STORMWATER MANAGEMENT DESIGN MANUAL

ORONOGO, MISSOURI

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STATE OF MISSOURI
CHRIS ERISMAN
NUMBER
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REGISTERED PROFESSIONAL ENGINEER

Prepared by
ALLGEIER, MARTIN and ASSOCIATES, INC.
Consulting Engineers
Joplin, Missouri

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STORMWATER MANAGEMENT DESIGN MANUAL

1. GENERAL

1) Stormwater Management Criteria - All new construction, installation, or improvements to existing stormwater management structures shall comply with the rules, regulations, and design criteria contained herein or by methods and procedures approved by the City Engineer.

2) A Stormwater Management Plan is required for each tract where development is planned.

3) All designs shall be directed by a Registered Professional Engineer licensed in Missouri and all Stormwater Management Plans shall be properly sealed.

4) Only the City Engineer may waive requirements specified in this Design Manual.

5) Criteria of other agencies may overlap or impact on projects covered by this Design Manual. Criteria developed by adjacent cities may not directly coincide with this manual. Rules and regulations of the State of Missouri promulgated by the Missouri Department of Natural Resources, Missouri Department of Transportation, and others may not be satisfied by compliance with these criteria. Federal requirements imposed by the Federal Insurance Agency or Federal Emergency Management Administration relative to 100-year flood plains and zones may not be addressed by these criteria. In each case, the developer is responsible for compliance with all applicable rules and restrictions regardless of level.

2. DEFINITIONS

Access Easement -	All detention structures except rooftops and parking lots shall be enclosed by an access easement. This easement shall extend at least ten feet beyond the maximum water surface area.
Channel -	A natural or man made structure for conveying flows.
Channelized Flow -	See System Flow
City -	Municipality having jurisdiction over a defined area.
City Engineer -	The person designated by the City to review and approve stormwater and drainage plans and studies.
Detention Facility -	A facility designed to discharge at a controlled rate which is less than its inflow rate.
Development -	Any activity that changes the surface characteristics of the land resulting increased runoff including grading as well as construction.
Drainage Basin -	The land area from which the surface runoff drains
Drainage Divide -	A line along a topographic high separating adjacent drainage basins.
Drainage Easement -	A property owner's authorization to use a designated area for the controlled movement of runoff from point to point.
Flood Plain -	The areas adjacent to streams, rivers, ponds and lakes which are subject to inundation during flood events.
Floodway -	The channel of a stream plus any adjacent floodplain areas that must be kept free of encroachment in order for the 100-year flood to be carried without substantial increase in flood heights. FEMA's standards allow an increase in flood height of 1.0 foot
Freeboard -	The difference in elevation between the top of a structure, such as a dam or open channel, and the maximum design water surface elevation or high water mark. It is an allowance against overtopping by waves or other transient disturbances.
Hydrograph -	A graphic display showing some property of surface water (generally flow rate) as a function of time or other variable.
Lag Time -	An element of the HEC-1 Computer Model which is equal to sixty percent of the time of concentration.
Overland Flow -	The flow of water over a land surface due to direct precipitation. The distance shall not exceed 300 feet in developed areas and 500 feet in undeveloped area for calculations required in this document.
Rainfall Intensity -	The average frequency of rainfall occurrence used for design determines the degree of protection afforded by a drainage system. Maximum intensity of rainfall of a given expectancy is greater for a short period of time than for longer periods. Therefore, it is assumed that the maximum runoff will occur as soon as all parts of the drainage area under consideration are contributing. The rainfall intensity can be determined from the included data once the time of concentration is known.
Registered Professional Engineer	An Engineer who is licensed and registered in the State of Missouri and Engineer authorized to practice within the State in an appropriate discipline.

Return Frequency -	A statistical term for the average frequency with which a given storm event is expected to occur, without assuming occurrence at regular intervals. May also be viewed as the reciprocal of the probability that an event will occur. A 100-year event has a probability of occurring in any given year of one percent (0.01).
Shallow Concentrated Flow -	Flow along side and rear lot swales without defined channels and are not considered overland flows.
Site -	The tract or contiguous tracts of land for which modification, development or changes are planned.
Stormwater System -	A complete approach to dealing with control of runoff which may include but is not limited to open or closed drainage systems, gutters, boxes, or detention facilities.
System Flow Time -	Flow in the street gutters, ditches, sewers, boxes and channels. The system flow time for calibration shall not be less than 5.0 minutes, regardless of calculated time.
Time of Concentration -	The time it takes for water to flow overland from the most distant point of the drainage basin to the measuring point. For purposes of calculation the time of concentration shall be the sum of the Overland Flow Time, the Shallow Concentrated Flow Time and the System Flow Time.
Velocity -	Average Velocity

3. HYDROLOGIC DESIGN CRITERIA

1) Computing Run-off and Peak Rates

Runoff rates may be determined using the Rational Method or approved Hydrograph Methods.

2) Runoff Calculations using Rational Method

The rate of runoff concentrated at any point may be determined by the Rational Formula if the upstream drainage area above the site is less than 300 acres (10 acres in the case of detention facilities):

Q =	CIA, in which
Q =	Runoff in cubic feet per second
C =	The runoff coefficient for the area
I =	Design rainfall intensity in inches per hour over the area. Rainfall intensity shall be based on time of concentration and the Rainfall Intensity Tables included, developed for the area.
A =	Drainage area, in acres
T_c =	Time of Concentration
L =	Length of the mainstream of the basin in feet
H =	Difference in elevation from the most distant drainage divide to the outlet in feet

Time of Concentration may be calculated using the sum of the Overland Flow Time, the Shallow Concentrated Flow Time and the System Flow Time or by using the equation

$$T_c = \frac{L^{1.15}}{7700\ H}$$

3) Time of Concentration

When using the hydrograph method to compute the runoff rates, the Time of Concentration shall be equal to the sum of the Overland Flow Time, the Shallow Concentrated Flow Time, and the System Flow Time. The following equations shall be used:

Overland Flow: $T_t = \frac{0.007\ (nL)^{0.8}}{(P_2)^{0.5}\ S^{0.4}}$

Shallow Concentrated Flow: $T_t = \frac{L}{3600\ V}$

Where $V = 16.1345(S)^{0.5}$ for Unpaved Surfaces
$V = 20.3282(S)^{0.5}$ for Paved Surfaces

System Flow Time: $T_t = \frac{L}{3600\,V}$

Where $V = \frac{1.49\,R^{2/3}\,5^{1/2}}{n}$ (assuming bank-full elevation)

Where:
T_t = Travel time (hr.)
N = Manning's roughness coefficient
L = Flow length (ft.)
P_2 = 2-year, 24-hour rainfall (in) = 2.8
S = Slope of hydraulic grade line, land slope (ft/ft.)
V = Average velocity (ft/s)
R = Hydraulic radius (ft.) And is equal to a/Pw
a = Cross sectional flow area (ft^2)
Pw = Wetted perimeter (ft.)

4) Runoff Coefficient

The runoff coefficient "C" is the variable in the Rational Formula least susceptible to precise determination and the one which requires the greatest exercise of engineering judgment because of the many characteristics which affect the coefficient. Among the factors to be considered in influencing the runoff coefficients are the following: present and future zoning; terrain; local ponding or depressions; the areas of pavement, roofs, turf, and other areas having varying degrees of imperviousness.

The selection of a coefficient should take into consideration the probable ultimate development of presently undeveloped or partially developed areas. Suggested values of runoff coefficients are included in the following table:

Suggested Runoff Coefficients and SCS Curve Numbers

Cultivated Land		.24	72
Pasture or Range Land		.30	76
Meadow		.22	68
Wood or Forest Land		.25	74
Open Spaces, Lawns, Parks, Golf Courses, Cemeteries, etc.			
Good condition, grass cover on 75% or more of the area		.22	68
Fair condition, Grass cover on 50% of the area		.25	74
Commercial and Business Areas (85% impervious)		.90	88
Industrial Districts (72% impervious)		.75	85
Residential			
Average Lot Size	Average % Impervious[d]		
6,000 s.f.	65	.51	82
7,500 s.f.	38	.47	79
10,000 s.f.	30	.45	78
15,000 s.f.	25	.35	76
1 acre	20	.25	74
Paved Parking Lots, Roofs, Driveways, Etc		.90	88
Streets and Roads			
Paved with curbs and storm sewers		.95	98
Gravel or paved with swales		.90	87
Dirt		.75	84

Note: SCS curve members are modified for typical area soils.

5) Hydrograph Methods

Hydrograph methods must be used for all conveyance systems with tributary areas exceeding 300 acres and for all detention facilities with tributary areas in excess of 10 acres but may be used in any case. Hydrographs may be developed either manually or by approved computer model.

The approved computer models are U.S. Army Corps of Engineer, Hydrologic Engineering Center HEC-1 "Flood Hydrograph Package", Version 4.0, September 1990.

SCS Technical Release No. 55 (TR-55) "Urban Hydrology for Small Watersheds", Second Edition, June 1986.

SCS Technical Release No. 20 "Project Formulating Hydrology", Second Edition, May 1983.

It is acceptable to calculate the volume and peak runoff rate sequentially at five minute intervals for:

a) Direct surface runoff routed
b) Routed Hydrographs on channel systems
c) Inflow hydrographs to detention facility
d) Storage volume and surface elevation for detention facilities
e) Discharge hydrographs for detention facilities

In these calculations, the following total 24 hour rainfall depths in inches shall be used with a Type II Rainfall Distribution.

	Recurrence Interval					
	2-Year	5-Year	10-Year	25-Year	50-Year	100-Year
Rainfall (in.)	2.8	3.6	4.1	5.0	5.6	6.2

4. SYSTEM HYDRAULICS

1) The Manning Formula shall be used to calculate the flow in pipes.

$$Q = \frac{A(1.486)(R^{2/3})(S^{1/2})}{n} \quad \text{or}$$

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

Where:

V =	Average Velocity in feet per second
Q =	Discharge in cubic feet per second
A =	Cross sectional area of flow in square feet
R =	Hydraulic Radius (R = A/P)
P =	Wetted Perimeter in feet
S =	Slope in feet per foot
n =	Roughness Coefficient

Typical Roughness Coefficients (Manning "n") Pipes

Concrete (coated)	0.014
Plastic	0.014
Concrete	0.012
Corrugated Metal	0.021

2) Friction Loss Equation:

Energy losses from pipe friction can be determined by re-writing the Manning equation as:

$$S_f = \frac{V^2n^2}{2.21} \text{ or } S_f = \left(\frac{Qn}{1.486\ AR^{2/3}}\right)^2$$

then head losses due to friction can be determined by:

$$H_f = S_f \times L$$

Where: L = Length of Conduit in Feet
H_f = Velocity Head Loss Due to Friction

3) Systems are required when the volume of flow equals or exceeds 5 cfs.

4) Buried Structures: All buried structures shall be designed and constructed in compliance with the following criteria and requirements unless variances are approved by the City Engineer in response to a written request:

A) Live load shall be H-20.

B) Soil unit weight shall be 120 pounds per cubic foot.
C) Minimum lateral earth pressure shall be 40 pounds per cubic foot.
D) Minimum cover shall be twelve inches for all conduits which span (diameter) 72 inches or less.
E) Minimum diameter shall be 15 inches or equivalent.
F) Minimum slope shall be selected to obtain the greatest practical velocities to minimize settling problems, but in no case shall the mean velocities be less than two (2) feet per second.
G) Minimum hydraulic capacity of the pipe or culvert crossing arterial streets shall be the 25-year peak discharge with a 0.5 foot minimum freeboard at the lowest point of entry.

The structure's hydraulic capacity shall be investigated to determine the design frequency with roadway overflow, which will produce no more than 1.0 foot of backwater. Backwater is defined as the difference in water surface elevation between the valley section with no structure, and the valley section with the proposed structure. If the backwater increase exceeds 1.0 foot, written acknowledgment and consent of affected property owners will be required.

H) Headwalls or flared end sections shall be provided at system inlets and outlets.

I) Inlets or transition segments shall be designed to meet standards of the Missouri Department of Highways and Transportation.

J) Inlets shall be provided along streets, as required, to limit the flow depth in the gutters during the ten-year event to 10 feet in width in streets 30 feet or less in width, and 12 feet in width in streets wider than 30 feet, back to back. No curb overtopping is allowed.

K) Manholes are required at change of flow direction or every 600 feet, for pipes 30 inches in diameter or less. For larger diameters, consult the City Engineer.

5. SYSTEM HYDRAULICS - OPEN CHANNELS

1) The Manning Formula shall be used to calculate the flow in open channels.

$$Q = \frac{A(1.486)}{n} (R^{2/3})(S^{1/2}) \quad \text{or}$$

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

Where:

V = Average Velocity in feet per second
Q = Discharge in cubic feet per second
A = Cross sectional area of flow in square feet
R = Hydraulic Radius = A/P
P = Wetted Perimeter in feet
S = Slope in feet per foot
n = Roughness Coefficient

Typical Roughness Coefficients (Manning "n") Open Channels	
Winding Natural Streams with Weeds	0.050
Grass or Sod Manmade Channels	0.032
Vegetated Flood Plains	0.030
Natural Streams	0.030
Straight Earth Channels	0.025
Concrete Channel (Smooth)	0.012
Concrete Channel	0.017

Hydraulic Calculations for open channels using the following models are approved:

A) "HY-7 WSPRO - A Computer Model for Water Surface Profile Computations" - Federal Highway Administration

B) "HEC-2 Water Surface Profiles" - U.S. Army Corps of Engineers, Hydrologic Engineering Center

C) "HEC-RAS River Analysis System" - U.S. Army Corps of Engineers, Hydrologic Engineering Center

2) Natural channels may be incorporated in drainage systems where the 10-year peak exceeds 500 cubic feet per second, except that the 1-year peak flow velocity may not exceed 3 feet per second.

3) In developed areas where the 10-year peak flow exceeds 200 cubic feet per second, but is less than 500 cubic feet per second, approved lining of the channel is required.

4) Acceptable channel linings include: concrete, gunite, grouted riprap, vegetative mesh or erosion net, or reinforced sod, depending upon velocities.

erosion net, or reinforced sod, depending upon velocities.

5) The minimum bottom width shall be 4 feet

6) Side slopes shall be as flat as necessary to prevent erosion. Concrete walls may range from vertical to 4 to 1. Riprap and vegetative walls shall not be steeper than 4 to 1. Gunite walls shall not be steeper than 2 to 1.

7) Channel depth shall be at least sufficient to accommodate the 10-year peak flow plus a 0.5 foot freeboard. When lined, the lining shall also extend to at least this height. The depth or height above invert shall be increased at transitions or bends, as calculated below.

8) The minimum radius at bends shall be calculated as follows, keeping in mind that wall height must also be adjusted.

$$R = \frac{V^2 W}{8D}$$

R = Radius of centerline in feet
V = 10-year average water velocity in feet per second
W = Channel's water surface width at 10-year design flow
D = Depth of 10-year design flow in feet

9) When improving open channels, bends in channels may require an alteration to the channel geometry. When the radii of curvature of the centerline of the channel is less than five times the water surface width in the channel for the 100-year return frequency, then the height of the outside wall of the channel shall increase in height according to the following equation:

$$Z = \frac{V^2}{g r_c} \quad \frac{T}{2}$$

Where:

Z = Increase in water surface elevation along outer wall
V = Average Water Velocity
T = Water surface width in channel
r_c = radius of curvature of centerline of channel
g = gravitational acceleration

10) All channels shall be properly maintained with all banks stabilized and vegetative cover provided where applicable. No channel bank line shall be within thirty feet of an occupied structure.

11) Minimum channel flow slope is 0.5 percent.

12) Maximum channel depth is four feet, without approval of the City Engineer.

6. DETENTION

1) Detention facilities shall be required for all land development on any site having a gross land area of one-half acre or more, regardless of land use. Exceptions to this requirement include:

A. Additions to, improvements, and repair of existing single-family and duplex dwellings;

B. Construction of any buildings, structures, and/or appurtenant service roads, drives, and walks on a site having previously provided stormwater control as part of a larger unit of development;

C. Remodeling, repairing, and improving any existing structure or facility and appurtenance that does not cause an increased area of impervious surface on the site;

D. Construction of any one new single-family or duplex dwelling unit, irrespective of the site area on which the same may be situated, unless the surrounding area has the potential to allow for more development;

E. The developer provides an adequate study by a registered professional engineer that quantifies the problems and demonstrates that a waiver of a specific requirement is appropriate;

F. Areas where the City Engineer agrees that detention facilities will serve little purpose, in which case, the City may accept payment in lieu of constructing a detention facility. Payment shall be as follows:

R-1 and R-2	All Other Zoning
$1,000 per lot	$1 per cubic foot for 1 to 30,000 cubic feet of storage
	$0.75 per cubic feet for 3,001 cubic feet and above

2) Detention storage capacity shall be determined by hydrograph routing methods.

Routing calculations shall be submitted in legible tabulated form. Proof of adequacy of the volume of detention and sizing computations for low-flow structures shall also be submitted. Features of stability and safety will also need to be documented if the scope of the project requires special attention in this area of design.

3) The following conditions and limitations shall be observed in the selection and use of method of detention

General Location: Detention facilities shall be located within the parcel limits of the project site under consideration with the following exceptions:

A) No detention or ponding will be permitted within existing public road rights-of-way without specific written approval of the City.

B) Location of detention facilities immediately downstream of the project will be considered by special request if proper documentation is submitted with reference to practicality, feasibility, proof of ownership or right-of-use of the area proposed, and provisions are made for perpetual maintenance.

C) Detention facilities shall be a part of a development where provisions are made for perpetual maintenance, and shall be within a dedicated easement. Maintenance of the facility will be the responsibility of the property owner.

D) When it cannot be proven that the facility will be perpetually maintained, the detention facility shall be dedicated to the City and the City shall be responsible for maintenance the same as if it were road right-of-way. The developer will be required to maintain the detention facility for a period of two years and correct any deficiencies found during that time. The developer will also be required to pay a one-time maintenance fee to the City.

Payment shall be as follows:

(Detention Pond Acres) x ($8,000)

Detention pond acres shall include the total area being dedicated to the City.

This payment is intended to cover the perpetual maintenance cost of the detention facility.

4) Dry Reservoirs: Wet weather ponds or dry reservoirs shall be designed with proper safety, stability, and ease of maintenance features. Maximum side slopes for grassed reservoirs shall not exceed one (1) foot vertical for three (3) feet horizontal (3:1). In no case shall the limits of maximum ponding elevation be less than two (2) feet vertically below the lowest sill elevation, nor should the maximum limits of ponding be designed closer than ten (10) feet from a building unless waterproofing of the building and pedestrian accessibility are properly mulched, sodded, or paved. A minimum of one (1) foot of freeboard is required above the spillway. The outlet structure shall be concrete or other equivalent material. Spillway areas shall be lined in accordance with open channel requirements. Details of spillway and outlet structures shall be provided.

5) Open Channels: Normally permitted open channels may be used as detention areas, provided that the limits of the maximum ponding elevation are not closer than thirty (30) feet horizontally from any buildings with habitable areas below ground level, and less than two (2) feet below the lowest sill elevation of any building. In no case shall the maximum limits of ponding be designed closer than ten (10) feet from a building unless waterproofing of the building and pedestrian accessibility are properly documented. No ponding will be permitted within public rights-of-way without specific written approval of the Director of Public Works. Maximum depth of detention in open channels shall be four (4) feet. Minimum flow line grade shall be 0.5 percent.

For trapezoidal sections, the maximum side slopes of the detention area of the channel shall not exceed one (1) foot vertical for three (3) horizontal (3:1). For design of other typical channel sections, the features of safety, stability, and ease of maintenance shall be observed.

The entire reservoir area of the open channel shall be seeded, fertilized and mulched, sodded, or paved.

The hydraulic elevations resulting from channel detention shall not adversely affect adjoining properties.

6) Permanent Lakes: Permanent lakes with fluctuating volume controls may be used as detention areas provided that the limits of maximum ponding elevations are no closer than thirty (30) feet horizontally from any building and less than two (2) feet below the lowest sill elevation of any building.

Maximum side slopes for the fluctuating area of permanent lakes shall be one (1) foot vertical to three (3) feet horizontal (3:1) unless proper provisions are included for safety, stability, and ease of maintenance.

Maximum fluctuation from permanent pool elevation to maximum ponding elevation shall be three (3) feet.

The entire fluctuating area of the permanent reservoir shall be seeded and fertilized and mulched or sodded or concrete paved. Any area susceptible to or designed as overflow shall be lined in accordance with open channel requirements.

7) Parking Lots: Detention will not be permitted in primary parking lots. A primary parking lot will be considered to be the most accessible 80 percent of total parking for a facility.

In non-primary parking lots, detention will be permitted to a maximum depth of twelve (12) inches.

In no case should the maximum limits of parking lot ponding be designed closer than ten (10) feet from a building unless waterproofing of the building and pedestrian accessibility are provided and properly documented.

When detention is being effected on parking lots by means of retaining walls or curbs, these retaining walls and curbs must be constructed of reinforced concrete.

The minimum freeboard from the maximum ponding elevation to the lowest sill elevation shall be two (2) feet.

8) Rooftops: Detention may be provided on rooftops. Details shall be provided, including structure information for review.

9) Detention facilities shall be provided with obvious and effective outlet control structures. These outlet structures may include V-notch weirs or rectangular weirs, as well as pipe.

The outlet structure shall be designed to control the discharge rates for the 2-, 10-, and 100-year return periods. The maximum release rates shall be equal to or less than the pre-developed runoff.

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

Overflow spillways will be required on all detention facilities that have storage volumes of 1,000 or more cubic feet.

The principal spillway shall be designed to convey all discharge from the detention facility in excess of the 100-year storm, and shall function without mechanical or electrical components. The overflow spillway shall exit into a natural or improved drainageway. If the drainageway does not provide for public access, then topographic detail, along with a profile of the centerline of the drainageway shall be provided from the overflow spillway to the point of public access. This detail shall show all topography within ten feet of the centerline of the drainageway, centerline profile, typical cross-section, and capacity of the drainageway.

If the capacity of the existing drainageway is inadequate to carry the total peak runoff, necessary improvements to the drainageway may be required to provide for the total peak runoff.

10) Special emergency spillways are required for dams exceeding ten feet in height. Dams impounding more than 30 acre-feet shall meet the requirements of the Missouri Dam and Reservoir Safety Council.

11) Off-site Detention: Stormwater detention facilities designed and constructed off-site or outside the limits of the proposed development will be considered for approval. This approval is contingent upon documentation being furnished to verify that drainage easements have been obtained for the channel area from the proposed development to the detention facility and including the detention area. The drainage easements must clearly set out provisions for maintenance.

12) Regional Detention: Detention facilities designed and located to provide detention on major drainage channels will be considered as a regional detention facility. The drainage area considered for a regional detention facility must be 640 acres or greater. The facility must provide a detention volume for a 100-year storm for the entire drainage area, and must be designed with a variable control outlet structure that has a one (1) year maximum outlet opening. The regional detention facility must be designed with a low flow concrete channel through the limits of the basin. Upon conceptual approval of the location and final approval of the design and construction, the City Engineer may accept the responsibility for the maintenance of the regional facility. Drainage and access easements will be required giving the authority to gain vehicular access to the facility from a public street.

13) Temporary Detention: It may be advantageous in some situations to delay the building of the permanent detention facilities until after the completion of the other improvements. In these situations, temporary detention facilities must be provided. The permanent or temporary detention facilities must be constructed and be functional before proceeding with any other construction.

7. EASEMENTS

Easements shall be platted and dedicated for all stormwater systems, which, when approved, will be accepted by the City.

Easements are required around private detention facilities and along open channels, and for buried systems.

The City Engineer may also require easements in other areas deemed necessary.

1) Buried structure permanent easements shall be at least fifteen (15) feet wide.

2) Channel permanent easements shall be at least thirty (30) feet wide.

3) Detention reservoirs shall have a minimum of a ten (10) foot permanent easement around the perimeter.

4) All structures for which the City assumes responsibility shall be accessible from a public right-of-way via an access easement.

8. MINIMUM REQUIREMENTS FOR STORMWATER MANAGEMENT PLAN

1) A plan of the drainage area shall be provided. This plan shall be prepared by a registered professional engineer licensed in Missouri.

2) The scale shall be a maximum 1" = 100 feet, with a one or two foot contour interval for areas of 100 acres or less, and 1" = 300 feet with a five foot contour interval for larger tracts. At least one benchmark shall be shown. Elevations shall be Mean Sea Level (MSL) datum/National Geodetic Vertical Datum (NGVD).

3) The plan shall show all proposed improvements, streets, blocks, lots, drainage, easements, drainage structures, and grading improvements, with flow quantities and direction of flow at all critical points.

4) All drainage areas and sub-areas shall be clearly distinguished on the plans.

5) Complete hydraulic calculations, nomographs, charts, hydrographs, and other applicable documents shall be provided for all street under-structures, inlet openings, and other locations where flows are removed from streets.

6) The downstream capacity of all drainage facilities and the effect of additional flows from the improved area shall be provided.

7) If the development is adjacent to a FEMA Floodway or flood plain, the limits and base flood elevations (BFE) shall be shown.

8) Upstream drainage that enters the site shall be delineated in acres and 2, 10, and 100 year runoff rates calculated and provided.

9) Plan and profiles shall be provided for proposed improvements at a horizontal scale of at least 1" = 50 feet and vertical scale of 1" = 5 feet. The following information shall be provided:
Location, flow line elevations and grade, sizes and types of pipe channels, boxes, and other drainage structures. Ten-year flows shall be provided for sub-basin or inlet. Where concrete structures are proposed, reinforcement and materials shall be described and shown in cross-section.

10) Where channels are proposed, the slope, side slope, bottom, and top width shall be shown, as well as the type of lining material (concrete, grass, riprap, etc.).

11) Detention facilities shall be described in detail as to size, bottom elevation, construction, and discharge control device. The water surface elevation and discharge rate shall be shown for 2, 10, and 100 year storms. If wet detention is proposed, the static water elevation shall be provided.

12) The Stormwater and Drainage Plan shall include the described items as a minimum, presented in such a manner as to facilitate review by the City Engineer. Any additional datum, drawings, or other information determined to be necessary by the City Engineer shall be provided. Two copies of all drawings and data shall be provided.

This table contains average rainfall intensities in inches per hour.

DURATION HR:MIN	2 YR	5 YR	10 YR	25 YR	50 YR	100 YR
0:05	5.47	6.42	7.30	8.43	9.22	10.31
0:06	5.25	6.16	7.00	8.09	8.85	9.89
0:07	5.04	5.92	6.73	7.78	8.51	9.51
0:08	4.85	5.70	6.49	7.50	8.20	9.17
0:09	4.68	5.50	6.26	7.24	7.92	8.86
0:10	4.52	5.31	6.05	7.00	7.66	8.57
0:11	4.37	5.14	5.86	6.79	7.42	8.31
0:12	4.23	4.98	5.68	6.58	7.20	8.06
0:13	4.10	4.83	5.52	6.39	6.99	7.84
0:14	3.98	4.69	5.36	6.22	6.80	7.62
0:15	3.86	4.56	5.22	6.05	6.62	7.43
0:16	3.76	4.44	5.08	5.90	6.45	7.24
0:17	3.66	4.32	4.96	5.75	6.29	7.07
0:18	3.56	4.22	4.84	5.61	6.14	6.90
0:19	3.48	4.11	4.72	5.48	6.00	6.75
0:20	3.39	4.02	4.62	5.36	5.86	6.60
0:21	3.31	3.93	4.51	5.25	5.74	6.46
0:22	3.24	3.84	4.42	5.14	5.62	6.33
0:23	3.16	3.76	4.33	5.03	5.50	6.20
0:24	3.09	3.68	4.24	4.93	5.40	6.08
0:25	3.03	3.60	4.16	4.84	5.29	5.97
0:26	2.97	3.53	4.08	4.75	5.19	5.86
0:27	2.91	3.46	4.00	4.66	5.10	5.76
0:28	2.85	3.40	3.93	4.58	5.01	5.66
0:29	2.80	3.34	3.86	4.50	4.92	5.57
0:30	2.74	3.28	3.79	4.42	4.84	5.47
0:31	2.69	3.22	3.73	4.35	4.76	5.39
0:32	2.65	3.16	3.67	4.28	4.68	5.30
0:33	2.60	3.11	3.61	4.21	4.61	5.22
0:34	2.55	3.06	3.55	4.14	4.54	5.14
0:35	2.51	3.01	3.50	4.08	4.47	5.07
0:36	2.47	2.96	3.44	4.02	4.41	5.00
0:37	2.43	2.92	3.39	3.96	4.34	4.93
0:38	2.39	2.87	3.34	3.91	4.28	4.86
0:39	2.35	2.83	3.30	3.85	4.22	4.80
0:40	2.32	2.79	3.25	3.80	4.17	4.73

DURATION HR:MIN	2 YR	5 YR	10 YR	25 YR	50 YR	100 YR
0:41	2.28	2.75	3.21	3.75	4.11	4.67
0:42	2.25	2.71	3.16	3.70	4.06	4.61
0:43	2.22	2.67	3.12	3.65	4.00	4.56
0:44	2.19	2.64	3.08	3.61	3.95	4.50
0:45	2.16	2.60	3.04	3.56	3.91	4.45
0:46	2.13	2.57	3.00	3.52	3.86	4.40
0:47	2.10	2.53	2.97	3.48	3.81	4.34
0:48	2.07	2.50	2.93	3.43	3.77	4.30
0:49	2.04	2.47	2.90	3.40	3.72	4.25
0:50	2.02	2.44	2.86	3.36	3.68	4.20
0:51	1.99	2.41	2.83	3.32	3.64	4.16
0:52	1.97	2.38	2.80	3.28	3.60	4.11
0:53	1.94	2.35	2.77	3.25	3.56	4.07
0:54	1.92	2.33	2.74	3.21	3.53	4.03
0:55	1.90	2.30	2.71	3.18	3.49	3.99
0:56	1.87	2.27	2.68	3.14	3.45	3.95
0:57	1.85	2.25	2.65	3.11	3.42	3.91
0:58	1.83	2.23	2.62	3.08	3.38	3.87
0:59	1.81	2.20	2.60	3.05	3.35	3.83
1:00	1.79	2.18	2.57	3.02	3.32	3.80
1:05	1.70	2.07	2.45	2.88	3.17	3.63
1:10	1.61	1.97	2.34	2.76	3.03	3.48
1:15	1.54	1.89	2.24	2.64	2.91	3.34
1:20	1.47	1.81	2.15	2.54	2.80	3.22
1:25	1.41	1.74	2.07	2.45	2.70	3.11
1:30	1.35	1.67	2.00	2.36	2.60	3.01
1:35	1.30	1.61	1.93	2.29	2.52	2.91
1:40	1.26	1.56	1.87	2.21	2.44	2.82
1:45	1.21	1.50	1.81	2.15	2.37	2.74
1:50	1.17	1.46	1.76	2.08	2.30	2.67
1:55	1.13	1.41	1.71	2.03	2.23	2.60
2:00	1.10	1.37	1.66	1.97	2.18	2.53
2:05	1.07	1.33	1.62	1.92	2.12	2.47
2:10	1.04	1.30	1.57	1.87	2.07	2.41
2:15	1.01	1.26	1.54	1.83	2.02	2.36
2:20	0.98	1.23	1.50	1.79	1.97	2.30
2:25	0.96	1.20	1.46	1.75	1.93	2.25
2:30	0.93	1.17	1.43	1.71	1.89	2.21
2:35	0.91	1.15	1.40	1.67	1.85	2.16
2:40	0.89	1.12	1.37	1.64	1.81	2.12

DURATION HR:MIN	2 YR	5 YR	10 YR	25 YR	50 YR	100 YR
2:45	0.87	1.10	1.34	1.60	1.77	2.08
2:50	0.85	1.07	1.32	1.57	1.74	2.04
2:55	0.83	1.05	1.29	1.54	1.71	2.01
3:00	0.80	1.01	1.24	1.49	1.65	1.94
3:30	0.71	0.91	1.12	1.35	1.49	1.76
4:00	0.64	0.82	1.03	1.24	1.37	1.62
4:30	0.59	0.76	0.95	1.14	1.27	1.51
5:00	0.54	0.70	0.88	1.07	1.19	1.41
5:30	0.50	0.65	0.83	1.00	1.11	1.33
6:00	0.47	0.61	0.78	0.94	1.05	1.26
6:30	0.44	0.58	0.74	0.89	1.00	1.20
7:00	0.42	0.55	0.70	0.85	0.95	1.14
7:30	0.39	0.52	0.67	0.81	0.91	1.09
8:00	0.37	0.50	0.64	0.78	0.87	1.05
8:30	0.36	0.47	0.61	0.75	0.83	1.01
9:00	0.34	0.45	0.59	0.72	0.80	0.97
9:30	0.33	0.44	0.57	0.69	0.77	0.94
10:00	0.31	0.42	0.55	0.67	0.75	0.91
10:30	0.30	0.41	0.53	0.65	0.72	0.88
11:00	0.29	0.39	0.51	0.63	0.70	0.86
11:30	0.28	0.38	0.50	0.61	0.68	0.83
12:00	0.27	0.37	0.48	0.59	0.66	0.81
12:30	0.26	0.36	0.47	0.57	0.64	0.79
13:00	0.25	0.35	0.45	0.56	0.63	0.77
13:30	0.25	0.34	0.44	0.54	0.61	0.75
14:00	0.24	0.33	0.43	0.53	0.60	0.73
14:30	0.23	0.32	0.42	0.52	0.58	0.72
15:00	0.23	0.31	0.41	0.51	0.57	0.70
15:30	0.22	0.30	0.40	0.50	0.56	0.68
16:00	0.22	0.30	0.39	0.48	0.54	0.67
16:30	0.21	0.29	0.38	0.47	0.53	0.66
17:00	0.20	0.28	0.38	0.46	0.52	0.65
17:30	0.20	0.28	0.37	0.46	0.51	0.63
18:00	0.20	0.27	0.36	0.45	0.50	0.62
18:30	0.19	0.26	0.35	0.44	0.49	0.61
19:00	0.19	0.26	0.35	0.43	0.48	0.60
19:30	0.18	0.25	0.34	0.42	0.48	0.59
20:00	0.18	0.25	0.34	0.42	0.47	0.58
20:30	0.18	0.24	0.33	0.41	0.46	0.57

Oronogo, Missouri Stormwater Management Criteria	Rainfall Intensity Table Table A

DURATION HR:MIN	2 YR	5 YR	10 YR	25 YR	50 YR	100 YR
21:00	0.17	0.24	0.32	0.40	0.45	0.56
21:30	0.17	0.24	0.32	0.40	0.45	0.55
22:00	0.17	0.23	0.31	0.39	0.44	0.55
22:30	0.16	0.23	0.31	0.38	0.43	0.54
23:00	0.16	0.22	0.30	0.38	0.43	0.53
23:30	0.16	0.22	0:30	0.37	0.42	0.52
24:00	0.16	0.22	0.29	0.37	0.41	0.52

CURB OPENING INLETS CAPACITY INSTALLED ON SLOPING GUTTERS

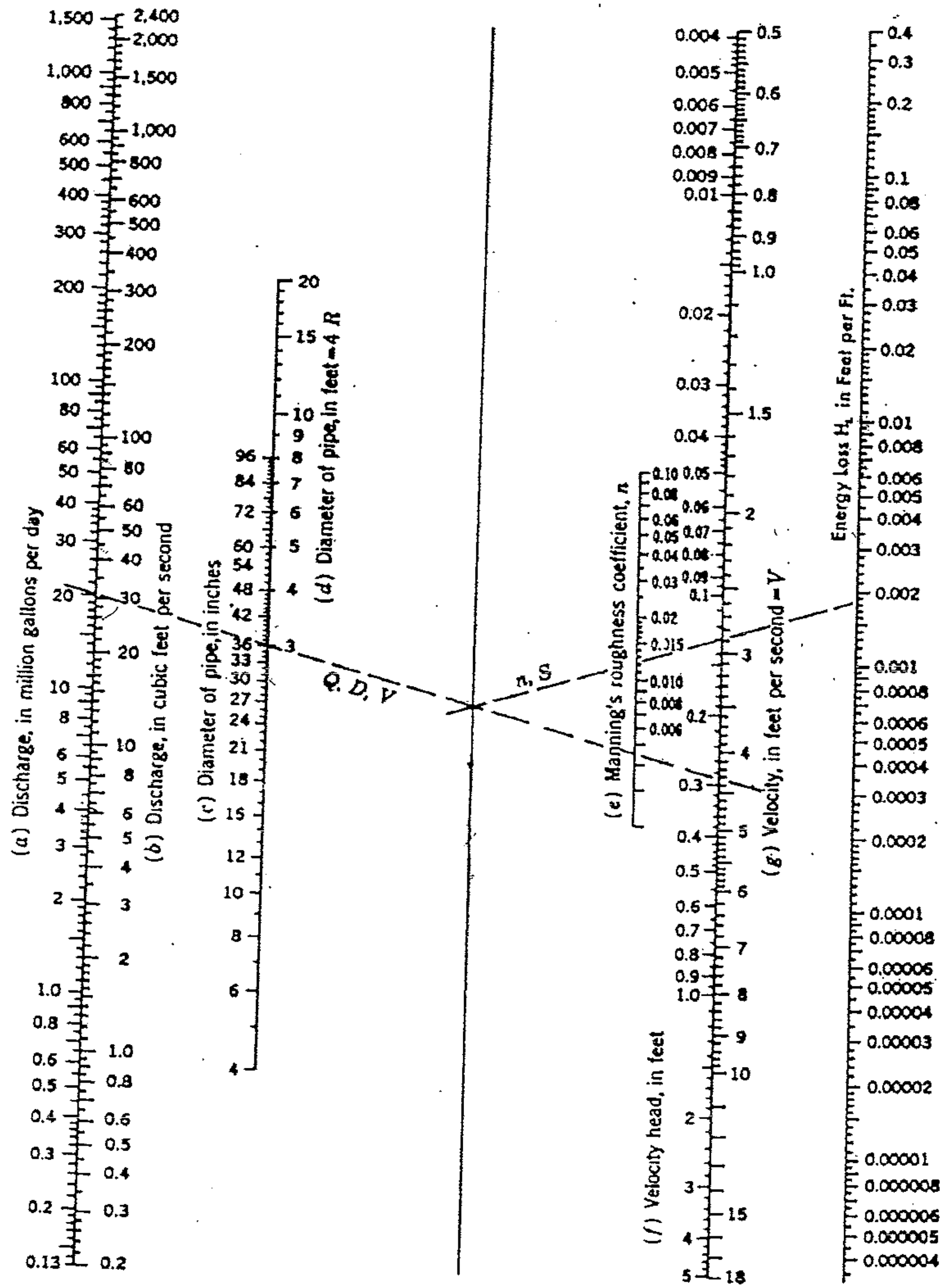
INLET INTERCEPTION CAPACITY IN CUBIC FEET PER SECOND (CFS)

Flow Depth at Curb (Feet)	Inlet Opening Length In Feet								
	4	5	6	7	8	9	10	11	12
0.05	0.14	0.17	0.20	0.22	0.24	0.25	0.27	0.28	0.28
0.10	0.33	0.41	0.48	0.54	0.60	0.66	0.71	0.77	0.81
0.15	0.55	0.67	0.79	0.91	1.02	1.13	1.23	1.33	1.43
0.20	0.78	0.96	1.14	1.31	1.48	1.65	1.81	1.96	2.11
0.25	1.03	1.27	1.51	1.75	1.98	2.20	2.42	2.64	2.85
0.30	1.29	1.60	1.91	2.21	2.51	2.80	3.09	3.37	3.65
0.35	1.58	1.96	2.33	2.70	3.07	3.43	3.79	4.14	4.49
0.40	1.87	2.33	2.78	3.22	3.66	4.10	4.53	4.95	5.37
0.45	2.18	2.72	3.24	3.77	4.29	4.80	5.31	5.81	6.31
0.50	2.51	3.12	3.73	4.34	4.93	5.53	6.12	6.70	7.28
0.55	2.85	3.55	4.24	4.93	5.61	6.29	6.96	7.63	8.29
0.60	3.20	3.98	4.76	5.54	6.31	7.07	7.83	8.59	9.34

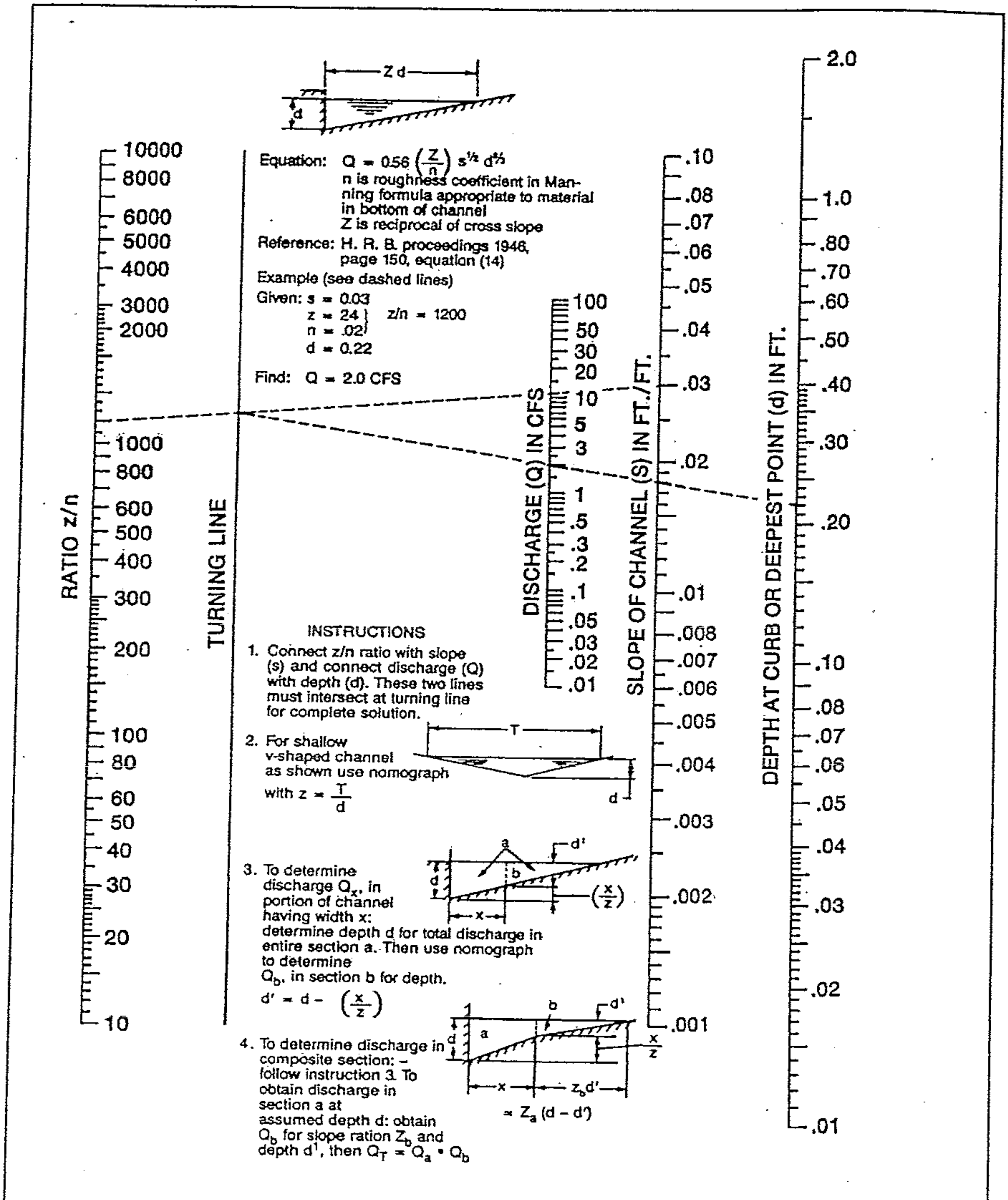
Installation Criteria:

Gutter Depression At Inlet = 4.0* (Minimum)
Clear Height Of Opening = 6.0* (Minimum)
Capacity Reduction For Clogging = 20%

Ref: MoDOT



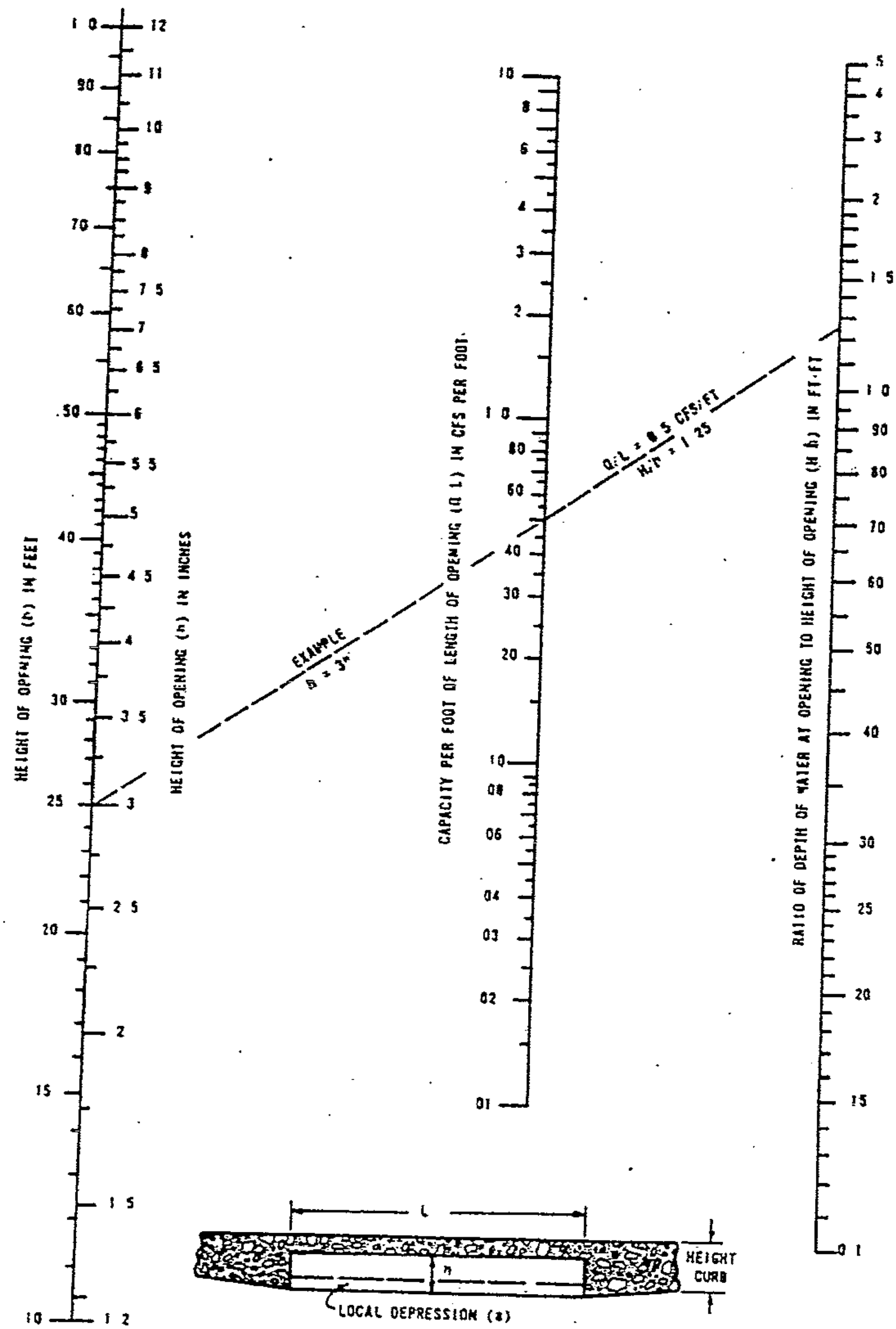
Oronogo, Missouri Stormwater Management Criteria	Alignment Chart For Flow in Pipes (Manning's Formula)
	Figure 1



Oronogo, Missouri
Stormwater Management Criteria

Street Gutter Hydraulics

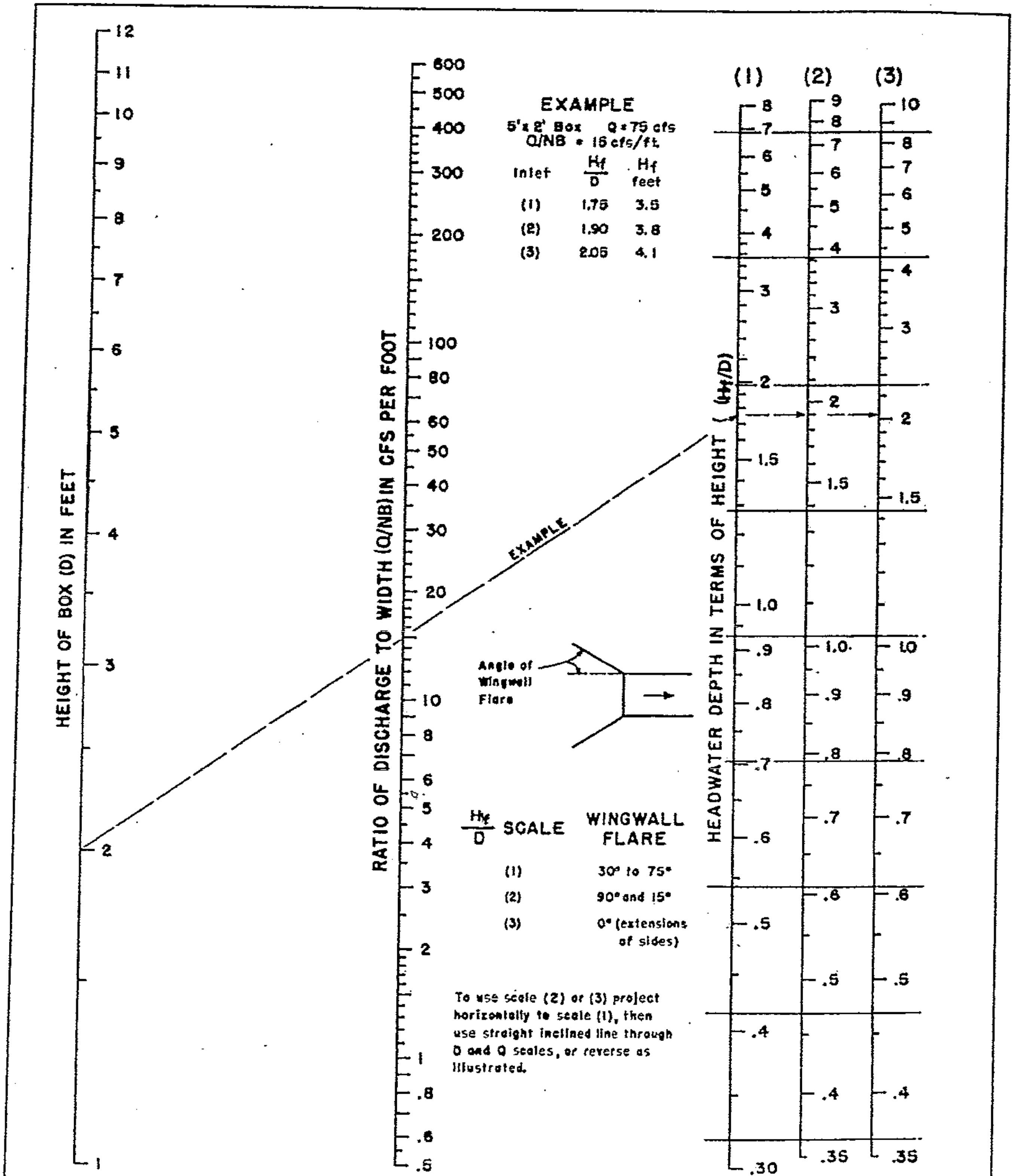
Figure 2



Oronogo, Missouri
Stormwater Management Criteria

Curb Opening Inlet
Capacity In Sump Locations

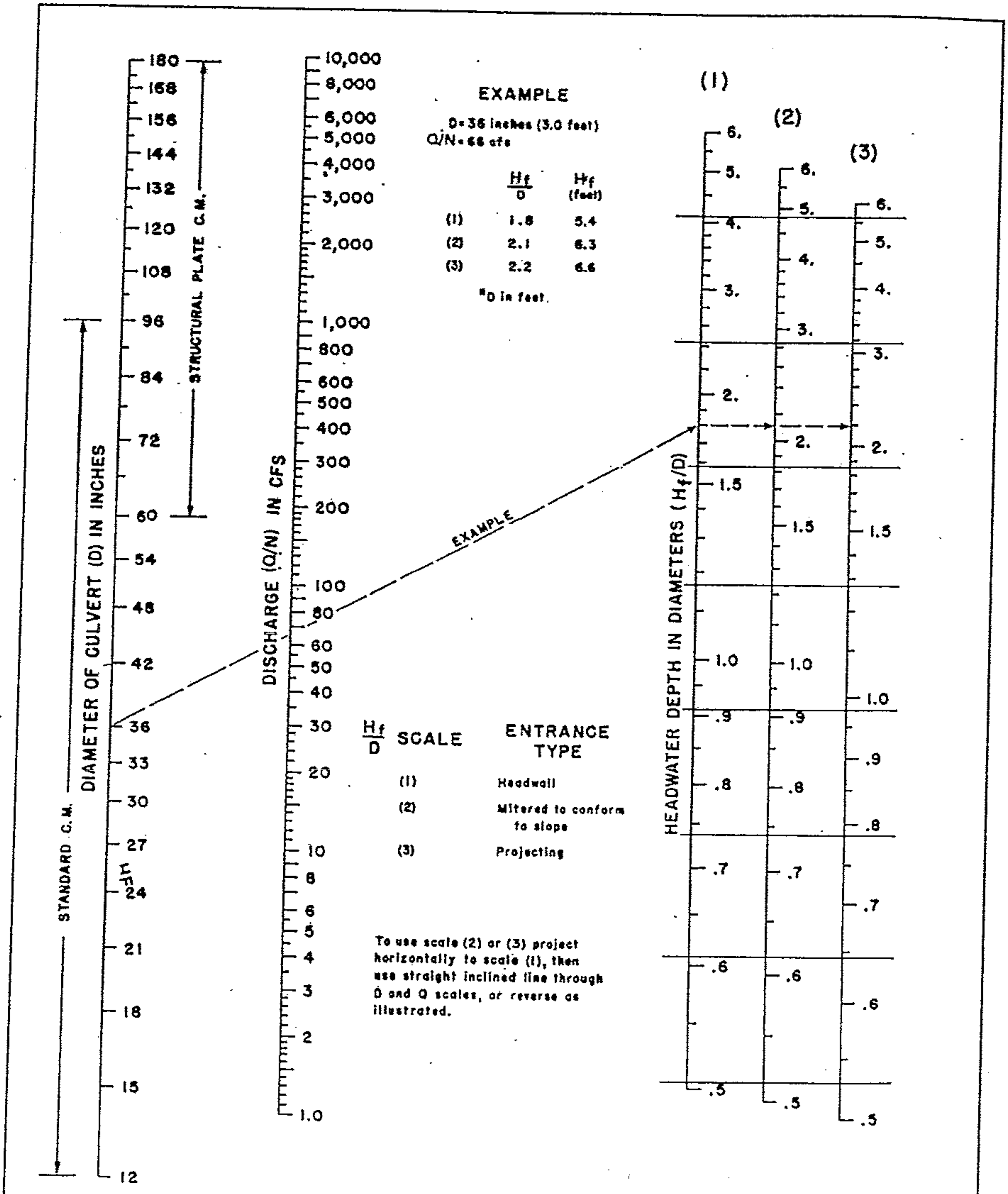
Figure 3



Oronogo, Missouri
Stormwater Management Criteria

Headwater Depth For Box Culverts With Inlet Control

Figure 4.1

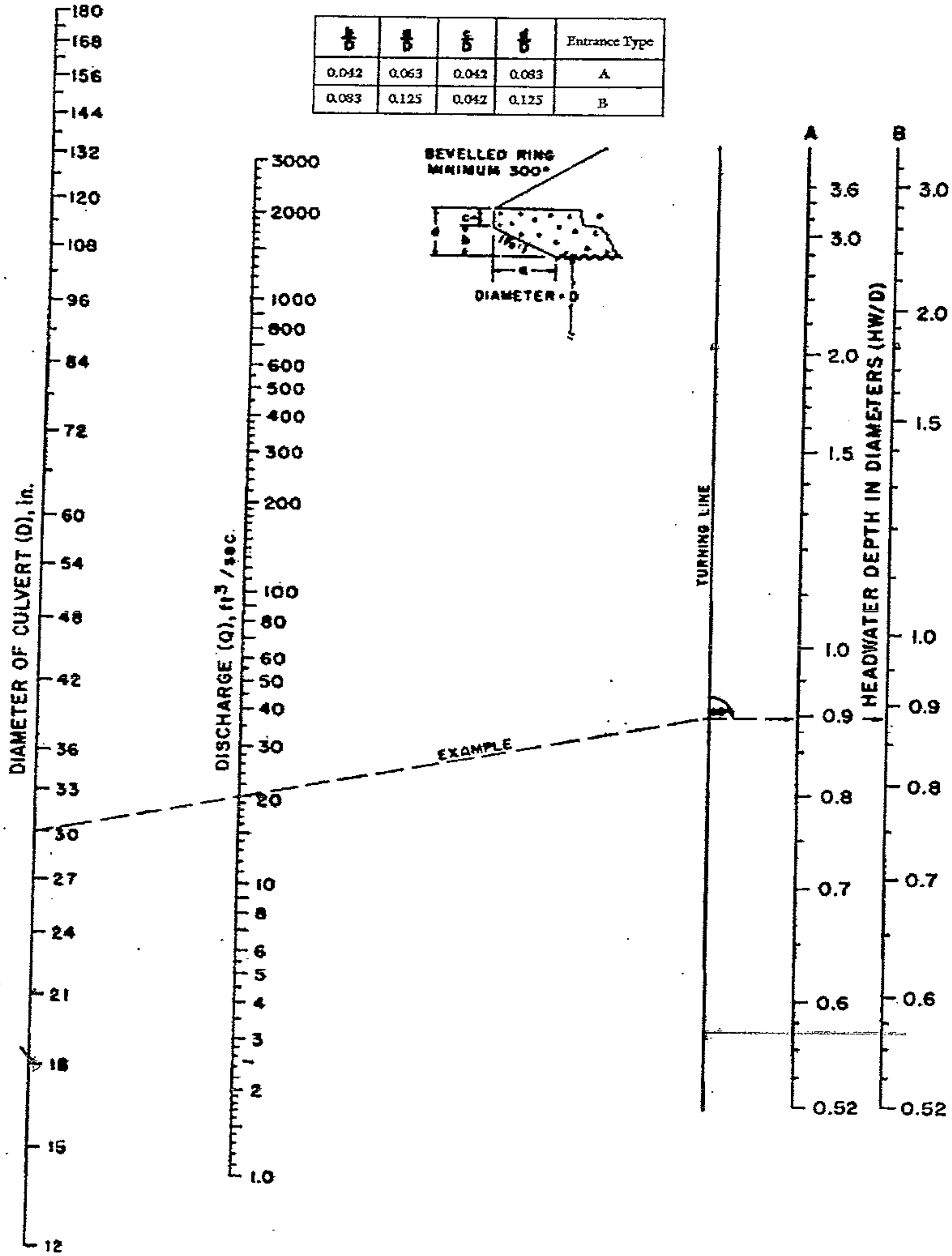


Oronogo, Missouri
Stormwater Management Criteria

Headwater Depth For Oval Concrete Pipe (HE) Inlet Control

Figure 4.2

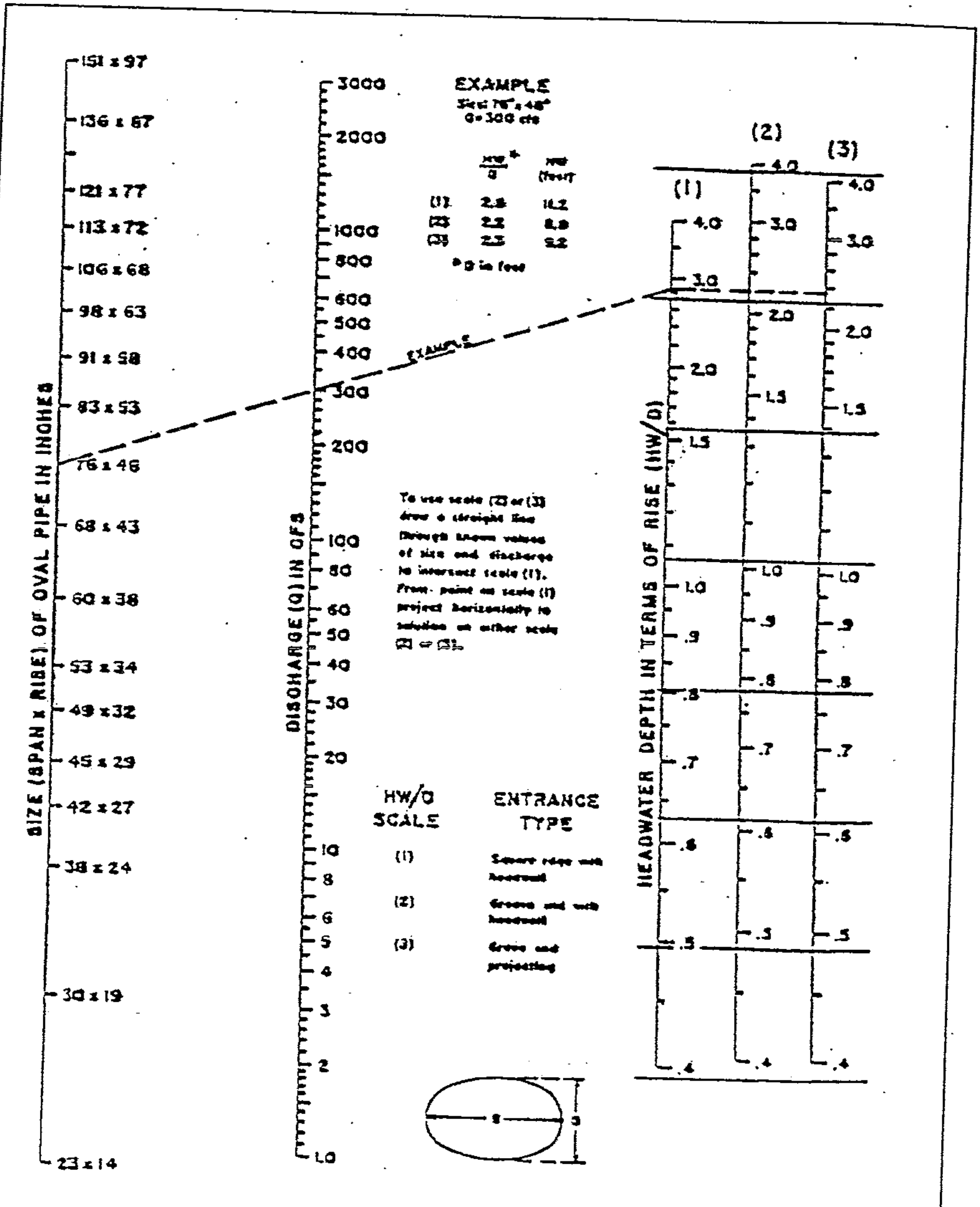
$\frac{a}{D}$	$\frac{b}{D}$	$\frac{c}{D}$	$\frac{d}{D}$	Entrance Type
0.042	0.063	0.042	0.083	A
0.083	0.125	0.042	0.125	B



Oronogo, Missouri
Stormwater Management Criteria

Headwater Depth For Circular Pipe Culverts With Bevelled Ring Inlet Control

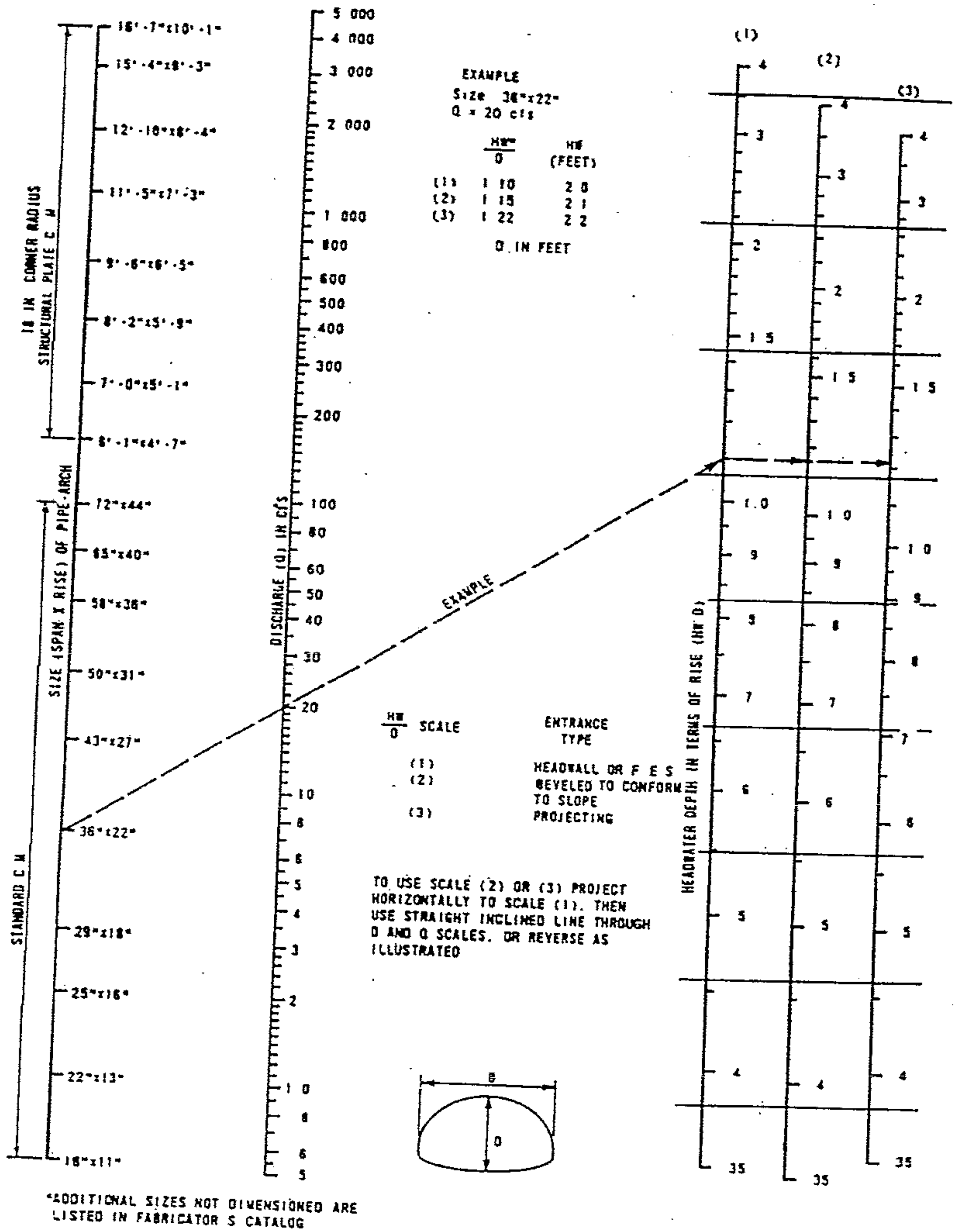
Figure 4.2A



Oronogo, Missouri
Stormwater Management Criteria

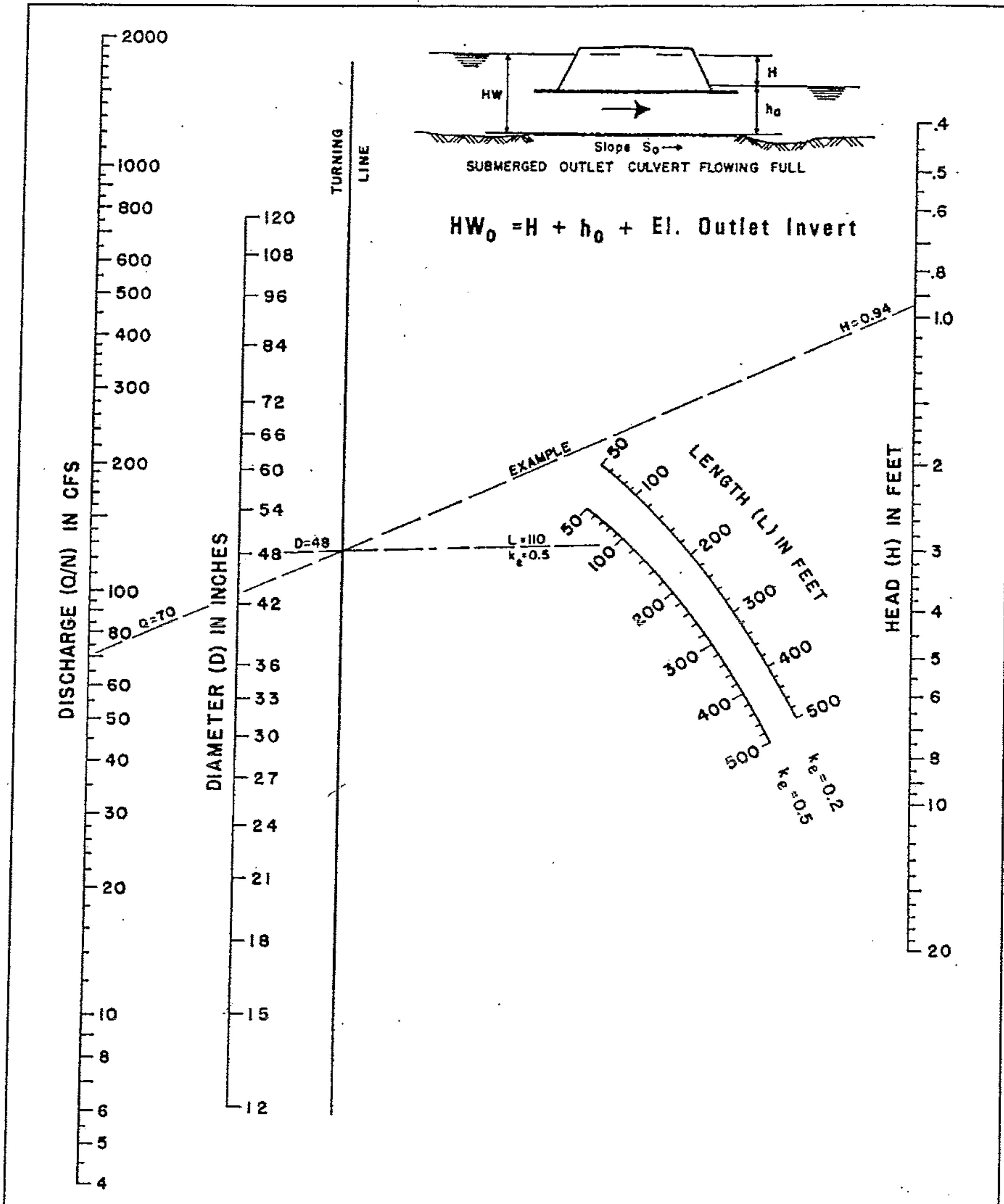
Headwater Depth For
Oval Concrete Pipe (HE)
Inlet Control

Figure 4.3



Headwater Depth For C.M. Pipe-Arch With Inlet Control

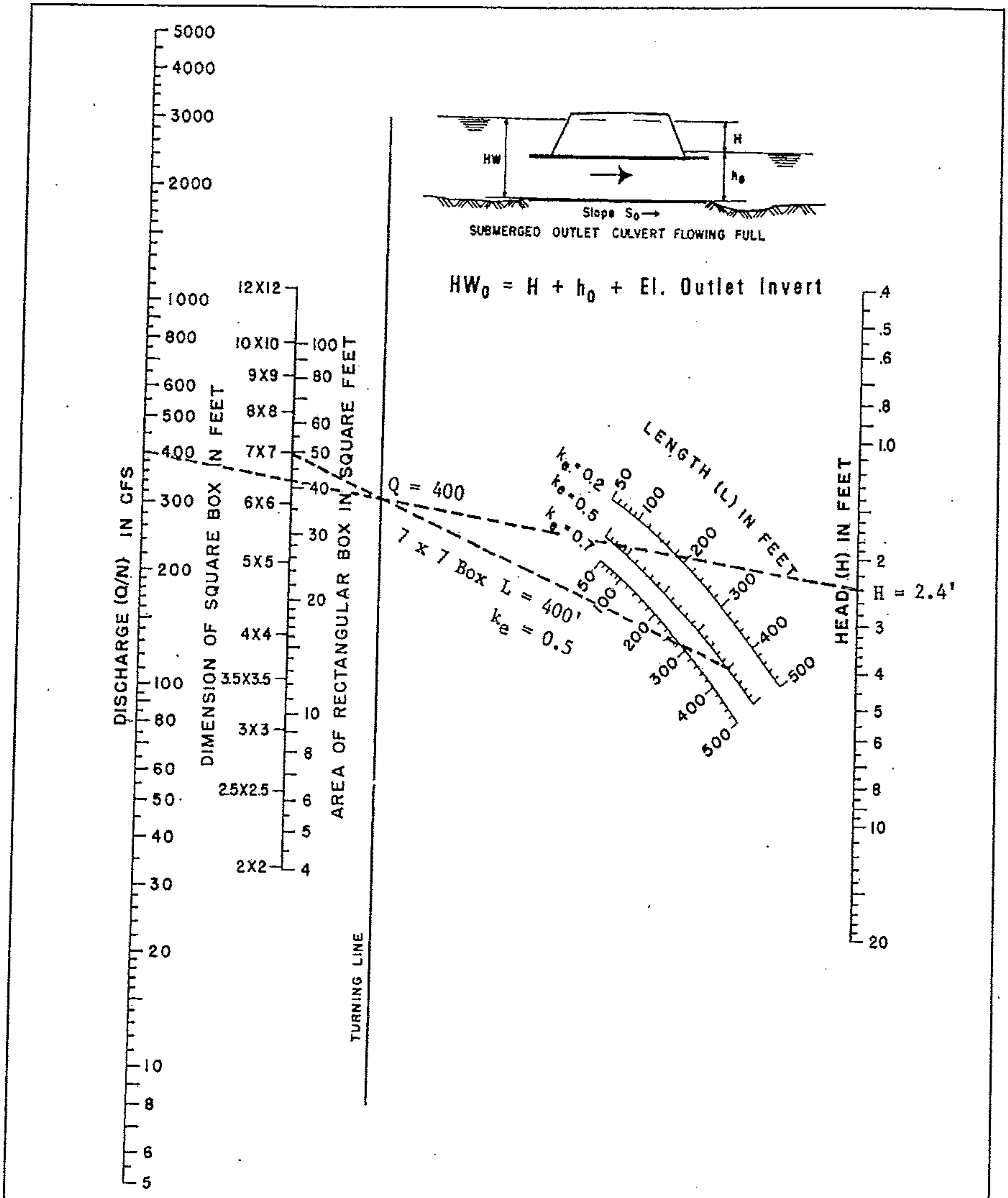
Figure 4.4



Oronogo, Missouri
Stormwater Management Criteria

Head for Concrete Pipe Culverts Flowing Full

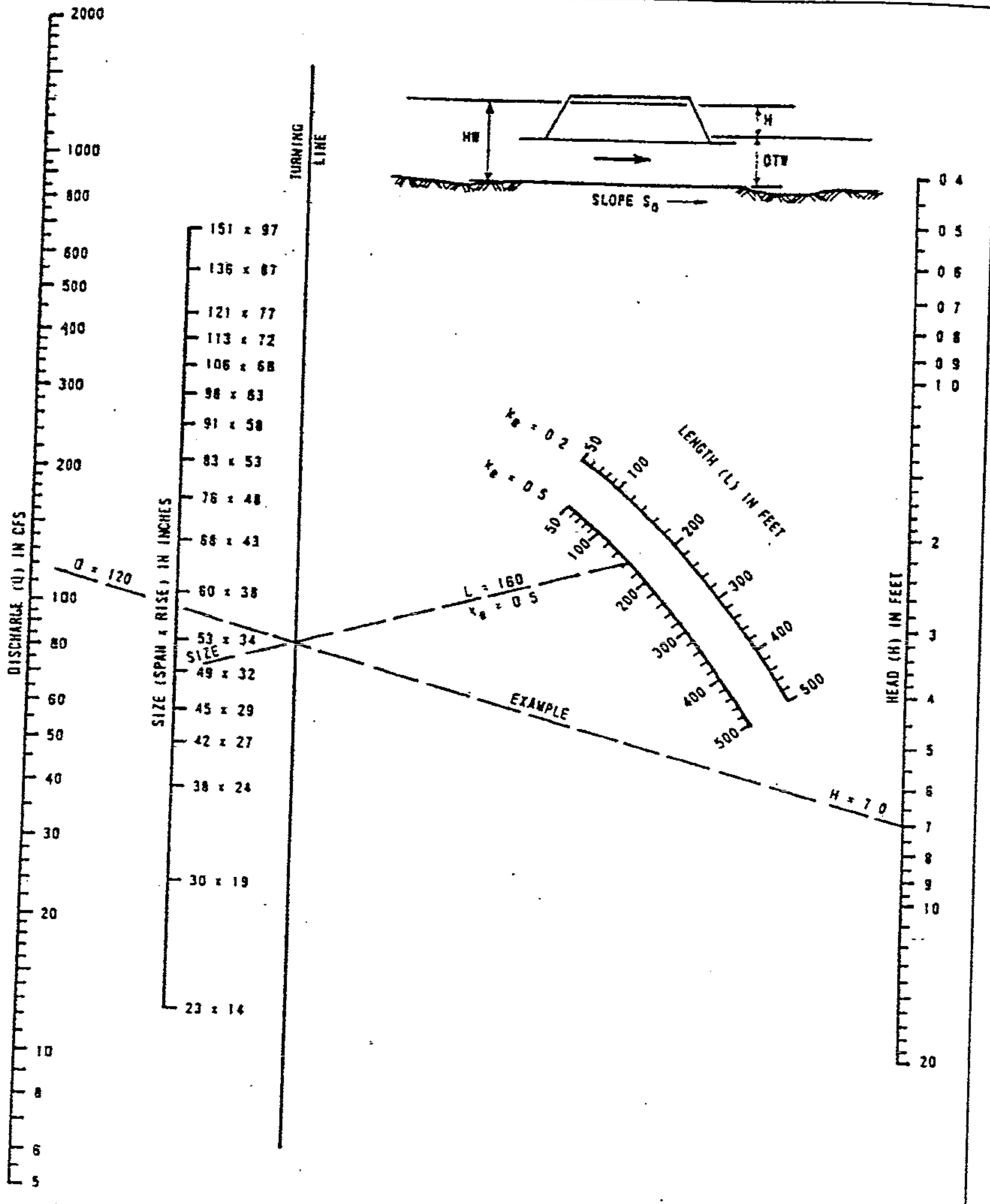
Figure 5.1



Oronogo, Missouri
Stormwater Management Criteria

Head for Concrete Box Culverts Flowing Full

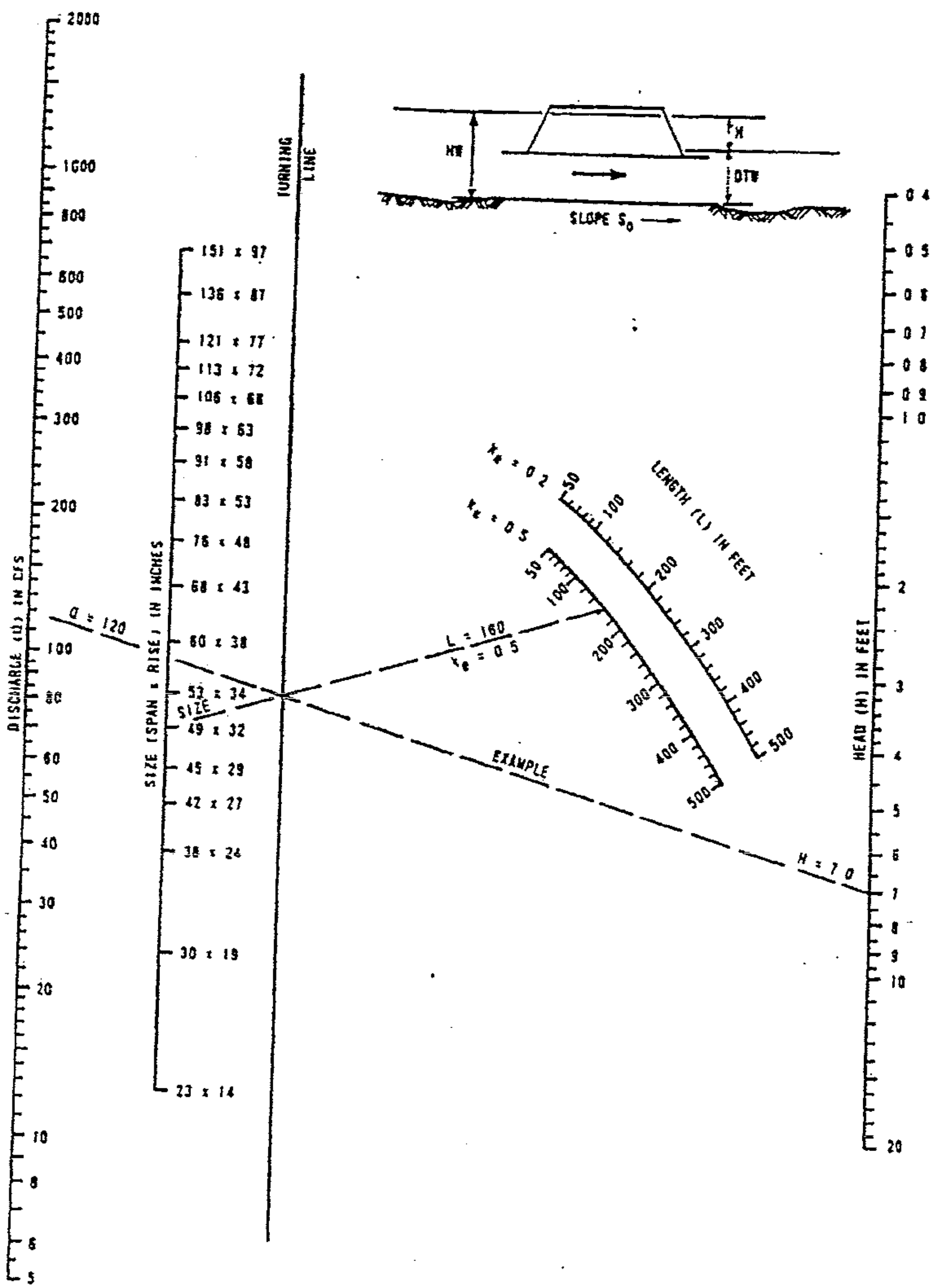
Figure 5.2



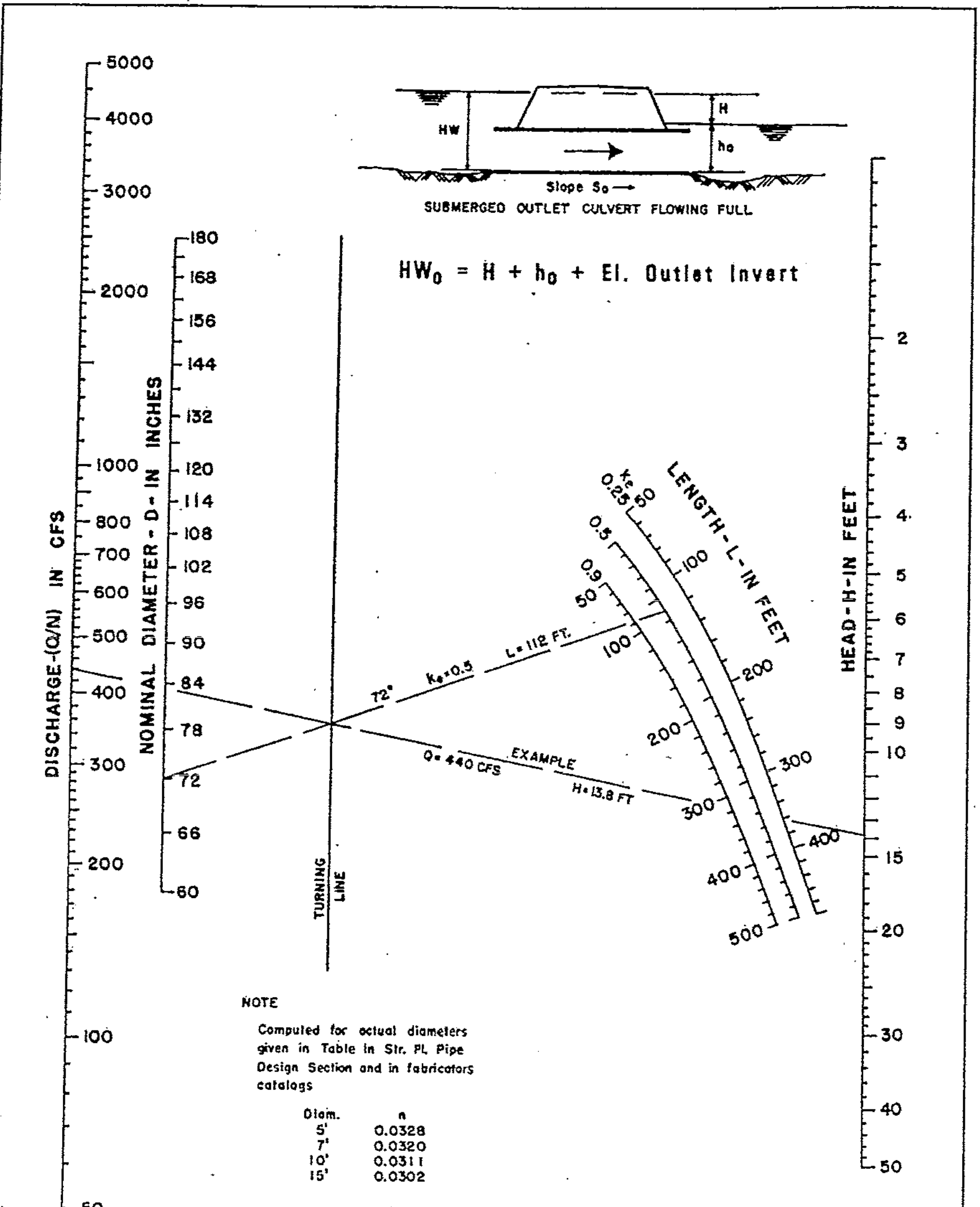
Oronogo, Missouri
Stormwater Management Criteria

Head for Oval Concrete Pipe Culverts Flowing Full (Long Axis Horiz. or Vert.)

Figure 5.3



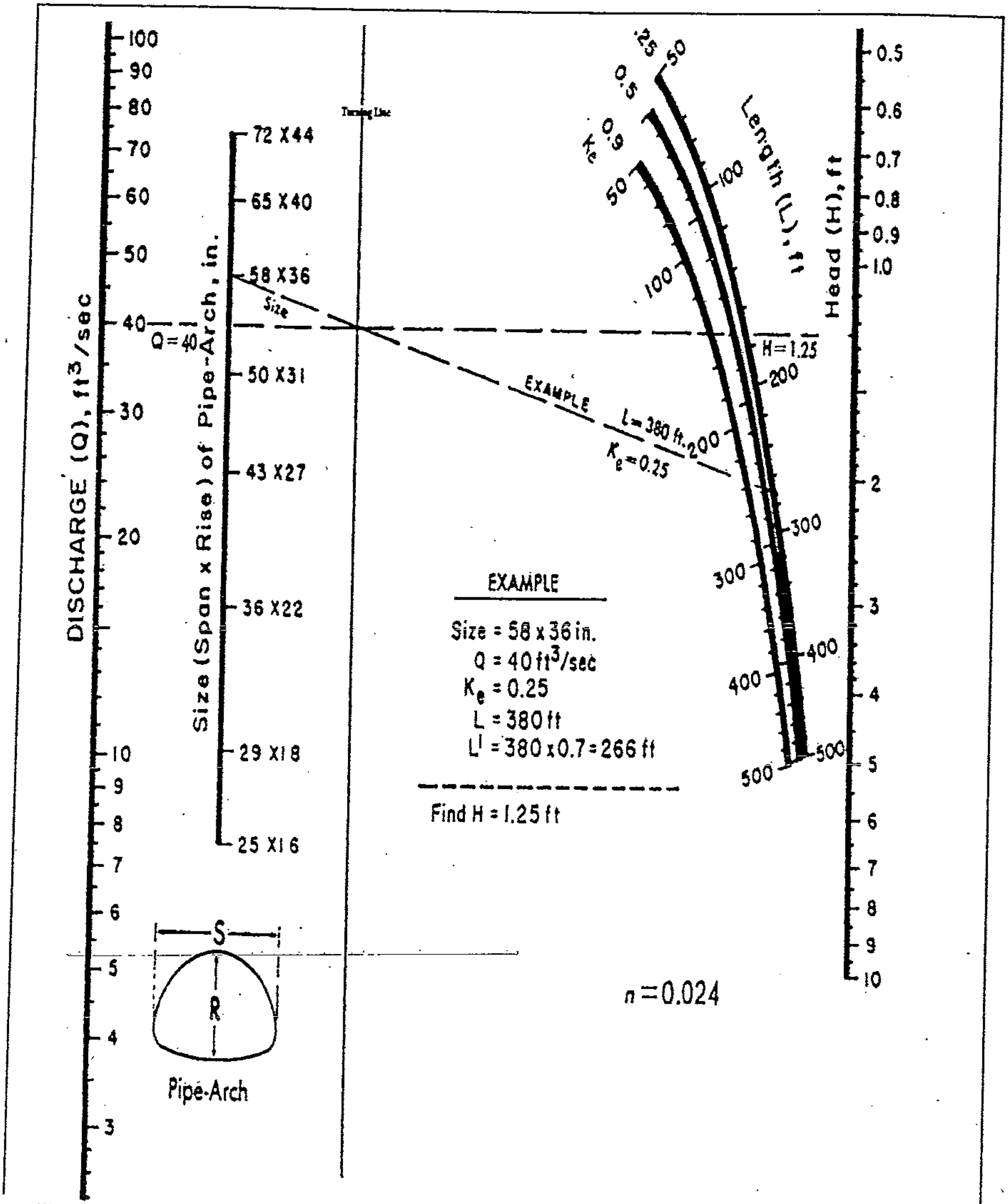
Oronogo, Missouri Stormwater Management Criteria	Head for Standard Corrugated Metal Pipe Culverts Flowing Full
	Figure 5.4



Oronogo, Missouri
Stormwater Management Criteria

Head for Structural Plate Corrugated Metal Pipe Culverts Flowing Full

Figure 5.5



Head for Standard C.M. Pipe-Arch Culverts Flowing Full

Figure 5.6