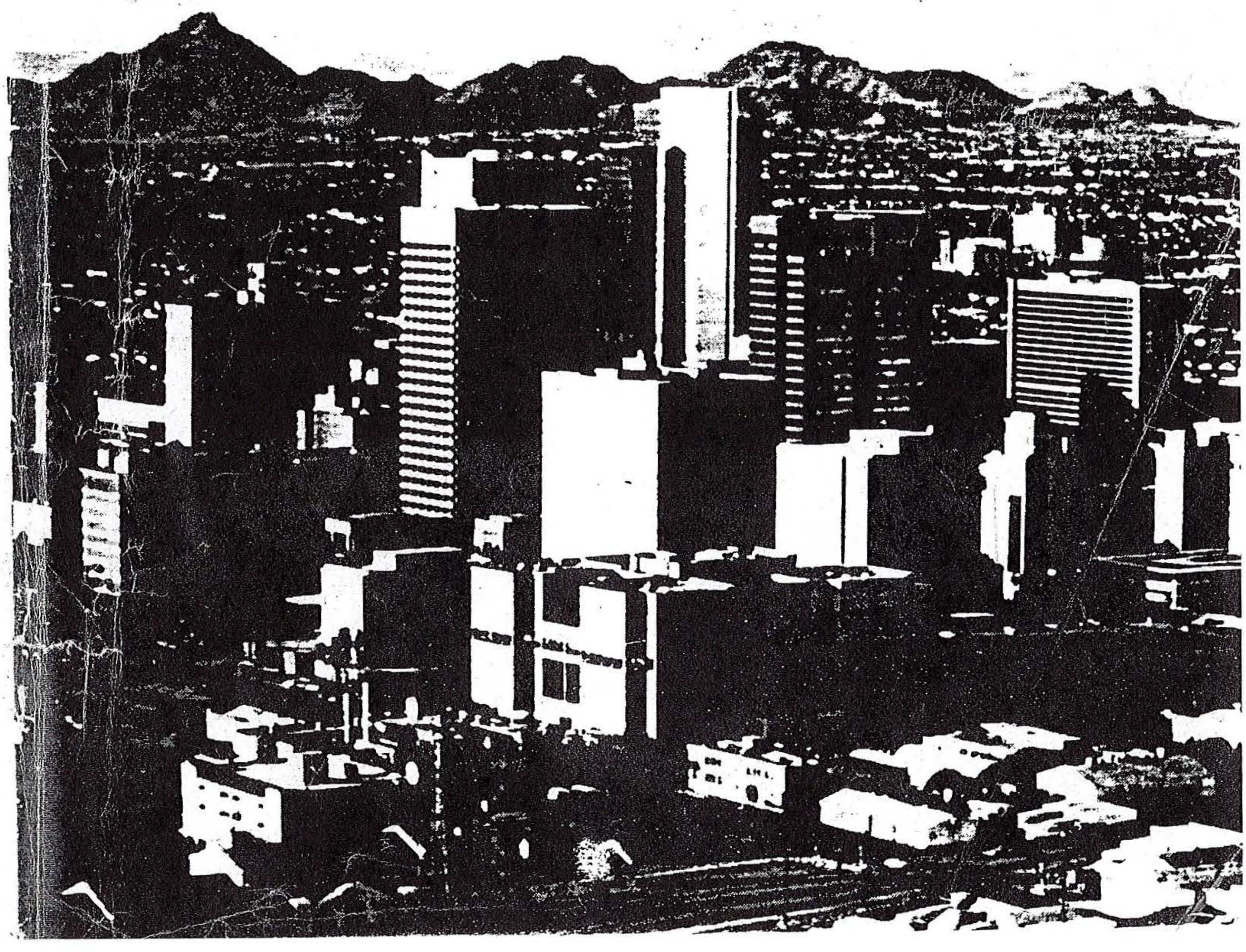
CITY OF PHOENIX

STORM DRAIN DESIGN MANUAL

Subdivision Drainage Design

Development Services
Infrastructure Review
July 1988



INTRODUCTION

Procedures outlined in this manual are intended to provide guidance for hydrologic and hydraulic design of storm drain facilities installed in conjunction with new development in the City of Phoenix, Arizona.

INDEX SHEET

NEW SUBDIVISION DRAINAGE DESIGN POLICY

GENERAL

This manual is intended as a guide for Engineers and Architects designing drainage facilities for private developments within the City of Phoenix. Design criteria and procedures contained in the manual may be used when determining drainage flows that affect a given development and, computed properly, will be accepted by the City of Phoenix. However, this manual and the design criteria contained is to be used only when more comprehensive drainage studies have been performed by Federal Agencies, contractors for the Government Agencies or under contract to the City of Phoenix, private development Engineers are to use such data as a design base. When conflict arises between runoff values obtained by the aforementioned design and flow values established by comprehensive drainage studies, the values obtained from the comprehensive studies shall prevail. The Development Services Director may permit such exceptions in the guidelines as may be required to fit special conditions.

I. STREET DESIGN

a) Drainage shall not be concentrated in any street beyond the point of which the street will run full to the top of sidewalk, for the runoff from a 10-year storm. *The maximum drainage that may be carried in a street is limited to 100 cubic feet per second (cfs), for the 100-year storm. Open channels, underground facilities, or additional detention must be provided to accommodate the excess.* The maximum velocity allowed in a public street is 12 fps.

b) Where a drainage dead-end occurs and runoff leaves the public right-of-way and intrudes on private property, *adequate channels or underground facilities will be required to daylight this drainage back to public R.O.W or drainage easements.*

c) The minimum sized easement for right-of-way to be provided for drainage is 10 feet, easements shall be permitted for underground drainage only. Open channels shall be upon *dedicated right-of-way*, unless an approved Homeowner's Association exists which accepts the responsibility for channel maintenance.

=> is there a min. ELEV?

d) Finished floor elevations for houses or other buildings shall be elevated to a level above the runoff expected from a 100-year storm.

e) Minimum finished floor elevations shall be 14-inches above the top of low curb, and a minimum of 6-inches above the top of high curb. There should be adequate openings in the fence for drainage when lot outfall is to the rear of the lot; *however, a drainage easement to right-of-way shall be provided in cases where there is lot to lot drainage.* Townhouse and condominium developments shall provide a piped drainage system and provide for maintenance of this system by the Homeowner's Association for yard to yard drainage.

f) Culverts or bridges shall be provided for street and alley crossings of natural drainageways, with the culverts sized for a 50-year storm. The culvert and a dip section together capable of carrying a 100-year storm to a maximum depth of 6-inches, with a maximum velocity in the dip section of 5 fps, providing adjacent property is not adversely affected.

g) Where new storm drain facilities for the transmission of runoff are not constructed drainage coming onto a new development from adjacent land must enter and leave the property being developed in essentially the same manner in which it previously drained.

h) Inverted crown streets are not permitted, unless constructed entirely of P.C. concrete.

II. NATURAL WASHES

a) When runoff from a 10-year storm in a wash terminating in a street exceeds the capacity of the street to the top of sidewalk, or the 100-year storm runoff exceeds 100 cfs additional drainage facilities to transmit the runoff through the development shall be provided. If a wash is to terminate in a street calculations shall be required indicating the water can be turned to stay within the street section.

b) When natural washes are to be retained as open drainageways, the channel shall be sufficient to contain the runoff expected from a 50-year storm with free board for additional 20% capacity, in no case will the depth of the channel be less than one-foot if the maximum flow velocities exceed 8 ft./sec.

c) No parking will be allowed within washes or selected floodways.

III. OPEN CHANNELS

1. Open channels shall be on dedicated right-of-way rather than easements, unless a Homeowner's Association accepts maintenance responsibility.

2. Open channels with filled sides or where natural channel alignment is altered shall be lined where design velocity exceeds 5 feet per second. A report from a Soils Engineer is required if deviation from this criteria is desired.

Items 3-18 apply to channels where the 100-year runoff is greater than 2,000 cfs.

3. Tractive force analysis preferred, however limiting velocity concept will be accepted.

4. Maximum superlevation in curve sections shall not exceed one-foot as calculated by the following:

$$S = \frac{v^2(b \quad 2zd)}{2\,(2gr - 2zr^2)}$$

5. Unlined trapezoidal channels should be avoided on curves with supercritical flows. In no case will less than one foot of freeboard above the 50-year design flow be allowed. In subcritical:

   F = 0.02d (trapezoidal sections) d = depth of flow

   F = 0.1d (rectangular sections)

   in supercritical:

   F + dc c = 1.5

6. No supercritical junctions will be permitted without sufficient design documentation. This could include a physical mode! study.

7. The channel design should avoid the area of hydraulic instability between 0.75 Critical Slope and 1.25 Critical Slope.

8. In transition areas: Max Convergence 28^{c}

   Max Divergence 25^{0}

9. The location and size of hydraulic jumps must be determined for the range of flows from channels' capacity to 10% (0.1) of channel capacity.

10. Water surface profiles may be computed by either the standard or direct step method. Either hand calculation or computer method may be submitted. In the event that computer methods are used, documentation will be required unless a standard program such as HEC 2 or WSP II are used.

11. The momentum method of analysis is recommended for pier losses.

12. All friction, expansion, contraction, eddy and other losses will be estimated or considered.

13. If the velocity head changes more than 15 percent between cross sections an intermediate section will be required to reduce computation errors.

14. All design water surfaces will be at or below natural ground. Freeboard requirements may be satisfied within fill sections.

15. In no case will levees be permitted that will obstruct side drainage to the channels.

16. Generally, for design flows in excess of 2,000 cfs unreinforced rigid channel linings such as grouted rip rap and gunite will not be accepted. All rigid linings shall contain adequate reinforcing to prevent sudden failure.

17. All channel plans submitted must contain a plan and profile as well as adequate cross sections. The plan review should show the horizontal alignment and dimensions as well as the type and extent of the proposed work. The profile should show the proposed invert, the calculated water surface profile, original ground at channel centerline, top of slope if necessary and top of proposed embankment and fill. Cross sections should be provided as necessary to describe the situation.

18. Access and channel crossings must be provided during flood events. In no case will the 100-year event be allowed to overtop a roadway by more than six inches or exceed five feet per second.

19. All channelization within designated floodplains must be designed so that the cumulative effect of all new development does not raise the 100-year water surface more than one-foot.

IV. HYDRAULICS

a) Hydraulic calculations for culvert capacity shall be in accordance with the latest addition of the Bureau of Public Roads Hydraulic Engineering Circulars 5, 10 and 13. These may be obtained from the U.S. Government Printing Office, Washington D.C. Proper consideration should be given to the wash downstream from the culvert. *Where culvert exit velocity exceeds 5 feet per second grouted rip rap or some means of soil stabilization shall be provided.*

b) All open channel and pipe capacities, other than culverts, shall be determined using Mannings formula. A graph is provided on Page 31, for convenience and sizing storm sewers.

c) Manning "n"
The following "n" values shall be utilized:
.012 precast concrete pipe
.012 cast in place concrete pipe
.012 asbestos cement pipe
.012 corrugated metal pipe full lined
As per Standard Detail 510 for unlined and paved invert corrugated metal pipe.
See Table 29 for "n" for open channels.

V. UNDERGROUND DRAINAGE

a) *Underground facilities shall be sized in accordance with current practices of the Storm Drain Design Group for the City of Phoenix Engineering Department.*

b) Systems outfalling in open channels, etc., will be sized so that pipe plus street capacity to top of curb is not less than the expected runoff from the 100-year storm.

c) In cases where the City may be responsible for maintenance of an underground system manholes shall be spaced as follows:
For pipe diameters of 30-inches or less every 330 feet.
For pipe diameters of 33-inches to 45-inches every 440 feet.
For pipe diameters of 48-inches and greater every 660 feet.

d) Inlets shall be City of Phoenix Standards and Capacities shall be computed using the graphs on Pages 34, 35 and 36.

e) Minimum connector pipe diameter shall be determined using procedures as outlined in City of Phoenix Storm Drain Design Manual, Storm Drains with Paving of Major Streets.

f) The minimum pipe size for underground storm drainage is 15-inches, if the City is to maintain the system.

g) Minimum desired velocity for pipe flow full shall be 5 feet per second. When this velocity in a pipe is limited to 20 fps.

VI. RETENTION FACILITIES

a) ALL DEVELOPMENTS, SHALL MAKE PROVISIONS TO RETAIN THE RUNOFF FROM A 100 YEAR, TWO-HOUR DURATION STORM FALLING WITHIN THE BOUNDARIES OF THE DEVELOPMENT, unless the drainage can be directly carried to a major channel or natural drainageway whose capacity is adequate from the development to a major drainage outfall such as the Salt River. This requirement may be waived by the Development Services Director for isolated developments under 1/2 acre in area when there will be no critical drainage problem created by the additional runoff from the proposed development.

In situations where the outfall is inadequate, the retention facility capacity shall be increased as necessary to reduce the frequency of ponding in streets.

b) Single lot commercial and industrial developments, and large residential lots where on-lot retention is permitted may compute the required storage volume using the rational formula in the manner shown on Page 37.

c) Multi-lot Developments.

1. Industrial subdivisions may provide either common or on-lot retention facilities.

2. Multi-family developments, such as townhomes and condominimums, are required to provide common retention facilities.

3. Multi-lot residential subdivisions and average-lot subdivisions in districts zoned R-2, R-3, R-3A, R-4, R-5, and R1-6 shall provide common retention areas. Other multi-lot residential subdivisions where the coverage by impervious material is less than 45% may provide on-lot retention.

   Development zoned as "Planned Community Development" (PCD) shall provide common retention areas serving multiple parcels, whenever possible.

   When a multi-lot residential development is required to provide a common retention area, the facility shall be located in a central location situated to intercept at least 50% of the runoff from the entire development. The facility shall be designed to be accessible primarily to residents of the development. The remaining lots, whose runoff is not intercepted by the common retention area, shall be provided with on-lot retention. A homeowner's association shall be formed to maintain the common retention area. A landscaping plan must be approved for the retention area prior to the issuance of a grading permit.

4. In cases where City Master Plans designate potential public spaces or proposed amenities suitable for joint-use retention, such as common open space, scenic corridors, parks, etc., and the City agrees to maintain a joint facility, the developer may provide a common facility. The facility shall be designated to Park Department's standards and shall be dedicated to the City.

5. In in-fill areas of the City, where storm drainage has been installed in an adjacent street, and the parcel to be developed is not larger than 5 acres, retention facilities shall be sized for the runoff from a 10-year, 2-hour storm.

d) Where possible, the required storage volume should be supplied in shallow ponding areas such as dished or bermed yards and/or open areas, the areas shall have a maximum depth of 3 feet. Deeper areas shall require approval of the City Engineer. These areas must be shown to be drained within 36 hours by either infiltration, controlled bleed off, dry-well or discharge pump. The required retention volume shall be provided on private property and not intrude upon the right-of-way. Maximum depth of retention within 10 feet of the right-of-way shall be 18 inches. Retention should not begin closer than 2 feet from back of sidewalk. If there is no sidewalk, retention should be held 6 feet from back of curb. Side slopes adjacent to the street are to be 4 horizontal to 1 vertical maximum.

Other side slopes shall be a maximum of 4:1 unless approval is received for a steeper slope.

e) Berms are not to be placed closer than 13 feet from the back of the curb, or 8 feet from the back of the sidewalk. Berms are not to be higher than 2-1/2 feet above the top of sidewalk or curb.

f) All developments shall be designed to drain to the adjacent streets once the on-site retention facilities are filled. In the event this criteria cannot be met, the designer shall adjust his finished grades to allow runoff to pond within one inch of the proposed finished floor elevation before outfalling from the site. Should drywells be proposed for this type of development, the theoretical capacity of the drywells shall be reduced by a factor of 50% to allow for silting and grate obstruction.

g) Retention requirements may be waived in cases where the average slope of the property exceeds 5%.

VII. DISCHARGE PUMP DESIGN

a) An electrically operated discharge pump is required if no gravity outfall is available for the detention facility.

b) Pump capacity shall be sufficient to empty the facility within 36 hours and shall have a maximum output of 1-cfs, unless otherwise permitted by the Salt River Project or other body controlling an acceptance of discharge.

c) Provide a 6-foot wide minimum paved apron around the inlet opening.

d) Provide automatic switch control with vertical float controlled mechanism and installed to the manufacturers recommendations.

e) Pump must be accessible with the lagoon full.

f) Screen pump inlet with 3/4 inch mesh for both vertical and horizontal faces.

VIII. HYDROLOGY

a) For urbanized tributary areas up to 1/10 square mile. Runoff shall be computed using the rational formula Q CIA. "C" values to be per the table on Page 26, and "I" from the graph on Page 26.

b) For tributary areas over 1/10 square miles the Soils Conservation Service methods as outlined on Pages 8-12, or a computer program TR-20 utilizing the SCS method shall be used for runoff termination. Curve Numbers (CN) as specified on Page 15 shall be used for either method.

c) Runoff calculations for the sizing of laterals and inlets shall be based on the rational formula.

d) Time of concentration for determining runoff based on the SCS method and TR-20 program shall be computed using the method outlined on Pages 21-23.

IX. REQUIRED SUBMITTALS

a) All grading and drainage submittals shall be accomplished by transmittal letter. This need not be a formal typed letter. A form letter with the project name, folder name, engineers name, materials submitted and purpose of the submittal, i.e., preliminary review, review of calculations, etc., will suffice. Additionally, *the Engineering Department Folder Number shall be placed in the lower right-hand corner of the plans and the plans shall be sealed by an Engineer Registered in the State of Arizona.*

b) Approved hydrology reports and grading and drainage plans must precede recordation of instruments of dedication when such material is necessary to determine required rights-of-way or facilities for drainage or finished floor elevations. Grading and Drainage plans cannot be approved until off-site grades have been received and tentatively approved. A permit for off-site construction cannot be issued prior to the grading and drainage permit. An offsite hydrology report is required on all projects unless specifically waived by the City Engineer.

c) Hydrology reports shall include but not be limited to the following items:

1. A drainage map that shows the Q's at points of concentration and clearly identifies the existing drainage system. Minimum scale will be 1-inch equals 600 feet. Where drainage areas are large or otherwise inappropriate other scales may be approved by the City Engineer.
2. A complete runoff analysis in tabulation from the storm drain computation sheets if underground facilities are required.
3. Calculations for the required supplied retention facilities. If more than one facility is proposed, calcs must be separated for each area, and each tributory area referenced to its respective detention facility.
4. Adjacent contributary drainage area if adjacent land drains into or is diverted around the development. Show data on the size of the adjacent drainage area and slope of the land. For any proposed drainage system show design flow and capacity calculations.
5. A lined drawing of the proposed drainage system.
6. Sufficient downstream information to determine the path of the water onto adjacent property, and the capacity of the outfall.
7. Average slope and typical cross sections of streets draining into arterials.
8. All drainage outfalls shall be shown on plan and profile on the improvement plans until a definite day light condition is established. When improvements have more than one unit the drainage outfall shall be shown as extending to the property boundary, and beyond if required, although it may not be constructed with the current unit developments. All temporary outfalls shall be shown both on plan and profile on the improvement plans
9. *Calculations as to the estimated cubic yardage of cut and fill must be submitted along with grading and drainage plans.*

d) Final grading and drainage plans shall include, but not be limited to the following:

1. Sufficient information to determine the outfall for each family unit.
2. Sufficient information to determine drainage patterns.
3. Sufficient information to determine that an adjacent property drainage pattern will not be adversely effected.
4. When the grading and drainage plans do not show detail for all drainage facilities copies of the off-site plans showing these details shall be submitted with the grading and drainage material.
5. All submittals must be logged in with the *Plans Review Information Center* and shall be accompanied by a letter of transmittal. This may be a form letter and should be to the attention of grading and drainage group supervisor. The project name, Engineer's name, material submitted and purpose of submittal (i.e., preliminary review, review of calculations, revision approval, etc.) shall be given on the letter. Refer to Building Log No. in transmittal. Grading and drainage plan check fees are authorized by Ordinance G-2225. For logged in plans, grading and drainage permit is prerequisite to issuing building permits. Project vicinity map must be shown on the cover sheet.

   The cover sheet of grading and drainage plan shall include the owner's name, address and telephone number. Also, provide address and/or legal description of project location. Standard notes on grading and drainage plans:

   (a) "A grading permit is required under Chapter 32A of the Phoenix City Code."

   (b) "Haul permits, when required, must be obtained prior to or concurrently with the grading and drainage permit.

(c) "Excavating Contractor must give location for wasting excess excavation and a letter from owner giving permission for dumping prior to starting onsite construction. If excess excavation exceeds 100 cubic yards, the dumping site will also require a grading and drainage permit."

(d) "City Engineer's office shall be notified before any onsite construction begins, telephone (602) 262-4960."

(e) Designate on the cover sheet which will be certified, finish floors or building pads. Certification of finish floor elevation is mandatory if structure is located in a floodplain. Add to the standard notes whichever of the following notes that applies:

"Staking pad elevations is the responsibility of the Owner and his Engineer. The Owner's Engineer shall submit two sealed copies of this Grading & Drainage plan designated as "Record Drawing" (each bearing an original signature) or two copies of a certification of constructed building pad elevations prior to the request for final inspection."

OR

"Staking finish floor elevations is the responsibility of the Owner and his Engineer. The Owner's Engineer shall submit two sealed copies of this Grading & Drainage plan designated as "Record Drawing" (each bearing an original signature) or two copies of a certification of constructed building pad elevations prior to the request for final inspection."

In addition, give name, address and telephone number of the Engineer responsible for providing certification.

(f) "A separate permit is necessary for any offsite construction."

(g) "An approved grading and drainage plan shall be on the job site at all times. Deviations from the plan must be preceded by an approved plan revision."

(h) "Drywells, when required, must be drilled a minimum of 5 feet into permeable porous strata or percolation tests will be required. The grading and drainage inspector must be present before backfill or wall pipes are placed within any drywells."

(i) "Grading and drainage plan approval includes the construction of all surface improvements shown on the approved grading and drainage plan, including, but not limited to, retention areas and/or other drainage facilities, drainage patterns, walls, curbs, asphalt pavement, and building floor elevations."

(j) "Contractor shall provide level bottom in all retention basins at elevations as shown on the plans. Retention basins side slopes shall not exceed 2:1 on private property unless noted otherwise on the plans."

(k) "Contractor is responsible for locating and confirming depths of all the existing utility lines within proposed retention basin areas. If the basin cannot be constructed as per plan because of conflict with underground utilities the contractor should request modification of basin configuration by submittal of a proposed plan revision."

(l) "All drainage protective devices such as swales, interceptor ditches, pipes, protective berms, concrete channels or other measures designed to protect buildings or property from storm runoff must be completed prior to any structure being built."

(m) "Soils compaction test results must be submitted to the City Engineer's office for building pads that have one (1) foot or more of fill material indicated. This information must be supplied prior to request for final inspection."

(n) "The design engineer shall indicate all known existing underground utilities within proposed retention areas. The basin should be designed to maintain a minimum 15" of cover over utility lines."

(o) Clearance for occupation of any building is denied until grading and drainage irr· ovements are completed.

(p) "The owner/developer shall be responsible for registering the drywells shown on plan with the Arizona Department of Health Services. For information about specific requirements, contact the Water Department Permits Unit at (602) 257-2270."

7. Net acreage on site.

8. Bar scale under north arrow on each street.

9. Elevation datum and bench marks (City datum required).

10. Engineer's Seal.

11. 100 year on-site retention (refer to City of Phoenix Storm Drain Manual for details).

12. Finish floor elevations safe from 100-year storm or per minimums specified in manual, whichever is greater.

13. Show existing contours or spot elevations and drainage arrows to indicate drainage pattern.

14. Top of curb and crown elevations on streets at lot lines and back of lot elevations.

15. Sheets to be 24" x 36".

16. Details at property lines, fences, berms, etc.

17. Off-site plans with drainage facilities should be submitted with grading and drainage material unless those details are shown on grading plan.

18. Proper consideration must be given to protection of underground parking and basements.

19. Finished floor elevations on grading and drainage plans cannot be approved until street grades are established. Therefore, paving plans should be submitted for review at approximately the same time as are grading plans.

20. Letter size is to be a minimum of 1/8" with a maximum pen size of #1.

21. Pencil drawings done on mylar are to be done with pencils, Turquoise Eagle Filmograph Pencil (E1, E2 or E3) or equal, in order to obtain a drawing dark enough to be microfilmed.

22. Indicate the name of the engineer, architect, or surveyor responsible for certification of finished floor or pad elevations. Also, give the mailing address and telephone number for the same.

e) Cases where site grading or building excavation extends more than 10 feet below the established curb level nearest the point of excavation (or ground level if no curb exists or is proposed) may require additional considerations concerning slope stability and/or protection of existing improvements. In such cases the Development Services Director may require additional plans and specifications prior to grading and drainage plan approval. Such cases would include (but are not necessarily limited to) developments with deep excavations, excavations adjacent to City right-of-way, excavations utilizing steep side slopes, grading in unstable material, groundwater problems, or any other unusual situation. Required submittals may include additional soils testing, special grading plans and details, shoring plans and diagrams, slope easements, and other additional information as deemed necessary to insure the safety, support and protection of adjacent facilities.

SOIL CONSERVATION METHOD

The method developed by the Soil Conservation Service for estimating runoff from drainage areas is based on recorded data and drainage basin characteristics such as area, shape, slope, vegetation type, percent of vegetative cover and the infiltration capacity of the basin soil.

Although none of the basic concepts of the Soil Conservation Service Method have been changed some of the procedures and data have been revised and updated in this report. Primarily, the climatological data used in the original Soil Conservation Service publication has been updated in this report by the use of more recent U.S. Weather Bureau Precipitation Maps.

The procedures developed by the Soil Conservation Service apply both to small drainage areas, i.e., areas of less than 10 square miles and with some modification, to drainage areas larger than 10 square miles.

Although the basic parameters for hydrologic design for both small and large drainage areas are identical, the design procedures and application of the various parameters are somewhat different. The design procedures as outlined will apply to drainage areas less than 10 square miles.

Design Data
General design data required for the application of the Soil Conservation Service procedure to a drainage area are: rainfall expected from a storm of specified duration and selected design frequency, size of the drainage area in percent, hydrologic soil cover complex number a/, and time of concentration in hours.

Design Frequency
The definition and the selection of the proper design frequency has been discussed previously.

Rainfall
Rainfall amounts can be determined by using the chart on Page 16 and multiplying by time in hours.

Drainage Area
This is the size of the area in square miles that contributes direct runoff to the point of design. Drainage areas should be obtained from City of Phoenix Contour Maps, air photos, or field surveys.

In some special cases a portion of the drainage area may contain permeable soils with high infiltration rates or area with sufficient storage from natural depressions, ponds, reservoirs, etc., that essentially no runoff occurs. These areas should be considered noncontributing and excluded from the drainage area total.

Hydrologic Soil-Cover Complex
A determination of vegetative cover types, hydrologic condition of cover types and hydrologic soil group must be made for the drainage area. Ordinarily only broad categories of soils and cover types are delineated.

a/Hydrologic Soil Cover Complex - a combination of a hydrologic soil group and a type of vegetative cover.

b/Hydrologic Condition - condition of vegetative cover of a drainage area which reflects its ability to retard runoff.

c/Hydrologic Soil Group - a group of soils having the same runoff potential under similar storm and cover conditions.

These curve numbers are used to determine the volume of direct runoff (Q) from the design rainfall. As indicated on Page 20 curve numbers and consequently direct runoff varies with vegetation type, vegetative cover density and hydrologic soil group.

Hydrologic Cover Types
Vegetative types that basically affect the runoff process are divided into the following groups.

Desert Brush: includes such plants as mesquite, creosote bush, black bush, catclaw, cactus, etc. — desert brush is typical of lower elevations and low annual rainfall.

Herbaceous: includes short desert grasses with some brush, herbaceous is typical of intermediate elevations and higher annual rainfall than desert areas.

Mountain Brush: mountain brush mixtures of oak, aspen, mountain mahogany, manzanita, bitter brush, maple, etc., — mountain brush is typical of intermediate elevations and generally higher annual rainfall than herbaceous areas.

Juniper-Grass: juniper areas mixed with varying grass cover that is generally heavier than desert grasses due to higher annual precipitation — typical of higher elevations.

Ponderosa Pine: ponderosa pine forests typical of high elevations and high annual precipitation — found along the Mogollon Rim, the Kaibab Plateau, the White Mountains, etc.

If one-half or more of the drainage area has a given vegetation type consider all the drainage area as having that vegetative type. If the vegetative type appears about equally divided among all types of hydrologic cover, consider it all as herbaceous as this results in average values.

Hydrologic Cover Density
Hydrologic cover density is defined as the percent of the ground surfaces covered by the crown canopy of live plants and litter.

The Soil Conservation Service determines vegetation cover density by field surveys of carefully selected locations within the drainage area. However, for highway drainage design where runoff from numerous small drainage areas is to be determined, an approximation of the vegetative cover based on visual observation will be adequate.

Three broad ranges of vegetative cover density have been established.

Poor 0 - 20% Vegetative cover
Fair 20% - 40% Vegetative cover
Good 40% Vegetative cover

Urban Areas
For urban areas and areas expected to urbanize use existing zoning and the curve number from the table on Page 15.

Hydrologic Soil
Groups Surface soils which materially affect the rate of runoff have been classified into four major groups according to the infiltration rate of each soil. The distribution of these soils in Phoenix is shown in Page 18. These soils are defined as follows:

Group A: (Low runoff potential) Soils having high infiltration rates even when thoroughly wetted and consisting chiefly of deep, well to excessively well drained sands or gravels. These soils have a high rate of water transmission. Although Group A soils are found in Arizona they should not be used for design, rather Soil Group B should be substituted from them.

Group B: Soils having moderate infiltration rates when thoroughly wetted, consisting chiefly of moderately deep to deep, moderately well to well drained soils with moderately fine to moderately coarse textures. These soils have a moderate rate of water transmission.

Group C: Soils having slow infiltration rates when thoroughly wetted, consisting chiefly of soils with a layer that impedes the downward movement of water, or soils with moderately fine to fine texture and a slow infiltration rate. These soils have a slow rate of transmission.

Group D: (High runoff potential) Soils having very slow infiltration rates when thoroughly wetted, consisting chiefly of clay soils with a high swelling potential; soils with claypan of clay layer at or near the surface; and shallow soils over nearly impervious materials. These soils have a very slow rate of water transmission.

Rainfall — Runoff Equation
The rainfall-runoff equation developed by the Soil Conservation Service represents a relationship between accumulated rainfall and accumulated runoff based on data from experimental watersheds and empirical relationships.

This rainfall-runoff equation is shown graphically on Page 19 where the direct runoff (Q) is a function of the storm rainfall and a curve number (CN) which is based on a vegetative cover type and density and a hydrologic soil group.

Time of Concentration
The time of concentration (Tc) is defined as the time required for water to travel from the most distant point in the drainage area to the point of design. The time of concentration for a given drainage area may be found by measuring its hydraulic length usually the longest stream course and estimating the average velocity of travel along its main channel. Average velocity is usually computed by a flow equation such as Manning's from cross sections of the channel taken at representative locations. More commonly however, the time of concentration for highway drainage studies may be determined from charts and monographs that relate drainage area size, shape and slope to the time of concentration. Time of concentration for urban areas will be determined using the method on Page 23.

Hydrologic design procedure for drainage areas less than 10 square miles
Rainfall: Storm Duration For drainage areas less than 10 square miles the peak rate of runoff will occur from a standard storm of 1-hour duration. The rainfall for this 1-hour storm duration will be determined as outlined previously.

Drainage Area
In addition to the size of the contributing drainage area, the drainage area length, width and slope will be required.

Drainage Area Length:
The distance from the highway crossing to the most remote point of the drainage area measured along the flow path of the water.

Drainage Area Width:
The average width of the drainage area may be obtained by dividing the area expressed in square feet by the length in feet.

Drainage Area Slope: The average slope of the drainage area in percent. This value can be taken as the drop in feet from the highest elevation to the lowest elevation in the drainage area divided by the drainage area length in hundreds of feet. (If a sub-area equal to or greater than one-half the total drainage area in the primary source of runoff and if its slope differs materially from the average drainage area slope, the slope of this sub-area should be determined rather than the average slope of the entire drainage area.)

Time of Concentration
For drainage areas less than 10 square miles the time of concentration (Tc) is a function of drainage area size and average slope and should be determined from Page 21.

For urban areas, or areas expected to urbanize use the method on Page 23 to compute Tp.

Hydrologic Soil-Cover Complex
The hydrologic soil-complex and associated curve number (CN) should be determined as outlined previously.

Discharge Equation
The solution for the peak runoff (Op) for the selected design frequency, the 1-hour storm rainfall and the drainage area characteristics is determined by the following equation:

$$Qp = \frac{484AQ}{TP}$$

where:

Qp peak rate of discharge in cfs
A contributing drainage area in square miles
Q storm runoff in inches
Tp time of peak in hours where
Tp (Tc) (Width factor)
The value of 484 is a constant for the units used.

Design Procedure

1) From City of Phoenix criteria select the recommended design frequency.
2) Determine the drainage area characteristics of size, length and slope.
3) Determine drainage area width and the width factor (WF) from the table on Page 21.
4) Determine vegetative cover type and vegetative cover density from either field study or aerial photos.
5) For the project location, obtain hydrologic soil group from the generalized soils map, Page 18. When an area is composed of more than one soils group use the soils group with the lowest infiltration rate.
6) Precipitation: Use the 1-hour precipitation from Page 16.
7) With hydrologic soil group, a particular vegetative type, and a certain density of vegetative cover, obtain a curve number (CN) for the drainage area from Page 20.
8) Determine the volume of runoff (Q) using the 1-hour point rainfall from Step 6-b, and the curve number (CN) obtained in Step 7.
9) With the drainage area and the slope, obtain time of concentration (Tc) from Page 21.
10) Compute the time of peak (Tp) by multiplying the time of concentration (Tc) by the width factor (Wf). Tp(Tc)(Wf)
11) Compute peak discharge Qp in cfs by equation:

$$Qp = \frac{484AQ}{TP}$$

REQUIRED SUBMITTALS
FOR COMPUTER GENERATED DRAINAGE ANALYSIS PROCEDURE

1. Prepare a map of the drainage area (approximate 1" 600').
2. Divide the study area into sub areas. Select sub areas such that the maximum area does not exceed 0.5 square miles and also such that the time of concentration is greater than 10 minutes. Of course, the topography of the study area will be important in sub area selection.
3. On the map, indicate the flow pattern within each individual sub area to the concentration point.
4. Show how the flow is routed from one point of concentration to another.
5. For each sub area provide the following:
   a) The zoning. Use the City of Phoenix zoning maps. If more than one zoning class is found with a sub area, list all and establish a weighted average based on the area of each class. If the slope of the ground exceeds 10%, designate the sub area as mountainous and, regardless of the zoning, assign a curve number of 98.
   b) The hydrologic soil type or types. The different hydrologic soil types found in the City of Phoenix are contained in a publication entitle "Soil Survey of Maricopa County, Arizona, Central Part" by the U.S. Department of Agriculture, Soil Conservation Service. If any sub area contains more than one soil type, each soil type must be used separately to assign a curve number. The various curve numbers can then be used to obtain a weighted average curve number based on areas.
   c) The contributing area in square miles.
      1) If any part of a sub area is bermed or has any features that prevent contribution, exclude such part.
      2) If a sub area is zoned commercial or industrial and is already developed without retention, use 100% of the area as contributing. If there is retention, exclude the area for which the retention is effective.
      3) If a sub area is zoned commercial or industrial and is not yet developed, use 40% of the area as contributing with a curve number from the table on Page 15.
   d) The equivalent curve number, CN.
   e) The time of concentration, tc. Analyze the terrain and the development called for the zoning when computing the velocities of flow for each reach of the system.
      1) For surface flows use ground slopes and either gutter flow charts or the "upland method" to compute time of concentration, up to street capacity.
      2) For flows that exceed street capacity. Use Chart Page 22.
      3) For the first computer run, assume velocity in pipes to be 5 fps; then later perform the first iteration using calculated pipe velocities.
6. Use the rainfall table in the input to the program.
7. Depending on the service to be provided, use the 24-hour precipitation values in the executive command part of input to the program.
8. Request that the printout include Summary Tables 1, 2, and 3.
9. Show the following calculations:
   a) In tabular form, the time of concentration for each sub area (show hydraulic distance and the velocity used).
   b) In tabular form, the determination of the equivalent curve number for each sub area (show hydrologic soil type, zoning, and weighted averaging).

10. Add to the drainage area map the computer node numbers so easy identification can be made between locations and the expected flows as computed and printed out.

HYDROLOGIC DESIGN DATA SHEET

S C S METHOD: PART 1 (less than 10 sq. mi.)

LOCATION DATA: City ____________

Subdivision County ________________________ County ____________

Location ____

Name of Wash ____

DESIGN DATA:

Design Frequency ____________ years

Drainage Area ____________ square miles

Drainage Length ____________ feet

Elevation

Top of Drainage Area ____________ feet)

____________ feet Fall

At Structure ____________ feet)

Drainage Area Slope ____________ %

Drainage Width feet Source
Width factor Wf ____________

Vegetative Cover Type ____________

Vegetative Cover Density ____________ %

Soil Group ____________

DESIGN COMPUTATION:

Precipitation P = 1 hour = ____________ inches Fig.

Curve Number ____________ Fig.

Runoff Q = ____________ inches Fig.

Time of Concentration To ____________ hours Fig.

Time of Peak Tp = (TC)(Wf) ____________ hours

Peak Discharge Qp = $\frac{484AQ}{TP}$ = ____________

= ____________ cfs

Computed by ________________________ Date ____________

CURVE NUMBERS BY ZONING
FOR USE WITH SCS OR TR-20 METHODS OF DETERMINING RUNOFF IN THE CITY OF PHOENIX

ZONING	TYPE B	TYPE C	TYPE D
RE-43) S-1)	77	83	86
RE-35	79	84	87
RE-25	79	84	87
E1-18	80	84	87
R1-14	80	85	88
R1-10	81	85	89
R1-8	82	87	90
R1-6	84	88	90
R-3	85	88	90
R-4) R-40) R-5)	86	89	91
A-1)	85	91	93
A-2)			
C-1) C-2) C-3)	92	94	95
CO	88	91	93
PSC	95	95	95
HR	95	95	95
R4A	87	90	92
Hillside (over 10% sloping).	98	98	98

Rainfall Table

(Percent total rainfall/100 by 0.5 hour increments for 24 hour storm)

.000	.004	.008	.013	.018
.022	.026	.031	.035	.040
.044	.048	.053	.057	.062
.066	.071	.075	.080	.093
.107	.120	.14	.17	.50
.83	.86	.88	.893	.907
.92	.924	.928	.933	.937
.942	.947	.951	.956	.96
.964	.969	.973	.978	.982
.987	.991	.995	1.00	1.00

PHOENIX WBO RECORDS*

(24-hour duration storm)

Return Periods, Years	Precipitation, Inches
1	1.02
2	1.44
5	2.10
10	2.53
25	3.12
50	3.57
100	4.04

*Technical Memorandum WBTM WR-44

ESTIMATED RETURN PERIODS FOR SHORT-DURATION PRECIPITATION IN ARIZONA
(Inches)

Station: Phoenix WBC
Latitude: 33° 26'
Longitude: 112° 01'
Elevation (feet): 117

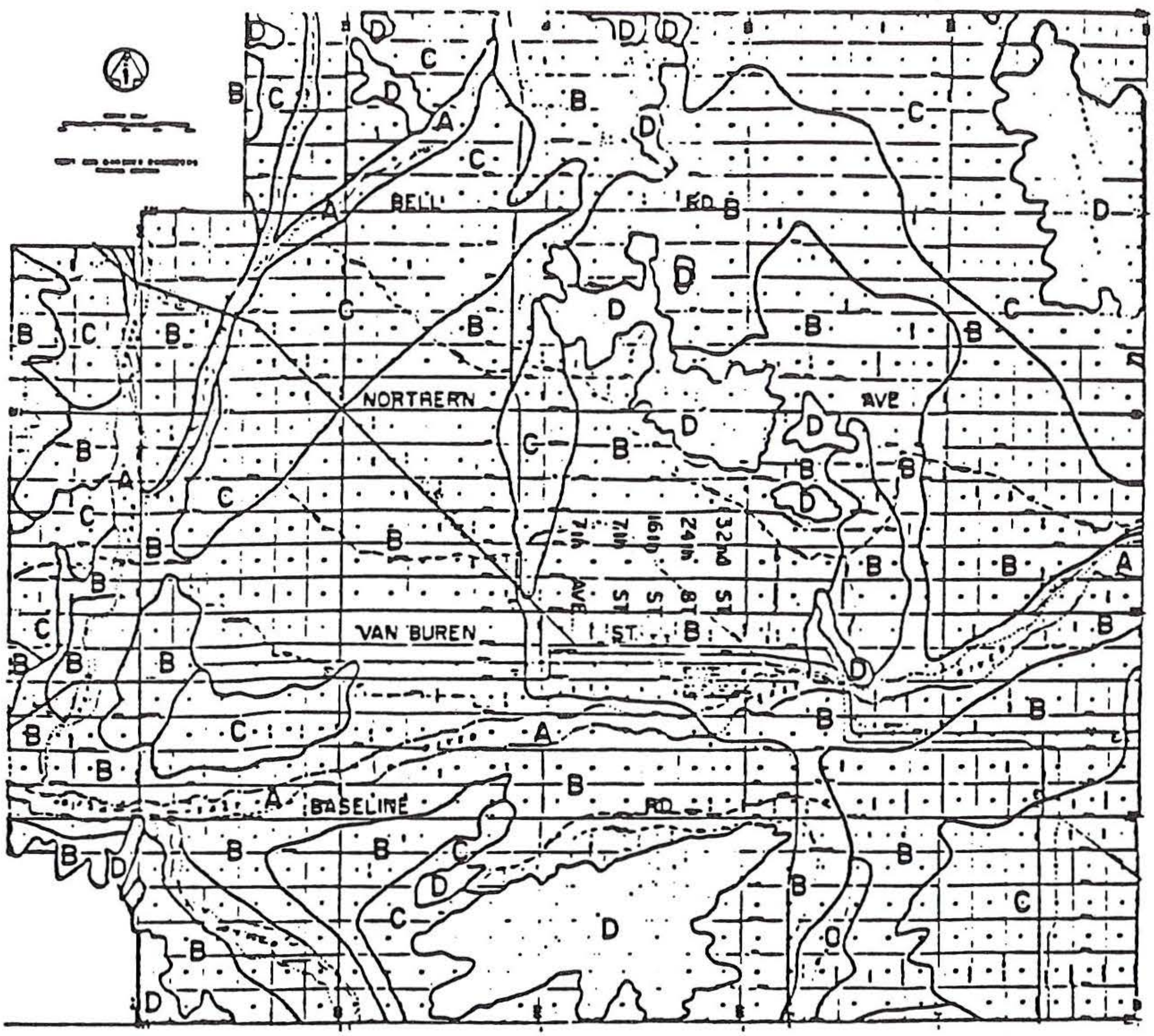
RETURN PERIOD (YEARS)

		1	2	5	10	25	50	100
	5 min.	0.17	0.26	0.38	0.47	0.59	0.66	0.77
D	10 min.	0.27	0.40	0.59	0.72	0.81	1.06	1.20
U	15 min.	0.34	0.50	0.74	0.92	1.15	1.34	1.52
R	30 min.	0.47	0.70	1.3	1.27	1.60	1.86	2.10
A	1 hr.	0.80	0.88	1.30	1.61	2.02	2.35	2.66
T	2 hr.	0.65	0.94	1.39	1.72	2.15	2.49	2.82
I	3 hr.	0.68	1.01	1.48	1.82	2.27	2.62	2.97
O	6 hr.	0.81	1.16	1.70	2.07	2.57	2.96	3.35
N	12 hr.	0.91	1.30	1.90	2.30	2.84	3.25	3.69
S	24 hr.	1.02	1.44	2.10	2.53	3.12	3.57	4.04

SOIL TYPES

FROM "GENERAL SOIL MAP OF MARICOPA COUNTY"
U S Department of Agriculture, Soil Conservation Service
Phoenix, Arizona - 1969

PLATE A



GROUP A — 2" per hour & over
Undifferentiated sandy alluvial soils subject to overflow.

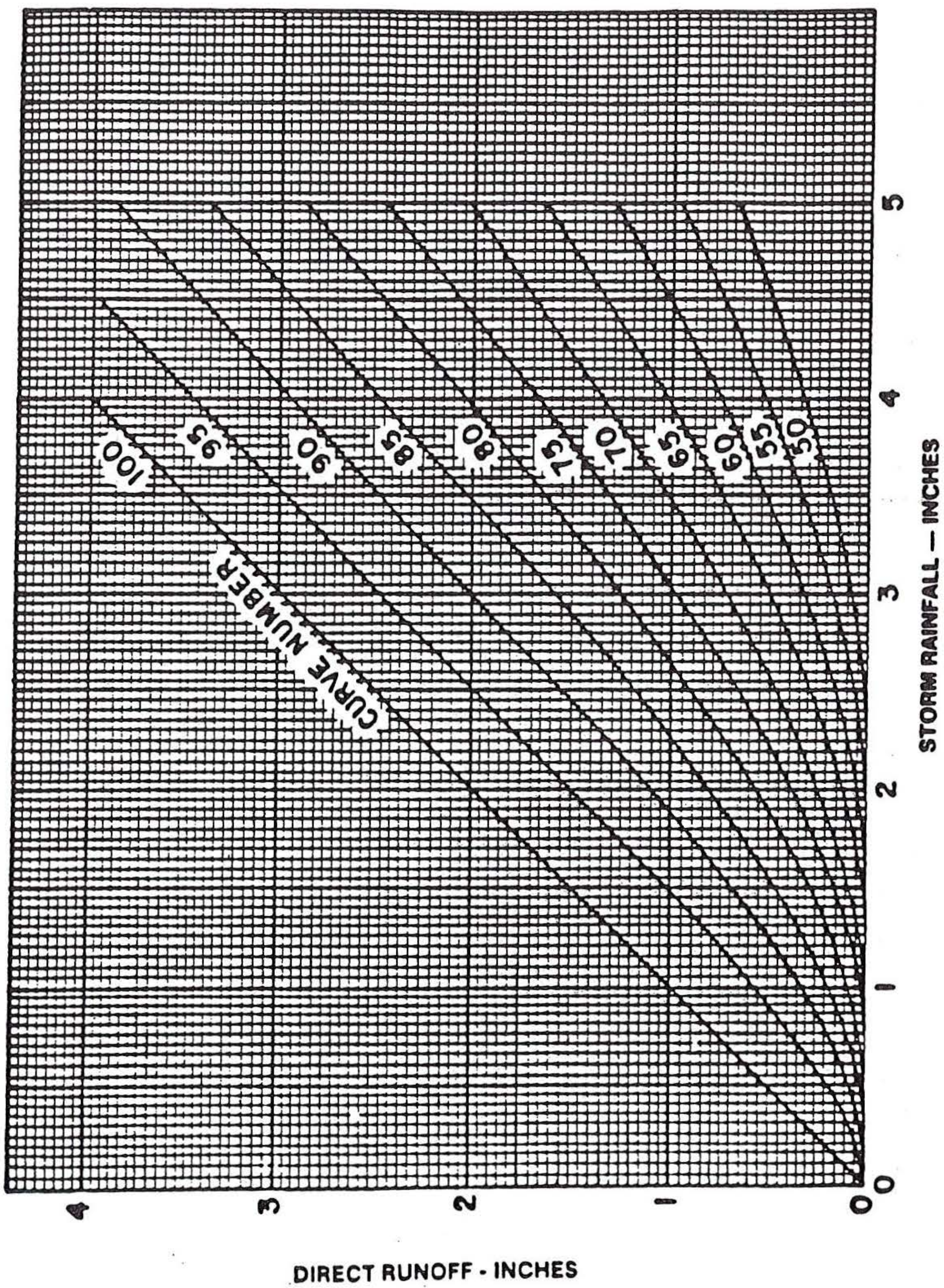
GROUP B — 0.15" to 0.30" per hour & over
Torrifluists recent alluvial soil
Calciorthids high calcium soils.

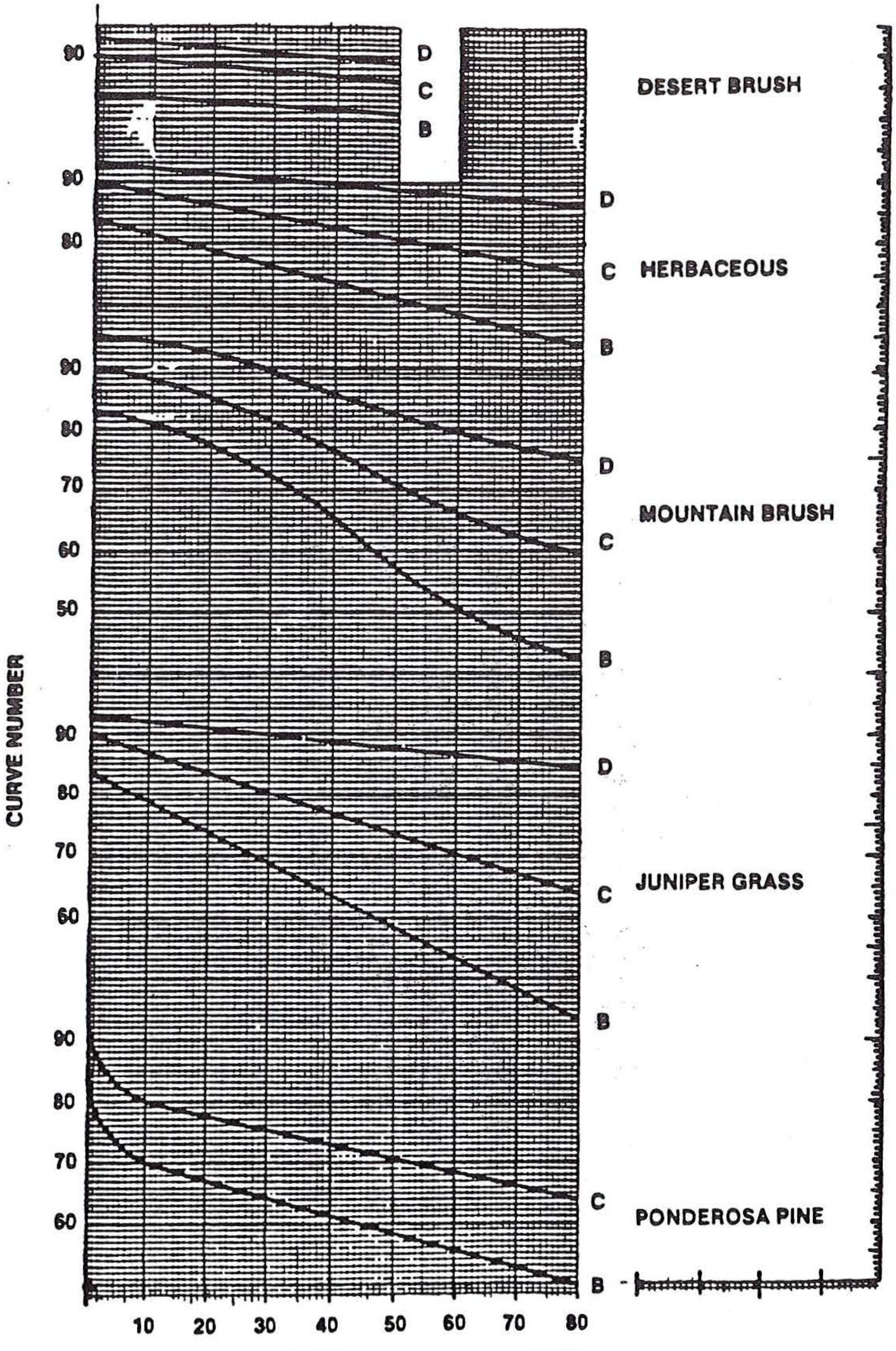
GROUP C — 0.05" to 0.15" per hour & over
Haplargids stratified clay soils.

GROUP D — Less than 0.05" per hour
Rock outcroppings stony mountainous soils on steep slopes

NOTE Minimum infiltration rates shown are from "WATER" — The Yearbook of Agriculture (1955) U.S. Department of Agriculture, page 157.

SOLUTION OF
RAINFALL — RUNOFF EQUATION





COVER DENSITY — PERCENT

HYDROLOGIC SOIL — COVER COMPLEXES
AND ASSOCIATED CURVE NUMBERS

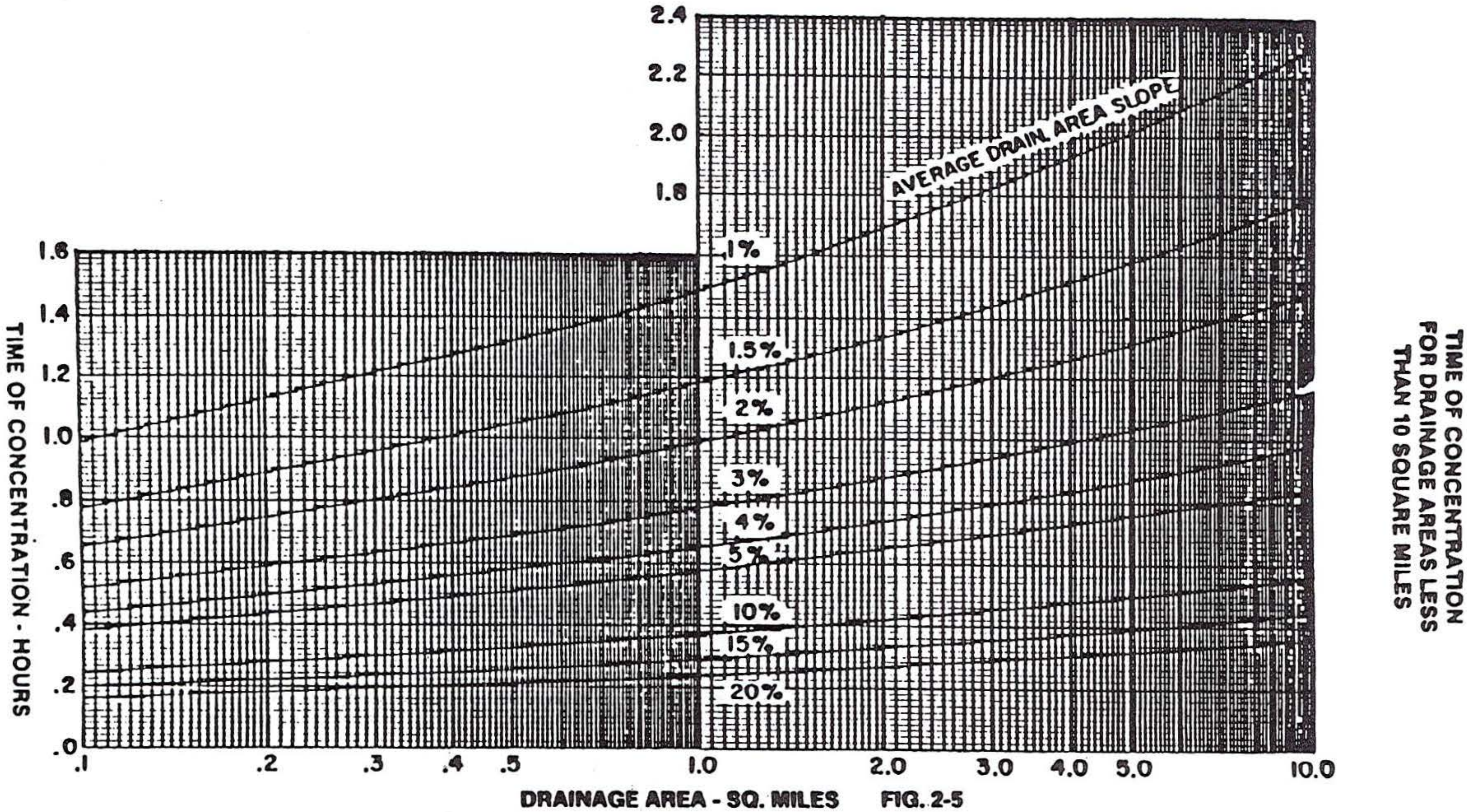
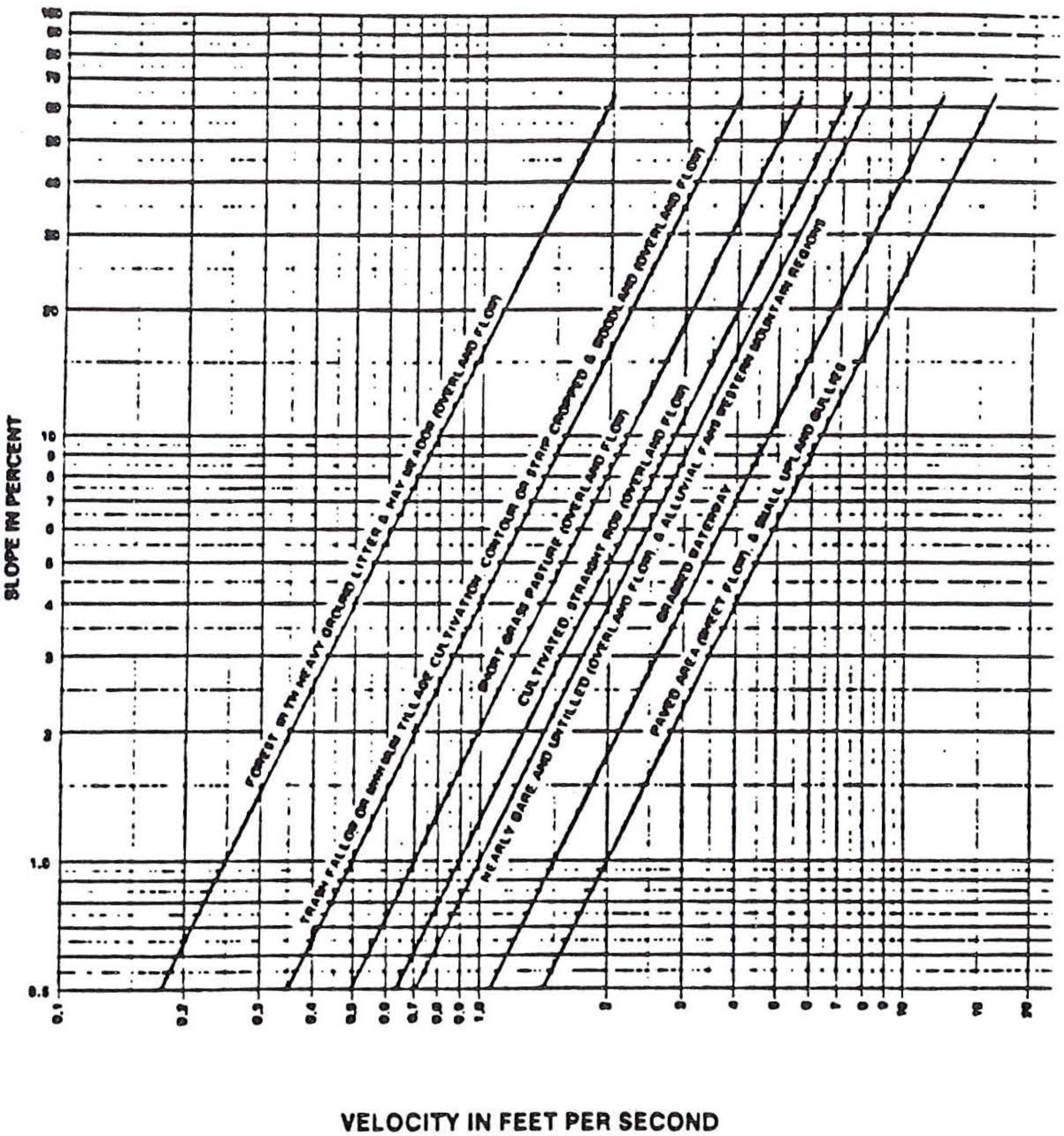


FIG. 2-5

FOR FOLLOWING AVERAGE DRAINAGE AREA WIDTHS, MULTIPLY GRAPH VALUE BY CORRESPONDING FACTOR:

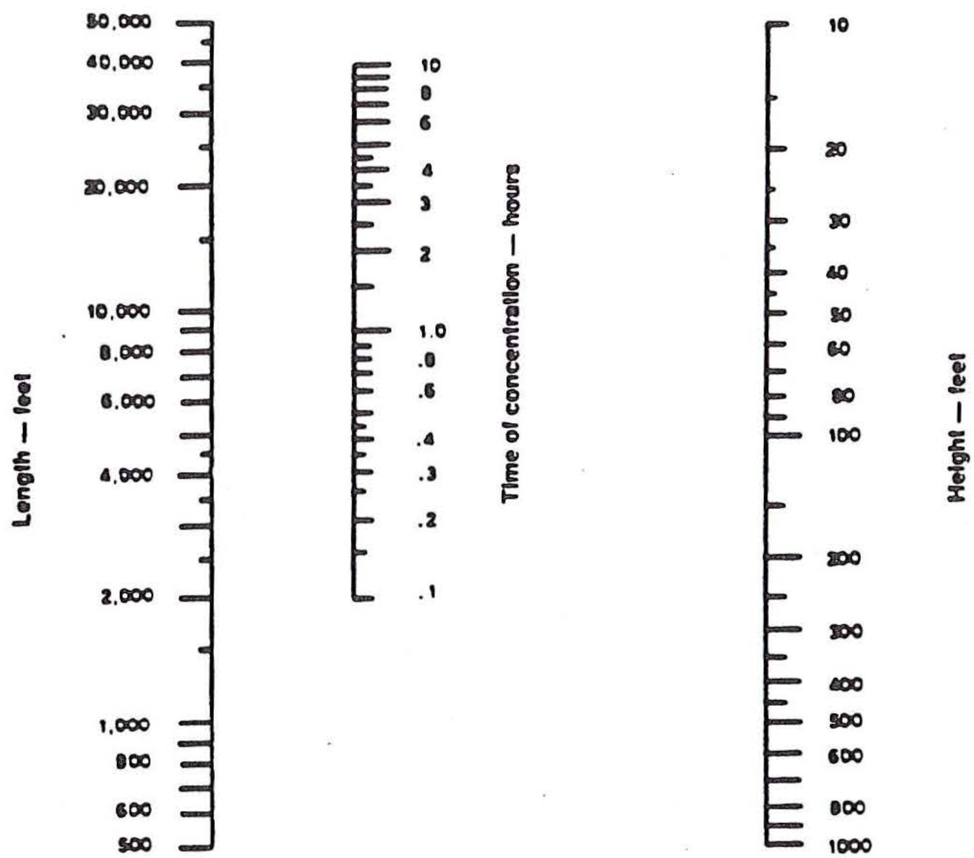
AVERAGE AREA WIDTH FT.	WIDTH FACTOR W_f
0 - 600	1.24
600 - 1200	1.10
1200 - 2400	1.00
2400	.89

$T_p = T_c (Wf)$



Velocities for upland method of estimating Tc

TIME OF CONCENTRATION
FOR DRAINAGE AREAS GREATER THAN 10 SQ. MILES
AND FOR LONG AND NARROW DRAINAGE AREAS OF ANY SIZE
(FOR OVERLAND FLOW ONLY)



$$T_c = \frac{L^{1.15}}{7700\, h^{.38}}$$

Tc = time of concentration — hours
L   length of drainage area — feet
H   elevation — feet
S   slope in percent

If the right side of this equation is multiplied by 60 to express T_c in minutes and if $\underline{SL}$ is substituted for H, this equation becomes

$$T_c = \frac{0.0448\, L^{0.77}}{S_{0.38}}$$

This is almost identical to the equation in Fig. 2-13.

Soil Conservation Service

RATIONAL METHOD

For urbanized and urbanized tributary areas under one-tenth of a square mile, runoff shall be computed using the Rational Method. The Rational Method is based on the Rational Formula!

$$Q = CIA$$

Q is defined as the maximum rate of runoff in cubic feet per second (cfs). C is the runoff coefficient which reflects the percentage of rain that appears as direct runoff from a given watershed. (See Page 26 for typical C Values). The I is the average intensity of rainfall in inches per hour for a duration equal to the time of concentration. The time of concentration is defined as the time required for the runoff to flow from the most remote point of the watershed to the concentration point being investigated. A is the drainage area in Acres.

When using the Rational Formula the following assumptions must be considered:

1.) The maximum rate of runoff for a particular intensity occurs if the duration of rainfall is equal to or greater than the time of concentration.

2.) The maximum runoff is directly proportional to the rainfall intensity when the duration of rainfall is equal to or greater than the time of concentration.

3.) The frequency of occurrence of the peak discharge is the same as that of the rainfall intensity from which it was calculated.

4.) The coefficient of runoff remains constant for all storms on a given watershed.

.Since these limitations reasonably fit urbanized areas with drainage facilities or fixed dimensions and hydraulic characteristics, care should be exercised when using the Rational Formula for determining the peak runoff for urbanized areas.

TIME OF CONCENTRATION

The time of concentration (Tc) is defined as the time required for water to flow from the most remote part of the drainage area under consideration to the point of concentration in question. For urban areas, the time of concentration consists of any inlet time or overland flow time (ti) plus the travel time (tt) in the storm sewer, paved gutter, roadside ditch, or drainage channel. For non-urban areas the time of concentration consists of an overland flow time (ti) plus the travel time in a concentrated form, such as a small swale, channel or drainageway. The time of concentration can be represented by equation 3-2 for both urban and non-urban areas:

$$t_c = t_i + t_t$$

In which t_c = time of concentration (minutes)
(See Page 28 t_i = initial, inlet, or overland flow time (minutes)
t_t = travel time in ditch, channel, gutter, storm sewer, etc. (minutes)

INTENSITY

The intensity, I, is the average rainfall rate in inches per hour for the period of maximum rainfall of a given frequency having a duration equal to the time of concentration.

After a design storm frequency has been selected the intensity can be determined by entering in Page 27 the time of concentration for the drainage area and reading up to the selected frequency.

RUNOFF COEFFICIENT

The runoff coefficient, C, represents the combined efforts of infiltration, evaporation, retention, flow routing, and interception, all of which effect the peak rate of runoff. For this reason it's determination required judgment and understanding on the part of the engineer. Page 26 presents the recommended values of C for various types of land uses. This table should be used as a guide and not the absolute rule.

Where the drainage area is composed of several types of land use a weighted runoff coefficient should be determined according to the area of each type of land use.

DRAINAGE AREA

The drainage area in acres may be determined from contour maps, aerial photos, or field surveys.

DESIGN PROCEDURE

1.) From City criteria select the design frequency required.

2.) Determine the watershed characteristics by using detailing topographic maps and field investigations is possible. The watershed should be divided into subbasin areas according to the various surface runoff characteristics present.

3.) Compute the time of concentration.

4.) Compute the rainfall intensity for the selected design frequency and the time of concentration (From Page 27).

5.) Select runoff coefficients(s) from Page 26; use a weighted co-efficient whenever necessary.

6.) Compute peak runoff by equation.

$$Q = CIA$$

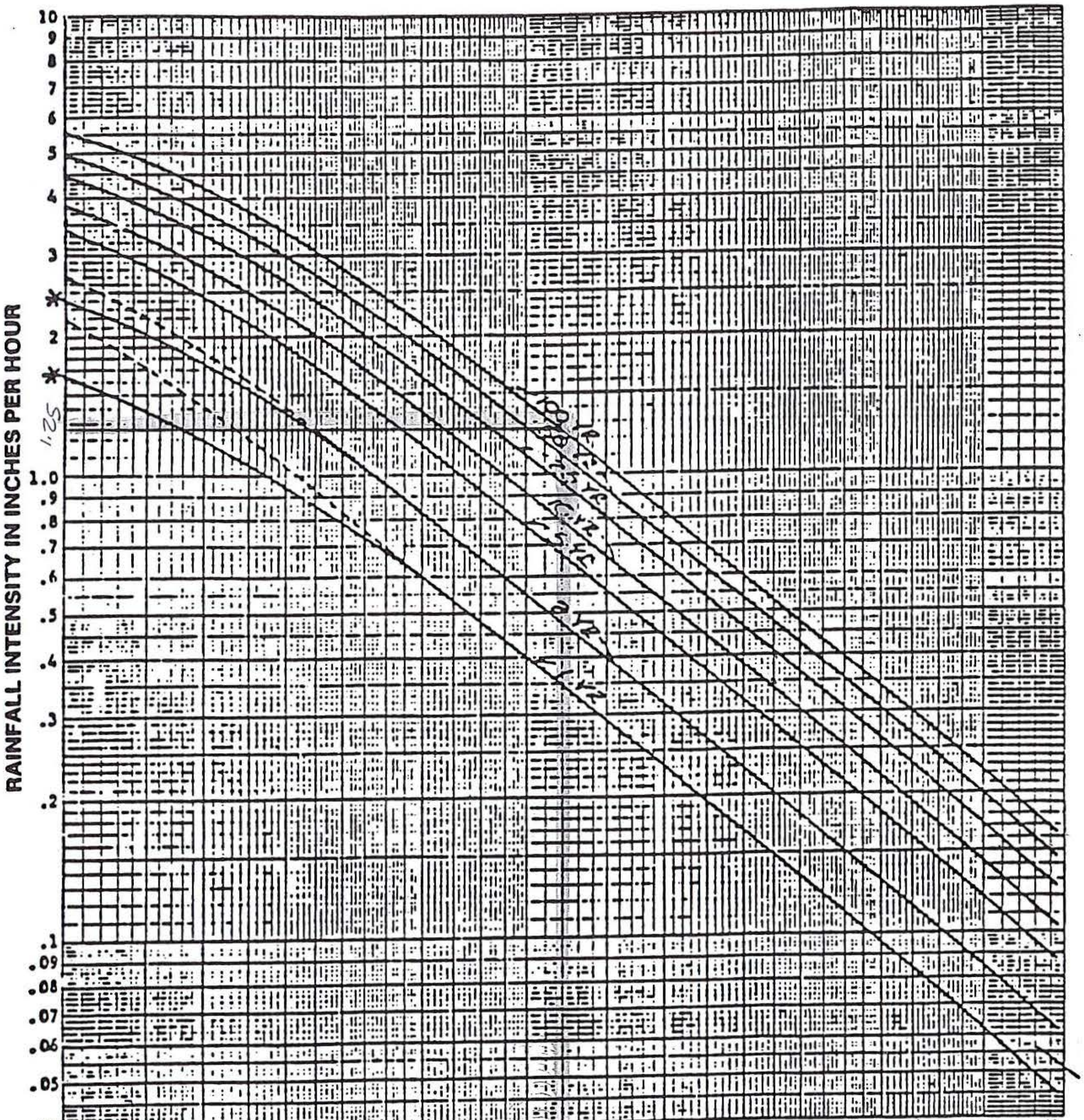
RUNOFF CO-EFFICIENTS FOR USE WITH THE RATIONAL FORMULA Q = CIA

100 YEAR EVENT

Land Use	"C" Value
Paved Street or Parking Lot	0.95
Commercial Areas	0.90
Residential Areas (Average lot zoning)	0.45
Townhouses	0.55
Apartments and Condominiums	0.65
Parks and Grassed Areas (no irrigation)	0.20
Railroad Yards	0.25
Undeveloped Desert	0.35
Mountain Terrain — slopes greater than 10%	0.70
Industrial Areas	0.90
Agricultural Areas	0.20

RAINFALL INTENSITY-DURATION-FREQUENCY RELATION FOR PHOENIX, ARIZONA

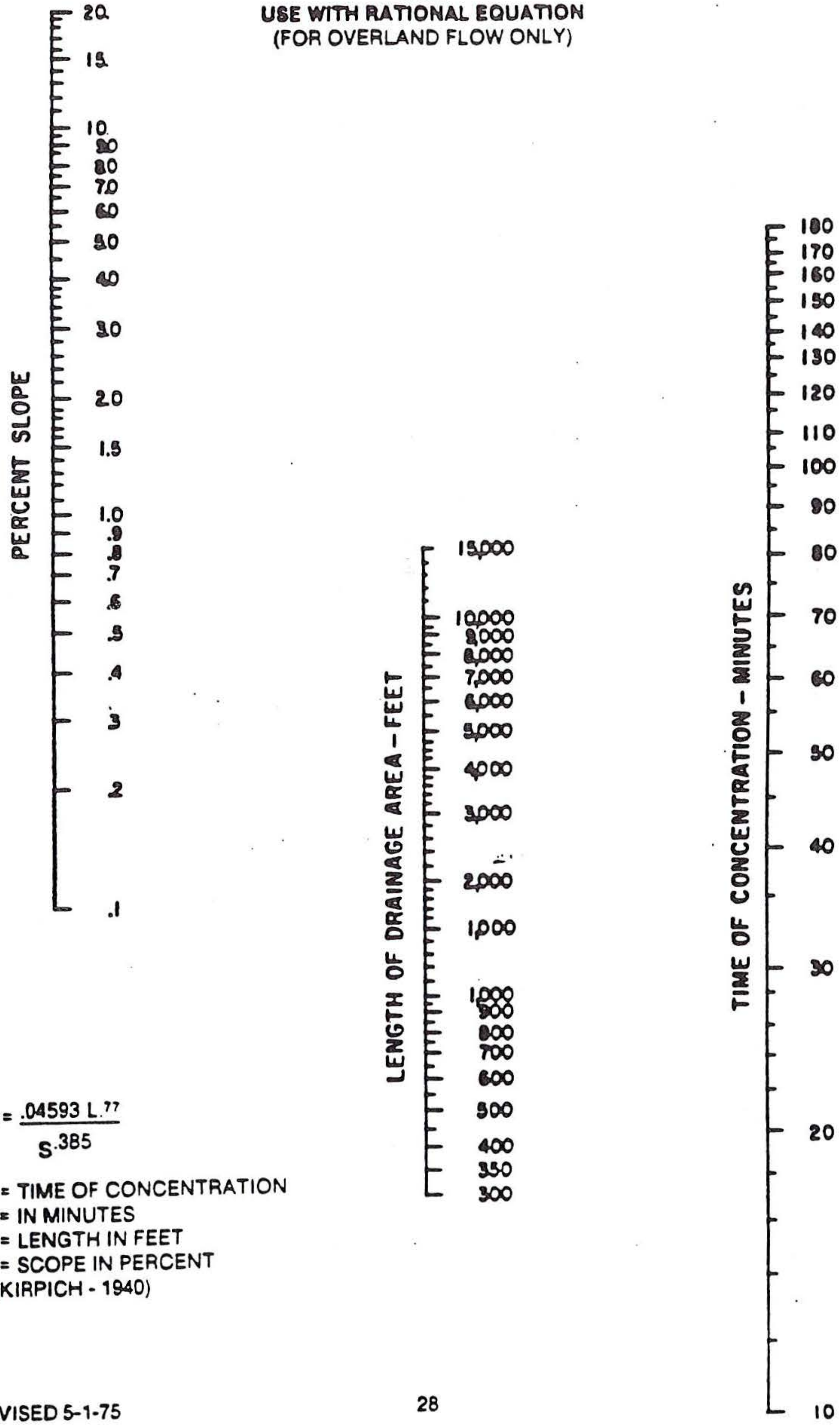
(Partial Duration Series)



Curves are based on methods of U.S. Weather Bureau Technical Papers Nos. 28 and 40 and rainfall data prepared by U.S. Weather Bureau Office of Hydrology for the Soil Conservation Service, March 1967

*Curves revised June 1975 to reflect new information from WR-44.

TIME OF CONCENTRATION FOR USE WITH RATIONAL EQUATION (FOR OVERLAND FLOW ONLY)



$$Tc = \frac{.04593\ L^{.77}}{S^{.385}}$$

Tc = TIME OF CONCENTRATION
= IN MINUTES
L = LENGTH IN FEET
S = SCOPE IN PERCENT
(KIRPICH - 1940)

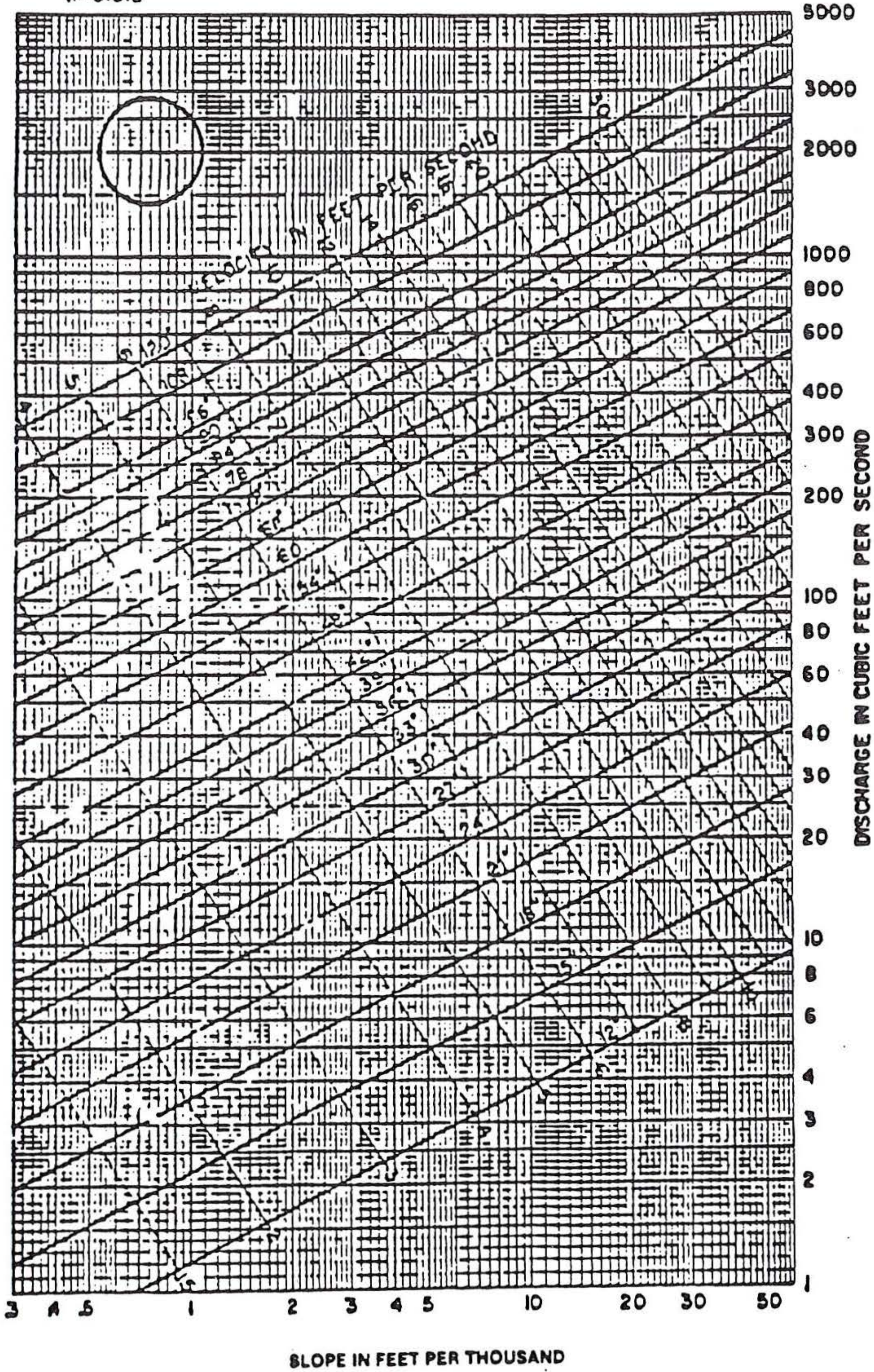
VALUES OF THE ROUGHNESS COEFFICIENT n

TYPE OF CHANNEL AND DESCRIPTION	MINIMUM	NORMAL	MAXIMUM
C. EXCAVATED OR DREDGED			
a. Earth, straight and uniform			
1. Clean, recently completed	0.016	0.018	0.020
2. Clean, after weathering	0.018	0.022	0.025
3. Gravel, uniform section, clean	0.022	0.025	0.030
4. With short grass, few weeds	0.022	0.027	0.033
b. Earth, winding and sluggish			
1. No vegetation	0.023	0.025	0.030
2. Grass, some weeks	0.025	0.030	0.033
3. Dense weeds or aquatic plants in deep channels	0.030	0.035	0.040
4. Earth bottoms and rubble sides	0.028	0.030	0.035
5. Stony bottom and weedy banks	0.025	0.035	0.040
6. Cobble bottom and clean sides	0.030	0.040	0.050
c. Dragline-excavated or dredged			
1. No vegetation	0.025	0.028	0.033
2. Light brush on banks	0.035	0.050	0.060
d. Rock cuts			
1. Smooth and uniform	0.025	0.035	0.040
2. Jagged and irregular	0.035	0.040	0.050
e. Channels not maintained, weeds and brush uncut			
1. Dense weeds, high as flow depth	0.050	0.080	0.120
2. Clean bottom, brush on sides	0.040	0.050	0.080
3. Same, highest stage of flow	0.045	0.070	0.110
4. Dense brush, high stage	0.080	0.100	0.140
D. NATURAL STREAMS			
D-1. Minor streams (top width at flood stage 100ft)			
a. Streams on plain			
1. Clean, straight, full stage, no rifts or deep pools	0.025	0.030	0.033
2. Same as above, but more stones and weeds	0.030	0.035	0.040
3. Clean, winding, some pools and shoals	0.033	0.040	0.045
4. Same as above, but some weeds and stones	0.035	0.045	0.050
5. Same as above, lower stages, more ineffective slopes and sections	0.040	0.048	0.055
6. Same as 4 but more stones	0.045	0.050	0.060
7. Sluggish reaches, weedy, deep pools	0.050	0.070	0.080
8. Very weedy reaches, deep pools, or floodways with heavy stand of timber and underbrush	0.075	0.100	0.150
b. Mountain streams, no vegetation in channel, banks usually steep, trees and brush along bank submerged at high stages			
1. Bottom: gravel, cobbles and few boulders	0.030	0.040	0.050
2. Bottom: cobbles with large boulders	0.040	0.050	0.070

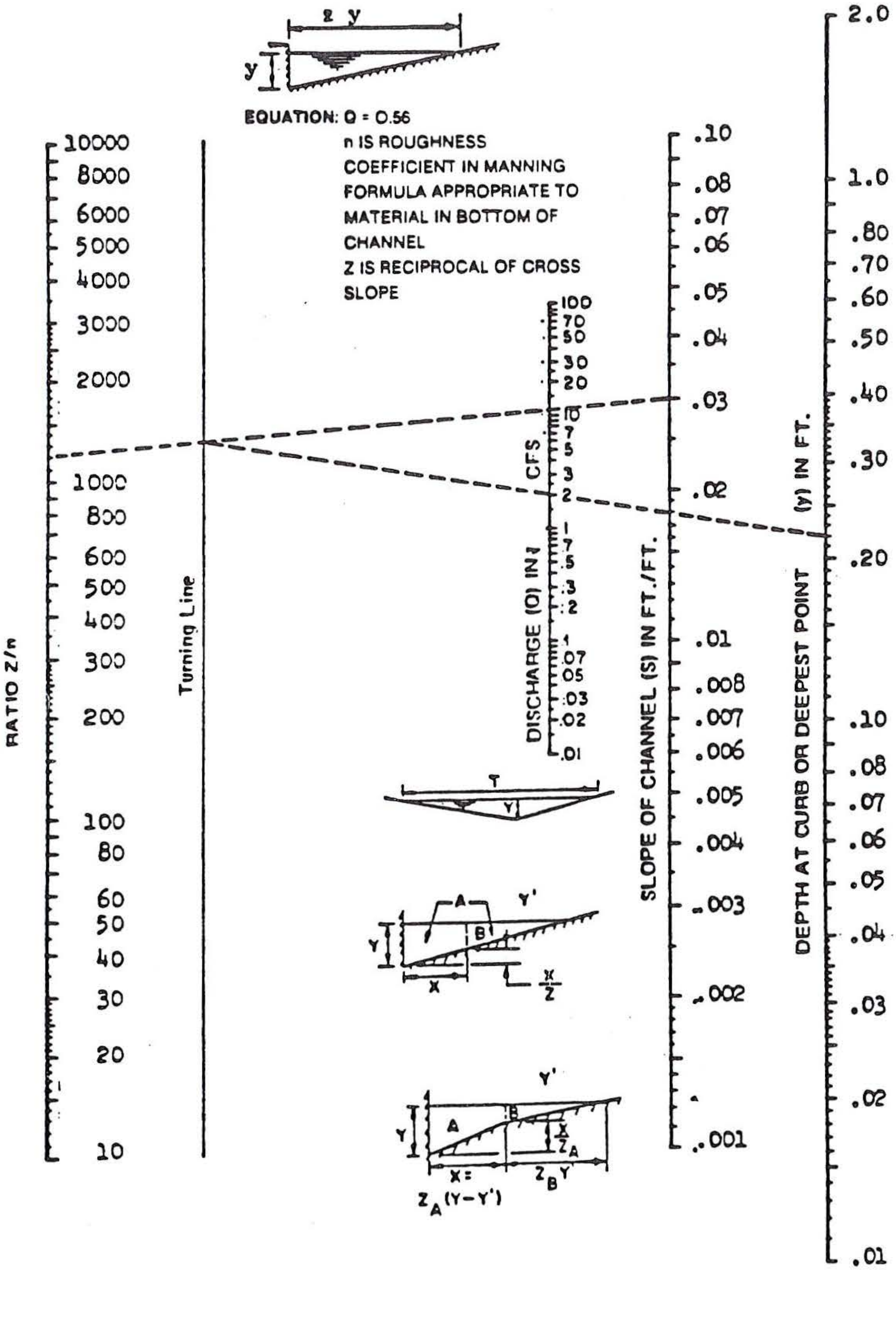
VALUES OF THE ROUGHNESS COEFFICIENT n

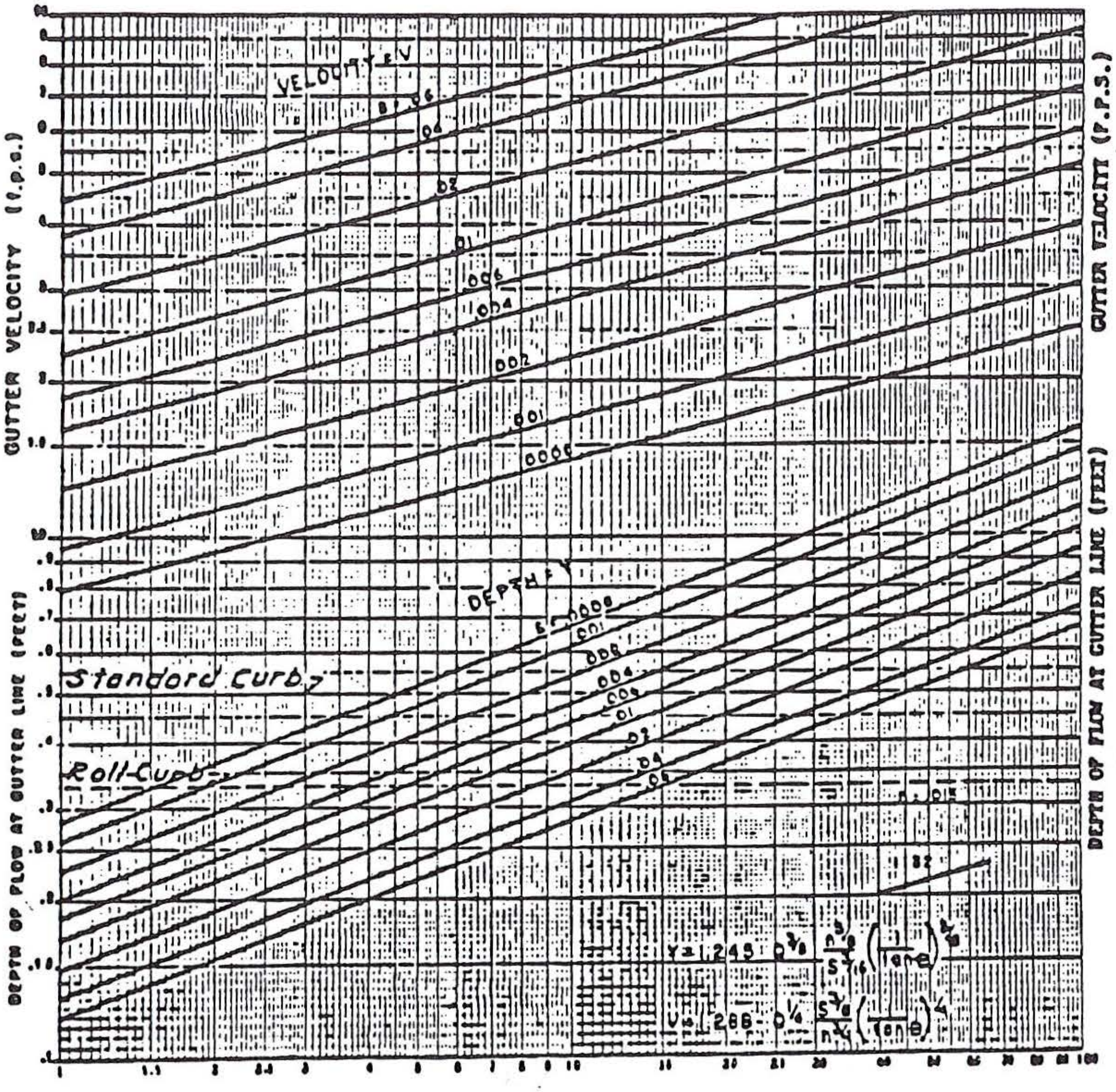
TYPE OF CHANNEL AND DESCRIPTION	MINIMUM	NORMAL	MAXIMUM
D-2. Flood plains			
a. Pasture, no brush	0.025	0.030	0.035
1. Short grass	0.030	0.035	0.050
b. Cultivated areas			
1. No crop	0.020	0.030	0.040
2. Mature row crops	0.025	0.035	0.045
3. Mature field crops	0.030	0.040	0.050
c. Brush			
1. Scattered brush, heavy weeds	0.035	0.050	0.070
2. Light brush and trees, in winter	0.035	0.050	0.060
3. Light brush and trees, in summer	0.040	0.060	0.080
4. Medium to dense brush, in winter	0.045	0.070	0.110
5. Medium to dense brush, in summer	0.070	0.100	0.160
d. Trees			
1. Dense willows, summer, straight	0.110	0.150	0.200
2. Cleared land with tree stumps, no sprouts	0.030	0.040	0.050
3. Same as above, but with heavy growth of sprouts	0.050	0.060	0.080
4. Heavy stand of timber, a few down trees, little undergrowth, flood stage below branches	0.080	0.100	0.120
5. Same as above, but with flood stage reaching branches	0.100	0.120	0.160
D-3. Major streams (top width at flood stage 100 ft.) The n value is less than that for minor streams of similar description, because banks offer less effective resistance.			
a. Regular section with no boulders or brush	0.025	—	0.060
b. Irregular and rough section	0.035	—	0.100

COMPUTED FROM MANNING'S FORMULA
n = 0.012



PIPE CAPABILITIES
FLOWING FULL

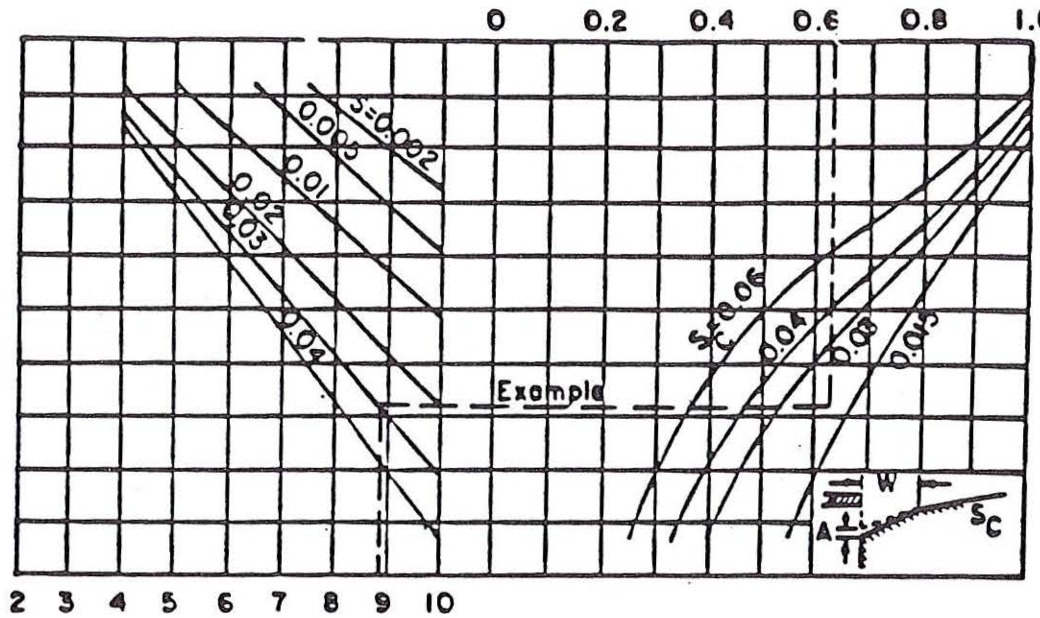

z y
y
EQUATION: Q = 0.56
n IS ROUGHNESS COEFFICIENT IN MANNING FORMULA APPROPRIATE TO MATERIAL IN BOTTOM OF CHANNEL
Z IS RECIPROCAL OF CROSS SLOPE
RATIO Z/n
10000
8000
6000
5000
4000
3000
2000
1000
800
600
500
400
300
200
100
80
60
50
40
30
20
10
Turning Line
DISCHARGE (Q) IN CFS.
100
70
50
30
20
10
7
5
3
2
1
.7
.5
.3
.2
.1
.07
.05
.03
.02
.01
SLOPE OF CHANNEL (S) IN FT./FT.
.10
.08
.07
.06
.05
.04
.03
.02
.01
.008
.007
.006
.005
.004
.003
.002
.001
DEPTH AT CURB OR DEEPEST POINT (y) IN FT.
2.0
1.0
.80
.70
.60
.50
.40
.30
.20
.10
.08
.07
.06
.05
.04
.03
.02
.01
T
Y
A
Y'
B
Y
X
X/Z
A
B
X/Z_A
X = Z_A(Y−Y')
Z_B Y'



GUTTER FLOW = Q (C.F.S.)

CAPACITY OF CURB OPENING INLET ON CONTINUOUS GRADE

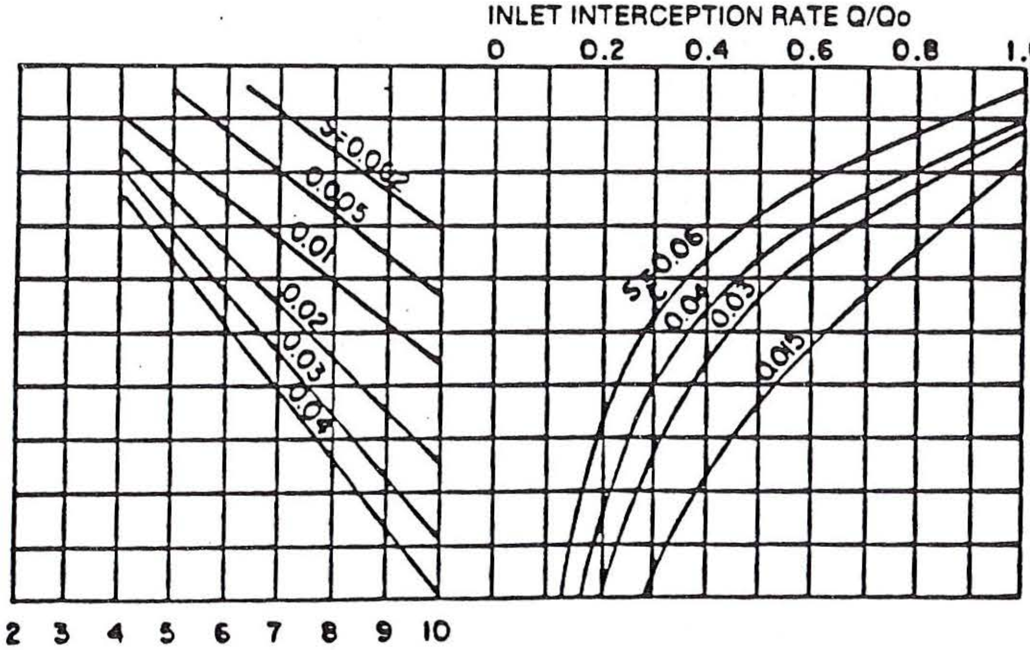
INLET INTERCEPTION RATE Q/Qo



GUTTER FLOW SPREAD, w (FT)

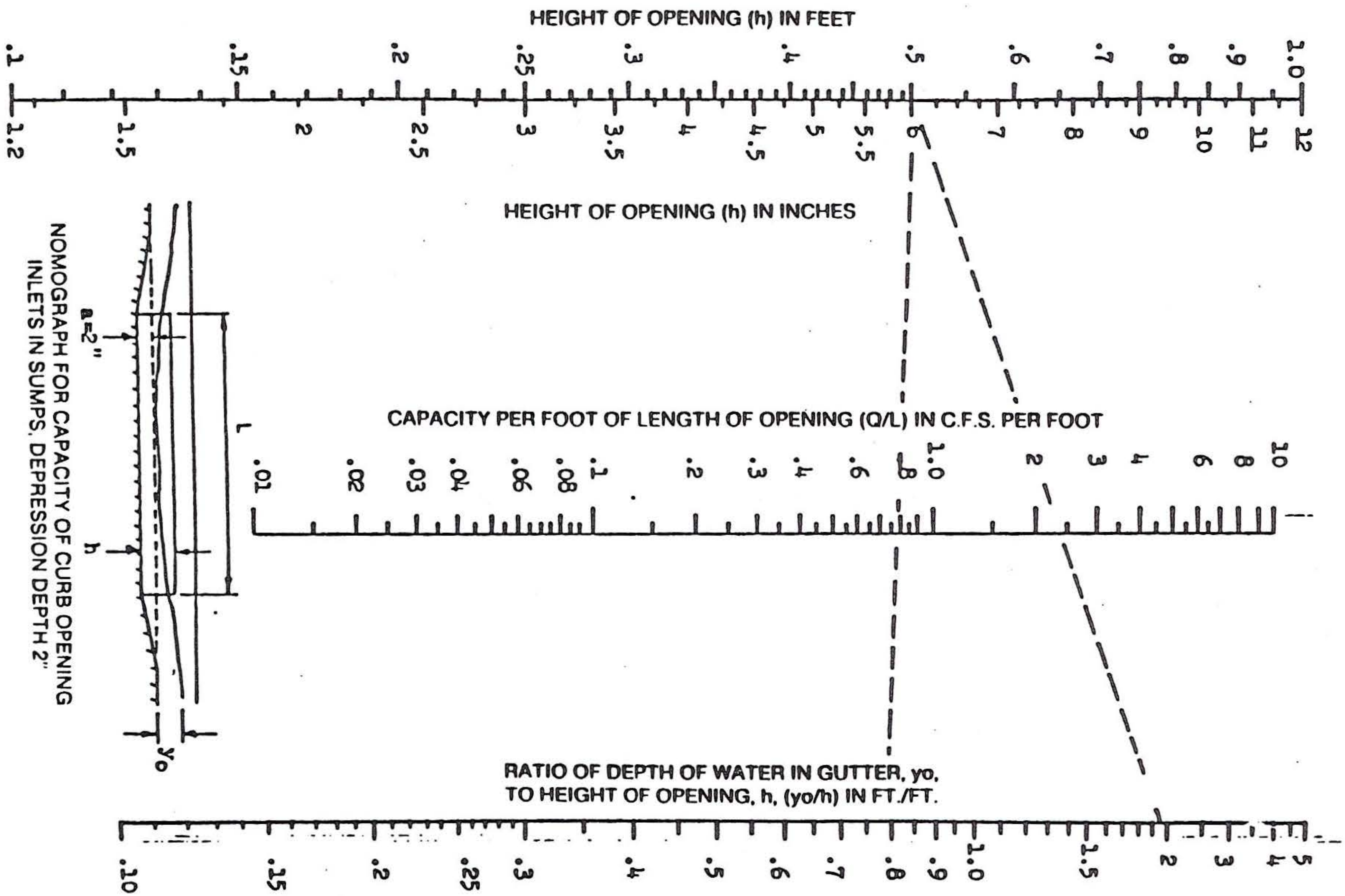
CAPACITY OF CURB OPENING INLET ON CONTINUOUS GRADE W = 2FT., a ≥ 2 IN., L = 10 FT., h ≥ yo

INLET INTERCEPTION RATE Q/Qo



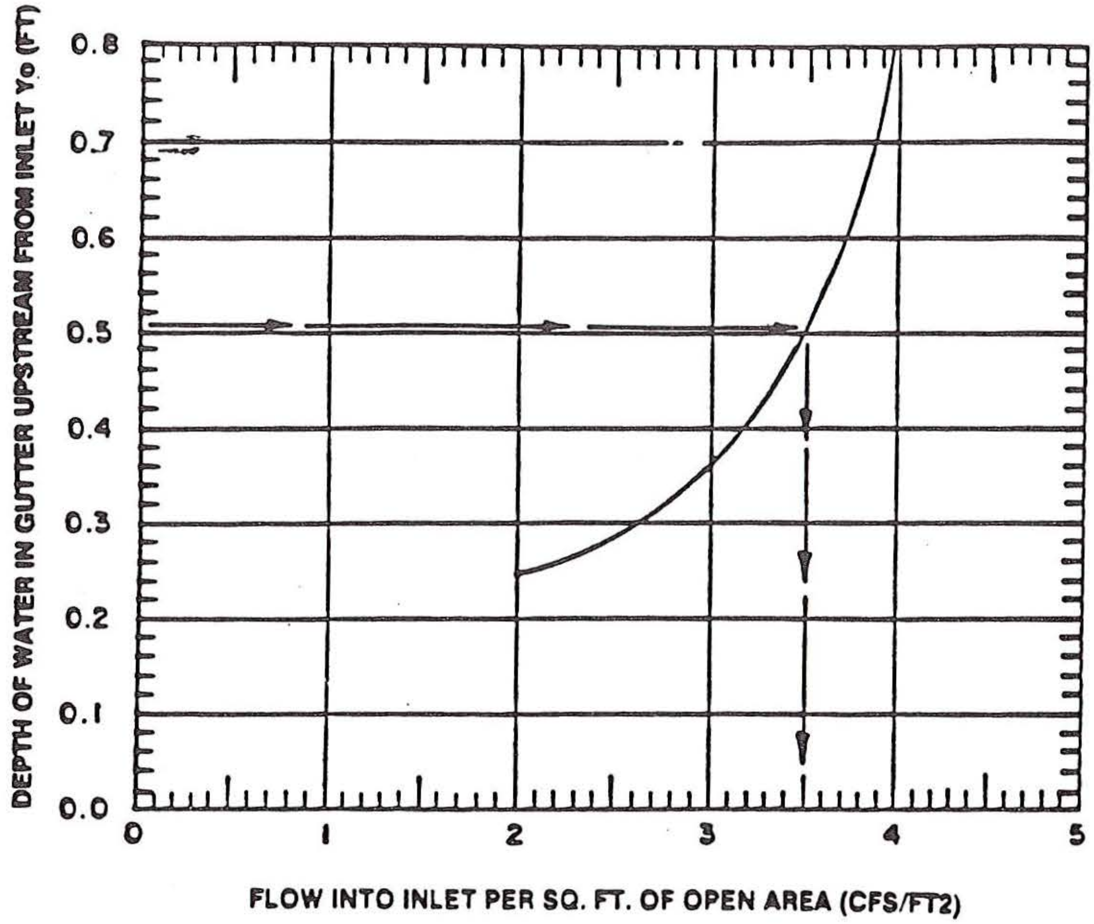
GUTTER FLOW SPREAD, w (FT)

CAPACITY OF CURB OPENING INLET ON CONTINUOUS GRADE GRADE W = 2FT., a ≥ 2 IN., L = 5 FT., h ≥ yo

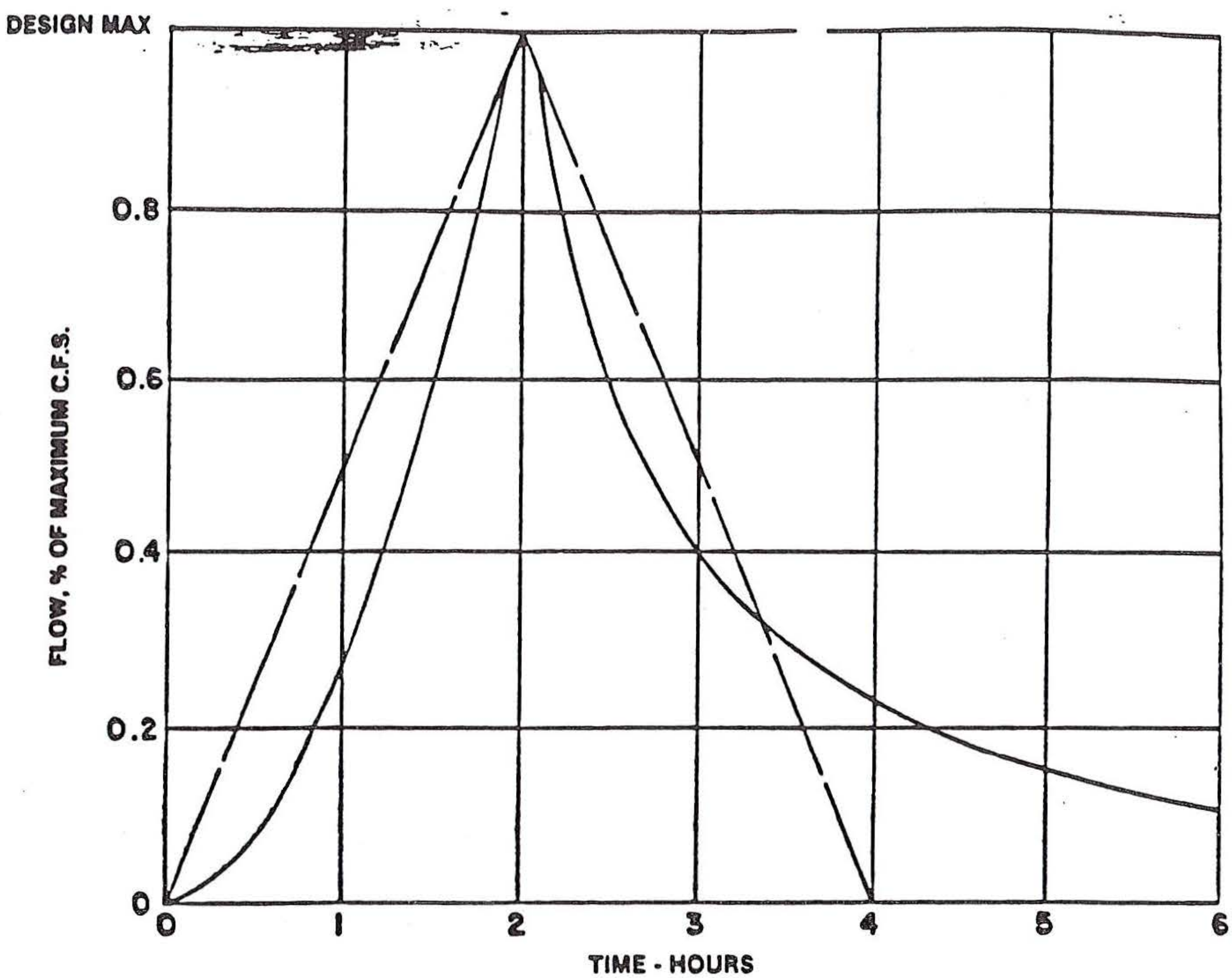


NOMOGRAPH FOR CAPACITY OF CURB OPENING INLETS IN SUMPS, DEPRESSION DEPTH 2"

CAPACITY OF GRADED INLET IN SUMP



DETENTION BASIN VOLUME



1. RUNOFF COEFFICIENT C DEPENDS ON LAND USE.
2. USE THE 2 HOUR INTENSITY FROM PAGE 27.
3. USE Q = CIA (RATIONAL METHOD) OVER ENTIRE AREA.
4. RETARDING FACILITY CAPACITY: AREA UNDER TRIANGLE = 1/2(4)(Q) (3600)=7200 Q (FT.3).

Capacity = 7200 Q

Q_{cap} = (7200) (CIA)