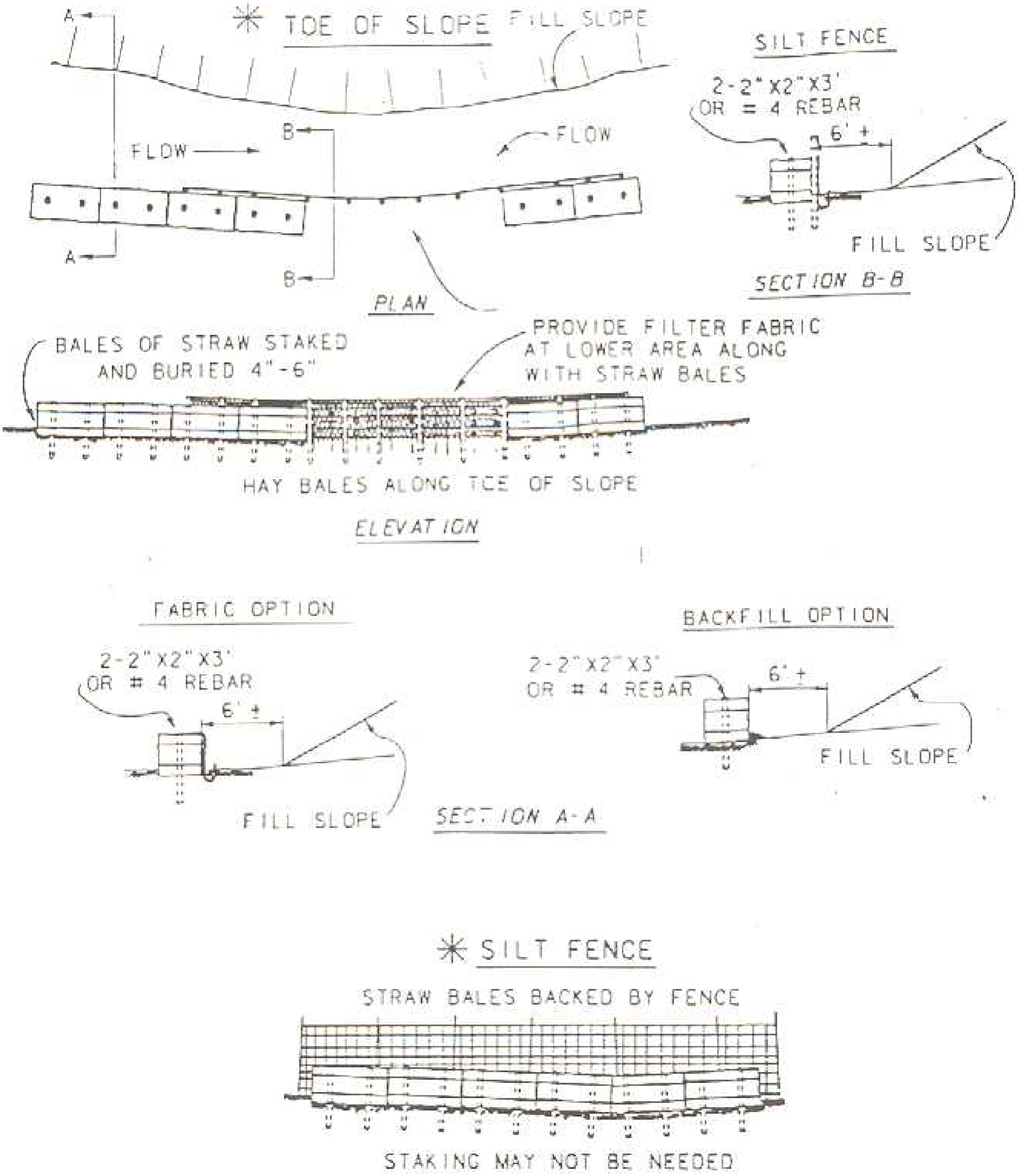
6.3 Control Facilities

6.3.1 Diversion Terrace

Diversion terrace is defined as a channel or dike constructed up the slope of a project for the purpose of diverting water away from the unprotected slope.

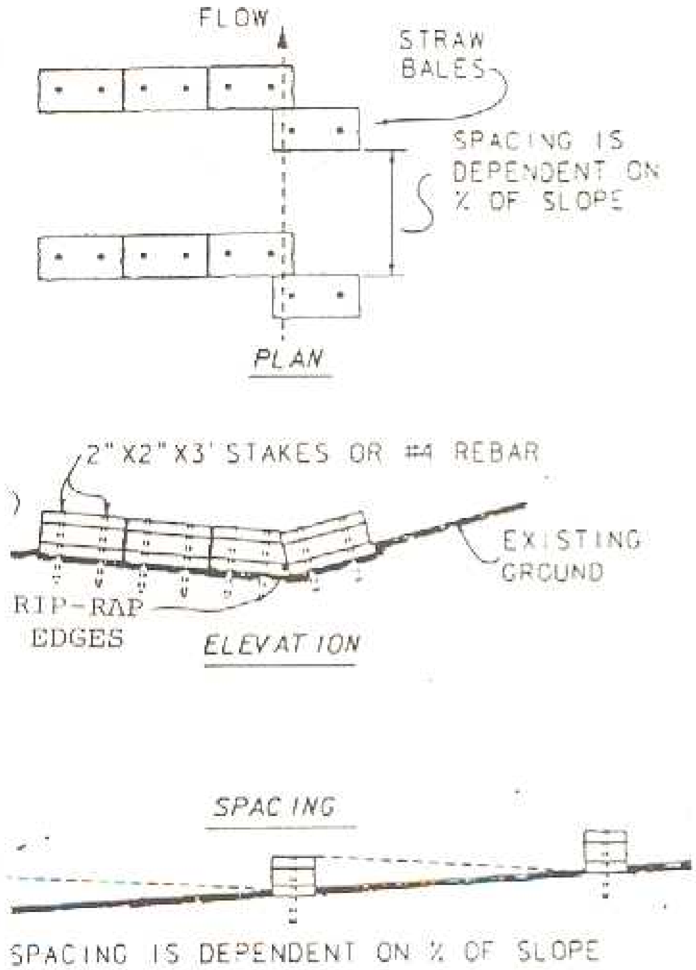
Diversion terraces shall be constructed up-grade of a project area to convey runoff around the project area. For temporary diversion, the channel shall have a capacity to convey 1.6 cubic feet per second per acre of land tributary to it.

Diversion terraces shall be grassed or lined with erosion resistant material to prevent accelerated erosion within the channel.



TEMPORARY BALED STRAW EROSION CHECKS

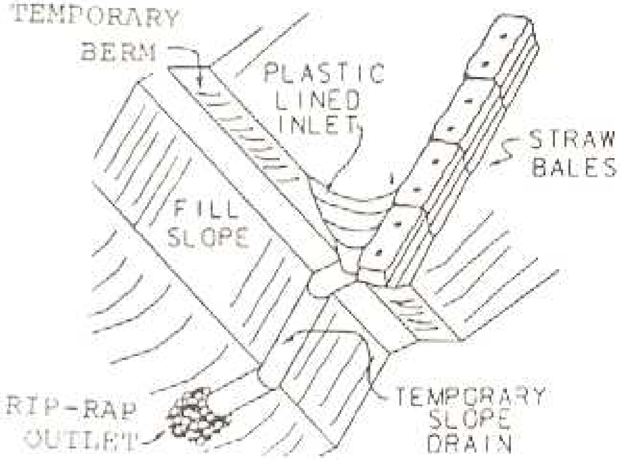
FIGURE 5

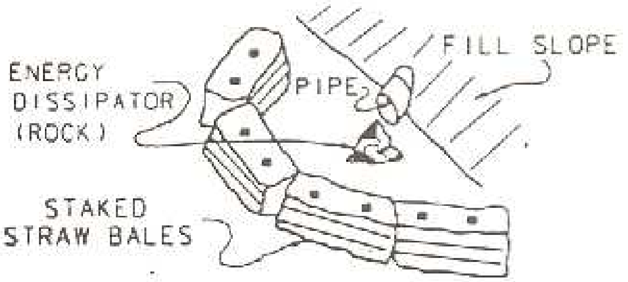


DITCH BLOCK

TEMPORARY SLOPE DRAIN

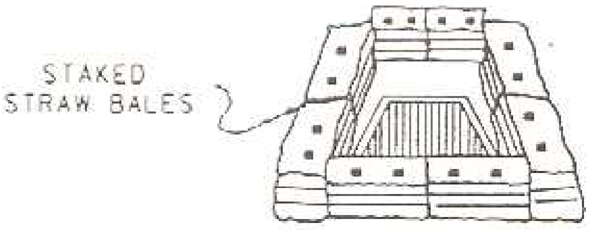
(HALF ROUND PIPE OR PLASTIC LINED)





PIPE OUTLET

*** DROP INLET**



TEMPORARY EROSION CHECKS (cont.)

FIGURE 6

Outlet structures shall be designed to maintain a discharge velocity of less than 3.0 feet per second and shall be stabilized before use.

6.3.2 Interceptor Channels

Interceptor channels may be used within a project area to reduce the velocity of flow and thus prevent accelerated erosion. The channel shall have a capacity to convey 2.75 cubic feet per second per acre of land tributary to it.

Water collected by interceptor channels shall be conveyed to sedimentation basins or to vegetated areas but not directly to streams.

Outlets to vegetated areas shall be designed to maintain an outlet velocity of less than 3.0 feet per second.

6.3.3 Sedimentation Basins

Sedimentation basins will be required to collect any accelerated erosion during the construction phase of the project. These basins shall have a capacity of 7,000 cubic feet for each acre of project area that is contributing accelerated erosion.