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DESIGN MANUAL

# STORM DRAINAGE DESIGN

**Baltimore County**
**Department of Public Works Design Manual**

# Storm Water Design Standards

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**Design Manual**

# Storm Drainage Design Standards

## I. General Information

### A. Existing Laws

Baltimore County operates under the Riparian principle of drainage and runoff as defined in the Annotated Code of Maryland. Under this doctrine, lands contiguous to watercourses ("riparian lands") have claim to stream waters solely based upon location. Rights to use of this water are incidental to ownership of the adjacent land, as well as location within the watershed of the body of water to which it is contiguous. The owner of riparian land is entitled to the water undiminished in quality and unpolluted, subject to usage by other riparian landowners for household and farm animal use. Non-use of these rights does not result in loss of the rights.

For drainage purposes, similar Riparian principles apply. Flowing water may not be diverted, obstructed or changed in quantity to the detriment of others or their property.

Design of storm drainage facilities shall be done in accordance with all applicable regulations of the County, State and Federal governments and with accepted engineering practices.

These Design Standards are intended to be compatible with all applicable requirements of the Natural Resources Conservation Service and the Maryland Department of the Environment (MDE), including COMAR 26.17.02, Stormwater Management, Authority, Environment Article §§ 4-201 and 4-203. MDE requirements shall take precedence in the event of a conflict between County and MDE regulations.

These Design Standards shall be used in conjunction with regulations promulgated by the Baltimore County Department of Permits and Development Management and the Baltimore County Department of Environmental Protection and Resource Management.

Developers and design professionals working on projects within this County shall be aware of all applicable laws, ordinances and policies applicable to their project during design and construction phases.

### B. Topography & Land Use / Zoning

Topographic and land use maps for the County are available from Geographic Information Systems in the Office of Information Technology (410-887-2233) for a nominal charge. Maps are also available in electronic format to qualified buyers, subject to a usage agreement. Zoning maps are available for reference or copies from the Zoning counter (410-887-3391) within the Department of Permits and Development Management.

## C. Drainage Problems Not Covered Herein

The Engineer should contact the Storm Drainage Section at 410-887-3711 before proceeding with design on capital projects when problems are encountered that are not addressed by this Section. In all cases of non-standard designs, the Engineer will be expected to provide supporting computations for their designs using established methods as presented within standard reference books (or their equivalents) listed in the References portion of this section.

## D. Authority and Applicability

The Storm Drainage Section of the Baltimore County ***Design Manual*** is intended to guide the design of County-maintained storm drainage facilities. Its suitability for other purposes is unintentional and incidental to that purpose.

This Section shall **NOT** govern the development of public or private storm water management facilities. This Section does **NOT** address the design of sediment or erosion control measures for construction. Storm water management and erosion and sediment control functions are governed by separate and independent sets of Standards promulgated by the State of Maryland's Department of the Environment (MDE), the County, State and Federal offices of NRCS, and the County's Department of Environmental Protection and Resource Management (DEPRM). The intent of this Section is to be in compliance with, and complimentary to, all applicable Standards of these agencies.

Inquiries regarding the subjects of storm water management and erosion and sediment control should be directed as follows:

- Existing erosion control facilities:

  DEPRM, Inspection & Enforcement – (410) 887- 3226

- Development of plans for proposed storm water management facility:

  DEPRM, Stormwater Engineering – (410) 887-3768

- Existing storm water management facilities:

  DEPRM, Stormwater Engineering – (410) 887-3768

Inquiries regarding design of storm drainage for private property under development should be directed to the County's Department of Permits and Development Management, Bureau of Development Plans Review, at (410) 887-3751.

## E. Easements and Right-of-Way Requirements

The County requires that all public storm drainage facilities that will be maintained by the County, including natural channels and improved surface or subsurface facilities, be located within either a County-owned **fee simple right-of-way** or a **drainage and utility easement**. As part of the subdivision process, floodplain reservations or easements based upon the 100-year riverine flood level shall be established and dedicated to the County for purposes of maintaining flood-tolerant land usage in these areas.

A minimum right-of-way or easement width of 15' is required for storm drain construction in order to facilitate maintenance of the installed facility. This may be reduced appropriately for individual circumstances with written approval of the reviewing agency.

The status of right-of-way for existing County drainage facilities should be checked with the Department of Permits and Development Management, Bureau of Land Acquisition, (410) 887-3280 before these areas are entered or disturbed for maintenance or improvement.

### F. Chlorinated or Industrial Water Discharges

Chlorinated water used for private commercial or industrial processes or water used for cooling shall NOT be allowed to flow overland to a stream, to the street or be piped directly to any part of a storm drain system. This water shall be considered wastewater and shall be delivered to a public sanitary sewer, as permitted and if available, or it shall be treated onsite.

### G. Groundwater and Sump Pump Discharges

Private drains from roof leaders, sump pumps, basement or subgrade drains may be connected directly to an available adjacent storm drain system at the expense of the property owner, subject to stormwater management regulations, as follows:

- An On-Site permit to perform the connection and work within the public easement shall be obtained by a plumber qualified for public utility work before any work is done. An additional permit is required for the portion of the connection on private property.

- For maintenance purposes, a vertical cleanout similar to that used for sanitary house connections, made of metal pipe, or having a metal cap for detection, and of suitable size relative to the drain diameter shall be installed on the drain outside of but within 2 feet of the easement / property line. Public maintenance of the drain will be limited to the pipe between the cleanout and the County's drain, with the property owner responsible for maintenance of the remainder of the drain installed on his property. The cleanout cap shall be indelibly marked “D” or “SD” using paint or equivalent permanent markings to differentiate the drain cleanout from the sanitary house connection cleanout.

- Connection of private drains having a diameter greater than 30 percent of the public pipe diameter OR having a diameter of 12 inches or greater shall require a Utility Agreement from PADM Development Plans Review.

- A backwater valve (provided by the property owner) may be required as directed by the County.

Contact the Bureau of Code Inspection, PADM regarding questions involving permitting requirements at 410-887-3620.

**Private drains** including roof drains, of 4" maximum diameter may be directed to an existing street and installed through a curb opening to the gutter in accordance with the plumbing code. However, in cases where new roads are being constructed or where curb and gutter are being installed, the Engineer shall make provision for underground collection of sump pump and other groundwater discharges rather than allowing discharges to enter the street directly. The 4" maximum normal curb openings shall be retained as overflows in case of freezing or blockage of the below-ground system. This collection system, where supplemental to the normal storm drainage system, shall be of adequate (8" minimum) size, have adequate access (via metal-capped cleanouts or manholes) for maintenance, and connection to a public drain system. Clean-outs for this supplemental collection system shall be clearly marked as a drain clean-out to avoid confusion with sanitary clean-outs. Where constructed, the sump pump collection system shall be documented as part of an as-built drawing to be placed in permanent records.

Discharges from private drains to the surface at other locations on private property shall occur at least 8 feet (for rain gutter downspouts; 10 feet for sump pumps and other discharges) from all property lines and shall not cause property damage, including erosion of soil (or deposition of sediment) upon other properties.

**Groundwater** encountered during excavation may be collected and conveyed with a private drain to a suitable outfall. Subsurface groundwater encountered after construction of a drain is complete may be connected at the property owner's expense, subject to these regulations and to requirements of the Baltimore County Plumbing Code. Note that surface seeps and springs are a regulated natural resource requiring protection during construction.

### H. Use of Infiltration Devices within Public Road Rights-of-Way

Devices designed to infiltrate water into underlying soils shall be used within public road right-of-way only with the approval of the Director of Public Works.

Designs incorporating infiltration within public road right-of-way shall be considered only if they will not in any way compromise either the safety of the road or the ability of the road to withstand design loads up to and including HS-27 loads occurring with Public Safety and other vehicles, including loaded Highway Maintenance and Solid Waste vehicles.

- Water from off-road areas shall NOT be directed to infiltration devices located within public road rights-of-way.
- The road base shall be protected to prevent infiltration into this stone. The design for this protection shall be approved by the Bureau of Engineering and Construction.
- An overflow structure and pipe of sufficient size to carry all flow reaching infiltration devices within or adjacent to road rights-of-way shall be provided in order to control flows greater than the design storm for the device and to allow for reduced infiltration rates over time. The outfall for this overflow shall be directed to storm drains, to roadside ditches that are adequately stabilized for the maximum discharges or to a curb and gutter section with adequate storm drains. Underground connection of the overflow to a drain system is preferred to prevent icing problems in the streets.

- Infiltration devices and appurtenances shall not interfere with utilities that are typically placed within or adjacent to public road rights-of-way.

**Bottomless infiltration chambers** shall not be used in County-maintained areas (such as parking lots) where relatively large ground settlement is unacceptable. These structures may be used for storm drainage infiltration in other areas only after a report addressing potential for settlement and failure is accepted by the County's Bureau of Engineering and Construction. This analysis shall be based upon:

- Assumed fully saturated soils, and
- Twice the expected dead and live loads resulting from proposed use of the area above the infiltration chamber.

## II. Hydrology

### A. Methods Criteria

1. Subject to requirements of other agencies, the **Rational Method** shall be applicable for storm drain system, channel, ditch and minor culvert design where the contributing drainage area is less than 100 acres in size, except as noted below. Each contributing sub-area must be uniform in land use and time of concentration (Tc). The Rational Method shall NOT be used for determination of discharges associated with floodplain determination without prior written approval of all County and State reviewing agencies.

2. Where desired by the Design Engineer, required by NRCS or other agencies, required for routing, where sub-areas have different runoff characteristics, or where drainage areas exceed limits for use of the Rational Method, the **NRCS TR-55** tabular method or the **NRCS TR-20** method shall be used for determining runoff, subject to the limitations of those methods.

3. Where **gage data** is available, hydrologic models should be checked against recorded gage data for accuracy.

4. Use of **GIS-based methods** for larger watershed studies will be considered on a case-by-case basis. All such studies shall be subject to approval by the Baltimore County Bureau of Engineering and Construction.

5. Hydrology will normally be reviewed based upon use of hand computations for the Rational Method and TR-55 or upon use of readily available computer programs that have been placed in the public domain such as TR-20. Use of computer programs that are NOT in the public domain and therefore not readily accessible to County employees is allowed only after evaluation and written approval by the Chief of Design, BCBEC.

   Acceptance of a program for use by Baltimore County does not imply acceptance by MDE and other agencies. Acceptance by other reviewing agencies should be obtained early in the project's design and verification of approval by other interested agencies will be required prior to the County's approval for use of the program.

### B. Drainage Area Maps

1. Drainage area maps shall be developed from the latest available topography for the area of study. Identify the source of the map and data shown. The map shall show all major storm drain systems and culverts and reference County and/or State drawing numbers for these drain systems. Each drainage area on the map shall have the following information clearly displayed:
   - Drainage area label
   - Hydrologic soil group
   - Zoning (Land use if permanent – cemeteries, schools, public parks, etc.)
   - Area
   - Percent Impervious

- RCN / ”C” Factor
- Tc Path and segments thereof
- Soil Names (Except where this would make the map too complex).

If TR-20 is used, show location of all TR-20 cross-sections and TR-20 structures.

2. Scale of the map shall be relative to the scale of the project, with 200 scale preferred for most purposes. Major watersheds will require use of 500 scale. Smaller scale mapping may be used as warranted.

3. All drainage area ridgelines shall be field verified, with special attention paid to the impacts of storm drain systems and culverts upon the delineation of sub-areas. Sub-areas shall be as uniform as possible in terms of land use, shape, size, and Time of Concentration. In some cases, natural boundaries may require modification to exclude non-contributing areas.

4. Sub-areas shall be properly labeled to coordinate with computations. Use letters or letter-number combinations, moving alphabetically from upstream to downstream.

5. Time of concentration paths shall be shown and segments labeled.

6. Drainage Area Maps taken from existing record drawings shall be field-verified.

## C. Rational Method

The Rational method for determining discharges was originally introduced in the late 1800’s. It remains the simplest approach for designs involving small storm drain systems, culverts and ditches. The following assumptions apply:

- With an error of about 1 percent, flow rate in acre - inches per hour is equal to flow rate in cubic feet per second.

- The entire drainage area will not contribute to the discharge until the time of concentration (Tc) has elapsed. For large drainage areas, the Tc can be so large that constant rainfall periods for such long periods cannot occur, causing a condition where shorter more intense storms will produce larger peak discharges. The area must therefore be small enough that the entire area contributes in a uniform manner.

- The frequency of peak discharge is the same as that of the rainfall intensity for a given Tc. Rainfall frequency, antecedent moisture condition and characteristics of the watershed drainage govern frequency of peak discharges. Where areas are small and predominantly impervious, rainfall frequency controls. Larger, less impervious areas are controlled by the other factors.

- The C-factor is independent of rainfall intensity or volume. This assumption is most applicable to impervious areas. A coefficient must therefore be selected that is as suitable as possible for storm, soil and land use conditions.

- The peak rate of runoff is sufficient for design, with no routing required.

The rational method is usually stated as $Q = CiA$ , where:

***Q*** is the maximum rate of runoff (in cubic feet per second),

***C*** is a runoff coefficient representing a runoff to rainfall ratio,

***i*** is an average rainfall intensity for a duration equal to Tc for a selected return period (expressed in inches per hour),

***A*** is the drainage area to the design point (in acres).

1. **Runoff Coefficient *C*** – represents the cumulative effects of many drainage parameters, including, but certainly not limited to soil groups, land use / zoning classification and average slopes, although these are the factors that are used in determining C factors. This factor shall be determined as a weighted average based upon sub-areas and using C-factors from charts included in this section. Soil types shall be as shown in the latest Baltimore County Soil Survey, with hydrologic groups (A,B,C,D) as shown in the latest USDA NRCS Soils Report (current is dated 1/10/97 on table; 2/5/97 on BCSCD cover memo).

$$C-factor = \sum CxA \; / \sum A$$

2. **Time of Concentration (Tc) –** The time of concentration Tc is that time required for water to flow from the hydraulically most distant point in the watershed to the point of design. Time of concentration consists of an *inlet time* plus time to travel within a drain system or open channel to the design point. The effects of retention in pipes or within a storm water management system shall not be considered in determining Time of Concentration.

   a. *Inlet time* is the time for water to flow over the surface of the watershed to the nearest inlet. It consists of
      - overland flow (limited to 75 feet – determined from nomograph, ***Plate DA-3***),
      - swale flow (determined from ***table, Plate DA-4***),
      - and gutter flow (determined from graph, ***Plate DA-5***).

   b. *Inlet time* for placement of new inlets shall be a minimum of 5 minutes regardless of zoning. Maximum inlet times for placement of new inlets are as shown on Design ***Plate DA-4.***

      Inlet time for existing inlets and for new inlets located within Resource Conservation (RC) zones shall be as determined by the engineer mathematically.

   c. *Travel time* within a piped system shall be calculated using computed partial flow velocities in the individual pipes.

   d. In cases where a highly impervious portion of an area causes a greater peak than if the entire area is considered, use the larger, more conservative discharge value.

e. In some watersheds, there may be an apparent reduction in peak discharges because the intensity values associated with the time of concentration will decrease faster than the watershed area increases. This may happen where the main channel is in natural condition and there are no significant tributaries.

When the i*A value decreases in this manner, the runoff shall not be decreased, but the greatest upstream value of runoff shall be held until the computations show an increase in runoff above this value.

**3. Rainfall Intensity / Frequency / Duration**

The rainfall intensity value shall be interpolated from the enclosed intensity – frequency – duration table (***Plate DA-6***) using the design storm frequency and the determined time of concentration.

**D. N.R.C.S. TR-55 / TR-20 Hydrology**

Where Environmental Site Design (ESD) techniques are used, the impact of those methods upon hydrology shall be analyzed and accounted for.

**1. Version**

For a new study, the following versions are required: Technical Release 55, dated June 1986 or later; Technical Release 20, dated October 1991, or later.

With approval of this Bureau, when an existing approved County study exists that was done in an earlier version of TR-20, that earlier version may be used to determine flood limits for County approval, on a case-by-case basis. Approval of other reviewing agencies such as MDE should be obtained for the use of these studies prior to submission to those agencies, however.

**2. TR-55 versus TR-20**

If the size of individual sub-areas differs by a factor of 5 or more, TR-20 shall be used in lieu of TR-55. Use of TR-20 is also desirable where

- There are many sub-areas with different runoff characteristics,
- Reservoirs and/or dams exist or are proposed,
- Historical storm events must be analyzed,
- A flood hydrograph is desired.

**3. Watershed Schematic**

In cases of a watershed having multiple sub-areas, a watershed schematic using standard TR-20 practice in accordance with the TR-20 Manual shall be provided for review as part of as part of any submittal involving hydrology for review. This schematic shall include RCN, Time of Concentration, drainage areas (both square miles and acres) section/structure locations, reach lengths and any x and m values used.

**4. Runoff Curve Number (RCN)**

a. SCS Runoff Curve Number method (***Chapter 2, TR-55***) to be used for all Computations.

b. RCN values shall be determined only from NRCS publications.

c. Graphical Peak Discharge method (***Chapter 4, TR-55***) and other methods using approximations for the discharge computations shall NOT be used. Use tabular forms and tabular hydrograph methods for all computations. A tabular form for computations is included in this Section.

d. ***Engineering Field Manual exhibit 2-10*** shall **NOT** be used to determine discharge or related parameters.

e. RCNs shall be based upon good hydrologic condition. This Bureau will consider exceptions only in cases where reliable long-term records acceptable to the Soil Conservation District demonstrate that another condition exists for a particular site.

f. Existing land usage shall be used for calibration of watershed studies to particular storm experiences, and where required for FEMA flood mapping. Baltimore County projects shall be based upon ultimate land usage per the following:

   1. TR-55 Ultimate Land Usage shall correspond to County zoning per the following table and notes:

| Baltimore County Zoning Designation | TR-55 Land Use (Table 2-2) |
|---|---|
| DR 10.5, DR 16 | 1/8 Acre or less |
| DR 5.5, RO, ROA | 1/4 Acre |
| DR 3.5 | 1/3 Acre |
| DR 2 | 1/2 Acre |
| DR 1, RC5 | 1 Acre |
| RAE, OR, O3, OT, SE, CB | Commercial |
| AS, BL, BM, BR, CB, CCC* | Commercial |
| IM*, ML, MR, MLR, MH | Industrial |

   a) *Note: Zoning Districts (H, H1, IM, CCC, CT, CR, M43, & RC [except RC5 as noted]) require special consideration by the Design Engineer when assigning RCN values. Use actual land uses in these cases. Contact BCBEC with any questions or changes.
   b) Manually determined RCN values in some long-established commercial and industrial Districts in older parts of the County may considerably exceed RCN values based on zoning because of the very high percentage of impervious area within parts of the County developed prior to zoning control. Central areas of Towson, Catonsville, Essex, Dundalk and Arbutus are examples of areas where zoning may not reflect sufficiently high RCN values. Use actual land uses in these cases.
   c) Resource Conservation (RC) zones, except as noted above, shall have RCN values based upon the current agricultural land use (cultivated,

pasture, meadow, wooded, etc.). Clustered areas of small lots within these zones shall be considered separately for RCN determination.

d) Where existing land use is the fullest and best use of the land or where zoned land use cannot be attained, such as in large cemeteries, school sites and parks, a modified RCN based upon the existing long-term land use shall be used. Parks, golf courses, school sites and other public land should be evaluated in terms of potential for future development or redevelopment.

e) Established lots of a similar size provide excellent guidance regarding determination of an RCN for newly developed lots. The property owner typically adds impervious area beyond that originally provided by the developer and builder.

f) Consideration shall be given to floodplains, wetlands, critical areas, bodies of water, steep slopes and other natural constraints as well as to the possible transfer of density rights in determining the RCN.

2. Agricultural Land Uses:
*Pasture* is grazed area. *Meadow* is the ungrazed equivalent of *Pasture*. A hay field is considered *Meadow*.

g. Soils:
Use hydrologic soil groups in accordance with soil classification table dated 1/10/97. Changes may be made to hydrologic soil groups only after review and approval by NRCS through the Baltimore County Soil Conservation District office. Adjustments to hydrologic soil groups because of compaction caused by construction (A to B, B to C) shall **NOT** be made for floodplain studies.

## 5. Time of Concentration

Use the SCS "overland flow" method as described in ***Chapter 3*** of ***TR-55 Manual***.

a. Selected existing conditions path shall be "typical" of entire area. Ultimate land use paths shall be established in a manner consistent with typical development patterns. In general, the ultimate conditions flow path will follow the general pattern of the existing conditions path, with changes to the flow type and velocity resulting from development. Mass-graded sites will require that a pattern of grading be established before the ultimate flow path can be determined. Buffers for wetlands and streams will also impact the nature of change to the drainage path.

b. Flow paths involving storm drains will require special attention and care when the capacity of the system will be exceeded by the storm being modeled.

c. Tabular determination shall be used.

d. Sheet flow shall be limited to 100 feet. A variance from this standard maximum length requires justification in the form of a case-by-case analysis of both topography and field conditions. A letter of variance will be required from the Soil Conservation District approving use of a sheet flow length greater than 100 feet.

e. Minimum $T_c$ = 0.1 hour.

f. Round off $T_c$ to nearest time for which hydrographs are provided in TR-55.

## 6. Hydrograph Computation

a. $I_a/P$ shall be rounded (TR-55).

b. Hydrograph values shall be linearly interpolated between adjacent charted $I_a/P$ values (TR-55).

c. The standard dimensionless unit hydrograph is the 484 hydrograph as included in the TR-20 program. The 484 **dimensionless unit hydrograph** shall be used for modeling most hydrographs in Baltimore County.

In rare cases, proper modeling of hydrographs in the southeastern portion of the County may require use of the 384 **dimensionless unit hydrograph** used to model hydrographs on the Eastern Shore. When the slope of the land indicates use of the 384 dimensionless unit hydrograph, additional measures are required. Field verification of the drainage area takes on increased importance. Velocities used in these areas are also a concern because of very flat waterway slopes and their impact upon peak attenuation.

d. **Type II Rain Table** shall be used (TR-20). The 0.25 hour table shall normally be used. When Times of Concentration are predominantly in the 0.1 to 0.25 hour range, or if reaches are short, the full NRCS 0.1 hour Rain Table with 0.0 starting time should be considered.

e. **Antecedent Moisture Condition 2** (AMC 2) shall be used in all cases except for calibration runs or historical modeling where the AMC is considered a factor in experienced discharges. For calibration purposes, revisions to RCNs may be a better choice than changing AMC because the RCN changes made “across the board” by changing AMC may not create the desired result.

f. 24-hour storm to be used, except when calibrating model to existing events.

g. **24-hour Rainfall Values** shall be as shown below:

## Baltimore County Rainfall Intensity (Inches)

| DURATION | FREQUENCY: 1 Year | 2 year | 5 year | 10 year | 25 year | 50 year | 100 year |
|---|---|---|---|---|---|---|---|
| **30 Minutes** | 1.0 | 1.2 | 1.6 | 1.8 | 2.2 | 2.4 | 2.8 |
| **1 Hour** | 1.2 | 1.6 | 2.0 | 2.4 | 2.7 | 3.0 | 3.5 |
| **2 hours** | 1.55 | 1.9 | 2.45 | 2.9 | 3.4 | 3.8 | 4.4 |
| **3 hours** | 1.7 | 2.0 | 2.5 | 3.05 | 3.6 | 4.2 | 4.5 |
| **6 hours** | 2.0 | 2.45 | 3.0 | 3.6 | 4.1 | 4.8 | 5.2 |
| **12 hours** | 2.3 | 2.8 | 3.6 | 4.2 | 5.0 | 5.5 | 6.1 |
| **24 hours** | 2.6 | 3.2 | 4.2 | 5.1 | 5.5 | 6.3 | 7.1 |

From U.S. Weather Bureau Technical Paper #40, May, 1961

Studies performed for the Department of Public Works shall determine discharges for the 2, 10 and 100 year storms at a minimum. Where erosion is a consideration, the 1 year storm discharge should also be determined. In cases where the intent is to determine the freeboard for a reservation within a development, only the 100 year storm needs to be determined. If backwater from proposed improvements are contained onsite, only the 100 year storm for ultimate land use based on zoning must be determined. Additional storms may be useful for calibration purposes. For land use requirements, see **section I-D-4** of this **Manual section**.

Each TR-20 model shall be verified in terms of the relationship between Time of Concentration, rainfall time increment, and the program time increment so that these values are within the parameters of the program as established by NRCS. Values outside acceptable ranges can have dramatic effects on the discharges determined by TR-20.

### 7. Valley Reaches

Travel time $T_t$ as used in **TR-55** shall be computed when the Time of Concentration path leaves the drainage area. These times shall be based upon the average flow velocity within the channel for the 2 year storm. When possible, velocities should be obtained from hydraulic models. If a hydraulic model is not available, use of Table 1 (SHA Drainage Manual page II-2-B-3) is acceptable. Round off $T_t$ to the nearest time for which hydrographs are provided in TR-55.

The **TR-20 REACH** method, preferred over **TR-55** when routing occurs, allows use of tabular cross-section data for an “average” valley section or the input of x and m coefficients for use in stream routings. The tabular method is always preferred. Each table should be generated by calculating the hydraulic parameters. Velocities and end areas should be verified to insure that they represent a reasonable model of the reach in question. Where valley conditions vary over short distances, the two dissimilar sections may need to be combined into an “average” section. This “average” section also must produce a reasonable and logical conveyance through the valley, and shall not present properties that don’t exist in the actual valley reaches.

Supporting computations are required to verify all cross-section tables. These calculations should indicate both velocity and end area for each flow.

Tables should include a minimum of 3 values to define a channel and 3 values to define each overbank. Additional points will be required to describe any unusual breaks in grade in overbank or channel.

### 8. Structure/Storage (Reservoir) Routing

Routing of hydrographs through structures is NOT required unless:

- significant storage is available, and
- the structure will have a significant impact upon, or control of, the storm flows.

Generally speaking, a storage area should be included if the ratio of the structure storage volume ($V_s$) to runoff volume ($V_r$) is 5 percent or more, or if the structure is intended to provide flood protection to structures in a 100-year storm event. If routings are performed, the application of routing should be uniform within that watershed to avoid distortion of the watershed discharge hydrograph.

Routing of stormwater management ponds and facilities shall NOT be done as part of a watershed analysis if the structure is not intended to provide flood protection to structures in a 100-year storm event. Future changes to the Stormwater Management Regulations could allow modification or elimination of the storage area currently available for performing a flood control function.

Structure / storage routing requires a detailed computational analysis of inlet controls and tailwater controls. Care must be taken that the structure table shows a reasonable change in both storage volume and discharges between two elevations. A constant value for either storage volume or discharges for two elevations will cause the program interpolation logic to fail, resulting in unpredictable and oscillating values in the leading and/or trailing portions of the determined hydrograph.

### 9. Hydrologic Calibration

Calibration and verification of TR-20 models to storms of record should be undertaken as part of most studies whenever historical data is available. The focus should be on matching hydrographs and past flood levels. A calibrated hydrograph should produce a reasonably close match with the peak or peaks, the shape and the volume of a historical hydrograph. Calibration seeks to attain a “best fit” curve while simultaneously maintaining standard modeling practices as outlined herein and in the program manuals. Proper engineering judgement should be exercised in attaining a balance between the various factors needed to produce a true hydrologic model of the watershed. Changes to AMC or to the dimensionless hydrograph should be considered only as a last resort. Experience has shown that $T_c$ times and reach routings normally require the most modification. The calibrated model should retain the most accurate rainfall intensity and distribution possible.

The Engineer should consult with the Storm Drainage Section regarding calibration of hydrologic models for major County watersheds when the calibration reaches a point where the Engineer has determined the impact of the various factors involved in the calibration upon his model.

## E. Watershed Diversions Analysis

The State of Maryland follows the Common law doctrine of Riparian rights. Baltimore County interprets the Civil Law rule of Natural Drainage and common law doctrine as meaning that any interference with the flow of a natural watercourse to the damage of another will result in liability.

The diversion of additional watershed areas onto the land of another constitutes a technical trespass and is generally prohibited in Baltimore County. The Director of Public Works or his designee, in conjunction with other agencies, shall approve or disapprove drainage area diversions **of any size** across watershed or sub-watershed ridge lines following a DPW review of technical issues involved in the diversion.

An engineering analysis, signed and sealed by a Registered Professional Engineer licensed to practice in Maryland, must demonstrate sufficiently that downstream impacts will be negligible and that the liability assumed by the County by approving the diversion is justified. At a minimum, the study must document the following:

- Establish the need for the diversion by providing a detailed analysis of hydrologic/hydraulic alternates to a diversion. This analysis should indicate that the diversion provides the best hydrologic and hydraulic benefits compared to other alternates.

- Discuss all impacts that the diversion would have upon adjacent and downstream properties:

  1. environmental ( wetlands, natural resources, potential for erosion, etc.);

  2. water surface elevations, flow rates, flow velocities and durations and scour potential at downstream public and private road crossings. Note current condition of these facilities in report. Computations provided must be for existing, proposed (with and without storm water management) and ultimate conditions (with and without storm water management).

- Explain why the project site cannot be redesigned to reduce the size of or eliminate the diversion, using hydrologic and hydraulic considerations.

- Discuss environmental and hydrologic/hydraulic **impacts** incurred by the construction and implementation of the diversion.

- Discuss the impacts of the diversion upon both the body of water (stream, lake, bay, as applicable) that will receive additional diverted water and to the body of water that the water was diverted from.

- Discuss the impacts of a diversion in light of the need to deliver runoff from larger storms to the management facility. Furnish a detailed technical analysis and design to ensure that the maximum managed storm (in the Storm Water Management Facility) will be intercepted and conveyed to the Storm Water Management facility without bypass. Full interception and conveyance shall be provided for storms up to and including the 100-year design storm.

- Discuss the impact of the functioning of the emergency spillway during major storms. What mitigation is required for those impacts?

- Discuss the need for control and management of the increased volume of runoff from the diversion in view of an expected increase in flow velocities and duration with respect to erosion and scour of downstream reaches, crossings and property. Determine the potential increases in rate of soil loss and provide remedial recommendations.

- Discuss the hydrologic/hydraulic **benefits** to Baltimore County and its citizens resulting from construction of the diversion. (Note: the elimination of a storm water management device or pond to be constructed by development interests is not necessarily considered to be a public benefit by itself. There should be other significant benefits to downstream property owners in addition to a reduction in maintenance and replacement costs.)

From Reference #73 – see page 59.

## III. Hydraulics of Storm Drainage

### A. General Criteria for Design

Storm water runoff is collected and conveyed in closed conduit systems (culverts, inlets, manholes and drains) and open channel systems (ditches, streams, rivers and improved open channels). Instructions for design of closed conduit systems, culverts and improved open channels are contained in this section.

Care shall be taken in making a selection of a suitable outfall for every constructed culvert, storm drain and improved channel. BCBEC reserves the right to approve the location of discharge for proposed drainage facilities.

Reductions in flow from stormwater management facilities located upstream of a proposed drain system shall NOT be considered in determining discharges for purposes of design of the drain system except with written approval of BCBEC.

### B. Storm Drain System Design

#### 1. Street and Gutter Collection / Inlet Selection and Design

##### a. Inlet Location

Inlets where required at intersections shall be 5' to edge of inlet upgrade from P.C. of existing, proposed or future curb. See Selection of Inlets, this Section, for spacing requirements.

##### b. Inlet Types and their Uses

Selection of the type of inlet to be used for a given set of circumstances shall be made in accordance with Storm Drainage ***Design Plate D-22***. Inlets with grates or gutter deflectors shall not be depressed in traffic lanes where parking is not permitted. Use of State Highway Administration (MdSHA) inlets shall be restricted to State Highway Administration right-of-way unless otherwise determined within BCBEC.

**Combination inlets** having both grates and curb openings shall be used on streets with existing, proposed or future curbs; either single or double Type “S” combination inlets or single or double Type “E” combination inlets shall be used depending on capacity requirements. These inlets may also be used in sump locations along curb and gutter streets if utilities allow.

**Curb opening inlets** (Type "A" or “B”) shall be used in sumps where existing utilities preclude construction of grates within the pavement. Type “A” or Type “B” inlets may also be used on grade if utilities do not allow placement of an inlet box within the road next to the curb. Use of Type “A” or especially Type “B” inlets should be avoided where there is a high probability that they would be subject to traffic loadings passing over the top slabs.

The use of **MdSHA COG or COS inlets,** especially those over 10 feet long, shall be avoided in particular along residential streets and along parking lanes for reasons of cost-effectiveness, collection capacity (COG), improper curb height preventing car doors from opening and/or too much depression to match standard County curb height. Use of these inlets within Baltimore County right-of-way requires written justification (and shop drawings) for their use from the Engineer on an inlet-by-inlet basis and approval from BCBEC based upon the ability of this sort of inlet, with appropriate modification, to address the mentioned issues.

**Grate inlets** (inlets with grates only) shall generally be used in alleys, yards or swales. Inlets without a curb opening shall not be used in a sump along a curb on paved areas such as parking lots where the grate is subject to clogging by debris, unless runoff can drain safely to another inlet structure adjacent to the (localized) sump.

**Swale Inlets** (Type “J”, “Special K” or “S” grate) are for use with swales. Special “K” inlets and yard inlets are not traffic-bearing and shall not be used adjacent to a road. The Type “J” and Type “S” inlets are traffic bearing and may be used in road shoulders or medians.

**Yard Inlets** (Types “Y-1” through “Y-5”) are inlets used to collect water in grassed areas not subjected to traffic. None of these inlets are capable of allowing passage of a vehicle safely and must therefore be kept at least 100 feet away from all public roads.

The engineer shall substitute a standard traffic-bearing grate inlet (Single or Double Type S, Type J with modified grate, or Type E grate) for non-traffic-bearing yard inlets (Type Y-1, Y-2, Y-3 etc.) when a proposed yard inlet is located within road right-of-way or in an area subject to being traversed by a licensed motor vehicle, in or out of control of the driver. In cases where a standard traffic-bearing grate limits capacity too much, consideration shall be given to use of a pipe stub out of the inlet or a special design allowing entrance of water under the grate frame where traffic safety will allow this. Where water is collected from a swale, Type J inlets per Standard Detail D-2.13 and D-2.14 shall be considered.

### c. Inlet Grates and Frames

For reasons involving both safety of County bicyclists and increased collection of gutter flow, Baltimore County requires use of a cast iron frame and a cast iron grate of the curved vane configuration for the various Type E and S inlets used within public road right-of-way. Existing grates of the cast iron parallel bar configuration, or the NR / WR reticuline configuration, as well as any fabricated steel frames for the reticuline grates shall be replaced with approved frames and curved vane grates when encountered within the limits of a Public Works project involving any drainage improvements within a public road.

Capacity of the Type E and Type S curved vane grates may be considered equivalent to the capacity of the corresponding parallel bar grate, assuming proper directional installation. See ***Design Plates DB-3 to DB-8.***

The Type E and Type S curved vane grates are directional in nature, efficiently accepting flow from one direction only, unless located in a sump. On plans, the Engineer shall show **directional arrows** on both sides of a proposed inlet on a plan view to indicate direction of gutter flow at that inlet.

**d. Inlet Spacing**

Inlets shall be constructed in all sumps and at all intersections where conditions of street crown and/or quantity of flow require. Inlets shall be spaced so that gutter flow limitations as described below are not exceeded.

Maximum permissible flow in a standard curb and gutter section along the route of the proposed drain shall be 5.0 cfs for a 10-year design storm. In no case shall water be allowed to flow to or across the crown of the road.

Where extensions beyond the proposed route of the drainage system would be required to limit the flow to 5.0 cfs, this limiting flow may be increased provided that the following conditions exist:

- Gutter Flow does not exceed gutter capacity. The selected curbs shall not be overtopped by design storm flows, nor shall stormwater spread flow across the crown of the road.
- No property damage or great inconvenience would be involved. Valley gutters will not be permitted to cross collector streets but may be used, upon approval of BCBEC, across short cul-de-sacs and minor streets. Valley gutters shall not be used where water or utility valves or manholes are located in their path.
- Inlets of sufficient capacity can be installed to intercept the gutter flow.
- Gutter flow should not have significant velocity (> 5fps) and should not flow over 2" in depth (10 year storm) at corner locations where pedestrians would be expected to cross a street.

Special situations may occur where additional inlets are required to handle storms greater than the 10/20-year storm, such as when collection by storm drain is necessary to direct water to a 100-year storm water management facility. In this case, the 100-year storm would need to be collected by the inlets for the desired level of management to occur. Where this is done, the storm drain plans need to have the storm drain clearly labeled as a 100-year design storm facility.

Additional inlets are required to collect stormwater to keep it from entering private property when **mountable curbs** are used in lieu of standard height curb. In addition to the requirements listed above, stormwater flow along a mountable curb and gutter shall be collected at an inlet when the capacity of the mountable curb and gutter to contain the water for the particular grade and cross-slope of the road is exceeded for the 10/20 year design storm.

**e. Capacity, Spread & Flow-by**

The Engineer shall submit computations for inlet bypass and spread based upon a **10-year design storm** as part of a 30% submittal plan in order that inlets may be satisfactorily located prior to any computations of pipe capacity or energy gradient.

Inlet capacities shall be determined from the capacity charts (***Design Plates DB-3 through DB-10***), taking into consideration street grades, road cross slopes, gutter capacities and permissible spread of surface flow in the gutter. Assume no **depression** when computing inlet capacity.

Permissible **spread** of gutter flow will depend upon the importance of the street, road section, economics of the drainage system and other features peculiar to each individual project. In general, spread of flow in a curbed street should be less than 10 feet, except in sumps where up to 12 feet or a 6 inch depth may be permissible. In no case should discharges be allowed to approach or to cross the crown of the road. Permissible spread shall be specified by BCBEC for each specific project.

Inlets shall be selected as to type and spacing to intercept a minimum of 85% of the gutter flow. Additional pickup may be required if the **flow-by** would flow out of the gutter pan into the road as a result of road geometry, such as points where the road transitions into super-elevated grading. The 85% pickup requirement may be waived at specific locations (where the spread and velocity is otherwise acceptable) if approved by the Bureau of Engineering and Construction. Assume no gutter depression when computing inlet collection capacities.

Inlet design shall include consideration of placement within County-maintained public roads to prevent excessive **icing** of the road causing a traffic hazard (e.g. water spilling across the road at a super-elevated grade; water entering travel lane from a side road). Excessive icing shall be considered to involve the driving lanes as opposed to parking lanes only. Parking lane icing shall be controlled on a case-by-case basis as a maintenance issue to prevent hazards to public safety.

**f. Setting Inlet Elevations Along Open Section Roads**

In cases where there is no curb and gutter to be constructed, the following procedure shall be followed in order that all stormwater passing down the inlet side of the street pass across the grate:

1. The designer shall request a surveyed cross-section perpendicular to the proposed road centerline at the location of the proposed inlet. The profile shall extend from the road centerline to a point 2 feet behind the proposed inlet.

2. The frame and grate (or lip of curb opening) shall be set so that the top of frame and grate are 1/2" (0.04 foot) minimum below the lowest elevation along the surveyed cross-section. The longitudinal (street) grade of the grate shall match the grade of the road. The cross-slope of the grate shall be

directed toward the headpiece as indicated on the applicable Standard Details.

3. The headpiece elevation will be set as required to match the grade of the grate and frame.

## 2. Physical Criteria-Pipes

### a. Pipe Location & Grades

(1) *In New Subdivisions.* In new subdivisions Storm Drains shall normally be installed at the centerline of the street, except in cases that have received prior County approval for another proposed location. Storm Drains shall be installed within the pavement area (no less than 6' from the curb or proposed curb) wherever possible. Where it is not feasible for manholes to be located within the pavement they shall be located wholly within the grass plot or wholly within the sidewalk. In no case shall drainage pipes be placed parallel to and under curb and gutter.

(2) *In Existing Developments.* In existing developments, drains shall generally be located as discussed above. However, the location of other existing and proposed utilities and traffic conditions shall be fully considered in determining the location of drains. Where the BCBEC has determined that two-way or one-way traffic shall be maintained, design engineers shall consider locating the drain between the curb and the property line. Where the drain is thus located, exact location shall be determined from the distance required for inlet connections but shall be no less than 3' behind the curb.

(3) *In Parks or Public Rights-of-Way.* Where location of drain would require removal of or damage to trees within parks or public rights-of-way, design engineers shall obtain a permit from the State Department of Forestry for drain alignment and for trees to be removed.

(4) *Relative to other underground pipe utilities and curb*. Where possible, storm drain pipe shall pass under curb and gutter at an angle as close as possible to 90 degrees. The same angle of crossing is desired at crossings of other underground pipe utilities to minimize the loading impacts of the crossing.

(5) *Minimum Grade* of constructed pipe shall be 0.5%, except as otherwise approved by BCBEC. *Maximum grades* shall be set by maximum allowable partial flow velocities for the pipe material used. Consideration shall be given to use of a drop structure whenever partial flow velocities in a pipe approach the allowable value.

(6) *Minimum Velocity* of partial or full flow in pipes shall be 3 fps wherever this is possible in order to keep sediment deposition in the pipe to a minimum.

Deviations from these policies shall be subject to the approval of the Bureau of Engineering and Construction (BCBEC).

**b. Pipe Loadings & Cover**

Minimum and maximum pipe covers for the size and type of pipe used shall be observed in all designs. In cases where this is impractical, alternate methods of pipe support such as pipe cradles or encasement may be used with proper design, subject to approval by BCBEC. Computations supporting submitted designs are required. Special methods of pipe support shall be fully detailed on the design plans.

Care shall be taken to use appropriate formulas for dead load analysis based upon the type of placement that the pipe will receive (trench condition, positive projecting pipe, etc.). The latest edition of **Reference 3**, ACPA's ***Concrete Pipe Design Manual*** provides formulas and examples of the type of computations needed for various concrete pipe laying conditions. Similar materials are available from manufacturers of pipes made from other materials.

Minimum and maximum permissible depths shall be in accordance with manufacturer's recommendations (see ***Design Plate DC-1*** for round concrete pipe).

Marston's theory and the following assumptions are used to compute the information for concrete pipe:

i. Weight of fill material 110# per cu. ft.

ii. Load bedding factor 1.3 (bedding of CR-6 / No. 57 stone per ***Section 303.03.02*** of ***Standard Specifications*** required).

iii. Live load HS-27 loading (impact additional).

iv. Safety factor: 1.0 for Reinforced Concrete Pipe.

Allowable stresses and method of considering loads for special structures (junction chambers, etc.) shall generally be in accordance with structural design of culverts as discussed in this section.

Where pipes and structures are to be placed in fill, the supporting fill material shall be compacted in accordance with ***Standard Specifications*** Section 204.03.04 prior to placement of the pipe. This compaction shall be called out on the plans when required.

**c. Pipe & Gasket Materials**

Different classes of the same size and type of pipe shall not be used on the same job site. The higher strength class shall be used exclusively in this case.

A list of the materials acceptable for storm drain construction is included below. Accompanying each material is the roughness coefficient to be used in the solution of the Manning Formula.

Each run of pipe between structures shall be uniform in size, shape and material.

In general, internal or external (internal preferred) **gaskets** for pipe shall be provided that prevent the movement of soil particles into the pipe joints. In a very few cases, watertight as well as soil-tight joints are required, possibly impacting the design by requiring different pipe that uses suitable watertight joints. The need for watertight joints should be discussed with BCBEC during the earliest stages of the project.

Pipe Materials and Manning "n"-Factors

| Material | Manning "n" | Application | ASTM Std. | AASHTO Std. |
|---|---|---|---|---|
| **RCCP, in lengths 8' and longer** | 0.014 | General Application (with ASTM C443 Joints) | C76 | M170 |
| **RCCP in lengths 4' and shorter** | 0.015 | Existing pipe only | - | - |
| **Horizontal Elliptical RCCP** | 0.014 | General Application (with External Joint Seals) | C507 | M207 |
| **Reinforced Concrete Arch Pipe** | 0.014 | General Application (with External Joint Seals) | C506 | M206 |
| **Reinforced Concrete Low Head Pressure Pipe** | 0.013 | Special Application Requiring Watertight Joints | C361 | - |
| **RCC Pipe Gaskets** | | | C443, C877 | |
| **Ductile Iron Pipe** | 0.013 | General Application - Check Costs | AWWA C150 | - |
| **Cast Iron Pipe** | 0.013 | Existing Pipe Only | - | - |
| **Plastic Pipe** | | For use only with approval of BCBEC | | |
| HDPE Pipe | | " | - | M294 |
| Smooth Interior Wall | 0.012 | " | - | M294 |
| Corrugated Interior Wall | 0.018-0.020 | " | - | M294 |
| PVC Pipe (12" to 15") | 0.012 | " | D3034 SDR35 | M304 |
| PVC Pipe (18" to 24") | 0.012 | " | F794 | M304 |
| HDPE Pipe Liner | | | | |
| Smooth Interior Wall | 0.012 | General Application | - | M294 |
| Corrugated Interior Wall (12" - 15" Dia.) | 0.018 | " | - | M294 |
| Corrugated Interior Wall (18" - 36" Dia.) | 0.020 | " | - | M294 |
| **Monolithic Concrete (Box Culverts, Concrete Inverts, etc.)** | 0.015 | General Application | C850 | - |
| **Vitrified Brick (Bends, Junction Chambers, etc.)** | 0.017 | General Application | | |
| **Galvanized or Aluminum Corrugated Metal Pipe (CMP)** | | Existing Pipe Only; Limited Replacement In Kind Subject to BCBEC Approval | | M36 |
| Unpaved circular or arch pipe, plain or coated | 0.024 | " | - | - |
| Circular pipe, 25% paved BCCMP | 0.021 | " | - | - |
| Circular pipe, 100% paved BCCMP | 0.013 | " | - | - |
| Arch pipe BCCMPA, 40% paved | 0.019 | " | - | - |
| **Structural Plate Pipe, Arches** | 0.032 | Existing Pipe Only - No Replacement In Kind | - | - |

* **Corrugated metal pipe** and structural plate pipe shall not be installed on any storm drains to be maintained by Baltimore County without explicit written approval by the Bureau of Engineering and Construction. The n-factor provided for this pipe is for use in analysis of existing drain systems using this pipe. Higher n-factors should be applied where the pipe invert is rusted through. ***HDPE*** or **PVC** pipes shall be used only for specific projects where the Bureau of Engineering and Construction has approved its use.

### d. Pipe Foundations

In all cases, proper foundations shall be provided for drains. Design engineers shall detail on contract drawings methods acceptable to BCBEC for supporting drains on unstable ground or fresh fill. This is particularly important where use of flexible pipe is allowed.

The engineer shall check for buoyancy of pipe used when groundwater is encountered during construction. **Flotation of pipe** will misalign the pipe and require resetting. The Engineer is responsible for taking countermeasures to prevent flotation of pipes to be maintained by Baltimore County.

**e. Manhole Placement & Spacing**

Manholes shall be used at the following locations:

- all changes of pipe size where there is no change in direction;
- all changes in direction. See design figure for limitations of use of manhole for change of direction.
- all changes of pipe grade.

Maximum spacing of manholes for straight runs of drain pipes shall be 300' in order to provide maintenance accessibility.

Manholes shall maintain a minimum of 6" of reinforced concrete wall between pipe openings in accordance with the applicable ***Standard Details***. Inlets and manholes shall be placed so that connecting pipes do not pass through or otherwise interfere with the corners of rectangular structures, in accordance with ***Standard Detail G-1***.

**f. Manhole Stacks and Access**

All manholes shall have a manhole stack, a frame and a cover. Manholes 60" or larger in diameter (Type C) with a 36" or larger through pipe shall be provided with a stack of suitable diameter and a 30" diameter manhole frame and cover for accessibility during maintenance (See ***Standard Details***).

Design engineers shall indicate manhole stacks on all bends, junction chambers and wye structures, unless alternate acceptable access along the trunk line is available within 10 feet of the structure. Bends, wye structures and junction chambers shall have frames and covers for maintenance and suitable access, sized in accordance with ***Standard Details D-4.01 through D-4.04***.

**g. Bends**

A bend structure or manhole shall be used to accomplish horizontal or vertical changes in direction. **Pipe joints shall not be flexed or distorted to create an angle at the joint.**

Bend structures as shown in the ***Standard Details*** shall be used to accomplish a change in direction where the downstream pipe is 30" and larger. A **prefabricated pipe bend** (with an adjacent manhole stack) of equivalent radius and sectional construction of the same material and joints as the pipe may be substituted if special details for the pipe bend are included on the Plans. A request to substitute a precast bend structure or a manhole for a brick bend, either as a shop drawing change or as a repair for a failed brick bend, shall be accompanied by an analysis of the impacts of such a substitution on the energy gradient, certified and sealed by the design engineer.

***Design Plate DB-19*** (General Criteria-Storm Drain Structures) indicates the limitations placed upon the use of the Brick Bend as a junction structure (e.g. with connection).

Minimum centerline length of Bends shall be 4 feet.

Where **reinforced concrete box conduits** change direction, the bend shall have a minimum centerline radius of two times the inside width of the conduit.

**h. Connections & Junction Chambers**

Cut-ins, wye branches, preformed concrete pipe fittings, manholes, brick bends (with or without connections) and Type I Junction Chambers as discussed below are ***Standard Details***. Type II Junction Chambers are special structures requiring a Special Detail on the Plans. ***Design Plate DB-19*** (*General Criteria-Storm Drain Structures*) illustrates typical use and limitations of the aforementioned structures. Brick Bends that are not in accordance with the limitations indicated on ***Design Plate DB-19*** are special structures requiring a Special Detail on the Plans.

**Decrease in pipe size** at structures will not be permitted for 21" and smaller pipe. For pipes 24" and larger, maximum decrease shall be the next smallest standard size (e.g. 42" to 36"). For elliptical and arch pipe, the above restrictions shall be applied to the **equivalent diameters**.

**Cut-ins** (small pipe inserted into side of an existing larger pipe) shall be permitted for inlet connection pipes where:

- The larger pipe is existing. Cut-ins shall not be used for connections where both pipes are being constructed.
- 15" pipes enter 33" and larger pipe, or
- 18" pipes enter 42" and larger pipe, AND
- a manhole or inlet providing adequate access for pipe maintenance is available within 10 feet of the cut-in connection.

Whenever possible, spring lines of pipes (center lines of circular pipes) shall be at the same elevation at junction points.

**Wye structures** or manholes (see ***Standard Detail D-4.04***) shall be used as indicated below:

- where 15" pipes enter 30" and smaller pipes, or
- 18" pipes enter 36" and smaller pipes.

Preformed reinforced concrete pipe wye branches may be substituted for standard wye structures, if access by manhole or inlet is otherwise available within 10 feet of the structure.

**Type I Junction Chambers** (See ***Design Plate DB-18*** and ***Standard Detail D-4.03***) shall be used for 48" and smaller pipes where velocities are less than 15 ft./second and where criteria prohibits the use of a less expensive structure.

**Special Junction Chambers** shall be used where velocities exceed 15 ft./second or largest pipe exceeds 48". They shall be of special design detailed on plans and streamlined to limit head losses.

### i. Utility Clearances

Clearance shall be measured between the outside of pipes. Storm drains crossing water main and sanitary sewers shall be constructed with a minimum vertical clearance of 6". Crossings of other utilities shall be made at a horizontal angle as near as possible to 90 degrees. Requirements for crossing the other utility shall be observed. Storm drains crossing gas mains shall maintain a vertical clearance of 12 inches, except as otherwise approved by BGE.

Where underground utilities are proposed in roads with drain crossings that the proposed utility must cross, the drain crossing sizing for ultimate conditions shall be checked whenever plausible so that future expansion of the drain crossing will not interfere with the utility. The utility shall be provided with elevations and clearances determined on a case-by-case basis depending upon the size and importance of the crossing, the potential for flooding upstream of the crossing, the value and level of development adjacent to the road, the value of the utility and other considerations applying to specific circumstances.

### j. Underdrains

Underdrains shall be perforated PVC or HDPE pipes, or pipes of equal strength. Where appropriate, show underdrain locations on the contract drawings.

### k. Multiple Pipe Drains

See ***Section* IV A 8*, Culverts,*** regarding spacing of multiple pipes.

Note that use of multiple pipes in storm drain systems will be limited by the size of connecting structures in the drain system. A study describing benefits and costs compared to an enlarged single pipe system should be provided to BCBEC for prior approval of proposed systems using multiple pipe conduits between any two points in a drain system.

## 3. Pipe Sizing

Pipes that are for use in storm drain systems within County Rights-of-Way and Easements shall have a 15" minimum diameter. Exceptions to this shall be made only with approval of BCBEC.

Drain sizes shall be established as described below using the following relationship. Adjustments of the sizes thus determined shall be made, if warranted, by the Energy Gradients.

$$Q = AV$$

where:

Q = quantity of flow in cfs = quantity of runoff as determined in 11-B-2 (Page DI)

A = required area in square feet

V = velocity in feet per second velocity shall be determined by the **Manning Formula:**

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

where

n = coefficient of roughness (see table following)

R = hydraulic radius in feet = cross sectional area / wetted perimeter

S = slope of energy gradient in feet per foot

Charts are readily available that offer a solution of the Manning Formula for the circular, arch and elliptical pipes normally encountered. These charts are based upon pipes flowing full. ***Design Plate DB-16*** offers solutions of velocity and discharge for partial depth flow.

**4. Energy Gradient Determination**

The energy gradient is a line connecting points to which water will rise in manholes and inlets throughout the system during the design flow. The energy gradient shall be based upon full flow in the pipes and shall be determined for the 10-year storm starting at the downstream end of the proposed drainage system.

- Where a proposed drainage system is connected to an existing drainage system the energy gradient at the point of junction shall be determined from the energy gradient computations of the existing drain on file at BCBEC. Where this existing downstream drainage system will be upgraded in the immediate future (plans approved by BCBEC), design of the upstream system shall be based on the new system only with written approval by BCBEC. Where a gradient is not shown on record drawings for an existing system, the engineer shall determine this gradient preliminary to determining the gradient in the upstream system.
- Where the proposed drainage system discharges directly into a large stream, the Engineer shall discuss the energy gradient starting elevation with BCBEC. Additional requirements may be made in locations involving a 100-year floodplain.
- When working in tidal areas, the mean highest tide elevation shall be used for tailwater calculations, as based upon the mean for the highest month. The minimum mean high tide for the lowest month shall determine the lowest invert elevation to occur in a storm drain system. **(Ref. 72)**
- Where the tailwater elevation is higher than the proposed crown elevation, the energy gradient shall begin at this tailwater elevation.
- Where free outfall conditions exist the energy gradient shall begin at the crown of the proposed drain.

Next, the friction loss (as discussed below) in the drain to the next structure shall be added. The loss in the structure (as discussed under Head Losses in Structures-this section) shall be added. The energy gradient to the upstream end of the proposed drainage system shall be determined by adding a series of friction losses in sections of drains and losses in structures.

The energy gradient for the design flows shall generally not be above an elevation of 1'-0" (use 1'-6" in tidal areas and for drains where self-flushing is a problem: $V_{FULL} < 3$ f/s) below the established street grade (as defined in ***Section VI B 2 b***) nor more than 6' over the crown of the pipe (unless water-tight pipe joints are specified with permission of BCBEC). Special cases shall be considered by BCBEC. Consideration shall be given to possible future extensions of the system and impacts that extension will have upon the energy gradient.

**a. Friction Loss**

Head loss due to friction in open channels and pipes with uniform flow shall be determined by the Manning Formula, rearranged as follows:

$$S_f = \frac{(Qn)^2}{(1.486AR^{2/3})^2} = \frac{n^2V^2}{2.208R^{4/3}}$$

$S_f$ = head loss (in feet per linear foot of drain) as described under Size of Drains, (this section).

**b. Head Losses in Structures**

***Design Plates DB-12 and DB-13*** (Head Losses in Structures) show curves prepared for the determination of head loss in cut-ins, wye branches, preformed concrete pipe fittings, manholes, brick bends (with or without connection and manhole) and Type I Junction Chambers. These curves are based upon surcharged pipes entering rectangular structures but shall apply to monolithic structures.

These curves are indicated as "A", "B", "C" and "D" losses. The "A" curve depicts loss due to entrance and exit. The "B" curve depicts velocity head, with the difference between incoming and outgoing velocity head counted as a "loss". Where the downstream velocity exceeds the upstream velocity, the "B" loss shall be the difference in velocity heads. Where the upstream velocity is the greater, the apparent gain may be used to offset other head losses in the structure. The "C" curve depicts loss in manhole due to change in direction, loss for wye branch and loss in brick bend. The "D" loss depicts loss due to incoming volume. The total loss in a structure is the sum of all "A", "B", "C" and "D" losses applicable to that structure. The total structural loss must be greater than or equal to zero for each structure.

These curves shall be applied for particular types of structures as described on ***Design Plate DB-11***. Loss due to change of direction in monolithic structures shall be as discussed below for long and short radius bends.

**5. Outfall Design**

Design storm (partial flow) velocities at storm drain outfalls shall generally not exceed a velocity that will cause erosion for the type of bed material encountered at the outfall. Sufficient stabilization shall be placed at the outfall to reduce velocities to non-erosive values. When this is not possible, alternate designs must be considered to dissipate the energy of the flow. This may take the form of stabilization utilizing non-erodible material, or a structural **energy dissipating device** or a **stilling basin**. Standard methods shall be used to design dissipating structures and full computations shall be submitted. Design computations shall indicate the final velocity as the flow enters downstream areas after leaving the stabilization or energy dissipating device. The designer is referred to the limiting velocities in the table shown in ***Section III-C-2-b***.

Refer to FHWA Hydraulic Design Series #11, *Design of Riprap Revetment*, #14, *Hydraulic Design of Energy Dissipators for Culverts and Channels*, and #15, *Design of Roadside Channels with Flexible Lining* for more specific information and design criteria.

a. Use of headwalls

**Standard Details D-1.00** through **D-1.09** illustrate standard headwalls for general use within Baltimore County Rights-of-Way. The designs as shown shall be assumed to be adequate for backfill loads up to the elevation of the top of the walls for a distance of 20 feet behind the walls. For earth loads in excess of this level, or for other added dead or live loads, the engineer shall perform a verifying analysis, and certify that the proposed wall is sufficient to act as a retaining wall to support the load (using standard factors of safety) without overturning or sliding sufficient to disjoint the pipe.

Where headwalls will act as retaining walls, a flexible joint should be placed between pipe and wall in order to allow some movement of the wall without simultaneously moving the pipe sufficiently to disjoint it and allow leakage. Take careful note of the requirement on the Standard Details that walls shall carry concrete to undisturbed earth. These walls will also require special drainage design to remove water from behind the walls.

Headwalls shall be suitably armored for protection against erosion using sized riprap where the wall is to be placed adjacent to a streambed.

The County reserves the right to require use of an alternate structure in place of a headwall after reviewing the specifics of a given application.

b. Use of precast headwall

Each of the Standard Details mentioned above carries a note allowing substitution of a precast wall for a cast-in-place structure. In cases where this is desired, the contractor shall provide a shop drawing showing all applicable dimensions that is signed and sealed by a Professional Engineer licensed to practice in Maryland addressing the following issues:

- Means of connection of toe to headwall;
- Means of filling voids under precast base;
- Means of moving headwall safely (adequate liftholes / lifthooks);
- Means of supporting headwall in position prior to backfilling behind wall;
- Means of meeting requirement to carry concrete to undisturbed earth and completely eliminating voids under the base;
- Means of providing drainage of water collecting behind headwall.

In addition to the shop drawing and computations, the Professional Engineer shall provide certification of the following at the time of delivery of the wall to the job site:

- The precast wall contains the appropriate concrete mix and the appropriate amount, grade and placement of steel reinforcement.
- Concrete cylinder test results.

The company constructing the precast wall shall be an approved Baltimore County supplier in good standing.

The County reserves the right to refuse approval of precast headwall designs.

c. Alternates to use of headwalls

When considering use of a headwall at an outfall, the engineer shall consider use of one of the following methods of outfall:

- End support wall – provides vertical support for the pipe without creating excessive sliding forces. See ***Standard Details D-1.02 and 1.03***.
- Grouted or ungrouted gabions at toe and on sides of pipe. Ungrouted gabions as wingwalls, if required.
- Pipe end sections compatible with type of pipe used, as shown on ***Standard Details D-1.10 to 1.16***.

Outfall design shall meet or exceed requirements of all reviewing agencies. Particular attention shall be directed to requirements regarding designated trout streams and their closure dates.

## C. Improved Open Channels

### 1. Location and Alignment of Improved Channels

Existing channel alignment shall be changed as little as possible. Some minor modification to channel alignment is desirable at road crossings in order to keep flow as close as possible to perpendicular to the road, in order to make the crossing as short as possible. Minor outfall channels for drains and culverts should be located at a property line if topography and environmental regulations allow.

The Engineer shall coordinate all designs for open channels, open section storm drain outfalls and other features that may impact wetlands, streams, Waters of the USA, wetland or stream buffers with DEPRM, MDE and the Corps of Engineers at the earliest possible opportunity. All designs that impact environmentally sensitive features or areas shall be designed to be in full compliance with the requirements of applicable Federal, State and County regulations.

### 2. Design of Improved Channel.

#### a. Shape

Improved Open Channels carrying flow in excess of 10 cfs shall be developed with a trapezoidal cross-section. Side-slopes shall be determined by available right-of-way, public safety, use and maintenance of adjacent overbanks, existing soils, construction materials and methods and flow considerations. In very large trapezoidal channels (see ***Standard Detail D-5.06***), channel bottoms may be excavated below the normal flat bottom of the sized trapezoidal section in order to allow for natural meander of flows below the level of a 1-year storm.

Channels with design flow depths in excess of 5 feet require prior approval of the design concept before plans preparation is started.

Areas that must be maintained by mowing shall have 4 foot horizontal to 1 foot vertical maximum side-slopes. Unreinforced earth slopes should not exceed the recommended slope for the soils encountered on the site. In no case will unstabilized earth slopes, or earth slopes with riprap exceed a slope of 2 feet horizontal to 1 foot vertical.

Improved channels utilizing **gabions** may have sideslopes as steep as the 2 to 1 slope discussed above. See ***Standard Details D-5.04, 5 and 6***. If, however, a gabion or imbricated riprap wall structure that supports the adjacent earth is used on very large channels, the channel side-slopes may approach vertical. Gabion walls shall be constructed in accordance with manufacturer's recommendations.

**Geotextile** fabrics and/or a **sand filter blanket** shall be provided under riprap used for channel stabilization. Geotextile fabrics shall be provided under gabions used for channel stabilization.

Reinforced channel slopes utilizing geotechnical methods of soil reinforcement shall be specially designed by an engineer registered to practice geotechnical engineering in Maryland. That engineer shall sign and seal plans and computations for that design prior to approval by the County. The design must address potential erosion issues as well as slope stability.

**b. Materials**

Smaller improved channels such as roadside ditches shall be constructed of sod, commercial matting, gabions or riprap, depending upon velocity of flow. The entire section of the improved channel will be stabilized with the material specified. See ***Standard Details D-5.04 and 5*** for examples.

| Material | n-Factor | Max. Allowed Velocity |
|---|---|---|
| Seed and Mulch | 0.030 | 2.5 fps |
| Solid Sodding, Good Lawn (flow depth > 6") | 0.040 | 4.0 fps |
| Solid Sodding, Good Lawn (flow depth < 6") | 0.060 | 4.0 fps |
| Soil Stabilization Matting | 0.040 | 4.5 fps |
| Earth Gutters and Ditches (Existing) | 0.025 | 1 to 3 fps |
| Concrete gutters, paving, ditches, channels | 0.015 | 25 fps |
| H.M.A. Surfacing with Concrete Curb | 0.016 | 10 fps |
| Stone-filled Wire Baskets (Gabions) | 0.030 | 25 fps |
| Grouted Riprap, Natural Shale or Rock | 0.025 | 25 fps |
| Stone Slope, Channel Protection (Riprap Cl. 0, 1) | 0.035 | Note A |
| Stone Slope, Channel Protection (Riprap Cl. 2, 3) | 0.041 | Note A |
| Natural Stream Channels | 0.035 to 0.150 | Note B |
| Existing Well-established Grasses, Short Blades | 0.040 | 4.0 fps |

Note A: Riprap size shall be selected to reduce flow velocity to a level acceptable for the unprotected downstream area. Refer to tables F-18-6 and 7, *1994 Maryland Standards and Specifications for Soil Erosion and Sediment Control.*

Note B: Refer to listed references for determining n-Factors for an existing channel. Allowable velocity is that which causes no erosion of channel material.

For channels not completely lined with vegetation, the following velocities are to be used as maximum velocities: (Ref: ***Chow, Open Channel Hydraulics***)

| Channel Material | Maximum Velocity |
|---|---|
| Sand and Sandy Loam, Silt Loam | 2.0 to 2.5 fps |
| Sandy Clay Loam, Clay Loam | 3.0 to 3.5 fps |
| Clay, Fine Gravel & Graded Loam to Gravel | 4.0 fps |
| Graded Silt to Cobbles | 4.0 to 5.0 fps |
| Shale, Hardpan & Coarse Gravels | 6.0 fps |

Larger improved channels will generally have a sod or riprap lined bottom (determined by flow velocity) with stabilized slopes or gabion walls. See **Standard Detail D-5.06**.

Use of **concrete lined channels** is limited by environmental requirements to short aprons at drain and culvert outfalls. Issues of heated water, unnaturally high velocities and maintenance problems prevent their use for larger channels.

**c. Required Waterway Area.**

In general, channels shall be designed to have a minimum of one foot of freeboard between the design water surface and the top of the channel to account for siltation and other considerations. Freeboard shall be increased as necessary to accommodate hydraulic jump within the channel, by designing the channel so that the energy grade line is below top of channel on both sides of the channel. Computations for the channel shall indicate critical depth and velocities. Determination of the design water surface will consider the impacts of flow around bends and the impacts of wave action within channels due to bends.

Channel sizing shall be based upon the 100-year storm for most large channels, defined as those channels carrying more than 10 cfs. Smaller roadside channels may be designed for the 10-year storm, but these channels shall also be checked to see that the corresponding 100-year discharges remain within County right-of-way.

Sufficient area within larger channels shall be provided for a meandering low flow area at the bottom of the channel as directed by regulatory agencies. The area provided for low flow shall not be included when sizing the overall channel for the design storm.

Maximum allowable velocities in a channel shall be in accordance with maximum velocities listed in Tables in **Section III, C, 2, b, Materials,** for the selected channel lining.

The waterway area required for channels shall be determined from the relationship:

$$Q = AV$$

where:

Q = quantity of flow in cfs = quantity of runoff as determined using accepted methods

A = required area in square feet

V = velocity in feet per second velocity shall be determined by the **Manning Formula:**

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

where:

n = coefficient of roughness (see table, page 32 )

R = hydraulic radius in feet = cross sectional area / wetted perimeter

S = slope of energy gradient in feet per foot

The Federal Highway Administration (BPR) Charts for channels that are readily available from various sources use this method. The charts are acceptable for channel sizing and design. (See WWW.FHWA.DOT.GOV/ENGINEERING/HYDRAULICS/ for publications).

Larger channels wider than 15 feet at the top and channels with an irregular or natural section or flooded overbanks shall be analyzed utilizing HEC-2 or HEC-RAS, with discharges determined by TR-55 or TR-20.

**d. Fencing and Guard Rail**

Chain link fence will be used adjacent to an open channel only with the approval of BCBEC. In no case will the chain link fence cross a 100-year floodplain. The height of the fence shall be in accordance with current zoning regulations.

Channels adjacent to roads shall receive guardrail in accordance with AASHTO and MdSHA guidelines for providing guardrail.

**e. Right-of-Way**

Improved Channels, including all fencing, shall be located within either property owned by the County in fee or within a Drainage and Utility easement. With DEPRM's approval, improved channels may also be placed within a forest buffer easement.

## IV. Stream Crossings

When waterways are encountered in the course of normal road and street design, the engineer shall provide an analysis of whether a bridge, pipe or box culvert or bottomless concrete arch shall be provided at the location. The analysis shall be provided to the County and all other reviewing agencies prior to beginning design of a structure, and shall include recommended sizing and geometric layout for the crossing in addition to a comparative analysis of the costs and environmental impacts of the various types and sizes of structures studied. In general, short crossings are preferred, subject to the impacts of relocating any existing approach roads. Stream crossing designs shall meet all requirements of applicable regulatory agencies, including but not limited to MDE, the Corps of Engineers, Fisheries and DEPRM.

Factors to be considered in recommendation of a type, size and location of a stream crossing shall include environmental impacts, provision of satisfactory service in view of the existing and future capacity of approaching roads, and costs.

In general, assuming normal soil conditions, normal stream characteristics and the usual road characteristics, culverts are most economical at less than a 20 foot span, with bridges and bottomless concrete arches becoming more economical as spans increase beyond 20 feet. Box culverts of normal length shall be sized as single or multiple cells based upon structural efficiency, except on designated trout streams where fish baffles and partially filled cells are necessary to allow fish passage, normally requiring a second cell with a dropped invert. In those limited cases where a box culvert will exceed 200 feet in length, use of a center wall should be considered. When the difference in elevation between high water and the traveled way is large, use of a culvert may result in excessive costs due to the amount of fill required and the length of culvert required between upstream and downstream slopes. Possible future widening of a road favors a culvert because the culvert is relatively easy to lengthen as required. Road alignment requiring special (e.g. curved) bridge design also favors use of a culvert. Use of a culvert with its large bearing area should also be considered when poor soil conditions would require use of pilings for bridge supports. Costs of future maintenance of each type of structure should also be factored into the cost comparison.

Crossings of a floodplain shall be made at an angle that is as close as possible to perpendicular to the direction of flow.

Assuming that equivalent hydraulic performance is available from all crossing alternates, the alternate requiring the least **maintenance** is preferred. Long-term maintenance shall be considered as part of both the alternate selection and of final design. Maintenance considerations shall include accessibility to upstream and downstream ends of the structure, ease of maintaining the waterway opening, impacts of scour on the foundations, siltation where flow velocities are low, collection and diversion of floating debris and protection of banks and overbank areas from scour and erosion.

Natural approach and exit channels are preferred for conveyance. When waterway improvements are necessary, preference is given to limiting that work to overbank excavation as opposed to channel excavation.

Each channelized flow area shall be evaluated for **sedimentation** potential. Where necessary, expected accumulations of sediment shall be made part of the evaluation of the structure's hydraulic capacity.

In cases where a structure will increase downstream discharges, the Engineer shall verify that no flood damage will result and that computed flood levels do not increase on adjacent private property. When additional floodplain encroachment occurs on private property, the Engineer shall notify BCBEC so that a decision can be reached regarding design modification versus a right-of-way purchase of the increased flood area.

Use of **bottomless arch structures** is limited to reinforced concrete structures when they must be used. These structures are considered to be difficult to properly install and maintain, with a relatively high potential for structural damage in use and during construction. Structural plate arches are expressly forbidden for use as part of publicly maintained facilities. No bottomless arch structure shall be installed without the following being addressed:

- Geological investigations shall be made, and those investigations shall indicate that sufficient protection can be provided against scouring of the supporting foundation.

- Approval of BCBEC's Structural Design Section is required.

When existing bridge and culvert structures at stream crossings must be replaced because of deterioration, consideration shall be given to replacing the structure with a structure that is of the same type, size and location (**“Replacement in Kind”**) as the structure to be replaced. This sort of replacement minimizes construction impacts. Careful analysis must be made to be certain that additional safety features, including guard rail on approaches and modern bridge parapets do not increase the 100-year floodplain level more than 0.1 foot upstream of the new structure. The replacement structure shall not adversely impact upstream or downstream channel stability.

Appropriate signing shall be provided at both ends of any crossing when the 100-year floodplain crosses a public road.

## A. Culvert Design

### 1. Hydrology

Hydrology computations shall be developed in accordance with the Hydrology section of this Design Manual for storm drainage. Reductions in peak flow as a result of retention in stormwater management facilities shall NOT be allowed for purposes of design of a downstream culvert.

The Design Storm for culverts shall be the 100-year storm, except as otherwise directed by the County.

### 2. Hydraulics

The culvert diameter or opening dimensions shall be established based upon the methods as outlined in the Federal Highway Administration ***Hydraulic Design Series #5, Hydraulic Design of Highway Culverts***, using the 100-year design storm. See the Federal Highway Administration web site at WWW.FHWA.DOT.GOV/ENGINEERING/HYDRAULICS/.

In addition to the HDS #5 analysis for the 100-year storm, in cases where storm drain inlets, manholes or pipe connections occur along the length of the culvert, the culvert and any branches shall also be analyzed using the storm drain energy gradient process, based upon a 20-year storm passing through the culvert barrel. Losses due to the connection or structure shall be added as minor losses to the culvert.

Where headwater must be held below 0.2D above the crown of a culvert (D=diameter of pipe or height of box structure), and culvert length is less than 100D, the structure won’t flow full. This condition requires a special design that considers the hydraulic effects of partial flow within the structure.

### 3. Location and Alignment

Each culvert shall be located as closely as possible to the natural drainage course that will be replaced by the culvert. Alignment will be generally along the path of existing flood flow, with consideration given to keeping the culvert as short as possible on designated trout streams. The alternate to a sufficiently short culvert in a trout stream would be to “daylight” the culvert at required intervals by using sufficiently short segments of culvert in place of one long culvert. The engineer will also consider any improvements upstream or downstream of the culvert that would result in a relocation of the streambed.

The grade of the culvert will follow that of the natural stream, with the line of the invert to lay 6” to 2’-0” below the natural streambed, depending upon conditions. Adjustments to the slope and/or size of the culvert may be considered where excessive velocities in the culvert result from use of the natural slope.

Curves and changes in alignment occurring under roadways shall be avoided, unless approved by the Bureau of Engineering and Construction.

Culverts that may become part of a future closed drainage system shall be designed in size, plan and profile to accommodate the future connections.

**4. Freeboard**

Except for special cases having prior approval of BCBEC, 100 year headwater elevation (based upon discharges determined for ultimate development based upon zoning) at the culvert entrance shall **not**:

- Exceed the top of banks of approach channels adjacent to improved property;
- Flow outside of existing or proposed dedicated floodplain reservations and/or drainage easements;
- Rise closer than 3.0 feet to the low point in the established grade of road in the vicinity of the culvert;
- Exceed 3 feet in elevation above the crown of the culvert pipe at the culvert entrance.

In cases where the difference between headwater and tailwater (when tailwater elevation is below elevation of culvert entrance invert, use headwater only) is greater than 10 feet and HW/D is greater than 2.0, consult Appendix B of *MD-378* (Latest Edition) regarding additional requirements for design.

## 5. Entrance Conditions

Each culvert shall be provided with an appropriate concrete or gabion-formed headwall or concrete end section at the entrance. Entrance coefficients are as follows:

**Culvert Entrance Loss Coefficients**

| Pipe | Structure | Entrance | Ke |
|---|---|---|---|
| RCCP | Std. Concrete Headwall | Square with headwall (Per Standard Details) | 0.5 |
| | Std. Concrete Headwall | Socket End of Pipe | 0.2 |
| | Std. Concrete Headwall | Rounded to $^{1}/_{12}$ D | 0.1 |
| | Std. Concrete End Section | Conforming to Fill Slope* | 0.5 |
| | Gabion Headwall | Square cut | 0.5 |
| | Gabion Headwall | Socket End of Pipe | 0.2 |
| Reinforced Concrete Box | Headwall Parallel to Embankment (No Wingwalls) | Square-Edged - 3 Edges | 0.5 |
| | | 3 Edges Rounded to $^{1}/_{12}$ D | 0.2 |
| | Wingwalls At 30° to 75° To Barrel | Square-Edged At Crown | 0.5 |
| | | Crown Edge Rounded to $^{1}/_{12}$ D | 0.2 |
| | Wingwalls At 10° to 30° To Barrel | Square-Edged At Crown | 0.5 |
| | Wingwalls Parallel Extension of Sides | Square-Edged At Crown | 0.5 |

Consideration shall be given as part of the preliminary study report to the need for further improvement to entrance conditions, as discussed in FHWA ***Hydraulic Engineering Circular 13,"Hydraulic Design of Improved Inlets for Culverts"***.

6. **Outfall Conditions**

A culvert shall be considered as having free discharge when the water surface downstream of the outfall is below the crown of the culvert at the outfall. The outlet shall be considered submerged when the downstream water surface is at or above the crown of the culvert at the outfall.

Design velocities at the culvert outfall shall generally not exceed 12 fps and shall in no case exceed 15 fps. Sufficient stabilization shall be placed at the outfall to reduce velocities to non-erosive values (see ***Table, Section III-C-2-b***). When this is not possible, alternate designs must be considered to dissipate the energy of the flow. This may take the form of a structural energy dissipating device or a stilling basin. Standard methods shall be used to design dissipating structures and full computations shall be submitted. Design computations shall indicate the final velocity as the flow enters downstream areas.

See **page 25**, **Item III-B-5** of this Storm Drainage Section regarding use of headwalls at outfalls.

7. **Materials**

Materials for use in under-road culverts shall be limited to round or elliptical reinforced concrete pipe or reinforced concrete box culverts. Concrete pipe shall meet or exceed all requirements for **ASTM C-76 pipe** with **C-443 joints**, except that **ASTM C-361 pipe** shall be used in those cases where design criteria of other agencies require waterproof joints.

8. **Multiple Pipe Installations**

When multiple pipe culverts are required in lieu of a larger single pipe culvert or a box culvert, the following criteria shall be followed:

- All pipes shall be set parallel to each other. One or more pipes may be set at a lower elevation if required.

- Pipes with outside spans or diameters greater than 48” shall be spaced a minimum of the lesser of 4 feet or one-half diameter/span apart. Smaller pipes shall be no less than 3 feet apart.

- Plans shall include a special detail showing bedding and haunching for multiple pipes. Computations for pipe loadings are required because the pipes are installed in a modified trench.

- Installation of a second (new) pipe adjacent to an existing culvert requires measures to protect the existing pipe from disturbance during construction. These measures shall be fully documented on plan documents for the supplementation project. Where condition of the existing pipe or pipe joints is in question, the Engineer will assess the need to repair or replace pipe sections or joints as part of the supplementation project.

9. **Pipe Cover**

See **Section III-B-2-b** of this **Manual**.

10. **Inlet Protection / Debris Rack**

The engineer shall consider provision of a debris rack structure for the culvert inlet and also for the upstream channels leading to the culvert. The intent of these structures is to prevent partial or total clogging of the culvert entrance or interior by debris. Factors affecting the design of these structures include the nature of the upstream watershed and its debris generating capabilities, available meander of the upstream floodplain, other natural or manmade “debris traps” upstream and an assessment of the importance of keeping the structure flowing during major storms. Debris control structures shall be considered as special design structures and shall be fully detailed on the design plans. Care shall also be taken during preparation of sediment and erosion control plans that stored materials and equipment not cause any potential for blockage.

The design engineer shall provide stabilization measures for the area surrounding the opening of entrance headwalls or end sections to prevent scour by entering waters and eddy currents.

## B. Bridges Across Waterways – Hydraulic Considerations

1. **Geometric Layout**

In general, new bridges shall be located and aligned to fit the natural waterway and design storm floodplain as nearly as possible. However, the design engineer may consider minor stream relocation <u>as part of initial alternates studies</u> to:

- Keep bridge skew angles to a minimum, as economy is greatest when the face of bridge abutments are at 90° to the centerline of road (abutments and piers to be aligned to minimize scour and resistance to 100-year flow);
- Improve the hydraulics and stability of upstream and downstream channels of the waterway;
- Better fit the adjacent property lines and other contemplated improvements.

Cost savings from reduced right-of-way and skew angle requirements must be weighed against the costs of mitigating any environmental impacts generated by a stream relocation.

2. **Size**

Determination of height and width of bridges are subject to the following considerations:

- **Span length** shall be determined by the opening required for the waterway. The opening shall be sufficiently wide so that design flows will not cause flooding of upstream property or degradation and/or accretion of the channel section.

- **Height** shall be a function of the roadway requirements for smooth road alignment and good sight distances. Design high water (100-year storm) shall be no higher than 2 feet below the lowest part of the bridge substructure.

- Bridge **width** shall be determined by the ultimate road width to be constructed that would cross the structure. This information can be obtained from the Highway Design Section, phone 410-887-3739. At the direction of BCBEC, where future traffic projections warrant, the existing road width shall be used for design, particularly in the case where an existing structure is to be replaced in kind.

- Quantity of flow for design sizing shall be for the 100-year storm and shall be determined as discussed in the hydrology portion of this ***Section*** of the ***Design Manual***, or as taken from a County study of record.

- Minimum freeboard between underside of superstructure and design high water shall be 2 feet, based upon 100 year frequency storm with ultimate development based on zoning, except when otherwise directed by BCBEC.

**3. Protection of Embankments**

Embankments adjacent to bridges shall be lined as required with stabilizing materials or methods to prevent erosion by flows in the waterway. This stabilization shall be carried to an elevation at least 1 foot above the energy gradient of the 100-year design flow. Stabilization shall be carried to points upstream and downstream of the structure to points that are fully stabilized and that will not be impacted by changes in flow velocity, direction or depth due to the proposed structure. The engineer shall provide an analysis and report regarding this stabilization as part of the structure design.

**4. Footings and Scour**

As part of the design of the bridge substructure, the engineer shall prepare an analysis of the potential for scour on the foundations of the proposed bridge. The evaluation shall be done in accordance with the **MdSHA Policy and Procedures Memorandum (PPM) "*Scour Evaluation of Bridge Design Criteria*", Memo D-91-42(4), latest edition,** and **MdSHA's ABSCOUR computer program, latest edition.**

Submission requirements for the report shall be governed by the PPM and shall include recommendations of measures that are to be taken to prevent undermining of the bridge's foundations by scour. The measures shall also be shown on final plans as approved by the County for construction.

5. **Hydraulic Losses Through Bridges**

   Determination of losses through bridges shall be in accordance with FHWA Hydraulic Design Series #1, *Hydraulics of Bridge Waterways*, or with HEC-2 / HEC-RAS criteria.

### C. Private roadway crossings over existing drainage courses or streams

Waterway crossings which serve as access to private property can be designed to a lesser hydraulic standard and must comply with the following:

1. A private pipe culvert shall be sized to carry the 20 year storm frequency discharge with pipe flowing full.

2. The private access road grade and culvert shall be designed to pass the 100-year storm discharge, with a 6" maximum water depth flowing over the roadway, and the backwater surface must be contained on-site with no adverse impact on downstream or upstream properties unless offsite permission is obtained.

3. Headwalls, end sections and slope protection should be provided to prevent future washouts on the upstream and downstream ends.

4. Maintenance of the culvert will be the responsibility of the property owner.

5. The size of the pipe shall be 12" minimum.

6. The design package must be sealed by an appropriate Design Professional who is licensed in the State of Maryland.

7. The owner is responsible for obtaining any and all federal and state waterway construction permits.

## V. FLOODPLAIN ANALYSIS

The Baltimore County Code defines the 100-Year Frequency Floodplain and Article 32 Title 8 of the Code defines activities that are acceptable within the 100-year floodplain.

### A. Definitions:

1. **100 Year Floodplain -** that area inundated by the runoff from a drainage area of 30 acres or more generated by rainfall which has a 1 percent chance of being equaled or exceeded in any given year (100-year frequency storm). The restrictions applied within the County Code regarding 100-year floodplains shall apply when the drainage area is 30 acres or more.

2. **100 Year Waterway -** that area inundated by the runoff from a drainage area of less than 30 acres generated by rainfall which has a 1 percent chance of being equaled or exceeded in any given year (100 year frequency storm). DPW has determined that proposals to modify waterways with drainage areas under 30 acres can be permitted. In these cases the 100-year frequency runoff shall be properly conveyed in accordance with the storm drains portion of this ***Section*** of the ***Design Manual***.

Where protection of the public is critical, the Department of Public Works may require, at its sole discretion, design in accordance with the 100-year floodplain design requirements outlined herein, regardless of contributing drainage area.

3. **100 Year Tidal Floodplain** – that area that is inundated by tidal and/or wind-blown waters with a 1 percent chance of being equaled or exceeded in any given year (100-year frequency). 100-year frequency tidal flooding is regulated by the ***Baltimore County Building Code***, based upon determination of tidal areas by the Federal Emergency Management Agency. The development of property within the limits of the 100-year tidal floodplain must adhere to those requirements.

   The floodplain at the interface between tidal and riverine flooding is determined by careful analysis and should be discussed with DPW to establish the proper starting condition.

## B. Studies of Record

When available, floodplain delineations of record filed with the Bureau of Engineering & Construction will be accepted by DPW without re-review. Those delineations that were "approved for filing" are subject to review as part of the current submittal. The Engineer shall verify all data obtained from sources outside the actual floodplain records with the review agency.

Frequently, a delineated 100-year flood plain for a given area will not be available. However, research may turn up accepted discharges and established downstream water surface elevations that will serve as a basis for expanding the study upstream to the area of interest.

When a new study is done based upon DPW information, the Engineer shall check with all appropriate review agencies to determine acceptability of the DPW material with that agency.

## C. Responsibilities of the Engineer of Record

Floodplain studies prepared for the development of land in Baltimore County will have the plan view signed and sealed by a Professional Engineer registered in the State of Maryland.

## D. Computer Programs

Use of computer programs shall comply with the section "Use of Computer Programs" in the ***General Instructions Section*** of this ***Design Manual***.

Hydrology programs shall be used only as stated in the ***"Hydrology – Methods Criteria" area (II,A,5)*** of the ***Storm Drainage Section*** of this ***Design Manual***.

Computer programs currently approved for use in the preparation of hydraulic studies are as follows:

**HEC-2**, US Army Corps of Engineers, latest version.

**HEC-RAS**, US Army Corps of Engineers, latest version.

**HY-8** Culvert Hydraulics Program, Federal Highway Administration, latest version.

Please note that acceptance of a program for use by Baltimore County does not constitute approval by the Maryland Department of the Environment (MDE). Acceptance by MDE, if required, should be obtained early in the project.

## E. Manual (Hand) Calculation Methods - Hydraulics

Equivalent and/or appropriate hand calculation methods may be used in lieu of approved computer methods of analysis with the approval of the Bureau of Engineering & Construction, or the Bureau of Development Plans Review, subject to the following:

**Manning's equation** is not considered to be an equivalent or appropriate method except within a step method type calculation and as allowed in the following:

1. Backwater conditions resulting from downstream controls such as dams, bridges, culverts or valley constrictions do not exist,

2. The floodplain study purpose is solely for determining a floodplain boundary to establish lot, easement and/or reservation boundaries,

3. The use of Manning's equation is limited to large lot subdivisions (1 acre or larger lots), and

4. Where steep slopes (25% and greater) abut the stream, the Bureaus of Engineering & Construction and Development Plans Review may also be consulted concerning alternate methods.

For freeboard requirements, see **Section F, Freeboard and Setbacks**.

The denial of a request to use Manning's equation for purposes of floodplain analysis is a technical issue that cannot be appealed outside of DPW.

## F. Freeboard and Setbacks

**Freeboard** required adjacent to riverine floodplains shall be as follows:

1. Where the drainage area is 30 acres or greater a 100 year frequency floodplain freeboard boundary will be created which is 1.0 feet greater in elevation than the regulatory 100 year floodplain elevation. The building setback in this case will be 20 feet from the freeboard floodplain with the first floor being 1.0 feet higher than the freeboard floodplain elevation. These **setbacks** are shown on ***Design Plate DF-1A***.

   The above requirements shall be modified as follows based upon type of survey information used:

   - Use of surveyed cross-sections will require 1 foot of freeboard as noted.

- The use of **GIS survey data** (with 2.0 foot contour intervals and a maximum error of 1.0 foot or less within the survey) will be permitted subject to approval of all involved review agencies. An increased freeboard of 2.0 feet shall be applied above the determined water surface elevation.

- Use of the **Manning equation** as discussed above in (E) will require application of a 5.0 foot freeboard above the determined water surface elevation. As an alternate, the use of a flood elevation based on 150% of the flow quantity may be used to establish the limits of the floodplain.

2. Where the drainage area is less than 30 acres:

   - application of freeboard is not required;

   - setback will be 10 feet from the 100-year frequency water surface boundary;

   - first floor elevation shall be set 2.0 feet above the 100-year frequency water surface elevation.

**G. Modeling Considerations**

Where drainage areas are greater than one (1) square mile, the floodplain analysis is subject to review by FEMA as part of a required Letter of Map Amendment (LOMA) application. In this case, the analysis must meet all applicable FEMA requirements.

1. The following storms shall be modeled, with runoff based upon ultimate development as indicated by zoning:

   - Development Studies – At a minimum, run the regulatory (100-year) storm. The 2 and 10-year storms may be required for MDE approval.

   - DPW watershed studies – Run the 1, 2, 10 and 100-year storms, or as directed by BCBEC.

   - Calibration storms as necessary, using land use conditions as they existed at the time of the storm being modeled.

2. **Cross-sections**

   - Cross-sections shall be located at points defining changes in the hydraulic characteristics of the valley as well as the channel.

   - Cross-sections represent the hydraulic flow section and as such shall be perpendicular to the flow path at all points across the valley. In certain cases it may be necessary to re-orient the cross-sections to account for the different flow paths resulting from different storm frequencies.

3. **Ineffective Flow Areas**

   Ineffective flow areas shall be shown on the floodplain maps and on the cross section plots. Ineffective flow areas can be modeled by using artificial levees, high Manning's coefficients or encroachment methods. The method of modeling these areas shall be made clear to reviewing agencies prior to review.

4. **Critical & Supercritical Flow**

   - Where flow is determined to be at critical depth, adjustments may be necessary to hydraulic characteristics, or to cross-section spacing.

   - In cases where supercritical flow conditions are modeled or where critical depth is repeatedly encountered, the water surface shall be considered to be equal to the computed or critical depth elevation, whichever is greater. The freeboard boundary shall be the greater of the water surface elevation with 1.0 foot added or the energy grade line elevation from the supercritical model. Supercritical models are rarely necessary for natural channels except in extremely steep slope situations.

5. **Roughness coefficients**

   - Channel and overbank roughness coefficients should be based on field reviews and on the anticipated flow depth. Photographs may be requested if there is a question regarding the roughness coefficients selected. The roughness coefficient shall be based on the worst hydraulic condition anticipated, including the effects of vegetation and debris. Use values based upon standard references.

   - The Manning's coefficient for future condition studies should take into account the changes proposed, including the replanting of the forest in the floodplain as required by re-foresting regulations.

6. **Reforestation Impacts**

   - Where the forest buffer is to be established through development, the hydraulic model shall include the effects of onsite plantings and a projection of the future planting limits and impacts offsite.

   - Planting a forest buffer that causes adverse impacts on private property without compensation to that property owner will not be allowed

7. **Debris & Maintenance**

   For improved channels of uniform section, runs should consider the effects that debris and maintenance could have on the hydraulics, in particular, the n-factor value. This shall be considered when determining whether sub-critical or super-critical flow conditions exist in any given area.

8. **Manning n-factors**

   - Flood plain analysis shall be based upon summer conditions, using n-factors appropriate to conditions where trees, brush and grasses are fully leaved.

- Where trees are to be planted within a floodplain, a minimum 10% increase in n-factor shall be applied above that used for the planted trees in order to account for the increase in n-factor that occurs as the trees grow.

### H. Activities in the floodplain

Activities in the floodplain are limited by County Code as defined in Article 32 Title 8. Only those activities permitted in the floodplain, as defined in Article 32 Title 8, can be approved by DPW. All other activities must be granted a waiver by the Hearing Officer.

Activities within riverine floodplains are also subject to authorization by DEPRM in accordance with Article 33, Title 3.

## VI. CONTRACT DRAWINGS AND DOCUMENTS TO BE SUBMITTED TO BCBEC

Attention is directed to General Instructions Section of this **Manual** for additional information.

### A. Preliminary Reports

#### 1. Storm Drain Systems

Preliminary Reports shall be submitted as stipulated in the General Instructions Section. Reports shall include a map (1" = 200') of the entire drainage area showing the proposed storm drains in conjunction with existing drains. See the ***Hydrology portion*** of this ***Section*** for additional items that must be shown on the drainage area maps. A flow tabulation shall also be included, along with a preliminary estimate of project costs. Hydrologic analysis for the project should be ready for approval, subject to minor changes in design, as part of the preliminary report approval.

#### 2. Waterway Crossings – Bridges, Bottomless Spans and Culverts

Preliminary Reports shall be submitted as stipulated in the General Instructions Section. Reports shall include a map of the entire drainage area showing the location of the proposed crossing structure and outlining the entire tributary drainage area. See the hydrology portion of this Design Section for additional items that must be shown on the drainage area maps. Flow calculations and a preliminary estimate of project costs shall be included. Hydrologic analysis for the project should be ready for approval, subject to minor changes in design, as part of the preliminary report approval.

Where architectural considerations are involved for bridges or large culverts, the preliminary report shall also include elevation sketches showing the principal architectural features.

When relocations of road and/or utilities are involved, the engineer shall submit, as part of the preliminary report, sketches of a sufficiently large scale to show the general plan and profile of the structure and its relationship to the relocation.

### 3. Floodplain Studies

a. DPW floodplain study submittals shall be as defined by the following or as required in the scope of work. Development floodplain studies shall be as defined by the following, except that only the information pertaining to the regulatory 100-year, ultimate development model need be submitted.

   Studies prepared for DPW projects that will require the Water Resources Administration, State Highway Administration, or another agency's approval shall be submitted with an additional complete copy for each involved agency. Check with reviewer regarding recipients and the number of copies required.

b. A report shall be submitted that addresses/includes the following:

   1. Introduction and Purpose of Study

   2. Location Map, with datum clearly stated

   3. Description of existing conditions, and sources of data used, including surveys

   4. FEMA study, if available

   5. Stream Classification

   6. Discussion of criteria for road crossings design (replace-in-kind vs. full 100 year design, etc.)

   7. Hydrology – in accordance with **Section II** of the Storm Drainage area of this **Design Manual**.

      Drainage Area Maps – **Section IIB**
      Watershed Schematic – **Section IID3**
      RCN and Tc Computations – **Sections IID4 and 5**
      Hydrograph Computation, Rain Tables, AMC – **Section IID6**
      Reach / Resvor Routing Data – **Sections IID7 and 8**

   8. Hydraulics and Mapping- the following shall be submitted in a report and/or presented on 100- or 50-scale maps (unless otherwise approved) to include the following:

      a. Data source for topography, stream cross sections
      b. Datum
      c. Post-construction 100-year ultimate land use floodplain delineation, including 1’ freeboard for development and record plat purposes.
      d. Pre-construction 100-year ultimate delineation (if necessary, for various alternatives, existing land use delineations)
      e. Calibration storm delineation (if necessary)
      f. Ineffective flow areas
      g. Structure size, type
      h. Cross section locations

i. Water Surface Elevation on map
j. Streets labeled for ease of identification

DPW projects shall include all floodplain maps and profiles in a 22" by 34" reproducible format unless otherwise directed. Profiles should be immediately below the corresponding plan view, when possible.

9. Stream Profiles - of each storm, for all land uses and alternates studied. Profiles should include stream inverts, flow rates, calculated water surface elevations and silhouettes of structures. Profile plots will be presented with a scale, no larger than 1"=100' horizontal and 1"=10' vertical. The scales may be modified upon the decision of the reviewing agency to allow for their inclusion in report

10. Cross Section plots - indicate roughness coefficients, ineffective flow areas, banks, top of roadway, low chords and other critical points, such as levee locations. Cross-section plots will be presented with a scale, no larger than 1"=100' horizontal and 1"=10' vertical. The scales may be modified upon the decision of the reviewing agency to allow for their inclusion in report

11. Existing & Proposed Structure Sketches or plots with roadway (weir section) as well as approach and exit channel details and limits. Material type should be noted on these plots or (alternately) on the profiles. Calculations which support the derivation variables used should be submitted.

12. Computations

- Starting water surface elevation - discussed including any assumptions used in making that selection.
- Discharge(s) used – a table of the flows used (with tr-20 cross section #) for each hydraulic cross section shall be provided.
- Loss Coefficients
- Cross-section orientation.
- Bridge modeling method
- Calibration - Where calibration is performed the supporting data must be included in the submission.

13. Computer Runs

Development Floodplain studies require submittal of a full printout of all data including the complete input and output.

DPW floodplain studies require submittal of a full printout of all input data including summary table output, and electronic files of full input and output data on an IBM format floppy disk.

4. **Watershed Diversions Analysis –** Refer to **Section IIE**, Hydrology.

**B. Contract Drawings.**

Contract drawings shall be prepared in accordance with the requirements of the ***General Instructions Section*** of this ***Design Manual***, in addition to requirements herein. Standard symbols and standard CADD methods of drafting shall be used. See the ***CADD Drafting Section*** of this ***Manual***. Hand drafting of drawings is permitted; however, the results shall be a drawing fully compliant with all current drafting practices in terms of symbols, scales and content.

Storm Drain contract drawings shall be prepared on their own sheets, separate from other utilities. Multiple sheet storm drain projects shall have a title sheet showing location and drainage area map, index of sheets, general notes and a list of contract revisions. Job order, contract and drawing numbers shall be obtained from BCBEC. The Sample Drawing illustrates these applications.

Where reference is made to another sheet in a multiple sheet set, that reference shall be by issued County drawing number rather than by sheet number.

All applicable items shown on the ***General Instructions Check List*** and the ***Storm Drainage Check List*** shall be clearly shown on the Contract Drawings and one copy of each Check List shall be submitted along with the Final Contract Drawings.

**1. Plan View**

The plan view shall be placed at the upper left of the drawing, north pointing toward the top or left side of the sheet. Plans shall be to scale and shall comply with surveys of the project area and with record drawings of existing utilities. The engineer is responsible to resolve any differences between survey data and existing record drawings.

**a. Scale** shall be 1" = 50', 1” = 30’ or 1” = 20’.

**b. Method of indicating location**

Generally, drains, inlets and manholes shall be located in plan by dimensions from property markers or other well-defined permanent physical features. Curb radii shall be shown for inlet location purposes. Where a baseline is established, drains, inlets and manholes shall be located by station and offset from that baseline. In areas where baselines and physical features are not available, coordinates of manholes and bearings of storm drains shall be used. Inlets, manholes and structures shall be numbered (working upstream) to coordinate with drainage area map, schedules of structures, profiles, computations, flow tabulation and notes.

**c. Direction of gutter flow** to street inlets shall be clearly indicated by bold arrows on each side of each inlet shown on the plans.

d. **Rights-of-way** See ***Land Acquisition Section*** of this ***Manual***.

2. **Profile.**

The associated storm drain profiles shall be located under the plan view whenever possible.

a. **Scale of drain profile** and inlet profiles shall be 1" = 50', 30' or 20' horizontal, 1" = 5' vertical; horizontal scale to match plan view scale. The true length between structures shall be shown by figures.

b. **Street Grades**

Approved established grade shall be obtained from BCBEC. When such grades are not available, they shall be established by the design engineer and submitted to BCBEC for approval.

Where drain is located in present or proposed pavement or shoulders the existing and proposed grade of road shall be shown. Where drain is outside pavement or shoulders, existing ground over drain shall be shown. If the drain is to be constructed on fill, profile of the undisturbed earth (at drain location) shall be shown.

The top elevation of all inlets, manholes, valve boxes or any other structure within a road area shall be shown on all plans. These elevations shall be computed from the established grade and shown in hundredths.

The profile shall indicate clearly the type, material and depth of paving over the proposed storm drain.

c. **Energy Gradient**

An energy gradient for the appropriate design storm shall be shown for storm drains and open channels.

3. **Other Utilities.**

Other existing and proposed utilities shall be accurately and clearly shown in plan and profile in accordance with standard symbols (see ***CADD Drafting Section***). The drawing numbers of plans of other utilities being prepared at the same time shall be shown. Reference drawing numbers shall be shown upon the applicable plan sheet within the drawing set for all existing utilities and for roadway geometry.

Pipe thickness/corrugations shall be indicated accurately on profile and cross-section views in order to provide an accurate picture of clearances at utility crossings. Minimum clearances applicable to the utility involved shall also be shown.

**4. Location, Drainage Area Map and Design Information**

A Drainage Area Map shall be shown on the first storm drain drawing of the Contract Drawings indicating the entire drainage area to be served both presently and ultimately by the proposed drains. Drainage Area map scale shall be 1" = 200', or 1" = 500' when space does not permit the larger scale map without extra drawings.

Where the drainage area map will not show at least two well-known streets or routes, a Location Map shall be added (1" = 2000') showing the location of the work.

Design Data, Bench Marks, Coordinate System notes, manhole, structure, test pit and inlet schedules shall be as shown on the Sample Drawing and as listed in the Check List.

**5. Special Details**

Structures or details not included in the Standard Details shall be clearly detailed on the contract drawings. Special details, when required, shall be shown to scale and shall comply insofar as possible with the County's Standard Details and with standard industry practices. See ***General Instructions Section*** for scale.

**C. Contract Specifications.**

See ***General Instructions Section***.

**D. Estimate of Quantities.**

The engineer shall submit a summary of quantities and an estimate of costs for each contract, including contingent items, as set forth in the ***General Instructions Section***.

**E. Design Calculations.**

Design engineers shall submit design data and computations for the project as specified in the ***General Instructions Section***. The data shall be comprised of generally the following items. This data shall be submitted at the same time the Contract Drawings are submitted for review.

**1. Hydraulic Design.**

a. Flow tabulation form.

b. Calculation of sizes and energy gradient.

**2. Structural Design.**

a. Drains. Structural calculations for all drains other than pipes shown in loading tables shall be submitted.

b. Special Structures. Design computations for all special structures shall be submitted.

3. **Coordinates.**

   Computations of coordinates shall be submitted where coordinates are shown on contract drawings.

4. **Results of Borings and Test Pits.**

   Where information pertinent to design, such as boring logs, has been collected, this information shall be submitted to BCBEC and included on Construction Drawings as required.

**F. Permits**

Where a project involves work in a stream, floodplain, wetlands, critical area or other protected area, or within buffers to these areas, the Design Engineer shall provide original and two (2) copies of approved permits to be included in the Contract package for use by the Inspector and Contractor.

Design Engineers for projects involving modification of streams and/or floodplains having a drainage area exceeding one (1) square mile shall be responsible for submittal of a Letter of Map Revision (or Amendment, as applicable) to FEMA. The Design Engineer shall include time in his proposal to complete this work.

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## VIII. DESIGN FIGURES.

## Appendix A: History of Drainage Design in Baltimore County

*As development of the large areas of Baltimore County surrounding Baltimore City proceeded from a rural to a more urbanized area, storm drain facilities were given relatively little consideration. With land readily available, it was easy to avoid low-lying areas with drainage problems.*

*In the early period of development, the Highway Department, as the only public works agency, accomplished all storm drain construction and maintenance. This work was confined almost entirely to maintaining all weather roads, and consisted principally of providing culverts to carry water under the roads and ditching along the road shoulders. Sizing of pipes was based largely on experience in judging the amount of storm flow any structure would have to carry, with little attention given to sizing for future land development. Most areas were still drained by systems of swales and ditches.*

*When the Metropolitan District was created in 1924, County government recognized that, with the extension of water and sewer facilities into the developing communities adjacent to Baltimore City, there would also be a need for enclosed storm drain systems. The Chief Sanitary Engineer of the Metropolitan District was authorized to supervise the design and construction of storm drains within the Metropolitan District.*

*Until 1946, the design of storm drains was accomplished entirely on an individual basis. Little or no consideration was given to areas adjacent to those being developed and the basis of design was left to the developer or his surveyor-engineer. In 1946, a design manual which covered sewer, water and storm drains was prepared by the Chief Engineer of the Metropolitan District in an effort to establish some uniformity in the design and construction of these facilities.*

*By 1950, the extent of building following World War II was such that previously isolated communities were being joined by new developments. Also, low-lying areas, by-passed previously as undesirable, had become valuable enough to be considered for development. Inadequacies due to previous poor planning and design began to appear during heavy storms. The increased run-off from new developments flowing into older downstream communities was flooding these communities because of inadequate systems. In the fall of 1950, a heavy storm caused severe flooding in many sections of the County; Parkville, Essex, Dundalk and Arbutus were particularly hard hit. Hurricanes during 1951 and 1952 reinforced the need for comprehensive planning in order to avoid increasingly damaging floods in many areas of the County. Although reconstruction of many collapsed systems and installation of new systems were immediate priorities, a complete analysis of all drainage facilities throughout the urbanized areas and a review of past and current policies and criteria was much more important. The County could not support the cost of major improvements to all of the streams and watercourses in the County.*

***Development of topographic maps***

*The lack of topographic maps of the County, other than at scales of approximately one inch to the mile, made it almost impossible to determine the actual drainage area for which a system should be designed, resulting in many recently designed facilities being undersized. In 1953, a contract was let for taking aerial photographs of 247 square miles of the County from which one-inch-equals-200-feet photogrammetric contour maps were prepared. In addition to their value for water, sewer and highway planning, they serve as a basis for planning of storm drains and also contribute a source of data for determining drainage areas. These maps were used as the basis for design in Baltimore County until the late 1990's when GIS mapping became available to the County.*

***Development Of Standards And Policy***

*To ensure uniformity of design from the many engineers submitting plans, the firm of Whitman, Requardt and Associates was engaged, in 1954, to prepare a detailed set of design standards for storm drains, water, sewer, roads and bridges. Streams requiring larger than 48-inch pipe were generally considered all-weather streams, and could be left open without becoming stagnant and a health menace. However, sufficient cross-sectional area had to be provided for stream flows to stay within the stream banks during heavy storms. To meet these requirements, a policy was established requiring developers, when building along open water courses, to set up and deed to the County a drainage reservation not less than 50 feet in width (wider where required) to handle the flow from a 50-year frequency storm falling on the tributary drainage area.*

*Because debris and silting often affect the capacity of open culverts and bridges along open watercourses, these structures were to be designed on the basis of a 50-year storm rather than the 10-year storm used for storm drain design. To further protect purchasers of homes along watercourses and tidal areas, the ground elevation around homes along open streams were to be a minimum of two feet above the elevation of the 50-year storm in the nearby stream.*

*In 1947, public works agencies responsible for conveying storm water drainage in the Baltimore area decided that future improvement and economy in this service could be achieved using scientific research. The Departments of Public Works of Baltimore City and Baltimore County, with the Maryland State Roads Commission, formed the Storm Drainage Research Committee with the Johns Hopkins University's Sanitary Engineering Department to sponsor a hydraulic research study of storm water control in urban areas. The committee had as two primary goals, to determine the hydraulic behavior of all existing types of storm water inlets to improve their design and increase their efficiency and to develop methods and equipment to measure storm rainfall and runoff. The results of this research have been published as a book entitled "The Design of Storm Water Inlets", in 1956. The inlet capacities established by that book are used in the*

*Baltimore County Design Standards and are incorporated in the design of public works projects. The most concrete evidence of this research is the development of the S-Grate inlet, which has greater capacity per unit of cost than any previously used. Additional research has resulted in bicycle-safe "reticular" grates used from 1976 to 1998 and in a new "curved vane" grate that combines bike-safe operation with high hydraulic capacity, introduced in 1998. Other testing and research has been done more recently involving pipe materials, flexible versus rigid pipe, use of geotextiles, inlet types, pipe joints and structure materials.*

*In 1955, arrangements were made with the US Geological Survey to establish gaging stations along larger streams in order to obtain statistical data as historical basis for discharge and flooding levels along assigned streams. This enabled the County to determine discharges from the largest watersheds in the County for which the formulas used for smaller areas were inadequate and misleading. A number of USGS gages operate along streams in Baltimore County to this day.*

*The Design Standards and research have been upgraded a number of times since the first standards were established in the 1940's. The most comprehensive upgrades occurred in 1955, 1964 and 1982, with interim upgrades occurring at other times to address particular issues.*

***A Master Drainage System***

*Planning and building an adequate storm drain system for the County includes the proper development of County streams and rivers as carriers of storm water and the drainage of streets and land areas through a pipe and channel network which discharges into the County streams or tide water. Accordingly, the master storm drainage system may be said to be the County's streams and rivers, and their proper development is the solution to the major drainage problems of the County.*

*A master drainage plan for County streams and rivers involves establishment of a floodplain for each stream so that safe elevations for building and road construction may be established and readily available to both development engineers and to County regulators. During the 1950's and 1960's, studies were usually limited in scope to areas where serious flooding occurred as opposed to areas where development would create future impacts, and methods used in studies were simplified for the application of a slide-rule level of technology.*

*After a series of storms in the early 1970's that culminated in Hurricane Agnes on June 22, 1972, the County realized that development in the County had reached a critical stage that, without appropriate control being applied would result in serious and lasting damages to the County's streams and to adjacent properties. Multi-jurisdictional task forces were quickly brought together on State and local levels in Maryland to strengthen existing regulations. By 1976, the County had adopted new sediment control and stormwater quantity management regulations* *in response to federal, state and local legislation. The 100-year storm replaced the 50-year storm as the regulatory storm. The FEMA program for flood insurance was adopted for the benefit of County residents and a flood purchase program for heavily impacted private residences was established with costs shared by County and State governments. By 1982, the most frequently flooded properties in Baltimore County had been purchased, residents relocated and improvements removed so that the impacted properties could be kept in flood tolerant use within every major watershed. Each problematic watershed had its own flood study establishing a 100-year floodwater limit. Development of these studies was aided enormously by the concurrent availability of computer programs that analyzed complex watershed hydrology and generated floodplain elevations based upon energy levels without making many simplifying assumptions.*

*During the 1980's, water quality became an issue that also had to be addressed. Stormwater management developed this second facet, to be enforced by a new Department within the County. Procedures were changed within the County when streams were involved to ensure that water quality was addressed. Mitigation procedures were developed for impacted wetlands and other critical areas. In this way, the County now addresses both the quality of its water resources and manages the quantities of discharge to its streams.*

- Adapted and updated from *"Baltimore County Department of Public Works – Progress and Accomplishments 1951-1957"*

**CHECK LIST**

**STORM DRAINS 30% (PRELIMINARY) SUBMITTAL**

PROJECT ______________________________

J.O. __________ DATE ___________________

CHECKED BY __________________________

APPROVED _____________ DATE _________

**DRAINAGE AREA MAP**

___1. Scale: 1"=200' preferred; Smaller for large watersheds
___2. Subareas shown (II B 3)
___3. Time of Concentration Paths shown, segments labeled (II B 5)
___4. Land use - Existing & Proposed shown
___5. Zoning, Soil Types & Hydrologic Soil Groups shown (II B 1)
___6. Note indicating Watershed location
___7. County & State storm drain systems shown with size & drawing number (II B 1)

**HYDROLOGY COMPUTATIONS**

___1. Rational Method used in accordance with Section II C of the Storm Drainage section of the Design Manual.
___2. Runoff coefficient C determined as area-weighted average, using Plate DA-2
___3. Overland flow time (II C 2 a)
  ___a. 75 foot maximum
  ___b. Determined per Plate DA-3
___4. Swale Flow time– Table, Plate DA-4 (II C 2 a)
___5. Gutter Flow time– Graph, Plate DA-5 (II C 2 a)
___6. Inlet Time (II C 2 b)
  ___a. Overland Flow Time
    + Swale Flow Time
    <u>+ Gutter Flow Time</u>
    Inlet Time
  ___b. Minimum of 5 minutes for new inlets (exception: as calculated in RC zone)
  ___c. As calculated for existing inlets
___5. Average Rainfall Intensity i (II C 3) - Interpolated using Plate DA-6 with computed inlet time (Tc)
___6. Total Q = Summation of subarea Q's
___7. Exceptions (II C 2 d,e)
  ___a. If a highly impervious subarea generates a Q larger than the entire area, use the larger value.
  ___b. Apparent reductions in Q downstream of higher Q's shall not be decreased.

**PRELIMINARY PLANS**

___1. Field surveys information established in field per County Standards and shown on plans. Property lines shown for properties involved in project.
___2. Inlet locations shown (III B 1 a,d). Show direction of flow in gutters adjacent to inlets, using bold arrows at either end of proposed inlets.
___3. Utility (Water, sewer, gas, storm drain, underground electric, telephone, CATV, etc.) locations shown in accordance with record drawings & checked against survey data.
___4. Preliminary layout of storm drain system shown.
___5. Mark suggested location of test pits to be requested.
___6. Proposed offsite easements and R/W shown.
___7. CADD/drafting in accordance with General Instructions Section, CADD section.

**HYDRAULIC COMPUTATIONS**

___1. Inlet bypass computations. (III B 1 d,a)
  ___a. Standard form used.
  ___b. 85% of gutter flow intercepted by each inlet.
  ___c. Combination inlets used where possible. (III B 1 b)
  ___d. Avoid inlet depression (III B 1 b)
___2. Preliminary flow tab with tentative discharges shown to establish pipe sizes for clearance from other utilities.

**PERMITTING**

___1. Location of SWM areas, if required.
___2. Stormwater management concept approved by DPW.
___3. Stormwater Management hydrology submitted to DEPRM.
___4. Waiver submittal complete, if applicable.
___5. Wetland Assessment requested, if required.
___6. Community meeting, if requested.
___7. Watershed diversions analysis (II E) if required.
___8. Joint Permit, if required, is filed based upon 30% plans.

**FIELD INVESTIGATION (by reviewer)**

___1. Drainage Area Maps from record drawings are to be field-verified. (II B 6)
___2. Drainage area map ridge lines correct. (II B 3)
___3. Time of Concentration Paths verified.
___4. Ground Cover verified.
___5. Use of Natural Topography & Land Cover where possible.

___6. Suitable Outfall Available.

- ___a. Downstream pipe system(s) suitably sized to carry proposed flow in addition to current flow reaching them without overflow onto road or private property.
- ___b. Downstream pipe systems verified to be in good condition by Bureau of Utilities.
- ___c. No erosion present at proposed ditch outfall.

**CHECK LIST**

**STORM DRAINS 70% SEMI-FINAL SUBMITTAL**

PROJECT ______________________________

J.O. __________ DATE ___________________

CHECKED BY __________________________

APPROVED _____________ DATE _________

PROJECT ENGINEER SHALL COMPLETE, SIGN AND SEAL THIS CHECKLIST AND INCLUDE THE ORIGINAL WHEN SUBMITTING 70% SEMI-FINAL PLANS FOR REVIEW.

**PRELIMINARIES FOR COMPLETION BEFORE DEVELOPMENT OF SEMI-FINAL PLANS**

___1. 30% Preliminary Plans and computations submitted to and approved by DPW-checklist attached. Field inspection has been completed.
___2. Stormwater Management waiver obtained or Stormwater Management concept and hydrology approved by DEPRM. (Copy on file in DPW).
___3. Wetlands assessment completed.
___4. Watershed Diversions Analysis report is accepted by County.
___5. Joint permit, if required, has been filed with 30% plans. Follow-up requests for adjacent resident notification and Engineer-In-Charge certification have also been completed.
___6. Plats for R/W, easements and work areas are prepared and submitted to Bureau of Land Acquisition.
___7. Test pit data has been obtained for utility crossings.
___8. Bureau of Utilities has inspected and reported upon condition of existing drain systems that will be connected to proposed system.

**70% PLAN**

**A. GENERAL**

___1. Existing topography is shown in accordance with General Instructions and standard symbols.
___2. Lines are shown in accordance with General Instructions and CADD Standards.
___3. All text is readable and in accordance with General Instructions.
___4. Standard Drawing title block is used. Title includes size, location of drain, local subdivision or population center name, election and Councilmanic District (in 13c1 format). See General Instructions.
___5. Limits of contract are shown.
___6. North Arrow with datum abbreviation, coordinate ticks (3 minimum), and datum note provided.
___7. Scales used are appropriate for legibility and in accordance with General Instructions. Scales noted in Title Block.
___8. Match lines used as necessary; reference adjacent drawings in accordance with General Instructions.
___9. Storm drain plan view, profile and structure tables on same sheet.
___10. Provide cross-reference note on each storm drain plan sheet to corresponding highway plan sheet.
___11. Title sheet
  ___a. Used for multi-sheet drawing sets only.
  ___b. Contents per General Instructions
___12. Baselines, centerlines, property lines
  ___a. Shown in compliance with standard linetypes
  ___b. Shown as necessary to clarify location of existing & proposed features
___13. Property Information shown in compliance with General Instructions – New & Existing R/W shown & dimensioned.
___14. Roads & Streets
  ___a. Existing & proposed shown; differentiated per General Instructions
  ___b. Existing & Proposed R/W shown & dimensioned.
  ___c. Type & thickness of existing paving indicated.
  ___d. Names & paving widths indicated.
  ___e. Existing & proposed curb & gutter labeled/differentiated graphically per General Instructions.
  ___f. Existing/proposed curb radii indicated.
  ___g. State Roads clearly labeled.
___15. Existing utilities
  ___a. Shown in approved symbols with size, type and drawing number labeled.
  ___b. Check record drawings against field run topo.
  ___c. Gas, underground electric & communications plans obtained from utility companies, checked against topo and shown per General Instructions.
  ___d. Utility manholes & structures labeled in accordance with record drawings.
___16. Proposed Utilities
  ___a. Shown in accordance with General Instructions
  ___b. Coordinated with approved plans for each utility.
  ___c. Shown on S.D. plan for location purposes – separate construction drawing per General Instructions.
___17. Bench mark reference, number, elevation & description shown.
___18. Location Plan, Scale 1" = 2000' minimum
  ___a. Shown on title sheet, if applicable; may be combined with drainage area map.
  ___b. Work site indicated.
  ___c. Distance from County population centers shown, major streets to site shown.
  ___d. Names of streets on which work is proposed, shown.

___19. Test Pits / Borings
- ___a. Locations shown and labeled on plan view using approved symbols.
- ___b. Boring data shown on separate sheet in a standard format.
- ___c. Test Pit Data shown in table; referenced by number on applicable pipe profiles.

___20. Drainage Area Map shown as approved as part of preliminary review.
- ___a. Scale 1”=200’. 1”=500’ may be used when larger scale will require multiple pages.
- ___b. Entire drainage area shown that reaches work site.
- ___c. Existing & proposed drain systems shown schematically, complete with manhole, inlet & structure numbers.
- ___d. Each tributary sub-area labeled by letter for reference to structure schedules and to flow tabulation form.

___21. Flow tabulation
- ___a. Uses standard form
- ___b. Includes sub-area letters as shown on DA Map, individual & cumulative tributary areas, C-factors, CA (adjusted for 20 year storm in sumps), cumulative CA, times of concentration, flow times, rainfall intensity and discharge.
- ___c. Includes pipe diameter, n-factor, grade of pipe, flow velocity and storm frequency where other than 10 year storm.

B. STORM DRAIN (PLAN VIEW)

___1. Proposed Drain
- ___a. Shown in approved symbols with size between structures and type of pipe labeled.
- ___b. Shown in proper location.
- ___c. Within State Roads, method of crossing labeled.
- ___d. Proper clearances from other utilities shown.

___2. Proposed Drain Structures – Inlets, Manholes, Bends, Connections, Junction Chambers
- ___a. Shown in approved symbols in proper location.
- ___b. Adequate access to structures provided.
- ___c. Proper clearances from other utilities shown.
- ___d. Gutter flow arrows (bold) shown upstream & down of street inlets.
- ___e. Numbered S-1, S-2 (Bends, connections, junction chambers & special structures), M-1, M-2 (Manholes), I-1, I-2 (inlets) starting from downstream end. End sections & endwalls numbered E-1, E-2, etc.

C. PROPOSED STORM DRAIN PROFILE

___1. Profile shown on same sheet as plan for given segment of proposed storm drain.

___2. Horizontal and vertical scale in accordance with General Instructions; scale shown in title block or prominently on profile.

___3. Proposed ground line labeled and checked against established road grade (B-5 profile).

___4. Existing ground shown per General Instructions & labeled as such with date.

___5. Name of Road and intersecting roads shown.

___6. Crossing and parallel existing utilities shown and labeled for type, size and invert/top elevation.

___7. Structure, manhole and inlet inverts labeled at all incoming and outgoing pipes.

___8. Each structure, manhole and inlet numbered to correspond with numbering on plan view.

___9. Drains between structures, manholes and inlets labeled for size, type, class & grade of pipe, quantity and velocity of flow.

___10. Arithmetic of grade and invert elevations checked.

___11. Limits of right-of-way shown and labeled.

___12. Hydraulic gradient shown for each proposed drain.

___13. Pipe checked against proposed grade shown for allowable cover. Show temporary construction berm over pipe as required and/or concrete cradle or encasement for permanent cover otherwise inadequate.

___14. Show stations of manhole & inlet centerline & face of endwalls, PC & PT of bends & junctions. Check stationing against plan.

COMPUTATIONS

___1. Flow tabulation complete and in agreement with storm drain plan and profile.

___2. Hydraulic Gradient computations ( )
- ___a. Appropriate starting elevation.
- ___b. Computations complete and grade line shown on plan.
- ___c. Required clearances observed.

___3. Preliminary Estimate (major items with percentage added as contingency) prepared & submitted with 70% plans for preliminary comments and budgetary process.

PERMITTING & SUBMITTALS

___1. Stormwater Management plans submitted to DEPRM for approval when 70% plans submitted to DPW.

___2. Sediment Control plans preparation begun upon approval of 70% plans.

___3. 70% plans prints given to Bureau of Land Acquisition for property owner contacts.

___4. 70% plans prints with copy of preliminary estimate given to Construction Inspection for comments.

___5. Follow up with status of Joint Permit. 70% Plans submitted along with reactions to any comments, as required.

___6. General Instructions Checklist completed and attached to this checklist.

___7. Plans sent to Utility companies for development of utility relocation plans & cost estimate.

**CHECK LIST**

**STORM DRAINS 95% FINAL SUBMITTAL**

PROJECT ______________________________

J.O. __________ DATE ___________________

CHECKED BY __________________________

APPROVED _____________ DATE _________

PROJECT ENGINEER SHALL COMPLETE, SIGN AND SEAL THIS CHECKLIST AND INCLUDE THE ORIGINAL WHEN SUBMITTING 95% FINAL PLANS FOR REVIEW.

**PRELIMINARIES FOR COMPLETION BEFORE DEVELOPMENT OF FINAL PLANS**

___1. 70% Semi-Final Plans and computations submitted to and approved by DPW.
___2. Stormwater Management plans submitted to DEPRM for approval. (Copy on file in DPW).
___3. 70% plans prints given to Bureau of Land Acquisition for property owner contacts.
___4. 70% plans prints with copy of preliminary estimate given to Construction Inspection for comments.
___5. Follow up with status of Joint Permit. 70% Plans submitted along with reactions to any comments, as required.
___6. Sediment Control plans preparation begun upon approval of 70% plans.

**95% (FINAL) PLAN**

**A. GENERAL**

___1. Plans are in accordance with General Instructions and CADD Standards in all respects.
___2. Plans as printed are complete (there are no hidden layers in CADD that are hiding information).
___3. Plans are stamped and sealed by Professional Engineer registered in MD, or an equivalent Design Professional accepted under MD law.
___4. Match lines references checked for final configuration of drawing set; all references take reader to appropriate sheet. in accordance with General Instructions.
___5. Provide cross-reference note on each storm drain plan sheet to corresponding highway plan sheet.
___6. Other proposed utilities shown on S.D. plan for location purposes checked with those utility plans for final locations and appropriate clearance at crossings.
___7. Storm drain plan view, profile and all related inlet, manhole and structure tables on same sheet.
___8. Inlet Schedule
  ___a. Includes inlet number, type of inlet, discharge to inlet, invert out and top elevation of inlet.
  ___b. Top elevation of road inlets per established top of curb or computed in accordance with ______ where no curb is to be added.
  ___c. Discharge to Inlet checked against inlet capacity at road grade and lateral cross-slope occurring at final location of inlet.
  ___d. Inlet numbers in agreement with flow tabulation, plan, profile and drainage area map.
___9. Manhole Schedule
  ___a. Includes manhole number, type of manhole, size (manhole diameter), invert out, top elevation of manhole and Standard Detail plate number.
  ___b. Top elevation set in accordance with road grade.
  ___c. Manhole numbers in agreement with flow tabulation, plan, profile and drainage area map.
___10. Structure Schedule
  ___a. Includes structure number, type of structure, size, invert out, top elevation of structure and Standard Detail plate number.
  ___b. Top elevation set in accordance with Standard Detail plate for type of structure used or with special detail.
  ___c. Structure numbers in agreement with flow tabulation, plan, profile and drainage area map.
  ___d. For special design structures, substitute sheet number showing special detail for Standard Detail Plate number.
___11. Coordinate Schedule for structures for GIS input
  ___a. Uses NAD83/[current] coordinate system, with a note to this effect.
  ___b. Table may be on separate sheet.
  ___c. All structures to be coordinated – inlets, manholes, endwalls, bends, connections, etc.
  ___d. Table to include structure/inlet/manhole number, northing and easting coordinate.
___12. Special Details
  ___a. Uses appropriate scales.
  ___b. Indicates location of top elevation indicated in Structure Schedule.
  ___c. Shown in accordance with Standard Details as much as possible.
  ___c. Concrete reinforcing is clearly detailed.
___13. Flow tabulation
  ___a. Check final configuration of storm drain plan against pipe lengths, travel times.
  ___b. Check discharges, pipe lengths and slopes against values shown on profile.

B. STORM DRAIN (PLAN VIEW)

___1. Proposed Drain
  ___a. Shown in approved symbols with size between structures and type of pipe labeled.
  ___b. Shown in proper location with dimensions from survey-established property lines & corners.
  ___c. Within State Roads, method of crossing labeled.
  ___d. Proper clearances from other utilities shown.
___2. Proposed Drain Structures – Inlets, Manholes, Bends, Connections, Junction Chambers
  ___a. Shown in approved symbols.
  ___b. Shown in proper location with dimensions from survey-established property lines & corners. Inlets dimensioned from PC of curb.
  ___c. Adequate access to structures provided.
  ___d. Proper clearances from other utilities shown.
  ___e. Curve data for cast-in-place junction chambers & bends checked & provided with layout detail.
  ___f. Numbered S-1, S-2 (Bends, connections, junction chambers & special structures), M-1, M-2 (Manholes), I-1, I-2 (inlets) starting from downstream end. End sections & endwalls numbered E-1, E-2, etc.

C. PROPOSED STORM DRAIN PROFILE

___1. Profile shown on same sheet as plan for given segment of proposed storm drain.
___2. Profile conforms with all requirements for profile as indicated on 70% Semi-Final checklist and in General Instructions.
___3. Pipe checked against proposed grade shown for allowable cover. Show temporary construction berm over pipe as required and/or concrete cradle or encasement when permanent cover is inadequate.
___4. Show stations of manhole & inlet centerline & face of endwalls, PC & PT of bends & junctions. Check stationing against plan.
___5. Trench compaction in accordance with _____ shown for all utilities within road right-of-way limits.
___6. All conflicts between proposed storm drain and other existing and proposed utilities have been resolved and corrections noted on plans.

COMPUTATIONS

___1. Flow tabulation complete and in agreement with storm drain plan and profile.
___2. Hydraulic Gradient computations
  ___a. Computations complete and grade line shown on plan.
  ___b. Gradient complies with ______
___3. Final Estimate prepared & submitted with Final plans for submittal to Construction Contracts Administration Division for bids.
___4. Estimate of working days based upon 1 day per 100 linear feet of pipe plus 1 day per inlet or manhole; 3 days per CIP structure plus time for clearing, cleanup, concrete, repaving, etc.

SPECIAL PROVISIONS

___1. Special Provisions complete and submitted for review with 95% plans.
___2. Special Provisions meet requirements of General Instructions.

PERMITTING & SUBMITTALS

___1. Stormwater Management plans approved by DEPRM, signed by BCSCD.
___2. Sediment Control plans approved and signed by BCSCD.
___3. All issues with Utility companies resolved.
___4. Check status of Joint Permit. Resolve any remaining issues, as required.
___5. General Instructions Checklist completed and attached to this checklist.

**CHECK LIST**

**FLOODPLAIN HYDROLOGY SUBMITTAL**

PROJECT ______________________________

J.O. __________ DATE ___________________

CHECKED BY __________________________

APPROVED _____________ DATE _________

**DRAINAGE AREA MAP**

___1. Scale: 1"=200' preferred; Smaller for large watersheds-fit major sub-watershed on I sheet
___2. Subareas shown (II B 3)
___3. Time of Concentration Paths shown, segments labeled (II B 5)
___4. Land use - Existing & Proposed shown
___5. Zoning, Soil Types & Hydrologic Soil Groups shown (II B 1)
___6. Note indicating Watershed location
___7. County & State storm drains shown with size & drawing number (II B 1)
___8. Show location of TR-20 cross-sections & Structures (II B 1)
___9. Provide watershed schematic for multiple subareas (II D 3)

**HYDROLOGY COMPUTATIONS**

___1. Use TR-55 or TR-20 only (GIS methods with permission) (II A 4, II D 2)
___2. Std. Computer Programs only (II A 5), Version (II D 1)
___3. Drainage areas (acres & square miles)
___4. Runoff Curve Numbers (RCN) (II D 4)
 ___a. Uses soil classification table dated 1/10/97 (II D 4 g)
 ___b. Soil classification NOT adjusted for compaction (II D 4 g)
 ___c. Tabular computation form used (II D 4 c,d) (No Fig.2.1 or Table 2.1 interpolation)
 ___d. Based on SCS "good" hydrologic condition (II D 4 c)
 ___e. Ultimate land use based on zoning (except for calibration runs to match storms of record, or for FEMA (with permission). (II D 4 f)
 ___f. Connected/Unconnected Impervious Areas, or Connected Areas assumed
 ___g. Adjustments
 ___h. Other_______________________________
___5. Time of Concentration Calculations (II D 5)
 ___a. Selected Path "typical" of area (II D 5 a)
 ___b. Tabular determination used (II D 5 c)
 ___c. Proper n-factors used (Sheet flow)
 ___d. Sheet flow $\leq$ 100 feet (II D 5 d)
 ___e. Proper velocities used (Shallow Concentrated & Channel Flow)
 ___f. Minimum $T_c$ =0.1 hr. for TR-55
 ___g. Closest hundredth of hour inputted for TR-20
 ___h. Capacity of drains in $T_c$ path not exceeded (II D 5 b)
___6. Time of Travel calculations-required when $T_c$ path leaves drainage area. $T_c$ & $T_t$ correctly rounded. (II D 7)
___7. Hydrograph Computation
 ___a. $I_a/P$ rounded or hydrograph values linearly interpolated between adjacent charted $I_a/P$ values. (II D 6)
 ___b. TR-20 used when subareas differ by ratio of 5 or more. (II D 2)
 ___c. TR-20 Type II Rain Table used (II D 6)
 ___d. AMC 2 used. (II D 6)
 ___e. 484 Dimensionless Unit Hydrograph used, as noted. (II D 6 c)
 ___f. 24 Hour Storm used.
___8. Reservoir Routing (II D 8)
 ___a. Flood Control Structures only.
 ___d. Structure must have "significant" storage volume.
___9. Appropriate Storms modeled (II D 6 g)
 ___a. 2,10,100 Year req'd.
 ___b. 1 Year req'd. where erosion is a consideration.
 ___c. Additional storms as required for calibration.
___10. Inches of Runoff-correct tabular values used
___11. Peak Discharges (Computed hydrographs for manual storage-indication routing

**FIELD INVESTIGATION (by reviewer)**

___1. Drainage Area Maps from record drawings are to be field-verified. (II B 6)
___2. Drainage area ridge lines correct. (II B 3)
___3. Time of Concentration Paths
___4. Ground Cover
___5. Downstream Hazards
___6. Suitable Outfall available
___7. Use of Natural Topography & Land Cover where possible

**CALIBRATION (II D 9)**

___1. Check discharge against available gage data. (II A 3)
___2. Use other accepted methods for comparison.

# CHECK LIST

## FLOODPLAIN DELINEATION SUBMITTAL

PROJECT ______________________________

J.O. __________ DATE ___________________

CHECKED BY __________________________

APPROVED _____________ DATE _________

PROJECT ENGINEER SHALL COMPLETE, SIGN AND SEAL THIS CHECKLIST AND INCLUDE THE ORIGINAL WHEN SUBMIT-ING PLANS FOR REVIEW.

LOMA/LOMR REQUIRED FOR WATERSHED > 1 SQ.MI.

### HYDROLOGY

___1. Hydrology submittal has been approved in accordance with Section II-D of the Storm Drainage Section of the Design Manual.

___2. Floodplain is riverine.
- ___a. Drainage area is in excess of 30 acres. (V-A-1) Freeboard per Design Plate DF-1A. Use of County GIS contours requires 2.0' freeboard rather than 1.0' specified for use with surveyed data.
- ___b. Drainage area does NOT exceed 30 acres. This area's discharge will be conveyed using storm drains in accordance with applicable provisions of this Design Manual. (V-A-2)
- ___c. Drainage area does NOT exceed 30 acres. Discharge requires design in accordance with floodplain regulations to protect the public interest, as directed by BCBEC. (V-A-2) Freeboard not required; setback 10 feet from 100 year water surface boundary; set first floor elevation 2.0' above water surface elevation. (V-F-2)

___3. Regulations in the Baltimore County Building Code pertaining to TIDAL floodplains are applicable to this area. (V-A-3). Mapping in accordance with FEMA Flood Insurance Rate Maps.

### COMPUTATIONS

___1. Manning Equation (V-E) may be used if:
- ___a. No backwater exists,
- ___b. Study purpose is limited to determining floodplain boundary for establishing lot, easement, reservation boundaries,
- ___c. Study vicinity is limited to 1 acre or larger lots.
- ___d. Requires use of 5.0' freeboard. (V-F-1)

___2. Steep slopes abut stream. Manual methods (Manning) may be considered.

___3. Std. Computer Programs (HEC-2, HEC-RAS, HY-8) used.

___4. Storm runs required (V-G-1):
- ___a. Development Studies: 100 Year Storm. 2 and 10 year may be required for MDE.
- ___b. DPW Watershed Studies: 1, 2, 10, 100 Year
- ___c. Calibration storms as necessary.

___5. Explain any of the following in computations:
- ___a. WSEL for lower year storm exceeds WSEL for higher year storm.
- ___b. Dramatic changes in WSEL, energy gradient or top width from section to section. Top width is to agree with plotted cross-section.
- ___c. Shifts from subcritical to supercritical flow without apparent reason.
- ___d. Sectional velocities higher in overbanks than channel. Does most of Q shift from channel to overbanks and back?

### MODELING

___1. Cross-sections located at points defining changes in flow direction and section, set perpendicular to flow. Sections re-oriented for different storms if flow path differs. (V-G-2)

___2. Ineffective flow areas – use artificial levee to model. (V-G-3)

___3. Supercritical flow – (HEC-2 critical flow repeatedly encountered) - water surface at greater of computed or critical depth; freeboard at greater of water surface +1.0', or supercritical energy grade line. (V-G-4)

___4. Roughness coefficients (V-G-5,6,7,8)
- ___a. Based upon accepted references.
- ___b. Based upon worst hydraulic conditions anticipated, including summer conditions, debris and future maintenance needs.
- ___c. Adjusted 10% upward for re-forestation impacts – no impacts to adjacent private properties allowed.

___5. Profile begun sufficiently far downstream to allow WSEL to stabilize before reaching area of interest. Use an exact elevation only if this can't be done and a value can be reliably determined.

### CROSS-SECTIONS

___1. Cross-sections based upon field-run topo; may be extended in overbanks using GIS topo with approval of reviewing agency.

___2. Cross-sections may be submitted on 8.5" x 11" paper if part of report, or on 24" x 36" mylar if requested by reviewing agency.

___3. Cross-section plots shall show:
- ___a. Labeling of section by number;
- ___b. Use appropriate scales in accordance with General Instructions Section V-A-6 or in accordance with instructions from reviewing agency. Scale indicated on each sheet.
- ___c. n-factors shown clearly relative to applicable portion of cross-section.
- ___d. Elevation and offset coordinate shown for each break point in cross-section.

___e. Stream inverts and limits of top of stream channel labeled & coordinated.
___f. Label stream invert.

**CULVERT & BRIDGE DESIGN**

___1. Culverts – Private roadway crossing culverts in accordance with Section IV-C of Storm Drainage section.
___2. Culvert – 100 year WSEL is 3 feet or more below sump in County road grade and is 3 feet or less above crown of culvert pipe at entrance. (IV-A-4)
___3. Culvert – 100 year WSEL shall not exceed the top of banks adjacent to improved properties and shall not flow outside of floodplain reservations/ easements. (IV-A-4)
___4. Culverts – Multiple pipe installations in accordance with Section IV-A-8.
___5. Open-bottom structures are in accordance with culvert requirements.
___6. Bridges – Minimum 2 foot freeboard between 100 year design high water and lowest point on suspended bridge structure. (IV-B-2)
___7. Bridges – Recommendations to prevent scour of bridge supports provided in accordance with MdSHA procedures. (IV-B-2)

**RIVERINE MAPPING**

___1. Base map:
___a. Use 1" = 100' scale or larger, labeled.
___b. Include vicinity map, 1" = 500' scale minimum.
___c. Label Datum, show contours. Map elevations supported by local survey data throughout extent of study.
___d. North arrow, 3 coordinate ticks at multiples of 250' apart. Label North arrow with datum.
___e. Show and label area roads by name, County bridges and culverts by size and number, if applicable.
___f. Show cross-section locations and extents. Also indicate location of hydrologic cross-sections and structures, to be labeled.
___g. Show all building improvements within 100 feet of determined floodplain.
___h. For projects that will use floodplain map to determine easements and/or reservations, provide surveyed property line information.
___i. Provide liber/folio property information for all adjacent properties.
___k. Include watershed and stream branch names, as applicable.
___l. Indicate data source and date for topography and cross-sections.
___m. Map originals and associated report signed and sealed by Professional Engineer registered in Maryland.
___2. Mapping – on 24" x 36" mylar
___a. Show pre-construction 100 year, post-construction 100 year, freeboard line.
___b. Other storms shown as directed.
___c. Shade & label ineffective flow areas.
___3. Floodplain profile - on 24" x 36" mylar
___a. Use scale compatible with mapping scale (same horizontal scale, 5x to10x vertical scale)
___b. Where possible, show profile on same sheet under corresponding section of map.
___c. Show 2, 10 and 100 year storm water surface profiles. Show water surface elevations and associated flow rates at cross-sections in tabular form.
___d. Show channel invert, left and right top of channel.
___e. Show basement and first floor elevations of adjacent houses and buildings at appropriate point along profile.
___f. Show cross-section locations, labeled with number corresponding to numbered sections on plan view.
___g. Show profile of upstream and downstream culverts, bridges and crossings.

**FIELD INVESTIGATION (by reviewer)**

___1. Topography shown on map is in agreement with observed field contours.
___2. Roughness coefficients used are acceptable for each reach.
___3. Cross-section locations reflect changes in flow direction for storm being modeled.
___4. Structure sizes are correctly noted.
___5. Verify entrance coefficients for each structure.
___6. Map indicates all buildings and obstructions (including fences) adjacent to stream and floodplain.
___7. Buildings located within floodplain have flooding susceptibilities noted in report.
___8. Observable high water lines on buildings, etc. are noted for calibration purposes. Try to verify these with area residents.
___9. Check for conditions such as scour indicating whirlpools, eddy currents and other localized non-linear losses that could invalidate a linear (HEC-2, HEC-RAS) model within that reach.

**CALIBRATION (II D 9)**

___1. Report to include runs made to verify accuracy of computer model for existing storm and existing known water surface elevations.
___2. Coordinate calibration of model with County reviewer.
___3. Report to include analysis of changes made to model in order to calibrate it to existing storms and water surface elevations.
___4. Determine sensitivity of model to changes in roughness coefficients, antecedent moisture condition, exclusion of ineffective areas, etc. Include commentary in report.
___5. Provide photos of channel, overbanks & structures in or adjacent to floodplain.

# TR-55 Design Computation Form

By_________ Project:__________________________________________ J.O.___________
Date________ Area No.__________________________________________ Dist_____ Sht.___ of ____
Company: ______________________

| Hydrologic Soil Group (1) | Land Use, Zoning, Hydrologic Condition (2) | Percent Impervious (3) | Runoff Curve Number (4) | Area (Acres) (5) | RCN (4) x Area (5) (6) |
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| | | | Totals = | | |

Weighted RCN = Col.(6)/Col(5) = _________ Rounded RCN = _________
Total Square Miles = _________ *5 Initial Abstraction = _________

| I.D. | Type of Flow | Flow Length (Ft) | A | Pw | n-Factor | Slope (%) | Velocity (fps) | Time (Hrs) |
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Time of Concentration (Tc) total = _________
Time of Travel (Tt) total = _________

For selection of CSM/In from Table 5-II, use final Tc = _____
For selection of CSM/In from Table 5-II, use final Tt = _____

| Frequency (Years) | Rainfall (Inches) *1 | Runoff (Inches) *2 | Ia/P | Peak CSM/In | Peak Discharge (cfs) *3 |
|---|---|---|---|---|---|
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*1 Chart, Rainfall in Inches for Different Frequency Events, Baltimore County values

*2 Q" = (P-0.2S)$^2$ / (P+0.8S), Equation 2.5, TR-55 Manual

*3 Peak Discharge = Peak (CSM/In) x Q" x Area (Sq.Miles)

*4 Discharge Table in CSM/In of Runoff for 24 Hr. Type 2 Distribution

*5 $I_a$ = 0.2 x S, where S = (1000/CN)-10

LOCATION: ____________________
BY: _________________
DATE: ____________

# GUTTER FLOW & INLET COMPUTATIONS

Sheet ___ of ___
J.O. __________ Dist. __c __
10 Year Discharges except as noted

| Inlet No. | Dr.Area No. | Acres | C Factor | Intensity "/hr. | Q cfs | Upstream Bypass | Total Q cfs | Pavement Slopes $(^{ft}/_{ft})$ | | Depth ft | Spread ft | Inlet Type | Percent Intercepted | Bypass Q (cfs) | Bypass to Inlet No. | Remarks |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | Longitudinal | Cross | | | | | | | |
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LOCATION: ____________________
BY: __________ CHECK:_______
DATE: ____________

## STORM DRAIN FLOW TABULATION

Sheet ___ of ___
J.O. __________ Dist. __c __
10 Year Storm Frequency, except as noted

| Location | | Area | Acres | | Coeff. | CA | ΣCA | Time of Concentration-Minutes | | | Intens. | Q=CiA | Pipe n = | | | | Remarks |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| From | To | | Sub. | Total | "C" | | | Inlet | Drain | Total | "i" | cfs | Size | Slope | Vel. | Length | |
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LOCATION: ____________________
BY: __________ CHECK:_______
DATE: ____________

# HYDRAULIC GRADIENT TABULATION

Sheet ___ of ___
J.O. __________ Dist. __c __
10 Year Storm Frequency, except as noted

| Structure | | Q1 | Q3 | Q2 | V1 | V2 | Pipe n= | | | | Structure | Bend | Pipe Loss | A Loss | B Loss | C Loss | D Loss | Σ Str | Gradient | Remarks |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| From | To | cfs | cfs | cfs | fps | fps | Dia. | Length | So | Sf | Type | Angle | Ft | Ft | Ft | Ft | Ft | Loss-Ft | Elev. - Ft | |
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| INLET SCHEDULE | | | | |
|---|---|---|---|---|
| **No.** | **Type** | **Q(cfs)** | **Inv. Out** | **Top Elev.** |
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| TEST PIT SCHEDULE | | | |
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| **T.P.#** | **Utility** | **Top Elev.** | **Ground Elev.** |
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| MANHOLE SCHEDULE | | | | |
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| **No.** | **Type** | **Size** | **Inv. Out** | **Top Elev.** |
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| STRUCTURE SCHEDULE | | | | |
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| **No.** | **Type** | **Size** | **Inv. Out** | **Top Elev.** |
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LOCATION: ____________________
BY: _________________
DATE: ________________

**CULVERT DESIGN FORM**

Sheet ___ of ___
J.O. ___________ Dist. __c __
100 Year Discharges except as noted

## HYDROLOGY

Method: ______________________
Drainage Area: ______________________
Other: ______________________

| R.I. (Years) | Flow (cfs) | TW (ft) |
|---|---|---|
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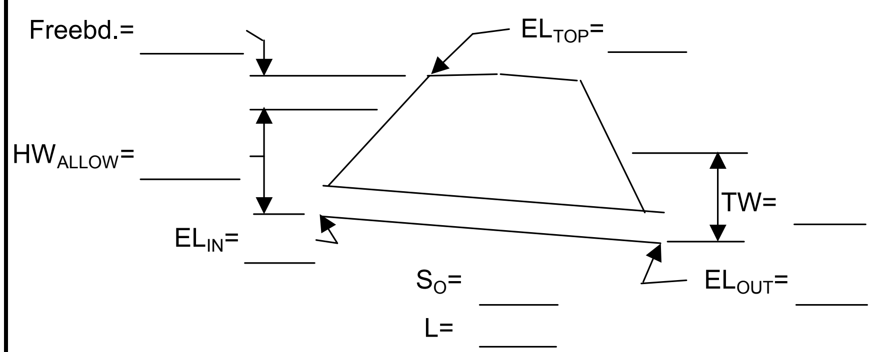


STATION______________

| Culvert Size & Description<br>Size, Entrance Type, Shape, Material | Q<br>(cfs) | Q/Ft.<br>of Width of<br>Box Culv. | HEADWATER COMPUTATION<br>Inlet Control<br>HW/D | HW | Outlet Control<br>TW | $d_c$ | $(d_c + D)/2$ | $h_o$ | $k_e$ | H | $LS_o$ | HW | Controlling HW | Comments |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
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Summary & Recommendations: