Montgomery County Government

Storm Drain Design Criteria

Department of Transportation

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STORM DRAIN DESIGN CRITERIA

MONTGOMERY COUNTY, MARYLAND

DEPARTMENT OF TRANSPORTATION

JULY, 1988

Approved: Robert S. McGarry 23 Aug 1988

Robert S. McGarry, Director — Date
Department of Transportation
Montgomery County, Maryland

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PREFACE

In 1968 House Bill No. 629 was enacted by the General Assembly of Maryland, transferring the jurisdiction over storm drainage systems within Montgomery County, with the exception of that portion of the City of Takoma Park lying within Montgomery County after June 30, 1968, from the Washington Suburban Sanitary Commission to Montgomery County. H. B. No. 629 went into effect on July 1, 1968. Pursuant to the legislation, Montgomery County's Department of Public Works, which is now the Department of Transportation, approved its first Storm Drain Design Criteria on July 1, 1968. Subsequently, some minor changes were incorporated into the Storm Drain Design Criteria to reflect technological advances. The 1968 criteria, as changed in 1975, has now been in effect for twenty years.

Consequently, in an effort to keep up with the state of the art in storm drain design and to provide more compatibility with the criteria of other local, State and Federal agencies, the Montgomery County Department of Transportation (MCDOT) in coordination with the Montgomery County Road Code Committee (ROCOCO) has developed this document to replace the 1968 criteria. It has been reviewed by the Washington Suburban Sanitary Commission, the Maryland-National Capital Park and Planning Commission, and the Montgomery County Department of Environmental Protection, as well as ROCOCO, representing local engineers, land surveyors, public utilities and developers.

The criteria is to be used in conjunction with the Montgomery County Department of Transportation's Design Standards and the Montgomery County Road Construction Code. It is intended to cover the more routine designs of drainage facilities. The criteria does not address all unusual situations that require unique solutions by the Design Engineer and the need to allow it users some flexibility with respect to its application is apparent. At its discretion, MCDOT will approve special designs in extenuating circumstances with adequate documentation presented by the Design Engineer.

Since this criteria is a part of MCDOT's effort to keep up with the state of the art, it is envisioned to be an evolving document, which will need to be updated periodically. An attempt has been made to draw upon and incorporate into this document much of the experience gained by local agencies, engineers, land surveyors and developers in the past twenty years. MCDOT will continue to draw upon the experience of the industry for updating purposes. To this end, any and all constructive criticism of the document is encouraged. The industry's cooperation in developing this document is greatly appreciated. Likewise, the industry's cooperation in making it "all that it can be" is respectfully requested.

PART ONE - GENERAL OVERVIEW.

I. Introduction.

The information contained herein, covers the minimum standard criteria to be followed by Design Engineers when preparing plans for the construction of public storm drain systems within the jurisdiction of the Montgomery County Department of Transportation (MCDOT) and covers such aspects as document submissions, flow determinations (hydraulics and hydrology), horizontal and vertical pipe alignment, etc.

A public storm drain system is defined as all drainage courses that convey concentrated stormwater flows from and within public rights of way or extensive tributary areas which will require storm drain construction beyond the limits of the property being developed. Plan approval from MCDOT is required for all public drainage improvements.

Improvements are considered to be, but not limited to, enclosure, channelization and stabilization of natural channels as a result of property development.

Exceptions are normally made when the 10 year design storm flow from off-site tributary areas is less than 5 cubic feet per second (cfs) and the improved system would not be extended upgrade beyond the developing property in the future. Those systems are considered to be private storm drain systems and are not maintained by MCDOT. Approval from MCDOT is required for connection of a private drain system into an improved public drain system.

Although these criteria are intended as a guideline, it shall remain the Design Engineer's responsibility to review and verify the applicability of all material presented herein as it pertains to the specific project under design and to submit as required by MCDOT all design computations, work sheets, right of way determinations et cetera as prescribed herein.

II. Project Drawings And Documents.

A. Submittal requirements

Submittals to MCDOT for the review and approval of storm drain plans shall include the following:

1 - MCDOT's Standard Transmittal form to include subdivision name, Engineering firm's name, reason for submittal and limits of approval requested.

1 - MCDOT's Standard Checklist for paving and/or storm drain plans.

1 - Complete submittal package as outlined on the check list under "1. Plans for Approval - Contents of Package Submittal".

NOTE: Storm drain and paving plans will not be accepted for review until the grade establishment plans have received final approval.

Submittals are to be made to MCDOT. After the plans have received final approval, they are returned to the Design Engineer who may then submit a Permit Submittal Package to MCDOT for processing.

B. General Requirements for Storm Drain Plans and Profiles

1. Drawings shall be prepared on tracings suitable for ready reproduction and microfilming with a maximum size of 24" by 36" and a minimum size of 18" by 24".

2. All supporting data shall be a minimum size of 8 1/2" by 11".

3. A scale of 1" = 50' horizontally and 1" = 5' vertically shall normally be used on pipe profiles.

4. Details of special structures, typical sections, etc., shall be of a sufficient scale for clarity.

5. Plans, profiles, special details, typical sections, etc. shall show the scale.

6. Each drawing must bear the professional seal, signature and registration number of the Registered Professional Engineer and/or Professional Land Surveyor (registered by the State of Maryland) who is responsible for the design. The first drawing shall have a certification, by the professional, that the design conforms to these criteria.

7. Notes common to all drawings shall be shown on the first sheet of the set of plans and labeled "General Notes for Storm Drain Construction".

C. Changes to Approved Storm Drain Plans

Any revisions to approved storm drain plans shall be submitted to MCDOT, for review and approval prior to construction.

D. Utility Coordination

Storm drain design will be coordinated by the Design Engineer with the location of water lines, sewer mains, wells and/or septic systems where applicable and all other utilities (hereinafter called utilities) to ensure there are no conflicts. The locations of all existing and proposed utilities are to be shown on the plans and profiles.

The Design Engineer will be responsible for the research, collection and collation of all pertinent data on existing utilities and proposed utility construction projects which may impact the storm drain design. The Design Engineer will also be responsible for obtaining precise locations of all existing utilities and physical features through field surveys and current records. The Design Engineer will be responsible for obtaining precise locations by test pits wherever exact locations of underground utilities are critical to the storm drain design, or where adjustment during construction would be costly and/or cause significant delay.

E. Discrepancies

If any discrepanies or ambiguities are found to exist in these criteria or if there are any conflicts between these criteria and any code, regulation, policy or criteria promulgated by any other jurisdictional agencies affecting the design, MCDOT shall be advised in writing and will render an expeditious interpretation and guidelines to be followed.

PART TWO - HYDROLOGIC AND HYDRAULIC DESIGN CRITERIA

I. General.

The design study is to contain all information necessary to support the physical storm drain design and is to include: a drainage area map, hydrologic computations, hydraulic computations, structural computations for nonstandard structures and hydraulic gradient profiles.

Storm drain systems shall be designed on the basis of ultimate development of the tributary watershed. The Maryland-National Capital Park and Planning Commission should be consulted by the Design Engineer to obtain the latest zoning or the latest adopted master plan for the purpose of determining the type of future development expected.

II. Drainage Area Map.

The drainage area map should be based on the most recent and accurate topographical data available. Recent field run or aerial photogrammetric topography and site grading plans are preferable. Where aerial photogrammetry is used, it must be supplemented by field run topography. In any case, the Design Engineer is expected to personally verify the actual drainage patterns by field inspection of the site.

The following items are required for a complete drainage area map:

1. Generally, the size of the map shall be 24" by 36". Exceptions may be made to allow a maximum size of 30" by 42".

2. The scale generally shall be 1" = 200'. Other scales may be used when a large off-site area is involved or to provide clarity of small areas. Supporting topographic information is to be provided when scales other than 1" = 200' are used.

3. All existing and proposed streets pertinent to the overall drainage area, as well as sufficient information concerning adjacent major streets, including an outline of the site of the proposed development, shall be shown to properly locate the area under consideration.

4. The entire area served by the drain system shall be outlined by a solid line thereby enclosing all the sub-drainage areas.

5. The tributary area to each inlet structure shall be delineated by dashed lines. The area, in acres, of every tributary area shall be shown near the structure.

6. The various land use/zoning, with run-off coefficients for the entire tributary area under design shall be shown on the map including, but not limited to, parcels, school sites, and parks.

7. The existing and/or approved storm drain systems, including all structures and pipes, shall be shown. The systems shall be marked as existing or future.

8. Existing streams and defined swales shall be shown.

9. The 100 year flood plain limits of surface drainage courses shall be shown.

10. The direction of flow within each tributary area shall be shown. This may be done either by using a sufficient number of flow arrows or contour lines.

11. The proposed storm drain improvements shall be shown on the drainage area map and must be differentiated from existing and approved future facilities. All structures shall be numbered and pipes labeled to correspond with the storm drain and paving plans.

12. At least 500 feet of the downstream drainage course shall be shown.

13. The title block shall contain the subdivision name, Engineering firm's name and address and date prepared.

III. Hydrologic and Hydraulic Computations

A. General

Generally, the 10 year storm frequency shall be used in designing storm drain systems. In cases where there is the possibility of property damage or public inconvenience should the capacity of a drain system be exceeded, a more intense storm frequency shall be used if required by MCDOT.

Computer programs and methods of design not referred to in these criteria, must be documented by the Design Engineer and approved by MCDOT. All assumptions are to be identified.

B. Quantity Of Stormwater Runoff

The Rational Formula, $Q = CIA$, shall be used to determine quantities of runoff except for areas over 400 acres where other applicable methods may be used subject to approval by MCDOT. For areas greater than 400 acres, the Soil Conservation Service TR-20 or TR-55 computer programs are recommended.

In the Rational Formula,

Q = Quantity of stormwater runoff in cfs at the study point.
C = Runoff coefficient
I = Intensity or rate of rainfall in inches per hour. "I" is dependent upon the time of concentration (t_c) and the storm frequency used.
A = Tributary area in acres.

In computing flow to any point under consideration, the runoff coefficient shall be a composite of the ultimate development "C" factors for all areas tributary to the point. In areas where the nature of future development is uncertain, the design shall be based on a "C" factor for the anticipated future type of development. If lack of zoning for a particular area does not allow an estimated land use, use a "C" factor comparable to that of adjacent developed areas.

"C" factors for development shall represent a weighted average based upon the proportion of the surface area covered by impervious materials or lawns.

The "C" factor shall be computed using the following values:

Impervious areas	0.90
Lawns	0.25

For the 100 year frequency storm, add 0.10 to the computed factor. Supporting documentation shall be provided for all "C" factors.

Attachment 3 may also be used as a guideline for computing "C" factors to be used as a function of zoning type.

The time of concentration is the period of time required for the water to flow from the hydraulically most distant point, within the tributary area, to the point under consideration. The time of concentration must be based on the ultimate storm drain system as can best be determined and is to be computed using the method in the Soil Conservation Service, Technical Release No. 55, Chapter 3, Figure 3-1, "Average Velocities for Estimating Travel Time for Overland Flow".

Using the computed time of concentration, the intensity can be determined from the following rainfall intensity formulas, which are valid for times of concentration from 5 minutes thru 60 minutes.

$$\text{2 years} \quad I = \frac{40.6}{(t_c+8)^{0.778}}$$

$$\text{5 years} \quad I = \frac{66.8}{(t_c+12)^{0.8283}}$$

$$\text{10 years} \quad I = \frac{142.7}{(t_c+18)^{0.9585}}$$

$$\text{25 years} \quad I = \frac{230.9}{(t_c+22)^{1.0183}}$$

$$\text{50 years} \quad I = \frac{271.1}{(t_c+23)^{1.0257}}$$

$$\text{100 years} \quad I = \frac{739.2}{(t_c+32)^{1.203}}$$

The tributary area is that area from which stormwater runoff flows to the study point.

C. Determination of Conveyance Size

Manning's Formula is to be used to correlate velocity, slope and friction for determining the size of storm drain required to convey the calculated flows. The MCDOT standard form may be used for pipe computations.

The roughness coefficients to be used are shown in Table 1 below:

TABLE 1

Concrete pipe and precast box culverts	0.013
Monolithic concrete in boxes, channels, etc.	0.015
Corrugated metal pipe - 2 2/3" x 1/2"helical corrugations:	
15" through 36" diameter	0.019
42" through 96" diameter	0.021
Corrugated metal pipe - 3" x 1" helical corrugations:	
36" through 84" diameter	0.021
96" through 144" diameter	0.024
Corrugated metal pipe-2 2/3" x 1/2" annular corrugations	0.024
Corrugated metal pipe-3" x 1" annular corrugations	0.028
Corrugated metal pipe arches	0.024
Structural plate pipe, pipe arches and arches - 6"x2" corrugations	0.034
Concrete or bituminous concrete lined channels	0.015
Bituminous concrete paving with concrete gutter	0.015
Grass gutters and ditches - flow greater than 6 inches	0.040
Grass gutters and ditches - flow less than 6 inches	0.060
Earth gutters and ditches	0.025
Channels not maintained - uncut weeds and brush	0.080 - 0.120
Natural stream channels	0.035 - 0.150
Gabions	0.030
Riprap - Class I (150 lbs. maximum stone weight)	0.038
Class II (700 lbs. maximum stone weight)	0.041
Class III (2000 lbs. maximum stone weight)	0.044
Soil stabilization matting	0.030

While it is true helical corrugated metal pipe may have a lower 'n' value than annular corrugated metal pipe, care should be exercised in the use of the reduced values. Since the low values depend upon the development of spiral flow across the entire cross-section of the pipe, the Design Engineer must verify that fully developed spiral flow can occur in the design situation. The 'n' values for annular pipe shall be used in place of those for helical pipe under the following conditions for which spiral flow cannot be achieved:

1. Partial flow in the pipe
2. Extremely high sediment load
3. Short culverts less than 20 times the diameter of the culvert in length
4. Non-circular pipes

When drains are composed of more than one of the above mentioned materials, a composite roughness coefficient must be determined in proportion to the wetted perimeter of the different materials.

D. Street Capacity (Spread)

Water shall not cross the centerline of secondary or tertiary roads. For all other classifications of roads, the spread shall not exceed 8 feet. The spread shall be computed considering the cross section through the gutter pan to equal the cross slope of the street paving.

The use of FHWA Hydraulic Engineering Circular No. 12, "Drainage of Highway Pavements", is recommended from which the following equations are taken:

$$Q = \frac{0.56}{n} S_x^{5/3} S^{1/2} T^{8/3}$$

and $d = TS_x$

where Q = flow rate in the gutter (cfs)
S_x = cross slope of the roadway (ft/ft)
S = longitudinal slope (ft/ft)
T = width of flow - spread (ft)
and d = depth of flow in the gutter at the theoretical flowline (ft)

E. Inlet Size and Capacity

Curb opening inlets shall be used for all roadways which require curb and gutter as a part of the standard roadway section, unless otherwise approved by MCDOT. No grate only inlets shall be used within the public system.

Curb opening inlets shall be sized to intercept a minimum of 70% of the flow coming to them with a maximum bypass from any structure not to exceed 4 cfs. Curb opening inlets shall be located at the upgrade side of all public and private road connections (intersections) where the gutter flow exceeds 3 cfs, where the allowable spread of water is exceeded or where the depth of flow will exceed the top of the curb.

The following equations may be used to size curb-opening inlets on a continuous grade:

The length of curb-opening inlet required for total interception of gutter flow on a pavement section with a straight cross slope is expressed by the following equation:

$$L_T = 0.6\, Q^{0.42}\, S^{0.3} \left(\frac{1}{n\, S_x}\right)^{0.6}$$

where L_T = curb opening length required to intercept 100 percent of the gutter flow.

Q = gutter flow (cfs)

S = longitudinal slope of the gutter (ft./ft.)

S_x = pavement cross slope (ft./ft.) and

and n = Manning's roughness coefficient

The efficiency of curb-opening inlets shorter than the length required for total interception is expressed by the following equation:

$$E = 1 - \left(1 - \frac{L}{L_T}\right)^{1.8}$$

where E = Interception efficiency of an inlet (in decimal form)

L = actual curb-opening length (ft.)

and L_T = curb-opening length for 100% interception

The length of a curb opening inlet in a sump is determined by the following relationship:

$$Q = 1.0L$$

where Q = flow to the inlet (cfs)
L = length of the inlet throat (ft)

The minimum length of a curb opening inlet in a sump shall be 10 feet. The 100 year storm overflow shall be contained within a surface drainage easement.

Computations shall be provided for all inlets within or that affect the public system. The MCDOT standard form may be used for inlet computations.

The use of FHWA Hydraulic Engineering Circular No. 12, "Drainage of Highway Pavements", is recommended for sizing all other inlet types.

M E M O R A N D U M

May 31, 1989

TO: ALL HOLDERS OF MCDOT'S 1988 STORM DRAIN DESIGN CRITERIA

FROM: Robert C. Merryman, Chief, Division of Transportation Engineering

SUBJECT: Equations to Compute Curb-Opening Inlet Lengths

The following equations to compute curb-opening inlet lengths are an acceptable alternate to the equations on page ten of the 1988 Storm Drain Design Criteria.

The length of curb-opening inlet required for total interception of gutter flow on a pavement section with a depressed gutter may be expressed by the following equation:

$$L_T = 0.6\, Q^{0.42}\, S^{0.3}\, \left(\frac{1}{n}\frac{1}{S_e}\right)^{0.6}$$

where Q = gutter flow (cfs)
S = longitudinal slope of the gutter (ft./ft.)
S_e = equivalent cross slope of pavement (ft./ft.)
and n = Manning's roughness coefficient

$$S_e = S_x + S'_w E_o$$

where S_x = pavement cross slope (ft./ft.)
S'_w = cross slope of the gutter measured from the cross slope of the pavement, S_x
= a/w (see Note 1)

where a = gutter depression (inches)
w = gutter width (inches)
and E_o = ratio of flow in the depressed section to total gutter flow
= Q_w/Q (see Note 2)

where Q_w = flow in the depressed section (cfs)
and Q = total gutter flow (cfs)

NOTES:

1. For Montgomery County standard curb opening inlets, a = 4" and w = 16".
2. Q_w must be computed algebraically rather than read from Chart 4, page 25, FHWA Hydraulic Engineering Circular No. 12.

For a more detailed explanation of the above equations, please refer to FHWA's Hydraulic Engineering Circular No. 12.

RCM:JAT:abc

F. Manhole, Inlet and Field Connection Energy Losses

Head losses are to be computed using the following formulas:

$$H_L = \frac{V_{OP}^2 - V_R^2}{2g}$$

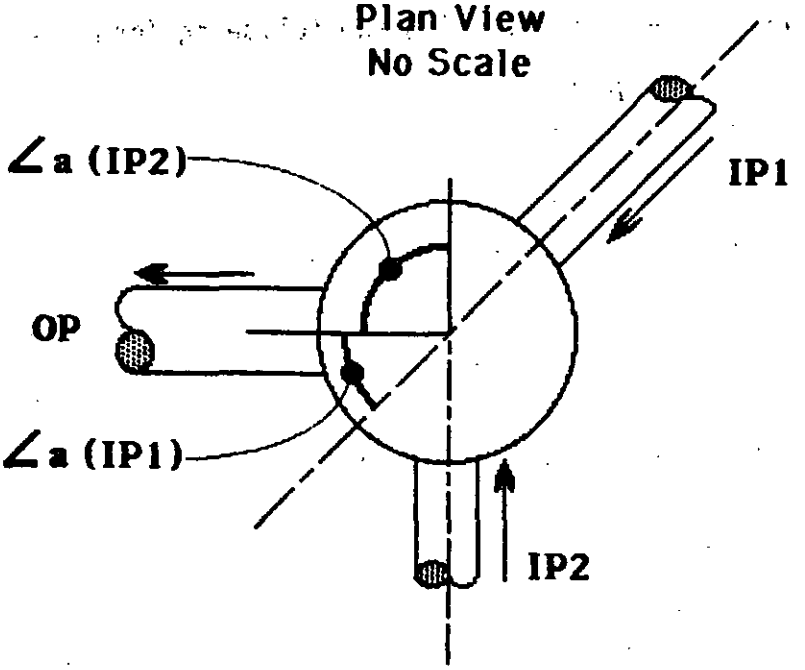
$$V_R = \frac{(QV \cos\frac{a}{2})_{IP1} + (QV \cos\frac{a}{2})_{IP2} + \ldots}{Q_{OP}} \quad \text{(Manholes and Inlets)}$$

$$V_R = \frac{Q_{IP}\, V_{IP}}{Q_{OP}} \quad \text{(Field Connection)}$$

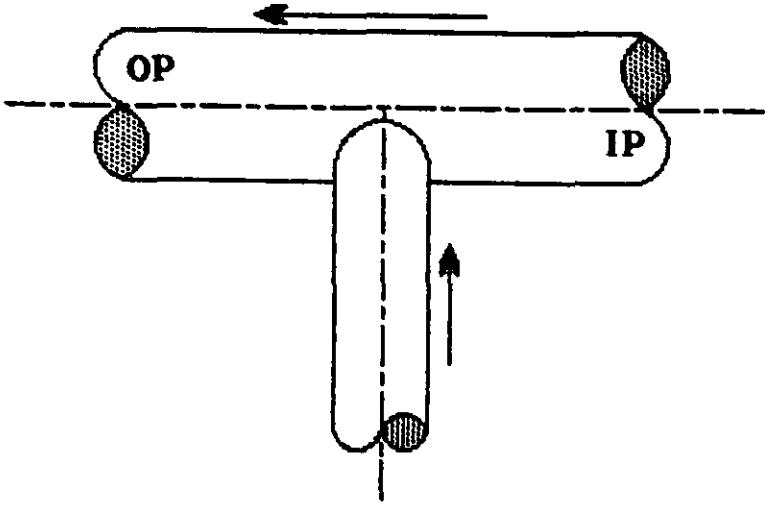
H_L = head loss (ft)
IP = inlet pipe (or main line inlet pipe for field connections)
OP = outlet pipe
g = acceleration of gravity (32.2 feet per second squared)
a = the angle between the inlet and outlet pipes
Q = quantity of water (cfs)
V = Q/A = velocity (fps)
V_R = resultant velocity (fps)
A = cross-sectional area of the pipe (sq. ft.)

A minimum structure loss of 0.25 foot is to be added to the head loss for inlets, manholes and special design structures. The factor of 0.25 foot is not required to be added to the head loss at a field connection.

HEAD LOSS THROUGH A STRUCTURE
Plan View
No Scale



HEAD LOSS THROUGH A FIELD CONNECTION
No Scale



G. Entrance Structures

Headwater computations for 10 year and 100 year storms shall be provided. The maximum relationship of the headwater depth to the pipe diameter (HW/D) shall be 1.2 for the 10 year storm.

When the entrance invert is placed below the existing channel, a gabion or concrete channel shall be used as erosion protection of the depression as well as a portion of the existing channel immediately before the depression. Where the channel invert is at a gradual slope, other erosion protection may be used with MCDOT's approval. An increase of one foot or greater in the 100 year headwater elevation off-site will require a 100 year flood plain easement. The use of Federal Highway Administration publications is recommended as sources of information on the design of entrance structures.

H. Outlet Velocity (other than driveway culverts)

The partial flow velocity based on the actual slope of the outlet pipe is to be computed. Computations must be provided to substantiate that the partial flow velocity is not greater than 10 fps for the 10 year storm unless a suitable energy dissipator is placed at the outlet.

Computations must also be provided to substantiate that the velocity, from the dissipator, concrete, gabion or riprap channel, etc., to the existing channel is reduced to 5 fps. Outlets that outfall into stormwater management facilities shall be subject to the approval of the Montgomery County Department of Environmental Protection.

When the grade immediately beyond the outlet protection is sufficiently steep for the flow velocity to increase beyond 5 fps, gabion or riprap protection is to be provided unless documentation is provided showing the vegetation and soil is erosion resistant.

I. Culverts (other than driveway culverts)

Generally, culverts shall be designed to pass the 50 year storm with a maximum ratio of the headwater depth to the culvert diameter (HW/D) of 1.2. In addition, the 100 year storm water surface elevation shall not exceed the profile grade line elevation at the low point of the road. If the culverts are within a 100 year flood plain area, they must be designed to pass a 100 year storm. Computations will consist of data required to determine the conveyance size and headwater based on entrance conditions or outlet control as appropriate. Outlet velocity computations, as mentioned above under item H, are required and the use of Federal Highway Administration Charts is recommended as a reference on inlet and outlet control.

J. Hydraulic Gradient

This gradient shall be computed for the design storm for all pipe sizes and shall take into consideration friction losses in the pipes and losses in the structures caused by differences in velocity, change in direction of flow, incoming volume, entrance, exit and other applicable conditions.

When the headwater is negative, the crown of the inlet pipe may be at the same elevation as the crown of the outlet pipe, if other applicable controls are met.

All enclosed systems shall be designed so that they will generally operate without hydrostatic pressure under design conditions. Where the hydraulic gradient is greater than one foot above the crown of the pipe, special joint treatment will be required.

Starting hydraulic gradient elevations must be determined at outlets. The existing and proposed 10 and 100 year water surface elevations must be shown and computations for the design storm provided at all outlets into swales, streams and stormwater management ponds.

K. Open Channels (Streams, Ditches, Swales, Etc.)

Computations shall be provided for all channels, accompanied by a typical section of each reach, and a plan view with typical section locations clearly marked. In the case of existing streams or swales which are to remain in a natural condition, field run survey data is necessary to prove the streams will remain in a stable condition.

1. Design Channels

Open channels may be used to convey stormwater when the discharge is greater than the capacity of a 72 inch pipe. When used, they must be designed for the 50 year storm with a minimum freeboard of six (6) inches to the top of the channel. Velocities in earth and sodded channels must be such that erosion will not occur (less than 5 fps).

Computations shall include slope, cross section, roughness coefficient, velocity and quantity of discharge for each section or reach of channel. A gabion or riprap protected invert shall be provided when a base flow will be present for extended periods.

2. Natural Channels

Any plans with natural channels receiving public stormwater must be reviewed and approved by the Department of Environmental Protection for safe conveyance. These channels must be stable and remain stable under ultimate development of the watershed. Computations shall be provided for the existing and the ultimate flow quantities and velocities.

Gabion or riprap protection is to be provided unless it can be shown that the channel is sufficiently erosion resistant to withstand ultimate watershed development flows and that the channel will remain within the flood plain easement.

3. Roadside Ditches

Generally, the use of these criteria for roadside ditches shall be used in connection with the design and construction of new rural roadways. However, the criteria may be applied in other cases, e.g., to existing roads without curb and gutter and to median ditches.

Ditches are considered integral components of the public drainage system. Generally, roadway ditches shall be "V" shaped in accordance with MCDOT standard details. Other channel cross sections will be considered for approval under certain conditions, e.g., along existing roadways when the standard "V" ditch design will not meet existing conditions. They shall be designed to provide sufficient hydraulic capacity to convey the estimated runoff from a 10 year frequency storm at a non-erosive velocity. The estimated runoff shall be calculated using the methods described herein.

Ditch capacity shall be calculated using Manning's formula. The appropriate roughness coefficient for the ditch lining under consideration shall be selected from Table 1. The maximum average velocity shall not exceed the following:

Grass (sodded) lining	4 fps maximum in fill sections 7 fps maximum in cut sections
Concrete lining	no maximum 3 fps minimum

The minimum acceptable grass ditch gradient is 2 percent. Concrete lining shall only be used when velocity exceeds the maximum allowable for grass ditches or when the ditch gradient is less than 2 percent. The minimum acceptable concrete ditch gradient shall be 0.5 percent. In certain instances when grass or concrete lining is not deemed to be appropriate by the designer, other materials may be considered and approved by MCDOT.

The maximum permitted depth of flow for any side ditch shall be one foot. When this depth is exceeded, the runoff must be intercepted by an appropriate storm drainage inlet and conveyed in a pipe from that point to an acceptable outfall. In those situations where introducing an enclosed drainage system is not feasible, with prior approval of MCDOT, a change in the ditch section characteristics may be permitted. Except at driveway crossings and street crossings where the outlet conditions allow for ditch flow, i.e., depth does not exceed one foot, enclosed pipe systems must be used in lieu of culverts.

The design plans for any roadway having a roadside ditch shall show for the ten year design storm the estimated velocity in fps, depth of flow in ft., and quantity of flow (Q) in cfs for the ditch on all sides of every intersection, at 500 feet intervals of road centerline length, on the uphill side of all inlets, on each side of the ditch leading into a sump or at other critical locations where ditch flow is significantly affected by either increased drainage area and/or a change in street gradient.

Ditch invert elevations shall be shown on the design plans around intersection fillets, at 50 feet intervals through crest and sag vertical curves, around the bulb of cul-de-sacs, through transitions from swale sections to full ditch sections and at other critical points, e.g., temporary turnarounds, low points and high points.

L. Riprap

Riprap channels placed at storm drain outlets as energy dissipators will be designed to reduce the velocity at the downhill end of the channel to 5 fps or less and shall be placed on a slope range of 0.1 thru 0.5 percent.

A typical section and plan view of the riprap channel will be provided. Additionally, it will be shown graphically on the storm drain plan and profile. The information required to be shown on the plans, shall include d_{50} stone size, class, side slopes, depth, length, width and thickness of blanket.

Using the method in the U.S. Army Engineer Waterways Experiment Station's, Technical Report H-74-9, page A12, computations will be as follows:

1. Determine tailwater, either within the receiving stream or normal depth within the design riprap channel, whichever is greater.

2. Determine the required d_{50} size of the stone:

   a. Circular and Square outlets:

$$\frac{d_{50}}{D} = 0.020 \frac{D}{TW} \left(\frac{Q}{D^{5/2}}\right)^{4/3}$$

   b. Rectangular and other shaped outlets:

$$\frac{d_{50}}{D} = 0.020 \frac{D}{TW} \left(\frac{q}{D^{3/2}}\right)^{4/3}$$

where d_{50} = Diameter of average size stone (ft).

D = Height of rectangular outlets, width and height of square outlets and diameter of circular outlets (ft).

TW = Tailwater depth above invert of storm drain outlet (ft).

q = Discharge per foot of width for rectangular and other shaped outlets (cfs/ft).

and Q = Discharge (cfs).

3. Determine the required length of the blanket.

   a. Circular and square outlets:

      1). TW less than 0.5D,

$$\frac{L}{D} = 1.8 \frac{Q}{D^{5/2}} + 7$$

2). TW equal to or greater than 0.5D,

$$\frac{L}{D} = 3\,\frac{Q}{D^{5/2}}$$

b. Rectangular and other outlets:

1). TW less than 0.5D,

$$\frac{L}{D} = 1.8\,\frac{q}{D^{3/2}} + 7$$

2). TW equal to or greater than 0.5D,

$$\frac{L}{D} = 3\,\frac{q}{D^{3/2}}$$

where L = Length of the stone protection (ft).

The riprap channel bottom width will be equal to the width of the flared end section, when used, or 1.75 times the inside diameter of the outlet pipe or width of the outlet. The riprap channel side slopes shall be a maximum of 3:1. The depth of the riprap channel shall be the diameter or height of the storm drain outlet.

The blanket thickness shall be 1.5 times the d_{50} stone size or the theoretical spherical diameter of the maximum weight stone within the class of riprap required, whichever is greater.

Rirap Classification

Class	W_{100}(lbs)	d_{100}(inches)	d_{50}(inches)
I	150	15	12
II	700	24	16
III	2000	34	23

NOTE: Maximum stone weights correspond to MSHA and WSSC riprap classifications.

A filter will be placed between the riprap blanket and the underlying soil surface. The filter can be of two general forms: a gravel layer or a filter cloth. A gravel filter, when used, shall be designed by comparing particle sizes of the overlaying material and the underlying soil surface. The filter cloth shall be as approved by MCDOT.

4. All privately maintained storm drains connecting to public storm drain structures are to be reinforced concrete pipe, corrugated metal pipe or solid, rigid PVC Pipe (6" diameter or less). No portion of the privately maintained structures shall extend beneath the paved roadway section.

5. The minimum pipe size to be used within the public system shall be 15 inches in diameter.

6. Inlet pipes shall be placed at a minimum of 90 degrees to the outlet pipe at all structures.

7. Pipe class is to be in accordance with the attached MCDOT load charts, entitled "RCP Supporting Strengths". NOTE: The charts are intended for use with circular pipe only. For loading conditions beyond the limits and scope of the charts, the Design Engineer shall provide computations verifying the pipe class required for H-20 truckload or E-80 Cooper trainload.

8. One foot minimum cover over the outside of the pipe is to be provided. A typical section shall be shown on the drawings.

9. Pipes 27 inches or larger in diameter may be curved horizontally and/or vertically. The joint opening is not to exceed 1/3 the length of the tongue in horizontal and crest vertical curves, and is not to exceed 1/4 the length of the tongue in sag vertical curves. All pertinent pipe curve data is to be shown on the drawing, i.e., radius, chord, tangent, arc, P.C., P.T. and P.I. for horizontal curves and P.V.C., P.V.T., P.V.I.,P.O.C. and the length of curve for vertical curves. Maximum laying length of pipe for each curve shall be shown.

10. Pipe shall not be designed on a slope less than 0.5 percent. However, to enhance self-cleaning characteristics, 15 and 18 inch diameter pipe are to be designed on an actual slope of 1 percent or greater.

11. Profiles of proposed storm drains shall indicate size, type and class of pipe, design grade and invert elevations at both ends of pipe run, Q_{10}, Q_{10}/A, and the minimum slope required for full flow in the pipe. The hydraulic grade line shall be shown on all pipe profiles. The actual flow velocities in pipe will be shown for all outlet pipes.

    Pipe elevations and grades shall be set to avoid hydrostatic surcharge during the design condition. Under special circumstances, when approved by MCDOT, head may be placed on these pipes. When the head on these pipes exceeds 1 foot, special treatment of the pipe joints will be required, e.g., rubber gasket joints or concrete collars.

12. A pipe schedule tabulating pipe lengths by size and class is to be included on the drawings. Separate pipe schedules will be shown for public and private systems.

13. The downsizing of storm drain pipe to one size smaller is permitted only once in any proposed storm drain system.

B. Manholes, Inlets and Field Connections

1. MCDOT standard structures are to be used where possible. The selection of an inlet type shall fit the site requirements.

2. Access structures shall be spaced as follows:

15" through 24" pipe	400' maximum
27" through 42" pipe	500' maximum
48" and larger	600' maximum, except with special approval by MCDOT.

3. A minimum slope of 1 percent or 0.1 ft. drop, whichever is greater, shall be provided through structure inverts.

4. Through structures are to be provided with a shaped channel, with a rounded bottom conforming to the inlet and outlet pipe. The sidewalls of the shaped channel shall extend to the crowns of the pipes in the structure. Where branch lines enter structures at a considerable elevation above the bottom of the structure, the shaped channel in the structure may be required to have a special lining.

   Where the drop on the main line through a structure is greater than that which can be accommodated by a shaped channel with the invert on a 1.5 foot horizontal to 1 foot vertical slope, the bottom of the structure shall be lined with granite blocks at least 4 inches thick. No shaped channel will be required for this type of construction, but the bottom of the structure shall slope at least 1/2 inch per foot toward the invert of the outlet pipe.

5. Field connections of branch lines into the mainline pipes may be used only where the main line pipe involved is 27 inches in diameter or larger. The branch line may be no larger than two-thirds of the diameter of the main line pipe.

6. Sufficient contours are to be shown around yard inlets to insure that positive drainage to the inlet is obtained. The limits of the area of inundation during the 10 and 100 year storms shall be shown on the plan and storm drain profile.

7. Inlets shall not exceed 12 feet in depth.

8. Street inlets shall be a minimum of 3 feet from the P.C. of the curb fillets.

9. Street inlets in sump areas shall be located at the low point of the street grade.

10. "B" type inlets shall not be used in sump areas.

11. All structures are to be numbered and listed in the structure schedule which shall include the following information:

    Structure type, Agency and agency's standard number, size, top elevations, slot elevations and location, if applicable, and modification notes, precast structure standard number and supplier, if applicable.

Separate structure schedules will be shown for public and private systems.

12. In general, private drains are to be connected to a public inlet or manhole.

13. In residential areas, a maximum concentrated flow of 5 cfs will be allowed to cross into the public right of way from off-site.

C. Entrance Structures

1. Entrances are not to be located on developed lots except in extenuating circumstances, with special permission of MCDOT.

2. Field run topographical information is to be shown on the plan view to show drainage path(s) to the structure and to ensure interception of the flow.

3. The limits of ponding for 10 and 100 year storms are to be shown on the plan and profile views.

4. The channel invert and tops of banks of the incoming drainage course(s) are to be shown on the plan and profile views.

5. Protection is to be provided, as necessary, to prevent erosion. Transition of the natural section to the protection section is to be shown on the plan and profile views along with typical sections.

6. An end section or headwall is to be used where the entrance is to be the terminus of the enclosed system. A cutoff wall may be used when future extension of the system is anticipated.

7. The structure shall be located sufficiently beyond the proposed development so that regrading will not be required on occupied lots of this development when the system is extended.

D. Outlet Structures

1. Outlets are not to be located on developed lots except in extenuating circumstances, with special permission of MCDOT.

2. Field run topographic information is to be shown on the plan and profile views to show the drainage path from the structure to an existing, established, drainage course.

3. The channel invert and tops of banks of the receiving drainage course are to be shown on the plan and profile views.

4. Protection is to be provided to prevent erosion. Transition of the protection section to the natural section is to be shown on the plan and profile views along with typical sections.

5. An end section or endwall is to be used where the outlet is the terminus of the enclosed system. A cutoff wall may be used when future extension of the system is anticipated.

6. The structure shall be located sufficiently beyond the proposed development so that regrading will not be required on occupied lots of this development when the system is extended.

7. Where the vertical height at the inlet/outlet of a storm drain system exceeds 4 feet, a 48 inch minimum height chain link fence will be required for safety purposes.

E. Clearance With Other Utilities

1. All proposed and existing utilities crossing or parallel to storm drain systems shall be shown on the plan view.

2. All proposed and existing utilities crossing the storm drain pipes/structures and sewer mains parallel to the system shall be shown on the profile view.

3. A minimum vertical clearance of 12 inches and a minimum horizontal clearance of 5 feet, wall to wall shall be provided between storm drain pipes/structures and other utilities.

4. Storm drain vs. utility crossing angles shall not be less than 45 degrees.

5. Protection shall be provided where concentrated stormwater flows across the trench of other existing utilities.

F. Open Channels-Designed and Natural

1. The channel invert and tops of banks are to be shown in plan and profile views.

2. For designed channels, a cross sectional view of each configuration shall be shown.

3. For designed channels, limits of grading shall be shown.

4. The limits of a recorded 100 year flood plain easement or surface drainage easement sufficient to convey the 100 year flow shall be shown. A standard storm drain right of way for improved systems is not to be obtained for natural channels.

5. For designed channels, transitions at the entrance and outlet are to be clearly shown on the plan and profile views.

6. Limits and types of bank protection are to be shown on the plan and profile views.

G. Rights of way.

1. Storm drain rights of way are required for all publicly improved systems which do not lie within dedicated public rights of way.

2. At system entrances and outlets, including all transitions to meet existing conditions, the rights of way shall be of sufficient width to accommodate maintenance equipment. The easement width at the proposed channel construction shall include a 10 foot wide area for equipment along one side and a 2 foot wide area to faciliate maintenance on the other side both extending beyond the channel construction limits. The easement shall extend 10 feet in length beyond the limits of the proposed channel construction (including transitions to existing).

3. The minimum rights of way widths for pipe are as follows:

Pipe Size	R/W Width
15" - 24"	20'
27" - 48"	25'
54" - 72"	30'

Minimum widths of storm drain rights of way, as shown above, may not be adequate for installations that are deeper than normal. In such cases, the guideline for determining minimum rights of way widths is as follows:

a. Trench width equals outside pipe diameter plus 18 inches on both sides of pipe or two times the outside diameter of the pipe, whichever is narrower.

b. Trench walls may be vertical up to 5 feet.

c. Slopes equal to the angle of repose of the soil, but not steeper than 1 to 1, from 5 foot vertical trench wall to existing ground.

d. Additional width of 2 feet on one side and 10 feet on the other side to accommodate equipment.

NOTE: The above guideline is only to be used for the purpose of determining minimum rights of way widths for storm drain installations deeper than five feet. Applicable OSHA rules and regulations will dictate the actual trench excavation limits and shoring methods to be employed by the storm drain contractors.

4. The storm drain will be placed within the rights of way as set forth above with a 5 foot minimum clearance between the outside of the pipe/structure and the right of way line.

5. Every effort will be made to keep storm drain rights of way off lots along the road frontage. No storm drain rights of way which are parallel to the roadway are allowed beyond the Public Improvement Easement.

LIST OF ATTACHMENTS

1. Transmittal Form
2. Design Check List
3. Percent Impervious vs. Zoning Table
4. Rainfall Intensity Table
5. Pipe Load Charts
6. Pipe and Inlet Computation Forms
7. General Notes for Storm Drain Construction

MONTGOMERY COUNTY, MARYLAND
DEPARTMENT OF TRANSPORTATION
DIVISION OF TRANSPORTATION ENGINEERING

TRANSMITTAL FORM

To: Subdivision Development Section
Room 901, Executive Office Bldg.
101 Monroe Street
Rockville, Maryland 20850

_____
Date

From: _____
Engineer's Name

_____
Address Zip Code

_____
Telephone Number

Re: _____
Subdivision

We hereby submit _____
Identification of Plans

_____

_____

_____

_____

For Tentative ( ) Final ( ) Approval.

We request that a _____
Grading, Paving, Storm Drainage, Stabilization

permit be prepared for issuance for _____

_____

_____

_____

_____

By: _____

****

Date Received _____ By: _____

March 1983

March 1983

'ONTGOMERY COUNTY DEPARTMENT OF TRANSPORTATION
'IVISION OF TRANSPORTATION ENGINEERING

heck List for Paving and/or Storm Drainage Plans

treet(s) _____ Subdivision _____

. Plans for Approval - Contents of Package Submittal

(a) ( ) Montgomery County Department of Transportation standard transmittal form listing streets and limits of work on each street by stationing or lot corners.
(b) ( ) Tracing of proposed paving and/or storm drainage plan.
(c) ( ) One (1) print of each sheet of proposed plans.
(d) ( ) One (1) print of certified drainage study with computations. Drainage study must agree with plans as submitted and not be based on a previous preliminary plan that has been revised.
(e) ( ) One (1) print of approved preliminary subdivision plan.
(f) ( ) One (1) print of each record plat showing recording data. If plats have not been recorded, submit one (1) print of each proposed plat and indicate approximate date plats will be recorded.
(g) ( ) One (1) print of approved grade establishment(s) for each street within the requested limits of approval.
(h) ( ) One (1) copy of proposed document to be recorded for each storm drain easement that is not shown on a record plat.
(i) ( ) Engineers estimate of quantities at final approval stage.

. Plans - General

(a) ( ) Scale 1"=50'
(b) ( ) North arrow
(c) ( ) General notes for paving and/or storm drainage
(d) ( ) Typical paving section(s)
(e) ( ) Name and address of firm or individual who prepared plans.

. Plans - Existing Features

(a) ( ) Curbs and gutters, paving and sidewalks.
(b) ( ) Storm drainage
(c) ( ) Water and sewer
(d) ( ) Underground utilities
(e) ( ) Utility poles
(f) ( ) Streams or drainage ways
(g) ( ) Buildings or other permanent structures

ONTGOMERY COUNTY DEPARTMENT OF TRANSPORTATION
IVISION OF TRANSPORTATING ENGINEERING

heck List for Paving and/or Storm Drainage Plans

. Plans - Proposed Work (Paving)

(a) ( ) All proposed work shown clearly.
(b) ( ) Proper tie in or transition to existing features.
(c) ( ) Details of all special or non-standard work. (Refer to Montgomery County, WSSC or Md. SHA standards for standard work).
(d) ( ) Show proposed water and sewer.
(e) ( ) Handicap ramps at all street intersections and intersection type driveways for curb and gutter streets.
(f) ( ) Where shoulder and ditch work or pavement widening along existing roads are required by PIA, show sufficient plans and typical sections to accomplish this work. Any necessary utility relocation should also be shown.
(g) ( ) Mid-block crosswalks

Plans - Proposed Work (Storm Drainage)

(a) ( ) Pipe schedule, showing lengths, pipe sizes, materials and class or gauge.
(b) ( ) Structure schedule, showing structure types, elevations, dimensions, with proper reference to Montgomery County, WSSC and Md. SHA standards.
(c) ( ) Where precast inlets are proposed, show manufacturer's name and structure type for each structure.
(d) ( ) Structure numbers on plan to match structure schedule, pipe profiles and drainage study.
(e) ( ) Required storm drain easements, whether shown on record plat or to be recorded by separate instrument.
(f) ( ) Outfall treatment, with existing topography at and 100' below outfall.
(g) ( ) Details of special structures.

. Storm Drain Profiles

(a) ( ) Horizontal scale 1" = 50'
(b) ( ) Vertical scale 1" = 5'
(c) ( ) Structure numbers to match plan, structure schedule and drainage study.
(d) ( ) Pipe lengths to be shown by stationing at each structure.
(e) ( ) Pipe size, material and class or gauge for each run.
(f) ( ) Quantity of flow, slope and velocity for each run. When pipe will not flow full because actual slope is steeper than required, actual partial flow velocity must be shown.
(g) ( ) For pipes 27" diameter and larger, show hydraulic gradient.
(h) ( ) Outfall treatment - show class and length of riprap, filter cloth required and cross section of outfall channel.

IONTGOMERY COUNTY DEPARTMENT OF TRANSPORTATION
'IVISION OF TRANSPORTATION ENGINEERING

heck List for Paving and/or Storm Drainage Plans

Approvals Required

(a) ( ) Impression seal or replica of seal and signature of Professional Engineer or Professional Land Surveyor who is responsible for plans. Unsigned plans will not be reviewed.
(b) ( ) Work in public space permit from WSSC prior to final approval of paving and/or storm drainage plans.
(c) ( ) WSSC approval if storm drainage is to be constructed prior to installation of water and sewer.
(d) ( ) Maryland State Highway Administration approval and/or permit where proposed street connects to existing State highway.
(e) ( ) Maryland Water Resources Administration approval where applicable.

All items that are applicable to the plans being submitted for review should be checked (X). Items that do not apply should be indicated (N/A). Items that do apply but are not checked must be explained. Attach a separate sheet of paper, if necessary.

Reference Files

(a) ( ) Approved Profile File No. _____.
(b) ( ) Preliminary Plan File No. 1-_____.
(c) ( ) Record Plat No. 2-_____.

_____ _____
ite Name of Firm

_____
Signature of Responsible Person

_____
Type or Print Name

TABLE 1

PERCENT IMPERVIOUS AS A FUNCTION OF ZONING

Zoning Category	Code	Min Lot Area Per Dwelling (Sq. Ft.)	Lot/Tract Max. Building Coverage (%)	Required Minimum Green Area (%)	Avg. Percent Imperviousness
Residential					
One-Family Estate	RE-1	40,000	15	-	12
(Cluster)	RE-1C	15,000	15	-	12
One-Family	R-200	20,000	25	-	25
(Density-Controlled)	R-200DC	15,000	25	-	25
(Cluster)	R-200C	10,000	25	-	25
One-Family	R-150	15,000	25	-	30
(Density-Controlled)	R-150DC	10,500	30	-	30
(Cluster)	R-150C	8,000	25	-	30
One-Family	R-90	9,000	30	-	35
(Density-Controlled)	R-90DC	8,000	30	-	35
(Cluster)	R-90C	5,000	30	-	35
One-Family	R-60	6,000	35	-	41
(Cluster)	R-60C	4,000	35	-	41
One-Family Semi-Detached & Two-Family	R-40	4,000	40	-	47
One-Family Mobile Home	RMH-200	20,000	25	-	25
(Density-controlled)	RMH-200DC	15,000	25	-	25
(Cluster)	RMH-200C	10,000	25	-	25
Fouplex	R-4plex	-	35	50	50
Townhouse	R-T6.0	-	35	50	35
Townhouse	R-T8.0	-	35	50	40
Townhouse	R-T10.0	-	35	50	45
Townhouse	R-T12.5	-	35	50	50
Multiple-Family-Low Density	R-30	3,000	22	53	37
Multiple-Family-Medium Density	R-20	2,000	24	47	42
Multiple-Family-High Density	R-10	1,000	20	45	52
Multiple-Family-High Rise	R-H	1,400 to 1,000	20	50	47
Mobile Home	R-MH	-	-	30	42

6/20/88

Zoning Category	Code	Min Lot Area Per Dwelling (Sq. Ft.)	Lot/Tract Max. Building Coverage (%)	Required Minimum Green Area (%)	Avg. Percent Imperviousness
Commercial					
Transitional	C-T	-	35-45b	10	95
Office Building, Moderate Intensity	O-M	-	60/75	10/15	95
Office Building	C-O	-	100	-	100
Office Park	C-P	-	20/25	40	60
Convenience	C-1	-	-	10	95
General	C-2	-	-	10	95
Highway	C-3	-	-	10	95
Limited	C-4	-	25	10	95
Hotel-Motel	H-M	-	25	45	55
Country Inn	Cty Inn	-	10	50	50
Industrial	I-4	-	-	20	80
Light Industrial	I-1	-	-	10/15	90
Heavy Industrial	I-2	-	-	10	90
Industrial Park	I-3	-	25	5% + setbacks	70
Central Business District	CBD	-	50/75	-	100
Planned Development					
	PD-2	c	-	30	25
	PD-3	c	-	30	37
	PD-4	c	-	40	39
	PD-5	c	-	40	41
	PD-7	c	-	40	45
	PD-9	c	-	40	49
	PD-11	c	-	50	50
	PD-13	c	-	50	50
	PD-15	c	-	50	50
	PD-18	c	-	50	50
	PD-22	c	-	50	50
	PD-25	c	-	50	50
	PD-28	c	-	50	50
	PD-35	c	-	50	50
	PD-44	c	-	50	50
Town Sector	T-S	-	-	10	*
Planned Neighborhood Zone	P-N-Z	-	-	-	*
Planned Retirement Comm.	P-R-C	-	15	65	35
Transit Station-Resident	TS-R	-	35	d	75
Transit Station- Mixed	TS-M	-	60	d	90

a. See zoning text 59-C-2.411
b. See zoning text 59-C-4.303
c. See zoning text 59-C-7.13
d. See zoning text 59-C-8.44

* Based on approved zoning site plan

1. Transferable development rights not included, revised fee will be based on density granted.
2. Increased density for MPDU'S does not change fee for base zone.

Source: Montgomery County Department of Environmental Protection

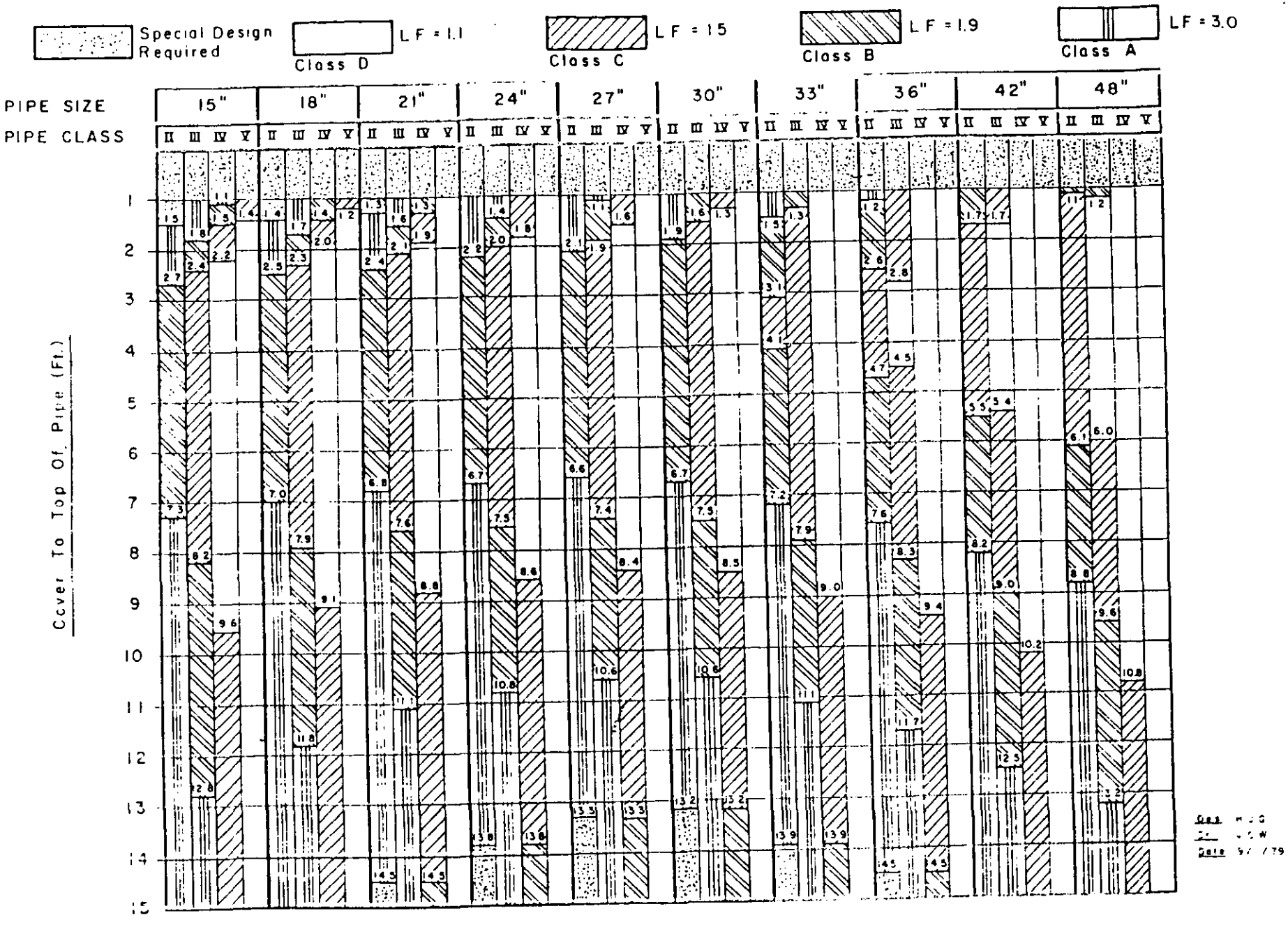
6/20/88

MONTGOMERY COUNTY, MARYLAND RAINFALL INTENSITY DATA (Inches/Hour)

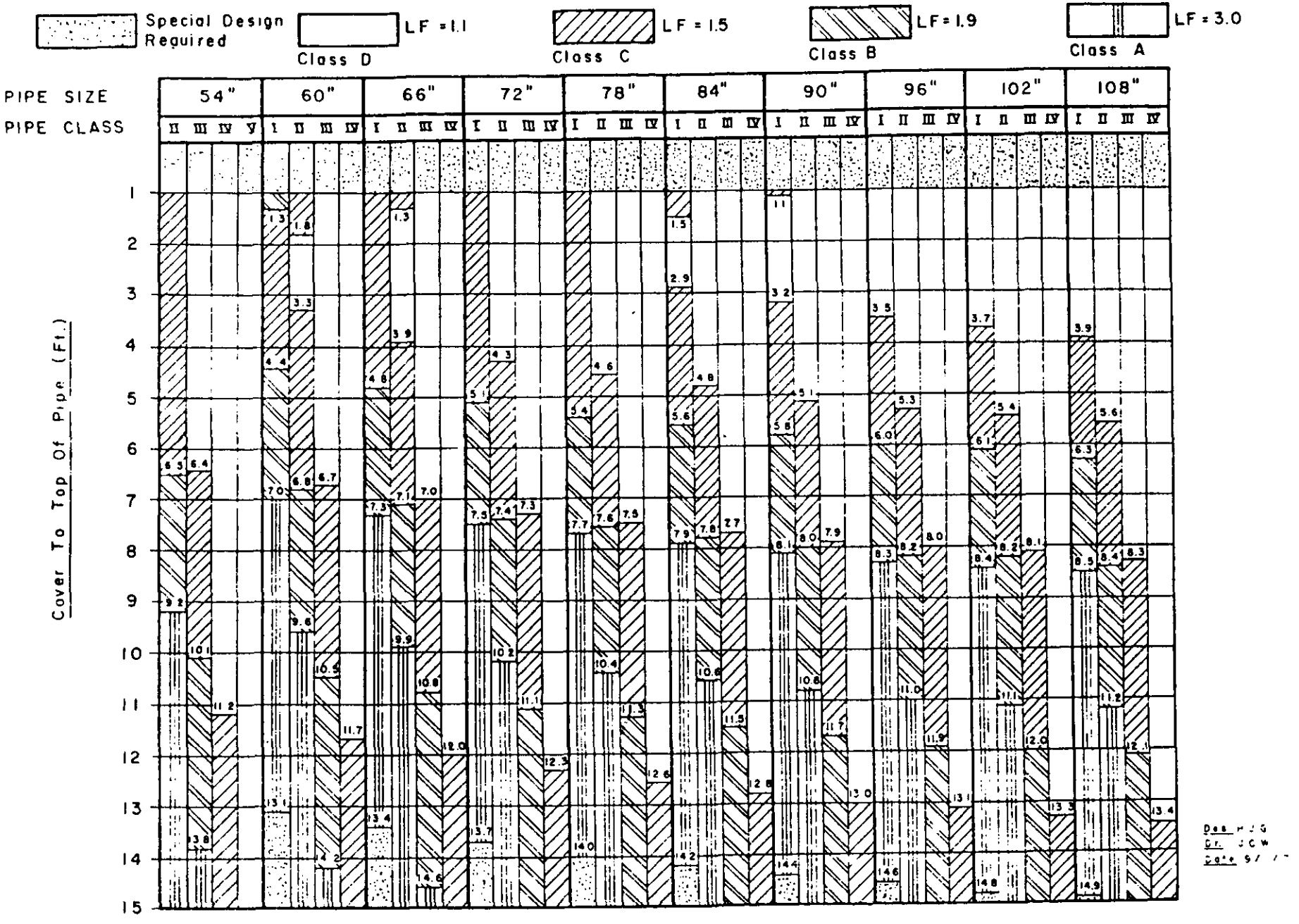
DURATION (MINUTES)	FREQUENCY INTERVAL 2 YR.	5 YR.	10 YR.	25 YR.	50 YR.	100 YR
5	5.52	6.39	7.07	8.05	8.89	9.60
6	5.21	6.10	6.78	7.76	8.57	9.30
7	4.94	5.83	6.52	7.49	8.28	9.01
8	4.70	5.59	6.28	7.23	8.01	8.74
9	4.48	5.37	6.06	6.99	7.75	8.48
10	4.28	5.16	5.85	6.77	7.51	8.24
11	4.11	4.98	5.66	6.56	7.28	8.01
12	3.95	4.80	5.48	6.37	7.07	7.79
13	3.80	4.64	5.31	6.18	6.87	7.58
14	3.67	4.50	5.15	6.01	6.68	7.39
15	3.54	4.36	5.00	5.84	6.50	7.20
16	3.43	4.23	4.86	5.68	6.33	7.02
17	3.32	4.11	4.73	5.54	6.16	6.85
18	3.22	3.99	4.60	5.40	6.01	6.68
19	3.13	3.89	4.48	5.26	5.86	6.52
20	3.04	3.78	4.37	5.13	5.72	6.37
21	2.96	3.69	4.26	5.01	5.59	6.23
22	2.88	3.60	4.16	4.90	5.46	6.09
23	2.81	3.51	4.06	4.79	5.34	5.96
24	2.74	3.43	3.97	4.68	5.22	5.83
25	2.67	3.36	3.88	4.58	5.11	5.71
26	2.61	3.28	3.79	4.48	5.01	5.59
27	2.55	3.21	3.71	4.39	4.90	5.48
28	2.50	3.15	3.64	4.30	4.80	5.37
29	2.45	3.08	3.56	4.21	4.71	5.26
30	2.40	3.02	3.49	4.13	4.62	5.16
31	2.35	2.96	3.42	4.05	4.53	5.06
32	2.30	2.91	3.36	3.97	4.45	4.97
33	2.26	2.85	3.29	3.90	4.37	4.87
34	2.22	2.80	3.23	3.83	4.29	4.78
35	2.18	2.75	3.17	3.76	4.21	4.70
36	2.14	2.71	3.12	3.70	4.14	4.62
37	2.10	2.66	3.06	3.63	4.07	4.54
38	2.06	2.62	3.01	3.57	4.00	4.46
39	2.03	2.57	2.96	3.51	3.93	4.38
40	2.00	2.53	2.91	3.45	3.87	4.31
41	1.97	2.49	2.86	3.40	3.81	4.24
42	1.94	2.45	2.82	3.34	3.75	4.17
43	1.91	2.42	2.77	3.29	3.69	4.10
44	1.88	2.38	2.73	3.24	3.63	4.04
45	1.85	2.35	2.69	3.19	3.58	3.97
46	1.82	2.31	2.65	3.14	3.52	3.91
47	1.80	2.28	2.61	3.10	3.47	3.85
48	1.77	2.25	2.57	3.05	3.42	3.80
49	1.75	2.22	2.54	3.01	3.37	3.74
50	1.72	2.19	2.50	2.97	3.33	3.69
51	1.70	2.16	2.47	2.92	3.28	3.63
52	1.68	2.13	2.43	2.88	3.24	3.58
53	1.66	2.10	2.40	2.84	3.19	3.53
54	1.64	2.08	2.37	2.81	3.15	3.48
55	1.62	2.05	2.34	2.77	3.11	3.43
56	1.60	2.03	2.31	2.73	3.07	3.38
57	1.58	2.00	2.28	2.70	3.03	3.34
58	1.56	1.98	2.25	2.66	2.99	3.29
59	1.54	1.96	2.22	2.63	2.95	3.25
60	1.52	1.93	2.19	2.60	2.92	3.21

6/20/88

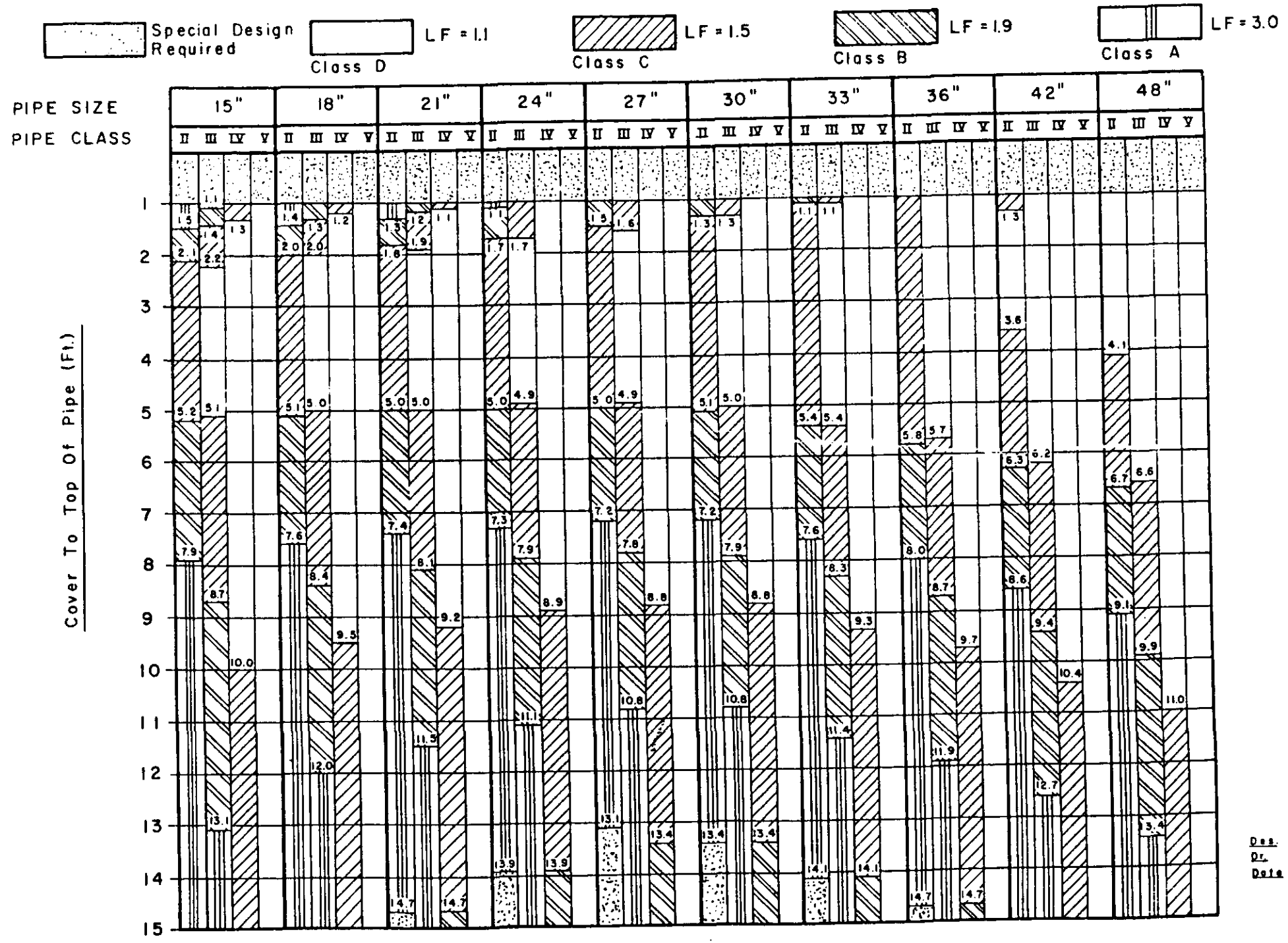
RCP SUPPORTING STREN HS – H20 TRAFFIC LOAD
TRENCH CONDITION



SUPPORTING STR GTHS – H20 TRAFFIC LOAD
TRENCH CONDITION

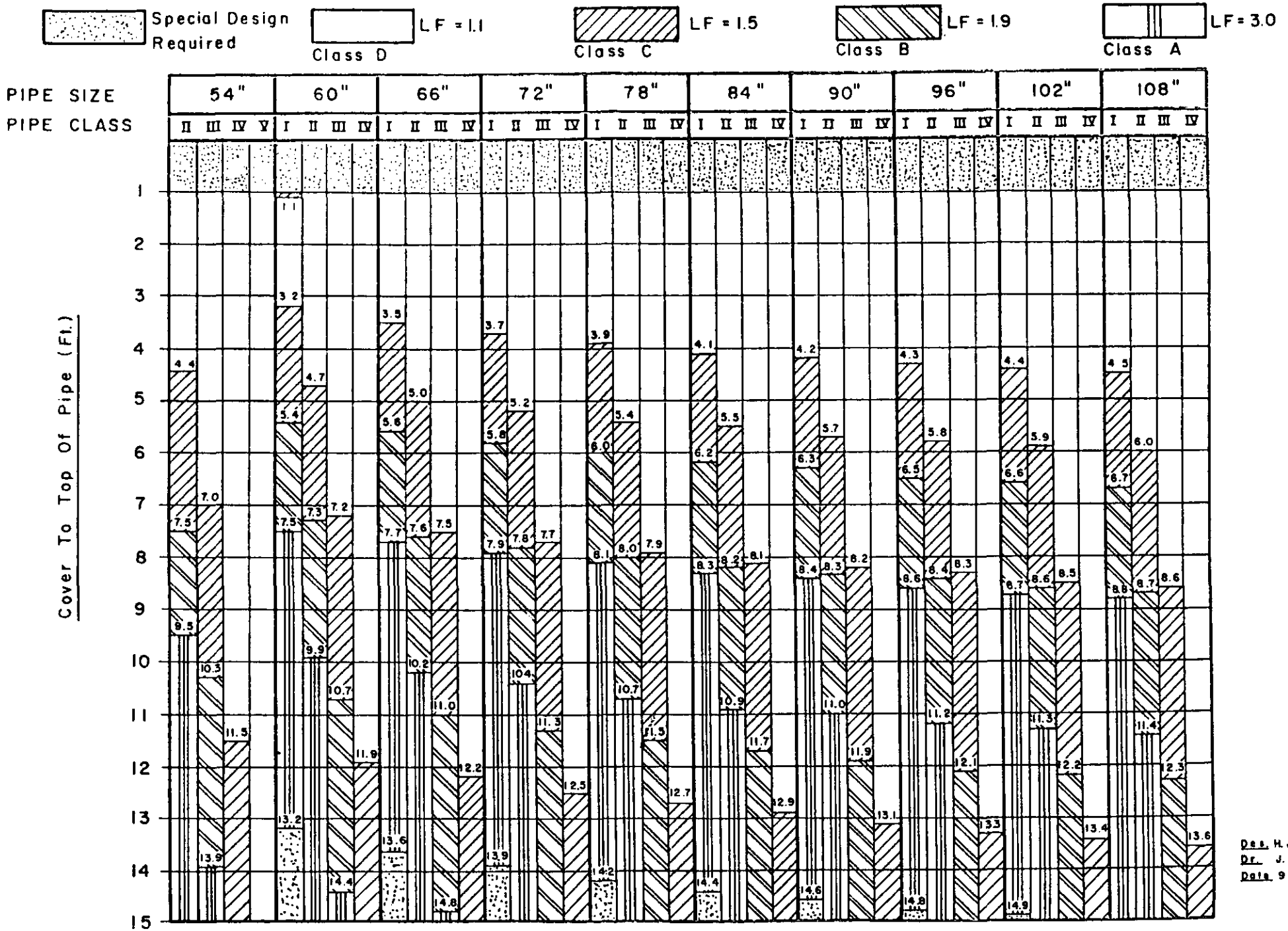


RCP SUPPORTING STRENGTHS — H 10 TRAFFIC LOAD
TRENCH CONDITION



Des. H.J.G
Dr. J.C.W
Date 9/1/

RCP SUPPORTING STRENG. .S — H 10 TRAFFIC LOAD
TRENCH CONDITION

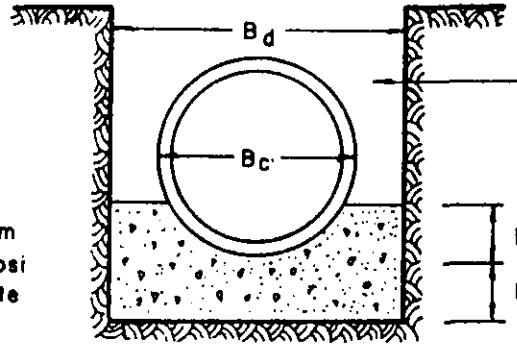


Des. H.J.G.
Dr. J.C.W.
Date 9/1/75

TRENCH BEDDING CONDITIONS

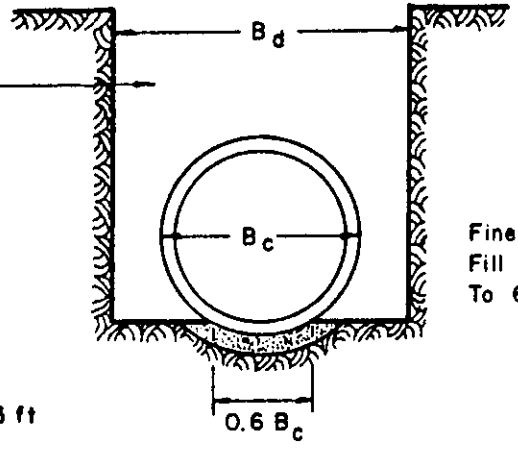
CLASS A

Concrete Cradle
LOAD FACTOR = 3.0



CLASS B

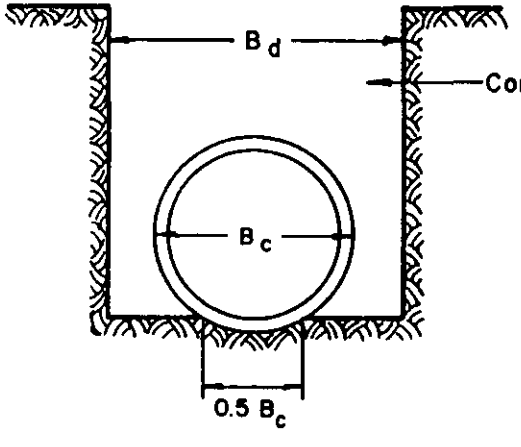
Shaped Subgrade
With Granular Foundation
Load Factor = 1.9



Note: $B_d = 2B_c$ or $B_c + 3$ ft
Whichever is narrower

CLASS C

Shaped Subgrade
Load Factor = 1.5



CLASS D

Flat Subgrade
Load Factor = 1.1

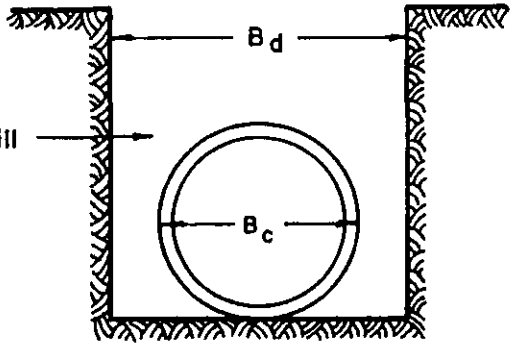


CHART BASIS

Supporting Strength: Based on the D-load to produce a 0.01" Crack in reinforced concrete pipe conforming to ASTM designation: C76.

Dead (Earth) Load: Based on the Marston Formula.

$$W_D = C_d \, w \, B_d^2$$

W_D = Backfill load per linear foot of pipe.
C_d = Dimensionless load coefficient relating soil properties, width of trench and fill height ($k\mu' = 0.130$).
w = Unit weight of backfill material, 120 lb / ft.^{3}
B_d = Width of the trench at the top of the pipe (ft.) by MSHA Specifications, 1968. ($B_d = 2B_c$ or $B_c + 3$ ft. whichever is narrower)

Live (Traffic) Load: Based on the area under the pressure distribution diagram (PCA).

$$W_L = B_c \left(\frac{P_1 - P_2}{2} + P_2 \right)$$

W_L = Traffic load per linear foot of pipe.
B_c = Width of the loaded area, limited to the outside diameter of the pipe.
P_1 = Primary or maximum soil pressure on loaded area.
P_2 = Secondary or minimum soil pressure on loaded area.

Impact Factor: Due to advances in pneumatic tires and vehicle suspension systems, impact effects may be safely neglected in most cases.

Factor of Safety: A factor of 1.0 based on the 0.01" crack was used.

MCDOT JULY, 1983

PIPE COMPUTATIONS

PIPE		AREA		R=C	AR	ΣAR	TC	I	Q	PIPE SIZE	MIN SLOPE	V	PIPE LENGTH	TIME IN PIPE	REMARKS
FROM	TO	INCR AREA	TOTAL AREA				MIN	IN/HR	CFS	INCHES	%	FPS	FEET	MIN	

(FIRM NAME)	PIPE COMPUTATIONS	COMPUTED	DATE
		CHECKED	
	(PROJECT NAME)	SHEET NO.	PROJECT NO.

MCDOT JULY, 1983

INLET NO.	INCR. AREA ac.	TOTAL AREA ac.	C=R	AR	ΣAR	T.C. min.	I in./hr.	BASE FLOW cfs	OVER FLOW cfs	TOTAL INFLOW cfs	FLOW INTER. cfs	FLOW BYPASS		INLET LENGTH		STREET SLOPE %	CROSS SLOPE ft./ft.	CURB HEIGHT ft.	THROAT DEPRESS. in.	GUTTER FLOW	
												cfs	TO	COMP. ft.	ACTUAL ft.					DEPTH ft.	SPREAD ft.

(FIRM NAME)	INLET COMPUTATIONS	COMPUTED	DATE
		CHECKED	
	(PROJECT NAME)	SHEET NO.	PROJECT NO.

MOMENTUM AT NO.

MOMENTUM AT NO.

MOMENTUM AT NO.

MOMENTUM AT NO.

MOMENTUM AT NO.

MOMENTUM AT NO.

(FIRM NAME)	STRUCTURE HEADLOSS	COMPUTED	DATE
		CHECKED	
	(PROJECT NAME)	SHEET NO.	PROJECT NO.

GENERAL NOTES FOR STORM DRAIN CONSTRUCTION

1) All storm drains shall be constructed in accordance with the latest Edition of the Standard Specifications of the Maryland State Highway Administration and Montgomery County.

2) Type of structure refers to the latest Design Standards of MCDOT, Standard Details of the Washington Suburban Sanitary Commission and Book of Standards of the Maryland State Highway Administration, unless otherwise noted.

3) Where the drop on the main line through a structure can be accommodated by an invert slope of 1.5:1 or flatter, a rounded channel lined with sewer brick on edge shall be built to the crown of the pipes.

4) Information concerning underground utilities was obtained from available records, but the Contractor must determine the exact location and elevation of the utilities by digging test pits by hand at all utility crossings, well in advance of trenching. If clearances are less than specified on this plan or less than 12" when not specified, contact the Montgomery County Department of Transportation's Inspector and the appropriate utility owner before proceeding with construction.

5) Where any part of the storm drain system is located in a fill section, provide select fill material compacted to 95% AASHTO T-99 density from approved subgrade to the structure bottom slabs and/or the pipe bedding.

6) All storm drain pipes shall be installed with class "C" bedding as shown on Montgomery County Department of Transportation, "RCP Supporting Strength" loading charts.

7) Call "Miss Utility" at 1-800-257-777748 hours prior to beginning excavation to determine the location of existing utilities.

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