Storm Water

Design

Standards

July 2003

City of Frankfort
and
Franklin County,
Kentucky

Table of Contents

Table of Contents (continued)

1.0 Introduction

The City of Frankfort and Franklin County, Kentucky, (referred to as City/County) acting in cooperation have established new design criteria for the design and implementation of stormwater facilities in new development or redevelopment. The purpose of these standards is to provide a common set of guidelines that will produce consistency in design for stormwater facilities constructed either publicly or privately. This is necessary because in many cases the City/County becomes ultimately responsible for maintenance and operation of stormwater infrastructure that was originally intended for private ownership. This document is intended to be revised in the future as the need for new regulations arises and as the City/County continues to progress. In the near future new sections pertaining to Water Quality Regulations and Geographic Information Systems (GIS) will be incorporated.

These standards serve as a guideline for routine development. The City/County may at any time require additional analysis or may deviate from these guidelines in special circumstances. This applies especially to development adjacent to rivers, streams, and sinkholes, or development in or immediately upstream of known problem areas. Additionally, the City/County may initiate a “fee in lieu of “ program where it will be advantageous to share the cost of constructing regional stormwater infrastructure.

These standards also develop a standard procedure for submittal of engineering plans and calculations for review by the City/County and will establish a methodology aimed at assuring uniform quality of design and construction. This document does not directly address water quality issues or the City/County’s Phase II Stormwater plan, however the stormwater criteria in this document is intended to be congruent with water quality Best Management Practices (BMPs).

These standards introduce a departure from past procedures in that the City/County will transfer responsibility for quality of construction and adherence to the approved design to the developer’s engineer. This will be accomplished by requiring the engineer to perform construction inspection services, and by requiring the engineer to document differences between the approved plans and the record drawings.

1.1 List of abbreviations

CN	Curve Number
COE	U.S. Army Corps of Engineers
BMP	Best Management Practice
FEMA	Federal Emergency Management Agency
GIS	Geographic Information System
HEC	Hydraulic Engineering Center
HGL	Hydraulic Grade Line
KDOW	Kentucky Division of Water
KPDES	Kentucky Pollutant Discharge Elimination System
KTC	Kentucky Transportation Cabinet
LFUCG	Lexington-Fayette Urban County Government
LOMR	Letter of Map Revision
NRCS	Natural Resource Conservation Service
SCS	Soil Conservation Service
Tc	Time of Concentration
T_{Lag}	Lag Time
TR-55	Technical Release 55
UIC	Underground Injection Control
USDA	U.S. Department of Agriculture
USGS	U.S. Geological Survey

2.0 Design of Stormwater Appurtenances

2.1 Design Storm

The following hypothetical design storms will be utilized for stormwater infrastructure design applications as shown in Table 2.1-1. Time vs. depth tabulations of each design storm are provided in Appendix A.

Table 2.1-1 Design Storm Applications

Design Storm	Stormwater Facility					
	Floodplains	Detention Ponds	Inlets	Storm Sewers	Culverts & Bridges	Constructed Channels
10 year – 1 hour		•	•	•		
100 year – 6 hour		•		•		•
100 year – 24 hour	•	•			•	

The Rational Method may be used to generate peak flow for sizing inlets, storm pipes, culverts, and channels where the drainage area is less than or equal to 10-acres. Rational Method "C" factors shall be weighted in proportion to the percentage of impervious cover ranging from 0.20 for zero impervious cover to 0.95 for 100% impervious cover.

Rainfall Intensities for use in the rational method are provided in Table 2.1-2. See sample calculations (Appendix E) for an example of the rational method.

Table 2.1-2 Design Storm Rainfall Intensity

Time of Concentration* (minutes)	Intensity (inches/hour)					
	2-yr	5-yr	10-yr	25-yr	50-yr	100-yr
6	4.3	5.3	6.0	6.9	7.6	8.2
10	3.5	4.5	5.2	6.0	6.6	7.2
15	3.0	3.8	4.4	5.2	5.7	6.3
30	2.0	2.7	3.2	3.8	4.2	4.6
60	1.3	1.7	2.0	2.4	2.6	2.8

Source: Kentucky Transportation Cabinet
* See Section 3.1 for calculation of Time of Concentration. The minimum Time of Concentration will be 6 minutes (0.1 hours).

2.2 Inlets

Either curb inlets or combination inlets may be utilized for street drainage. Inlets shall be placed at the following locations to prevent the flow of concentrated water across traffic lanes in the 10-year 1-hour design storm:

- Sags in roadway
- Upstream of intersections
- Upstream of transitions from normal crown to super-elevated roadway

2.2.1 Inlets on Grade

Inlets on grade shall be spaced at intervals as required to limit the spread of gutter flow into the traffic lane during the 10-year 1-hour design storm as follows:

- 6-feet into driving lane where design speed is less than or equal to 45 mph
- 4-feet into driving lane where design speed greater than 45 mph

The use of software such as CURBIN (Kentucky Transportation Cabinet) should be used to calculate interception capacity and spread of water when spacing inlets on grade.

2.2.2 Inlets in a Sag

Inlet design curves (see Appendix B) should be used to determine interception capacity of street inlets and surface (yard) inlets located in a sag condition.

2.3 Storm Sewers

Storm Sewers shall be sized to flow under gravity conditions for the 10-year 1-hour design storm and shall be able convey the 100-year 6-hour storm without overflows. In general, storm sewers will be appropriate for 100-year peak flow rates less than 100 cfs. Constructed channels should be utilized for larger flows. The following elements will be incorporated in storm sewer design:

- Minimum pipe slope of 0.5%
- Minimum full velocity of 3 fps
- Maximum manhole spacing of 300 feet
- Inaccessible junctions shall not be utilized
- Pipe material shall be selected as per KDOT specifications

Storm sewers should be designed using software capable of generating a profile of the HGL for a given peak design flow, such as StormCad by Haestad Methods.

2.4 Constructed Channels

Constructed channels are typically utilized to provide drainage in low density developments of at least 1 acre or to convey flows too large for underground storm sewers (~100 cfs). If a constructed waterway is in regulatory waters (see Section 4.0) a 401/404 permit (see Section 5.1) will be required. Constructed channels shall be designed using the Manning Equation (Appendix E) according to the following criteria:

- Channel depth shall be as necessary to convey 100-year 6-hour (see Table 2.1-1) peak discharge
- Utilize side slopes no steeper than 2-H:1-V for channels with a rock or rigid lining and 3-H:1-V for grass or vegetative lined channels.
- Channel bottom shall have a 12H:1V cross slope if bottom width > 10 feet.
- Channel freeboard shall be the larger of 1-foot or two velocity heads
- Utilize a channel lining which is stable at the 100-year discharge (Section 2.4.1)
- Easement width shall be the larger of 20 feet or twice the channel topwidth
- Utilize concrete trickle channels to prevent standing water in residential areas

Constructed channels shall be sized using the Manning's N values listed in Table 2.4-1.

Table 2.4-1 Manning's N Values

Lining Type	Manning's N
Concrete	0.013
Grouted Stone	0.030
Stone Masonry	0.032
Bare Soil	0.020
Rock Cut	0.035
Jute Net	0.022
Straw with Net	0.033
Curled Wood Mat	0.035
6-inch D_{50} Riprap	0.050
12-inch D_{50} Riprap	0.060
Grass	0.045
Natural Streams	0.045
Floodplains	
Pasture, no brush	0.035
Brush	0.10
Trees	0.12

Source: LFUCG Storm Water Manual

2.4.1 Erosion Protection

Constructed channels shall be lined with a material that is resistant to erosion. After a constructed channel has been designed, a stable channel lining must be selected. The Tractive Force method (Appendix E) shall be utilized to compare the shear stress exerted by the 100-year runoff at normal depth, to the allowable shear stress that a particular channel lining can withstand. Acceptable channel lining materials are presented in order of preference (with allowable shear stress) in Table 2.4-2

Table 2.4-2 Acceptable Channel Linings

Channel Lining	Allowable Shear (lbs/ft^2)
Grass	1.0
Grass with Turf Reinforcement Mat	1.5-8
Gabion mattress (6-inch rock)	35
Hard Armor (i.e., masonry or tri-loc)	10-25
Concrete	>25

Source: LFUCG Storm Water Manual

Turf Reinforcement Matting should be used instead of dumped stone or rigid linings where possible. Several different varieties with varying resistance to erosion are available.

2.5 Culverts and Bridges

For the purpose of this document a culvert is defined as a one-barrel or multiple barrel structure with a combined clear span of less than 20 feet. Bridges are defined by span equal to or greater than 20 feet.

2.5.1 Culverts

Culverts shall be sized to limit the 100-year 24-hour headwater depth to 2 feet below the top of roadway. Culvert crossings designed for detention (see Section 2.6) must incorporate an emergency spillway conduit below the roadway. Culvert crossings where the top of road is higher than the finished floor of an upstream structure must be designed to pass 150% of the 100-year peak runoff to provide extra protection incase of debris blockage. Culverts will incorporate the following design elements:

- Size so that headwater depth is no greater than 1.2 times the height of conduit during 100-year storm (except in cases of detention)
- Minimum diameter will be 15 inches except for driveways or turnouts
- Conduit shall follow the alignment and slope of the natural channel
- Where upstream drainage area > 1 square mile culverts should preferably incorporate a natural channel bottom
- Utilize concrete headwalls on inlet and outlet
- Roadway alignment shall be within 10 degrees of perpendicular to flow

Culverts will be designed by calculating the difference in head across the length of the culvert for both inlet and outlet control and designing for the case that produces the highest differential at the design discharge. A software program that follows this methodology should be utilized for this design. Examples of such culvert design software include HY8 found in HYDRAIN by GKY and Associates or HYPACK by Kentucky Transportation Cabinet.

2.5.2 Bridges

Bridges shall be sized so that 100-year 24-hour upstream water depths do not increase more than 1.0 foot above the existing condition unless a drainage easement is provided for the area to be inundated. Bridges will also be sized so that the 100-year water surface is at least 2-feet below the finished floor elevation of existing residential, commercial, or industrial buildings. Bridge decks shall be high enough to pass the 100-year storm with at least 1-foot of clearance between bottom of the bridge and the water surface. An analysis of contraction scour and localized scour at piers and abutments must be performed.

Bridges will require a Stream Crossing Permit from the Kentucky Division of Water. HEC-2 or HEC-RAS software, by the U.S. Army Corps of Engineers shall be utilized for backwater and scour analyses.

2.6 Detention Ponds

Detention ponds will generally meet the following criteria. If a proposed detention structure exceeds any of these criteria the Dam Safety Section of the Kentucky Division of Water will be consulted to see if additional design guidelines are necessary.

- Drainage area less than 1-square mile
- Height of impoundment less than 15 feet as measured vertically from top to downstream toe
- Storage volume less than 25 acre-feet
- Nearest roadway, walkway, or building in the downstream floodplain is separated by a distance equal to at least forty times the height of the structure.

Detention ponds will be designed to limit the post development peak runoff to the pre-developed value for the 10-year 1-hour and 100-year 6-hour storms. Additionally, detention ponds shall incorporate an emergency spillway capable of conveying the 100-year 24-hour peak flow rate assuming the principal spillway is fully clogged. Detention ponds will incorporate the following design elements:

- Minimum drainage area of 1 acre
- Minimum freeboard of 1-foot above 100-year peak stage
- Maximum emptying time of 24 hours
- Safety fencing will be installed when interior embankment slopes exceed 3H:1V
- Provide anti-seepage collars for pipes through impoundment structures/dams
- Multiple smaller orifices may be used however the outflow conduit must not be smaller than 15 inches in diameter
- Provide access (and access easements) for maintenance equipment if maintenance will be performed by City/County
- Ponds that are designed to be normally dry shall incorporate a slope of at least 2% for positive drainage or incorporate a concrete trickle channel.

- Impoundments must be designed by a professional geotechnical engineer licensed in the Commonwealth of Kentucky

Detention Ponds shall be designed by performing flood routing calculations where inflow and outflow hydrographs are computed. Peak flow rates from the detention pond outflow hydrograph are then compared with the peak flow in the pre-developed condition. Several software programs perform reservoir routing calculations such as HEC-1 or HEC-HMS by the U.S. Army Corps of Engineers.

Dual Purpose detention ponds are designed to enhance water quality as well as to control water quantity. Such basins may incorporate a first flush volume with an increased detention time, or may be designed with sand filter or a permanent wet pool containing plant species common to wetlands.

3.0 Watershed Analysis

New developments where more than 5000 square feet of impervious area will be added, or subdivisions of two or more lots, will require a watershed analysis to determine the effect of the post development runoff on downstream receiving waters and drainage structures. Most of these development projects will require that a hydrologic computer model be created to generate and route runoff hydrographs of the design storm through the drainage network and to the downstream receiving waters.

Additions of impervious areas less than 5000 square feet will require hydrologic analysis on a case by case basis, as determined by the City/County, depending on the location of the project and the capacity of downstream drainage structures.

3.1 Hydrologic Modeling

Any software package that uses the U.S.D.A. Natural Resource Conservation Service (formerly Soil Conservation Service, SCS) Unit Hydrograph method may be utilized in modeling the watershed. The U.S. Army Corps of Engineers HEC-1 or HEC-HMS software is recommended.

The SCS Technical Release 55 Method (TR-55) will be used to calculate Time of Concentration and Curve Number values. The following methodology will be utilized in determining the modeling parameters:

- Drainage Area - Subcatchments should be arranged and sized as necessary to calculate hydrographs at critical points in the watershed such as the confluence of tributaries and the inlet to stormwater structures.

- Curve Number (CN) - Curve Numbers are listed in Table 3.1-1. Curve Numbers for a broad range of land uses are found in TR-55. Weighted Curve Numbers are calculated as shown in Work Sheet 2 of TR-55 (Appendix C). SCS hydrological soil groups for all soil types in Franklin County are listed in Table 3.1-2. Copies of published SCS soil maps are contained in Appendix D.

- Lag Time (T_{Lag}) - Lag Time is calculated as $T_{Lag} = 0.6*(Tc)$, where the Time of Concentration (Tc) is calculated as shown in Work Sheet 3 of TR-55 (Appendix C). The minimum Tc is six minutes (0.1 hour). The maximum overland flow length used in calculating sheet flow travel time on pervious areas will be 150-feet.

- Time Step – The time step duration used by the hydrologic model is dependent on the Lag Time of the fastest draining subcatchment in the watershed. The maximum time step duration is calculated as $\Delta t = 0.29*(T_{Lag})$ to avoid numerical instability.

- Storm Input – Design storms for input to the model are tabulated in Appendix A. Design storm applications are shown in Table 2.1-1.

Table 3.1-1 Curve Numbers

Land Use	Percent Impervious	Hydrologic Soil Group			
		A	B	C	D
Urban Areas					
Parking Lots, Roofs, Driveways, and Streets	100	98	98	98	98
Commercial Development	85	89	92	94	95
Industrial Development	72	81	88	91	93
Residential Development					
1/8 acre lots or less	65	77	85	90	92
¼ acre lots	38	61	75	83	87
1/3 acre lots	30	57	72	81	86
½ acre lots	25	54	70	80	85
1 acre lots	20	51	68	79	84
Pervious Areas					
Lawns, Parks, Golf Courses, Cemeteries, etc.	-	39	61	74	80
Pasture for Grazing (not mowed)	-	39	61	74	80
Meadows (mowed for hay)	-	30	58	71	78
Brushy Areas	-	30	48	65	73
Woods	-	30	55	70	77

Source: USDA Natural Resource Conservation Service

Table 3.1-2 SCS Hydrologic Group for Franklin County Soils

SCS Soil Series	Soil Symbol	SCS Hydrologic Soil Group
Ashton	As	B
Boonesboro	Bo	B
Faywood	Fd, Fe	C
Dunning	Du	D
Eden	Ef	C
Elk	Ek, El	B
Fairmount	Fa, Fc	D
Huntington	Hu	B
Lawrence	Lc	C
Lindside	Ld	C
Lowell	Lw	C
Maury	Ma	B
McAfee	Mc, Md	C
Melvin	Me	D
Nicholson	Nh	C
Newark	Ne	C
Nolin	No	B
Otwell	Ot	C
Rock Outcrop		D

Source: USDA Natural Resource Conservation Service

3.2 Extent of Study Area

The City/County may require a watershed study to extend downstream of a proposed development to determine the impact that the proposed development has on receiving waters including floodplains and existing downstream infrastructure. This is especially applicable to cases where future development downstream or in adjacent tributaries is anticipated.

The limit of downstream study shall be determined by the City/County on a case by case basis depending on the circumstances of each development but in general will be according to the following guidelines:

- In cases where a new development drains directly to a stream or river with a drainage area at least ten times the size of the new development, a downstream analysis may not be required.
- In cases where a new development drains through an existing structure or flood prone area with a total upstream drainage area less than ten times the size of the new development, a downstream analysis of the existing structure may be required.

3.3 Sinkholes

Drainage of post development runoff to a sinkhole will not be permitted unless the following requirements are satisfied:

- Stormwater detention is implemented that limits post development runoff rates flowing into the sinkhole to the pre-developed conditions for the 10-year 1-hour and 100-year 24 hour design storm, or a portion of the sinkhole drainage area is rerouted so that the post-developed runoff volume flowing to the sinkhole is no greater than the pre-developed volume.
- If additional runoff volume is anticipated, a study is performed that shows the additional runoff will not aggravate flooding on the proposed development, adjacent lands, or connected karst systems.
- If the spring (outlet) of the karst system the sinkhole is draining to is offsite, and the runoff volume flowing into the sinkhole is increased, written approvals shall be obtained from the owners of all properties potentially affected by flooding of the karst ground water flow system.
- A permit to discharge to a Class V Underground Injection Well is obtained from Region 4 of the Environmental Protection Agency (EPA) and all water quality best management practices (BMP's) stipulated in the Underground Injection Control Program - Class V are implemented. Any other conditions of the permit must also be satisfied.

4.0 Development in Regulatory Waters

Regulatory waters (Waters of the Commonwealth of Kentucky or Waters of the United States) are identified by any of the following attributes:

- A solid or dashed blue line on a 7.5 Minute USGS Quad Map
- Any waterway with a water line below which no vegetation normally exists
- Wetlands*

  * Wetlands are areas saturated by water at a frequency or duration sufficient to support a prevalence of vegetation adapted to life in saturated soils. Positive identification of wetlands may involve soil sampling/testing and generally requires the services of a professional.

Construction in regulatory waters requires a 401/404 Permit (Section 5.1). The following structures associated with new development are routinely permitted for construction in regulatory waters.

- Roadway, pedestrian, and utility crossings
- Channel/Pipe outfalls
- Bank Stabilization/Erosion Control measures

More extensive construction or relocation of regulatory waters will require mitigation measures such as erosion control or riparian improvements to the affected waters (or other regulatory waters), as provided for by the 401/404 permitting process.

4.1 Development Adjacent to Regulatory Waters

All new residential, commercial, and industrial structures shall be built such that the lowest above grade floor, basement window wells, crawl space entrances, and landings for stairs leading to below grade basements are at least two feet above the 100–year floodplain elevation.

A Letter of Map Revision (LOMR) from FEMA will be required upon completion of construction if obstructions are built in the floodplain or discharge is increased causing the post development floodplain to increase in elevation or width. The developer shall be responsible for all costs associated with revising the floodplain. The City/County will typically require the developer to provide security, up to a specified amount, for such costs through a Letter of Credit.

5. Permits

5.1 401/404 Water Quality Permits

401 Certifications are administered by the Kentucky Division of Water (Water Resources Branch) while 404 Permits are administered to the U.S. Army Corps of Engineers (COE). Both involve construction in a stream or wetlands and are intended to limit the discharge of sediment or other contaminants to receiving waters, and to minimize loss of regulatory waters and associated aquatic habitats. The City/County will require a 401/404 permit or a letter from KDOW/COE stating that a permit is not required for all proposed construction in the waterway.

5.2 Floodplain Construction Permits

Floodplain Construction Permits are administered by the Kentucky Division of Water (Floodplain Management Section) and are required for any construction along or across a floodplain or flood prone area with a drainage area greater than 1 square mile or if the proposed construction raises the backwater elevation by more than 1 foot. The permits cover bridges, dams, or fills of any kind, and pipe crossings above and below grade. The City/County will require a Floodplain Construction Permit or a letter from KDOW stating that a permit is not required for all proposed construction in the floodplain.

5.3 KPDES General Stormwater Permits

KPDES General Stormwater Permits are administered by the Kentucky Division of Water and are required for sediment and erosion control of construction sites. The permit requires the following tasks to be performed. The City/County will not approve grading until proof of these submittals has been provided:

- Submission of Notice of Intent to KDOW
- Preparation of a best management practices (BMP) plan
- Identification and signatures of all contractors/subcontractors responsible for installation of an erosion control measure
- Site inspections by qualified personal at least once per week or within 24-hours of a rainfall event of 0.5 inches or greater
- Notice of Termination to KDOW with certification that all discharges associated with construction have been eliminated

5.4 Local City/County Permits

The following is a list of City and County Permits and Approvals that must be acquired prior to construction. The City Planning Director acts as Floodplain Coordinator for the City. The County Planning Director acts as Floodplain Coordinator for the County.

- City Grading Permit, City Building Permit
- City Elevation Certificate (required for construction in floodplain)
- County Construction Approval, County Building Permit

6.0 Submittals and Documentation

All projects presented to the City/County for review involving construction of stormwater infrastructure shall incorporate the following information. Submitted documentation will generally be in the form of an organized notebook with a list of attachments and labeled dividers. A submittal checklist and sign-off sheet is contained in Appendix F.

6.1 Hydrologic Information

- List of assumptions
- Computer Model Input/Output Summary Sheets
- 36"x 24" Plan View showing location of all sub-basins
- A table showing Drainage Area, Time of Concentration (Tc), Impervious Percentage, Curve Number (CN), and Peak Runoff Rate for each sub-basin.
- Expected future level of development in upstream watersheds

6.2 Inlets, Storm Sewers, and Manholes

- List of assumptions
- Computer Model Input/Output Summary Sheets or hand computations
- Plan View showing the following:
    - Drainage areas
    - Street Layout, lot boundaries
    - Catch basins with type, station and offset, invert elevation
    - Pipes with size, type, slope
    - Manholes with size and type, station and offset
    - Headwalls with type, invert elevation
    - Utilities
    - Flow arrows
    - Existing and proposed 2-foot contours
    - Details

- Profile showing the following:
    - Underground Utility Crossings
    - Existing and proposed ground surfaces
    - Curb inlets with type and elevation
    - Manholes with type and elevation
    - Pipes with size, slope, type, class, length
    - Headwall type and elevations
    - Proposed peak flow
    - Hydraulic grade line

6.3 Culverts and Bridges

- List of assumptions
- Copies of computer summary sheets
- Allowable headwater and minimum top of roadway elevation
- Culvert performance curves and type of control
- Outlet erosion control/energy dissipation measures

6.4 Constructed Channels

- List of assumptions
- Profiles showing channel invert, 100-year water surface, and velocity
- Cross-sections used for capacity determination and location
- Design analysis for channel lining stability
- Energy dissipation design and calculations
- Copies of computer analysis

6.5 Detention Ponds

- Plan view showing 1-foot contours, utilities, and principal/emergency spillways
- Design calculations
- Drainage area map
- Embankment cross section
- Top of embankment and peak stage elevations
- Principal spillway details
- Emergency Spillway Details

6.6 Erosion and Sediment Control Plan

Site Map showing the following:

- Pre-construction topography showing drainage ways, property limits, construction limits, trees to be preserved, and utilities
- Finished grades, building locations, paved areas, construction entrances, access and haul roads, stockpile areas, and equipment storage areas
- Location of all planned BMP's
- Areas not to be disturbed

Description of the following:

- ♦ Location and size of disturbance area
- ♦ Beginning and completion dates
- ♦ Construction sequencing
- ♦ Listing of erosion and sediment control BMP's

6.7 Record Drawings

Record drawings shall be submitted at the end of construction. A list of all deviations from approved construction plans, with explanation of each, will be submitted with the record drawings.

7.0 Statement of Responsibilities

The following record of responsibilities of the City/County, Developer, and Developer's Engineer is provided to eliminate ambiguity as to who will be responsible for a specific task or performance.

7.1 Responsibilities of the City/County

- Comply with all City/County requirements regarding infrastructure development
- Make decisions and carry out responsibilities in a timely manner

7.2 Responsibilities of the Developer

- Comply with all City/County requirements regarding infrastructure development
- Select an Engineer to design the infrastructure and inspect the construction
- Select a construction contractor to construct the infrastructure and assume all related cost
- Conduct periodic inspections during construction to ensure satisfactory progress
- Construct the infrastructure in accordance with the approved or submitted documents and provide unlimited access to the City/County during design and construction
- Obtain all local, state, and federal permits

7.3 Responsibilities of the Developer's Engineer

- Comply with all City/County requirements regarding infrastructure development
- Prepare plans, specifications, and other submittals in accordance with City/County requirements
- Provide construction inspection services
- Prepare record drawings of the completed infrastructure
- Be responsible for the technical accuracy of its services and all resulting documentation, and acknowledge that the City/County will not be responsible for discovering deficiencies or errors therein.
- Attend neighborhood and City/County meetings as required

Appendix A

Design Storm
Time vs. Depth Tabulations

1-Hour Rainfall Distribution

	Cummulative Depth	
Time	10-Year	100-year
(min)	(in)	(in)
0:00	0.00	0.00
0:03	0.04	0.06
0:06	0.11	0.15
0:09	0.20	0.28
0:12	0.31	0.44
0:15	0.45	0.63
0:18	0.65	0.90
0:21	0.93	1.30
0:24	1.23	1.73
0:27	1.48	2.08
0:30	1.65	2.30
0:33	1.71	2.39
0:36	1.76	2.46
0:39	1.80	2.52
0:42	1.84	2.57
0:45	1.87	2.62
0:48	1.90	2.66
0:51	1.93	2.70
0:54	1.96	2.74
0:57	1.98	2.77
1:00	2.00	2.80

6-Hour Rainfall Distribution

	Cummulative Depth	
Time	10-Year	100-year
	(in)	(in)
0:00	0.00	0.00
0:10	0.02	0.03
0:20	0.04	0.06
0:30	0.06	0.09
0:40	0.09	0.12
0:50	0.12	0.16
1:00	0.15	0.20
1:10	0.17	0.24
1:20	0.21	0.29
1:30	0.25	0.34
1:40	0.29	0.40
1:50	0.34	0.47
2:00	0.39	0.54
2:10	0.45	0.62
2:20	0.52	0.72
2:30	0.61	0.83
2:40	0.85	1.17
2:50	1.47	2.02

	Cummulative Depth	
Time	10-Year	100-year
	(in)	(in)
3:00	2.33	3.21
3:10	2.47	3.39
3:20	2.58	3.55
3:30	2.66	3.66
3:40	2.72	3.74
3:50	2.78	3.82
4:00	2.83	3.90
4:10	2.88	3.96
4:20	2.92	4.01
4:30	2.95	4.06
4:40	2.99	4.11
4:50	3.02	4.15
5:00	3.05	4.19
5:10	3.08	4.23
5:20	3.11	4.27
5:30	3.13	4.31
5:40	3.15	4.34
5:50	3.18	4.37
6:00	3.20	4.40

24-Hour Rainfall Distribution

	Cummulative Depth	
Time	10-Year	100-year
	(in)	(in)
0:00	0.00	0.00
0:10	0.01	0.01
0:20	0.01	0.02
0:30	0.02	0.03
0:40	0.03	0.04
0:50	0.04	0.05
1:00	0.04	0.06
1:10	0.05	0.07
1:20	0.06	0.08
1:30	0.06	0.09
1:40	0.07	0.10
1:50	0.08	0.11
2:00	0.09	0.12
2:10	0.09	0.13
2:20	0.10	0.14
2:30	0.11	0.15
2:40	0.12	0.16
2:50	0.12	0.17
3:00	0.13	0.18
3:10	0.14	0.19
3:20	0.14	0.20
3:30	0.15	0.21
3:40	0.16	0.22
3:50	0.17	0.24
4:00	0.19	0.26
4:10	0.20	0.28
4:20	0.22	0.30
4:30	0.23	0.32
4:40	0.25	0.34
4:50	0.26	0.36
5:00	0.27	0.38
5:10	0.29	0.40
5:20	0.30	0.42
5:30	0.32	0.44
5:40	0.33	0.46
5:50	0.35	0.48
6:00	0.36	0.50
6:10	0.38	0.52
6:20	0.39	0.54
6:30	0.40	0.56
6:40	0.42	0.58
6:50	0.43	0.60
7:00	0.45	0.62
7:10	0.46	0.64
7:20	0.48	0.66
7:30	0.49	0.68
7:40	0.50	0.70
7:50	0.52	0.72

	Cummulative Depth	
Time	10-Year	100-year
	(in)	(in)
8:00	0.53	0.74
8:10	0.55	0.76
8:20	0.57	0.79
8:30	0.59	0.82
8:40	0.61	0.85
8:50	0.63	0.88
9:00	0.66	0.91
9:10	0.68	0.94
9:20	0.70	0.97
9:30	0.72	1.00
9:40	0.74	1.03
9:50	0.77	1.07
10:00	0.80	1.11
10:10	0.83	1.15
10:20	0.87	1.20
10:30	0.90	1.25
10:40	0.94	1.31
10:50	0.99	1.37
11:00	1.04	1.44
11:10	1.10	1.52
11:20	1.17	1.62
11:30	1.25	1.73
11:40	1.49	2.06
11:50	2.08	2.89
12:00	2.92	4.05
12:10	3.05	4.23
12:20	3.16	4.38
12:30	3.24	4.49
12:40	3.30	4.57
12:50	3.35	4.65
13:00	3.40	4.72
13:10	3.45	4.78
13:20	3.48	4.83
13:30	3.52	4.88
13:40	3.56	4.93
13:50	3.58	4.97
14:00	3.61	5.01
14:10	3.64	5.05
14:20	3.67	5.09
14:30	3.69	5.12
14:40	3.71	5.15
14:50	3.74	5.18
15:00	3.76	5.21
15:10	3.78	5.24
15:20	3.80	5.27
15:30	3.82	5.30
15:40	3.84	5.33
15:50	3.87	5.36

	Cummulative Depth	
Time	10-Year	100-year
	(in)	(in)
16:00	3.88	5.38
16:10	3.90	5.40
16:20	3.91	5.42
16:30	3.92	5.44
16:40	3.94	5.46
16:50	3.95	5.48
17:00	3.97	5.50
17:10	3.98	5.52
17:20	4.00	5.54
17:30	4.01	5.56
17:40	4.02	5.58
17:50	4.04	5.60
18:00	4.05	5.62
18:10	4.07	5.64
18:20	4.08	5.66
18:30	4.10	5.68
18:40	4.11	5.70
18:50	4.13	5.72
19:00	4.14	5.74
19:10	4.15	5.76
19:20	4.17	5.78
19:30	4.18	5.80
19:40	4.20	5.82
19:50	4.21	5.84
20:00	4.23	5.86
20:10	4.23	5.87
20:20	4.24	5.88
20:30	4.25	5.89
20:40	4.26	5.90
20:50	4.26	5.91
21:00	4.27	5.92
21:10	4.28	5.93
21:20	4.28	5.94
21:30	4.29	5.95
21:40	4.30	5.96
21:50	4.31	5.97
22:00	4.31	5.98
22:10	4.32	5.99
22:20	4.33	6.00
22:30	4.34	6.01
22:40	4.34	6.02
22:50	4.35	6.03
23:00	4.36	6.04
23:10	4.36	6.05
23:20	4.37	6.06
23:30	4.38	6.07
23:40	4.39	6.08
23:50	4.39	6.09
24:00	4.40	6.10

Appendix B

Sag Inlet Capacity Charts

PB84-215003

DRAINAGE OF HIGHWAY PAVEMENTS

City of Frankfort and Franklin County, Kentucky

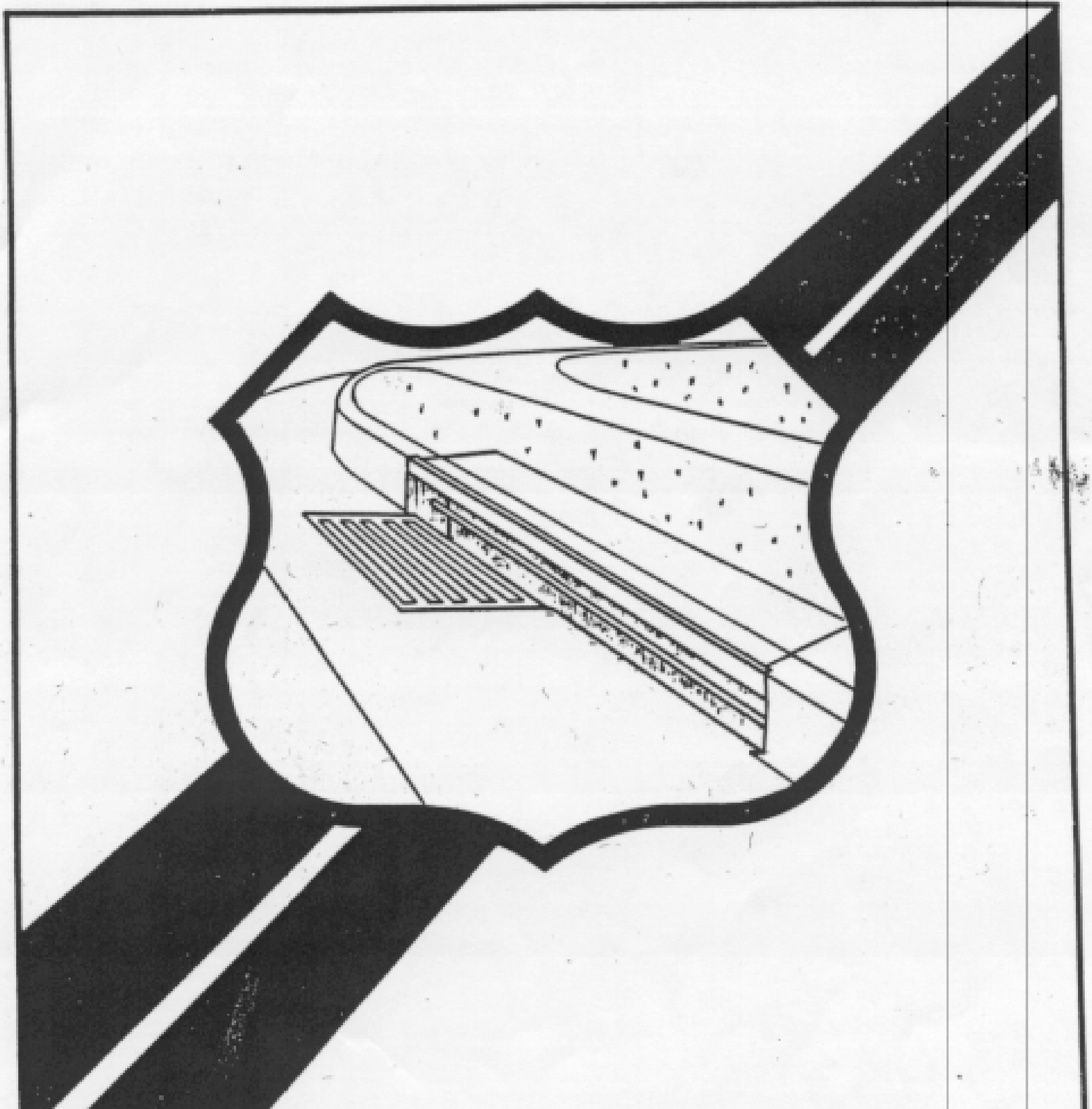
Hydraulic Engineering Circular No. 12

FHWA-TS-84-202

March 1984

U.S. Department of Transportation

Federal Highway Administration



This document is available to the U.S. public through the National Technical Information Service, Springfield, Virginia 22161

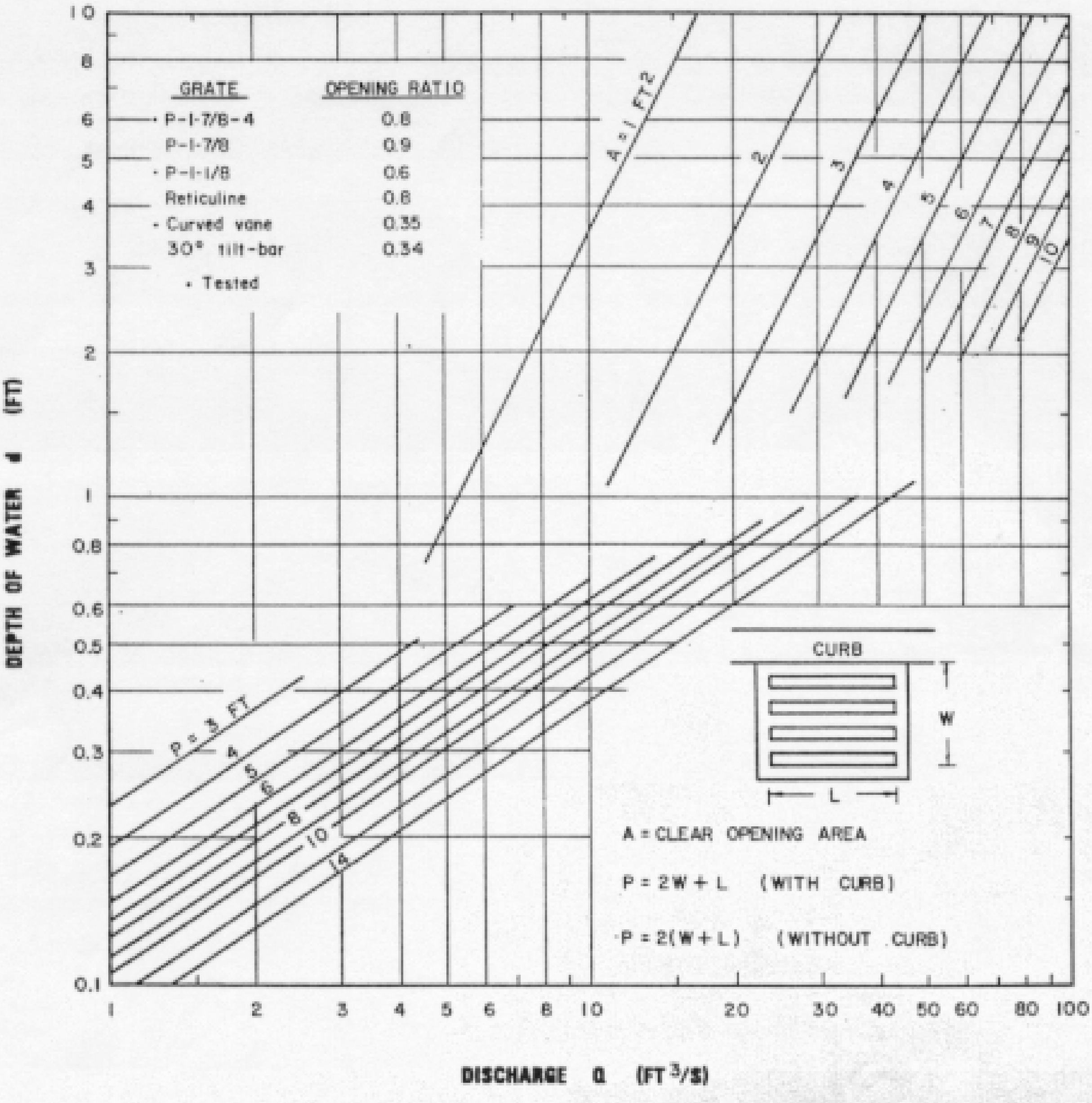


CHART 11. Grate inlet capacity in sump conditions.

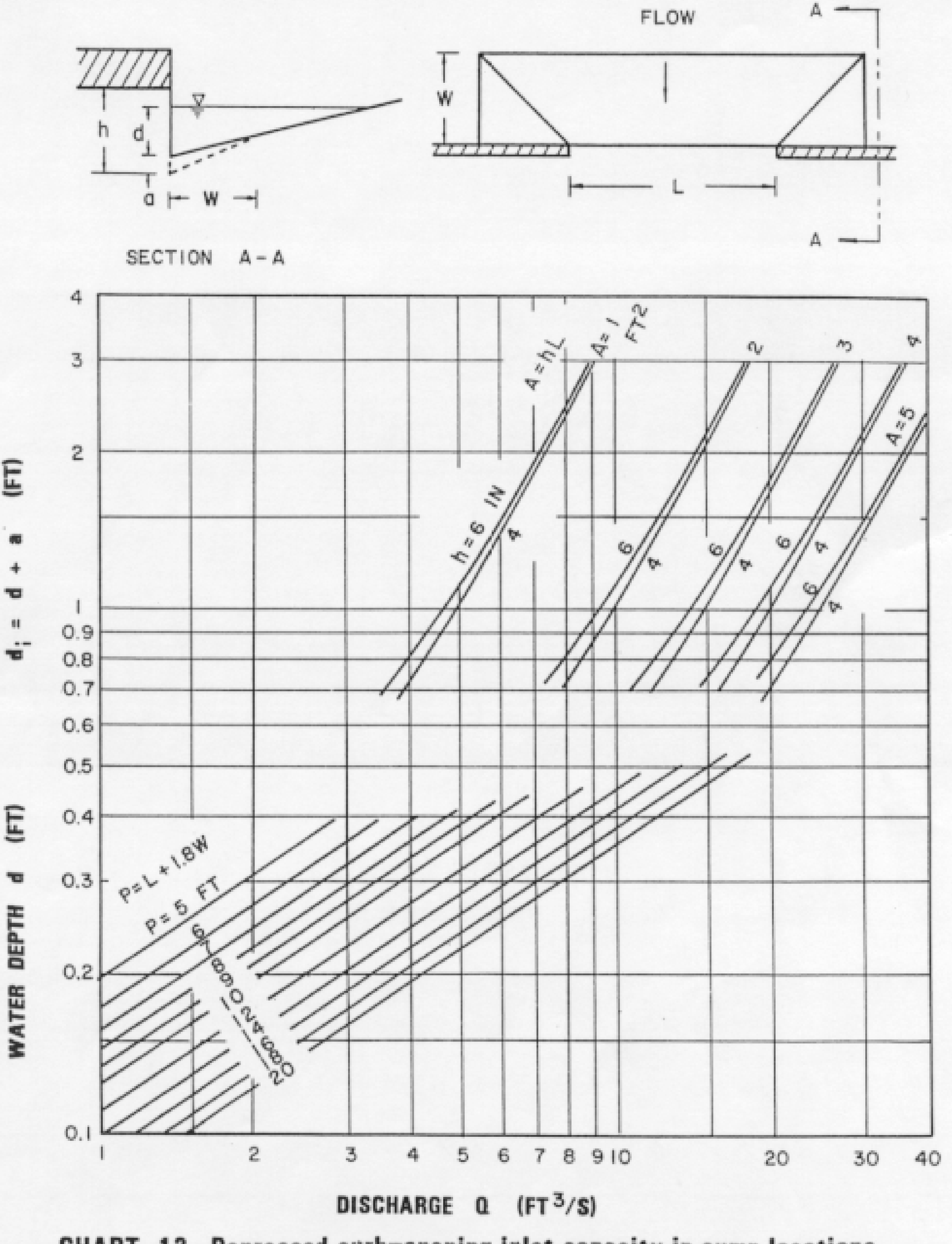


CHART 12. Depressed curb-opening inlet capacity in sump locations.

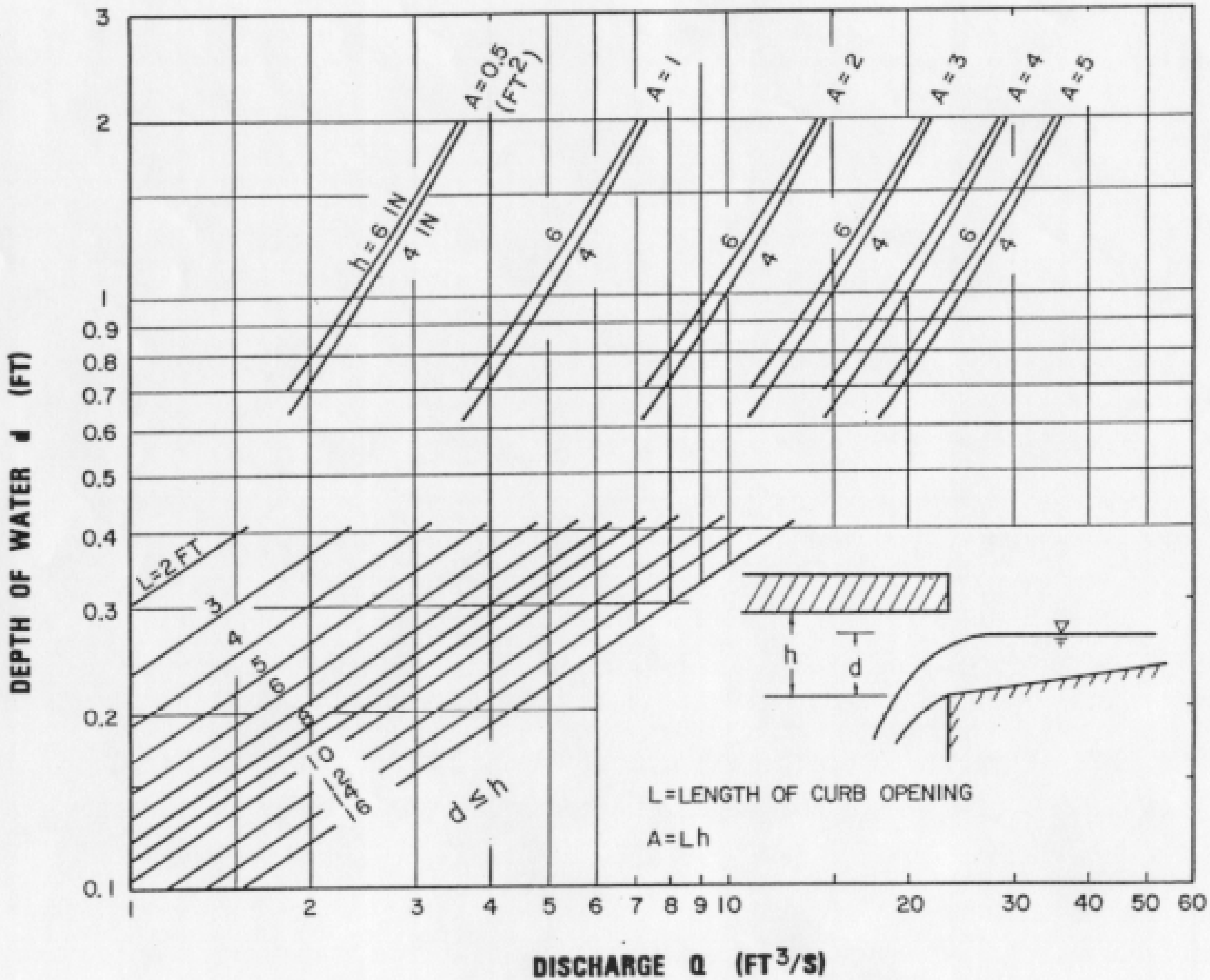


CHART 13. Curb-opening inlet capacity in sump locations.

Appendix C

Time of Concentration/Curve Number Worksheets

Worksheet 3: Time of concentration (T_c) or travel time (T_t)

Project ______________________ By _____ Date ________

Location ______________________ Checked _____ Date ________

Circle one: Present Developed ______________________

Circle one: T_c T_t through subarea ______________________

NOTES: Space for as many as two segments per flow type can be used for each worksheet.

Include a map, schematic, or description of flow segments.

<u>Sheet flow</u> (Applicable to T_c only) Segment ID

1. Surface description (table 3-1) ....
2. Manning's roughness coeff., n (table 3-1) ..
3. Flow length, L (total L $\leq$ 300 ft) .... ft
4. Two-yr 24-hr rainfall, P_2 .... in
5. Land slope, s .... ft/ft
6. $T_t = \dfrac{0.007\ (nL)^{0.8}}{P_2^{\ 0.5}\ s^{0.4}}$ Compute T_t ...... hr ___ + ___ = ___

<u>Shallow concentrated flow</u> Segment ID

7. Surface description (paved or unpaved) .....
8. Flow length, L .... ft
9. Watercourse slope, s .... ft/ft
10. Average velocity, V (figure 3-1) .... ft/s
11. $T_t = \dfrac{L}{3600\ V}$ Compute T_t ...... hr ___ + ___ = ___

<u>Channel flow</u> Segment ID

12. Cross sectional flow area, a .... ft^2
13. Wetted perimeter, p_w .... ft
14. Hydraulic radius, $r = \dfrac{a}{p_w}$ Compute r .... ft
15. Channel slope, s .... ft/ft
16. Manning's roughness coeff., n ....
17. $V = \dfrac{1.49\ r^{2/3}\ s^{1/2}}{n}$ Compute V .... ft/s
18. Flow length, L .... ft
19. $T_t = \dfrac{L}{3600\ V}$ Compute T_t ...... hr ___ + ___ = ___
20. Watershed or subarea T_c or T_t (add T_t in steps 6, 11, and 19) .... hr ___

Worksheet 2: Runoff curve number and runoff

Project ______________________ By _____ Date ________

Location ______________________ Checked _____ Date ________

Circle one: Present Developed ______________________

1. Runoff curve number (CN)

Soil name and hydrologic group (appendix A)	Cover description (cover type, treatment, and hydrologic condition; percent impervious; unconnected/connected impervious area ratio)	CN 1/ Table 2-2	CN 1/ Fig. 2-3	CN 1/ Fig. 2-4	Area ☐ acres ☐ mi^2 ☐ %	Product of CN x area
				Totals =		

1/ Use only one CN source per line.

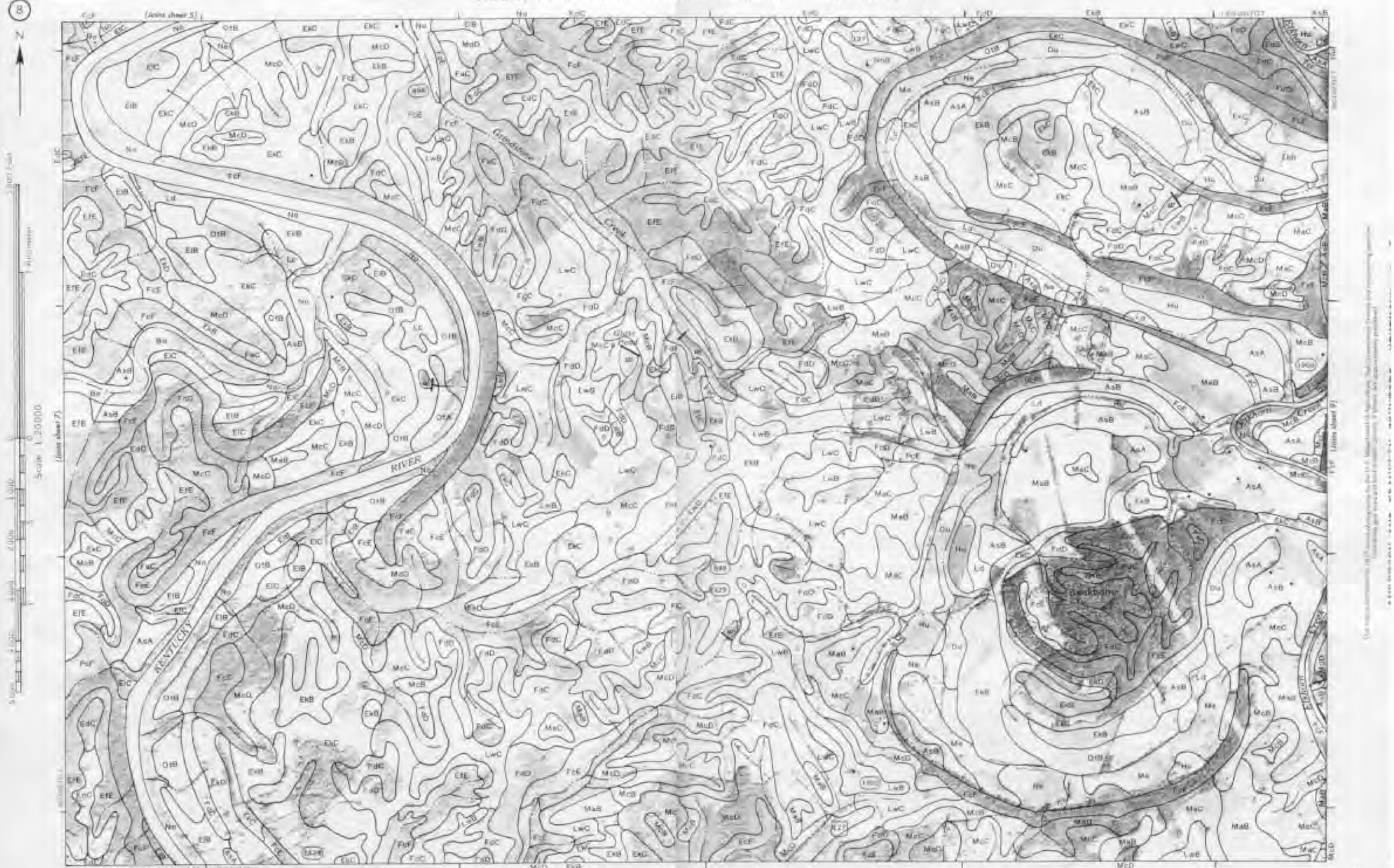
CN (weighted) = $\frac{\text{total product}}{\text{total area}}$ = ____ = ______; Use CN = ☐

2. Runoff

		Storm #1	Storm #2	Storm #3
Frequency	yr			
Rainfall, P (24-hour)	in			
Runoff, Q .... (Use P and CN with table 2-1, fig. 2-1, or eqs. 2-3 and 2-4.)	in			

Appendix D

SCS Soil Maps


8
N
(Joins sheet 5)
(Joins sheet 7)
(Joins sheet 9)
(Joins sheet 11)
Scale 1:20000
Grindstone
Creek
RIVER
KENTUCKY

ANDERSON AND FRANKLIN COUNTIES, KENTUCKY NO. 15

ANDERSON AND FRANKLIN COUNTIES, KENTUCKY NO. 11

Appendix E

Sample Calculations for Rational Method, Manning's Equation, and Tractive Force Method

Sample Calculations

Rational Method:	Q = CIA
Where:	Q = Peak Runoff Rate (cfs) C = Land Use Coefficient (dimensionless) I = Rainfall Intensity (in/hr) A = Drainage Area (acres)
Sample:	3.5 acre basin with 60% impervious area and 40% grassed landscape. Find 10-year peak runoff rate.
Weighted C Factor:	C = 60% (0.95) + 40% (0.20) = 0.65 I = 6.0 in/hr (from Table 2.1-2 w/Tc = 6 min) Q = 0.65 x 6.0 (in/hr) x 3.5 acres = 13.6 cfs

Typical C Factors

Land Use	C
Impervious Areas	0.95
Grassed, Wooded, Pasture, Farmed Areas:	
Slope $\leq$ 7%	0.20
Slope > 7%	0.30
Compacted Earth/Gravel	0.80

Sample Calculations

Manning Equation: $V = \frac{1.49}{N} R^{2/3} S^{1/2}$

Alternatively: $Q = \frac{1.49}{N} R^{2/3} S^{1/2} A$

Where:

- V = Velocity (fps)
- N = Manning's N (see Table 2.4-1)
- R = Hydraulic Radius = Flow Area (A) / Wetted Perimeter (P) (ft)
- S = Friction Slope (ft/ft)
- A = Flow Area (ft^2)
- P = Wetted Perimeter (ft)
- Q = Flow Rate (cfs)

Sample:

Given: Grass lined open channel with bottom width of 5 feet, 3H:1V side slope, and channel slope of 2%.

Find: Normal depth (Y) for Q = 1,200 cfs

$A = (5 + 3Y) \times Y$
$P = 5 + 2(Y^2 + (3Y)^2)^{½}$
$N = 0.045$ (Table 2.4-1)
$S = 0.02$
$Q = 1,200$

$$1,200 = \frac{1.49}{0.045} \frac{[(5 + 3Y)Y]^{5/3} (0.02)^{1/2}}{(5 + 2Y10^{1/2})^{2/3}}$$

$$1.68 \times 10^7 = \frac{[(5 + 3Y)Y]^5}{[5 + 2Y10^{1/2}]^2}$$

Root Solve: Y = 5.6 feet

Find: Required freeboard for above channel (required freeboard is the larger of 1 foot or 2 velocity heads)

$$\text{Velocity Head} = \frac{V^2}{2g}$$

$V = Q/A = 1,200/122 = 9.8$ fps
Velocity Head $= (9.8)^2/2(32.2) = 1.49$
Required Freeboard = 3.0 feet

Sample Calculations

Tractive Force Method: $\tau = 62.4YS$

Where: τ = Tractive Force (lbs/ft^2)
Y = Normal Depth (ft)
S = Channel Slope (ft/ft)

Sample: Find the tractive force (shear stress) exerted upon the grass channel in the previous example.

Y = 5.6 ft
S = 0.02

τ = (62.4 lbs/ft^3) (5.6 ft) (0.02) = 7.0 lbs/ft^2

From Table 2.4-2, the maximum allowable shear stress for a grass channel is 1.0 lb/ft^2; thus the grass lining is not acceptable. Recommend a gabion mattress or armored channel lining.

This is an iterative process since selecting a new channel lining will change Manning's N, resulting in a different normal depth.

Appendix F

Submittal Checklist and Sign-Off

Improvement Plan Submittal Checklist

The items below shall be submitted to the City/County along with the plans and specifications. Submitted documentation will generally be in the form of an organized notebook with a list of attachments and labeled dividers. If any item on this checklist is not applicable to a particular submittal, a sheet of paper with an explanation of the absence of that item shall be included in place of the omitted item. This checklist, signed and stamped by a professional civil engineer, will be included in the front of the submittal notebook.

1. Grading and Erosion/Sediment Control Plan
2. Hydrologic documentation (Section 6.1)
3. Post development floodplain and analysis
4. Design documentation for all storm water appurtenances (Sections 6.2 - 6.5)
5. List of all local, state, and federal permits that will be obtained

I hereby certify that the improvements plans, calculations, and other documents submitted herein have been prepared in accordance with the City of Frankfort or Franklin County, Kentucky regulations and ordinances in effect at the time of submission.

______________________________ _______________
Signature and Registration Number Date