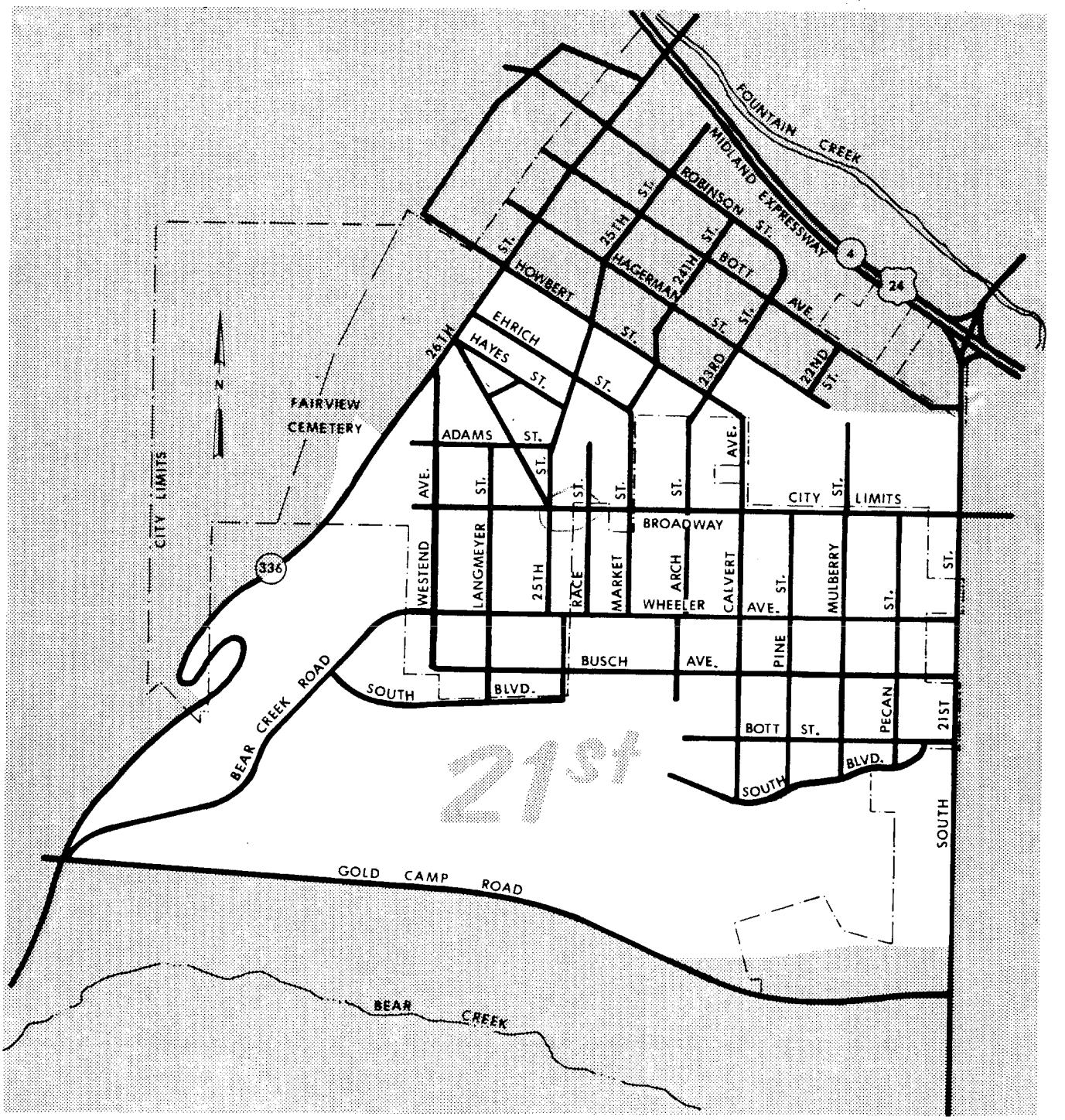
# SOUTH 21st STREET
# Master Drainage Basin Study

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**r. keith hook & associates, inc.**

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June 23, 1977

Mr. Dewitt Miller
Director of Public Works
P. O. Box 1575
Colorado Springs, CO 80901

Dear Sir:

Transmitted herewith is the engineering study of the South 21st Master Drainage Basin System.

This report has been prepared in conformance to those requirements as set forth in Contract No. 77-38, dated April 12, 1977, between the City of Colorado Springs and R. KEITH HOOK & ASSOCIATES, INC., Engineers and attached letter by the Engineer dated March 2, 1977.

Our technical data applied to this study is from latest drainage criteria prepared by the Department of Public Works.

As portions of this study extend beyond the present City limits, it is recommended joint meetings be held between the City and County Public Works Departments and the Drainage Board for review and comments prior to final approval.

Very truly,

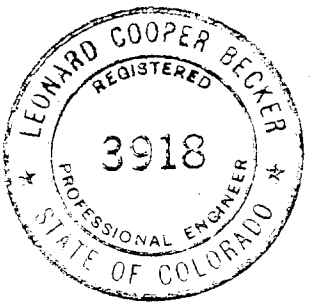
R. KEITH HOOK & ASSOCIATES, INC.

Leonard C Becker

Leonard C. Becker, P.E.
Executive Vice President/Director
Engineering Department

LCB/jml

Enclosure

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# HYDROLOGIC ENGINEERING STUDY

of the

# SOUTH 21st STREET

# DRAINAGE BASIN

for

THE DEPARTMENT OF PUBLIC WORKS

COLORADO SPRINGS, COLORADO

JUNE, 1977

R. KEITH HOOK & ASSOCIATES, INC.
CONSULTING ENGINEERS
2545 East Platte Place
Colorado Springs, Colorado 80909

CONTENTS

# I. DESCRIPTION

## A. Scope and Purpose

This report has been prepared to establish the improvements necessary to provide proper storm runoff facilities and systems and to establish a drainage basin fee for the area within the boundary of the 21st drainage basin, as delineated in this report.

Storm flow run-off has been computed, using design criteria of 3.5 inch intensity, 100 year storm frequency and 6 hour duration.

It is the intent of this report to direct surface flows along those routes and systems, that will eliminate excess concentration of storm waters at any location, that will basically maintain dry street and roadway conditions, that will utilize greenbelt and piping systems, that will however consider economics of possible alternatives to keep improvement costs appropriate and that will maintain aesthetic qualities of the basin area.

All existing street systems that will logically be improved, though presently are only gravel surfaced, are considered to be surfaced with curb and gutter. In analyzing surface runoff quantities and direction of flow, these streets will therefore be considered as conveying allowable surface runoff.

Those present roadway systems that would not logically be improved with curb and gutter, will convey surface runoff in side ditch sections. The delineation of these roadway and street systems are shown on the drainage plan.

Approximately 100 Acres of undeveloped land in the Southerly portion of the basin does not reflect future street extensions in this report as this area has not been considered as being conducive to typical subdivision developed. It is possible a few large parcels may develop commercially or industrially in the future, with access roads paralleling the slope. Minimum grading of site preparation would be required to maintain natural drainage courses. The westerly portion of this area is being used as gravel extraction and if land use changes in the future a detailed drainage report should be prepared.

Nearly all this lies outside the City limits. Approximately 80 Acres of land lies between South 26th Street and Bear Creek Road. This area is sparcely populated and due to steep grades, from 9 percent to 10 percent, is considered as not conducive to typical subdivision development. This area also does not reflect proposed street extensions.

B. Basin Description

South 21st Drainage Basin is comprised of 417 Acres more or less. 168 Acres lie within the City limits of Colorado Springs and 249 Acres are in El Paso County.

The basin is bounded on the west by portions of: South 26th Street, on the North by Howbert Street, on the East by South 21st Street, and on the South by Gold Camp Road.

No major drainage channel intersects the basin and surface flow entering the basin from the westerly and southerly portions initially contained in relatively small ditches and channels along with surface sheet flow characteristics.

The majority of the platted streets are unimproved, consisting of gravel surfaced roadways. Surface runoff at several street intersections is presently intercepted into grated inlets and thence into drainage channels. Flows in ditch sections are contained in existing pipes or culverts crossing under streets.

All surface flow in the basin outfalls at one (1) point, contained in a 10' x 10' culvert crossing under 21st Street and thence into Fountain Creek via a large channel.

All existing drainage ditches, channels, piping and facilities are shown on the drainage plan on Figure A.

Due to the majority of unimproved streets surface run-off during a nominal storm creates erosion to the streets and ditches requiring immediate repair.

During the course of preparing this report, residents within the area have called the City advising damage to their properties as a result of excess water and velocities overflowing ditches.

Presently the Southerly portion of the Basin is undeveloped, consisting of scarred land in the Southwest portion, as a result of gravel extraction and rather steep grassed slopes in the Southeast portion. From these areas surface flows are not specifically directed, other than natural surface flow routes, creating excess flows at points intercepting streets parallel and perpendicular to the surface run-off.

Average grades in these areas are 10 percent, creating excess velocities of surface flow as this run-off enters developed areas. Particular high velocities of surface flow was noted on South 21st Street and resultant flooding and erosion as a result of 7 per cent grades.

Of the present areas unplatted, and in view of the zoning established, it would appear the land will eventually be developed into commercial and industrial sites.

C. Hydrologic Soil Description

The undeveloped areas of the basin lie principally in the Southeasterly and Southwesterly areas.

In the Southwesterly area, the soil consists of gravels and alluvium formed from westerly mountain gravels overlying the Pierre shale group. This type soil has a hydrologic classification of relative high infiltration SC5 (A) rate and a high rate of water transmission. At the present time this area is used for gravel extraction and the surface area is hard packed and as a result of this and due to the 9-10 per cent grades, a higher run-off factor has been applied to this area.

The Southeasterly portion consists of vegetation and native grasses. This also has a relative high infiltration SC5(A) rate and a high rate of water transmission. A higher run-off factor, however has been applied to this area as the grades are also 9 to 10 per cent.

The soil characteristics in the present developed areas and those areas of planned development fall within the soil classification of SC5 "C" and "D" categories, consisting of lean clayey materials and fat clays with moderate to slow water infiltration and high transmission rates.

D. Storm Runoff Criteria

The procedures used in this report to establish runoff calculations, rainfall intensities, duration and storm frequency were adopted from the following manuals:

1. Determination of Storm Runoff Criteria, Colorado Springs, Department of Public Works
2. USDA - SC5, including "procedures for Determining Peak Flows in Colorado"
3. Bureau of Reclamation Design of Small Dams (Book) complex Synthetic Hudrograph Procedures

Basic calculations utilized a 3.5 inch rainfall intensity, a 6 hour storm duration and a 100 year occurrence.

Formulas for hydrualic calculations are shown in Section VI.

E. Major Drainage Channel Systems

The greenbelt system extends from the west side of South 21st Street westerly to its northerly termination at the intersection of Enrich and Market Streets. From the intersection at Mulberry extended, the greenbelt system extends southerly to a point 450 feet south of Bott Street, thence westerly to a point 500 feet south of Langmeyer Street extended.

A branch of the major greenbelt system extends northerly along Mulberry Street to a point of intersection.

2700 feet of the system lies within the City limits.

4200 feet of the system lies in El Paso County.

Portions of the above described major greenbelt system, as shown on the drainage plan, are present drainage channels, conveying surface runoff from the south and west portions of the basin to an existing outfall structure in the northeast corner of the basin and thence crossing under South 21st to its confluence with Fountain Creek.

It is the intent to provide the southerly portion of the major greenbelt system as an interceptor of the surface runoff from the undeveloped land in the extreme southerly portion of the basin. As previously mentioned, the grades in this area average 10 per cent.

F. Improvements

The proposed improvements described in this report and shown on the drainage plan consist of the following:

a - Greenbelt Channel System - Shaping and Lining

b - Drainage Piping System

c - Drainage Structures and Appurtenances

d - Drainage channels

e - Drainage Inlets and Catch Basins

f - Velocity Control Structures

g - Maintenance Access Roadways

h - On-going maintenance Program.

The location of proposed drainage facilities, including greenbelt systems, drainage channels, piping systems, catch basins and appurtenances are shown as a guide and recommendations for drainage improvements and as a guide to establish drainage basin fees. It is the intent that drainage improvements basically conform to this report.

In addition to upgrading the existing major channel and supplementing this channel and developing new channels into greenbelt systems, several of the existing pipe culverts crossing under streets, and existing ditches will require improving in order to maintain minimum flow in the street systems, a network of drainage piping is required in the southerly and westerly portions of the basin draining surface flows into the piping system and thence into the greenbelt systems.

Within the ditch sections, velocities will exceed 5 fps in some sections requiring velocity control structures. In addition, shaping existing greenbelt channels and lining will also be required.

The existing drainage structures and piping crossing under street systems or as portions of the existing drainage channel system are described and shown on the drainage plan and identified by hydrograph point numbers. Required improvement to these structures and piping is described in facilities improvements, page 36 and 37.

An analysis of the existing drainage structures and piping in the main drainage channel show deficiency in conveying a 3.5 inch rainfall

at peak flow. The cross-section of the proposed major greenbelt indicates the rise in water level if these deficient structures are not improved, as recommended.

Recommended catch basins sizes and locations are shown on the drainage plan, variations from standard design are required at certain locations and are described and shown on the drainage plan in the report.

Easements will be required for the southerly greenbelt system and to provide for this improvement requirement a contingency cost has been included in the cost estimates included in this report.

## COST ESTIMATE - CITY APPROPRIATED FUNDS

(All costs in place and projected to 1979)

| ITEM | QUANTITY | UNIT | UNIT COST | AMOUNT |
|---|---|---|---|---|
| Storm Drain Piping System | | | | |
| RCP: 21" | 160 | L.F. | $ 11.06 | $ 1,770.12 |
| 24" | 700 | L.F. | 12.99 | 9,093.00 |
| 27" | 70 | L.F. | 16.26 | 1,138.20 |
| 33" | 650 | L.F. | 25.99 | 16,893.50 |
| 36" | 700 | L.F. | 35.49 | 24,843.00 |
| 42" | 1900 | L.F. | 37.57 | 71,383.00 |
| 54" | 1400 | L.F. | 59.33 | 83,062.00 |
| 60" | 500 | L.F. | 70.39 | 35,195.00 |
| 58"x91" | 750 | L.F. | 116.05 | 75,432.50 |
| | | | | $318,810.32 |
| Catch Basins | | | | |
| DIOR: 4' | 1 | Ea. | $ 608.85 | $ 608.85 |
| 6' | 14 | Ea. | 839.03 | 11,746.42 |
| 10' | 11 | Ea. | 1,188.00 | 13,068.00 |
| 12' | 3 | Ea. | 1,470.15 | 4,410.45 |
| 16' | 4 | Ea. | 1,915.65 | 7,662.60 |
| | | | | $ 37,496.32 |
| Diversion Structures | 3 | Ea. | $ 1,300.00 | 3,900.00 |
| | | | | $ 3,900.00 |
| Major Drainage Channel: | | | | |
| Shaping, Lining | 2300 | L.F. | $ 40.00 | $ 92,000.00 |
| Slope Treatment | 2300 | L.F. | $ 10.00 | $ 23,000.00 |
| | | | | $115,000.00 |
| Manholes | 14 | Ea. | $ 1,200.00 | $ 16,800.00 |
| | | | | $ 16,800.00 |
| Drainage Channels | 3950 | L.F. | $ 22.00 | $ 86,900.00 |
| | | | | $ 86,900.00 |
| | | GRAND TOTAL | | $578,906.64 |

## COST ESTIMATE - DEVELOPER FUNDS

(All costs in place and projected to 1979)

| ITEM | QUANTITY | UNIT | UNIT COST | AMOUNT |
|---|---|---|---|---|
| Storm Drain Piping System | | | | |
| RCP: 18" | 1400 | L.F. | $ 9.06 | $ 12,681.90 |
| 24" | 550 | L.F. | 12.99 | 7,144.50 |
| 30" | 500 | L.F. | 19.45 | 9,725.00 |
| 36" | 550 | L.F. | 35.49 | 19,519.50 |
| 48" | 325 | L.F. | 48.93 | 15,902.25 |
| | | | | $ 64,973.15 |
| Catch Basins | | | | |
| DIOR: 4' | 4 | Ea. | $ 608.85 | $ 2,435.40 |
| 6' | 2 | Ea. | 839.03 | 1,678.06 |
| 8' | 2 | Ea. | 977.13 | 1,954.26 |
| 12' | 4 | Ea. | 1,470.15 | 5,880.60 |
| Grated Inlet | 1 | Ea. | 2,000.00 | 2,000.00 |
| | | | | $ 13,948.32 |
| Major Drainage Channel Systems: | | | | |
| Shaping, Lining | 5250 | L.F. | $ 40.00 | $210,000.00 |
| Slope Treatment | 5250 | L.F. | 10.00 | 52,500.00 |
| | | | | $262,500.00 |
| Manholes | 7 | Ea. | $ 1,200.00 | $ 8,400.00 |
| | | | | $ 8,400.00 |
| | | GRAND TOTAL | | $349,821.47 |

Total Assessable Area = 324.4 Acres

Gross Cost Per Acre (unadjusted) = $\frac{\$349,821.47}{324.4 \text{ Acres}}$ = $1,078.36/Acre

## COST ESTIMATE - BREAKDOWN AND SUMMARY

Total Basin Area = +/- 417 Acres

Total Platted Area = +/- 274 Acres

Platted Developed Area = 119.6 Acres
Platted Undeveloped Area =154.4 Acres

Total Unplatted Area = +/- 170 Acres

Platted Undeveloped Area + Unplatted Area = 324.4 Acres
(Area available for Drainage fee Assessment)

Total Developer Costs = $349,821.47

- Collected Drainage Fees= 14,194.43

= Adjusted Total Cost = 335,627.04

Cost Per Acre = $\frac{\$335,627.04}{324.4 \text{ Acres}}$ = $1,034.61/Acre + 10% Eng. & Contin.
Cost Per Acre = $1138.00

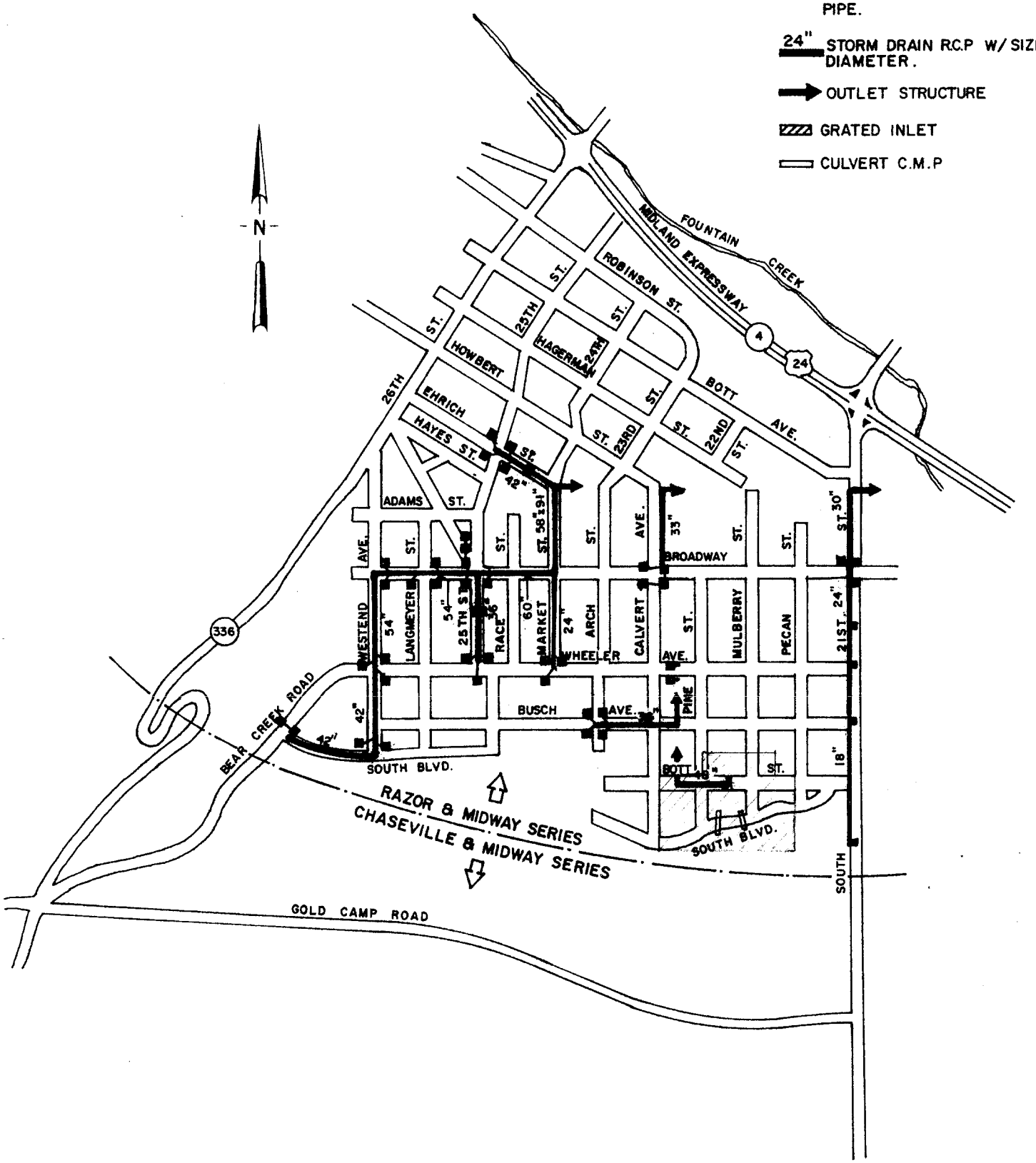
Total City Appropriated Funds Cost = $578,906.64

Remodeling of Existing = $10,727.96
Drainage Structures
(See Page 34)

Total Project Cost = $925,261.64

## SUMMARY OF AREA IN BASIN

| | ACRES | SQ. MILES | PERCENTAGE |
|---|---|---|---|
| In City Limits | 167.8 | 0.262 | 40.2 |
| In County Limits | 249.9 | 0.390 | 59.8 |
| TOTAL | 417.7 | 0.652 | 100.0 |




## STORM DRAIN PIPING SYSTEM

## SOUTH 21st BASIN

Hydraulic Calculations for Flow in Open Channels and Non-Presurized Pipe

Form: Mannings Equation

$$V = \frac{c}{n} \quad R\ 2/3 \quad s\ 1/2$$

Where:

V = Velocity in feet per second

C = Coefficient = 1.486

n = Mannings Coefficient

R = Hydraulic radius

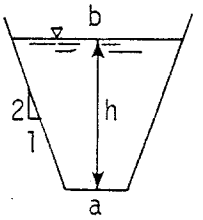
S = Slope in feet per 100 feet

## SUMMARY MANNING'S n VALUES

| | | | | |
|---|---|---|---|---|
| Concrete Lined | - | n | = | .013 |
| Earth Bottom, Concrete Sides | - | n | = | .022 |
| Earth or Rubble Bottom, Rubble Sides | - | n | = | .033-0.04 |
| Natural Stream | - | n | = | .04 |
| Natural Stream | - | n | = | .05 |
| Concrete Pipe or Culvert Box | - | n | = | .013 |
| CMP (3" x 1") | - | n | = | .027 |
| Asphaltic Pavement | - | n | = | .019 |
| Smooth Flow Pipes | - | n | = | .013 |

Example: Open Channel Calculations

Equation: Mannings
n = 0.013
Q = 180 cfs
Slope = 2.00% = 0.02




$$\text{Area} = \frac{1}{2}(a+b)\,h = \frac{(2a+h)\,h}{2}$$

$$WP = a+2\left(h^2 + \frac{h^2}{4}\right)^{1/2}$$

$$R = \frac{\text{Area}}{WP} = \frac{\frac{(2a+h)h}{2}}{a+2h\left(\frac{5}{4}\right)^{1/2}}$$

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

$$Q = VA$$

Solution: Size: a = 3.0 ft
h = 2.5 ft + F.S.
V = 18.63 fps
Q = 198 cfs

Example: Pipe Flow Calculations

(Non-Pressurized)

Equation = Mannings

$n = .013$

$Q = 315$ cfs

Slope = 6.77%

$$\text{Area} = \frac{\pi D^2}{4}$$

$$R = \frac{D}{4}$$

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

$$Q = VA$$

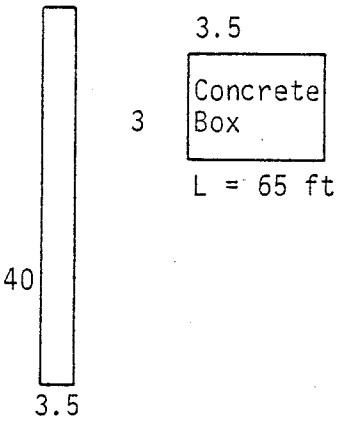
Solution: Size: D = 48"

V = 29.7 fps

Q - 373 cfs

HYDROGRAPH POINT #7

Existing Culvert on Broadway at Market




Drop = 1.0'

$S = \frac{1}{65} = .0154$

For Box

$A = 10.5\ ft^2$

$WP = 13\ ft$

$R = \frac{10.5}{13} = .8077$

$V = \frac{1.486}{.013} (.8077)^{2/3} (.0154)^{1/2} = 12.30\ fps$

$Q = VA = (12.30)(10.5) = 129.18\ cfs$

For grate

$Q = CA\sqrt{2gh} = (.6)(40)(3.5)\sqrt{32.2}$

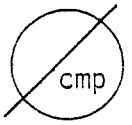
Q = 476.66 cfs

Q clogged = 317.7

Max Flow Allowable = 129.2 cfs

## HYDROGRAPH POINTS #8 TO 9

Existing Culverts on Enrich




Slope = 2.34%

$$A = \pi \quad (1.5)^2 = 1.767$$

$$R = \frac{D}{4} = \frac{1.5}{4} = .375$$

$$V = \frac{1.486}{.027} (.375)^{2/3} (.0234)^{1/2} = 4.378 \text{ fps}$$

$$Q = VA = 7.74 \text{ cfs} \quad @$$

HYDROGRAPH POINT #13

Existing Culvert on Busch between Colvert & Pine

35 LF

44"

70 LF CMP
60' Ø

For Pipe: $A = \frac{\pi \frac{66^2}{12}}{4} = 23.76 \text{ ft}^2$

$R = \frac{D}{4} = \frac{\frac{66}{12}}{5} = 1.375$

$S = \frac{1.1}{70} = .0157$

$V = \frac{1.486}{.027} (1.375)^{2/3} (.0157)^{1/2}$

$V = 8.53$ fps

$Q = VA = 202.69$ cfs

For Grating:

Assume 60% clear opening
Assume Max head to be curb heights = .5'
Seelye: $Q = CA\sqrt{2gh}$

c= .6
$A = (35)\frac{44}{12} = 128.33$
g = 32.2
h = .5'

$Q = (.6)(12833)[2)(32.2)(.5)]^{1/2}$
Q = 436.93 cfs
Q clogged = 291.28

Max Flow in present conditions = 203 cfs

HYRDRGRAPH POINT #14

Existing 3 side by side Culverts at Wheeler & Pine

Lowheads: 3' High = 36"
4' Wide = 48" 44" Ø circulate
53 lf
Drop = .75'
N = .027

$$A = \frac{D^2}{4} = \frac{\pi \left(\frac{44}{12}\right)^2}{4} = 10.56 \text{ ft}^2$$

$$WP = \pi D = \pi \left(\frac{44}{12}\right) = 11.52$$

$$R = \frac{A}{WP} = \frac{10.56}{11.52} = 0.917$$

$$S = \frac{.75}{53} = 0.0142$$

$$V = \frac{1.486}{.027} (.917)^{2/3} (.0142)^{1/2} = \underline{6.18 \text{ fps}}$$

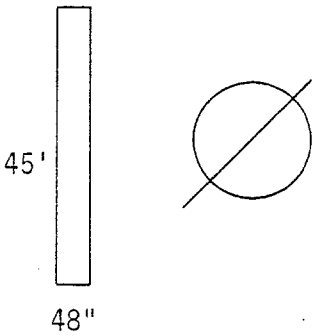
$$Q = VA \ (6.18)(.10.56) = 65.24 \text{ cfs}$$

Qt = 3Q = 195.7 cfs

## HYDROGRAPH POINT #15

Existing Culvert on Wheeler at Mulberry

Lowhead equal D =54" CMP




$$A = \frac{\pi \left(\frac{54}{12}\right)^2}{4} = 15.904 \text{ ft}^2$$

$$WP = \pi D = 14.137$$

$$R = \frac{D}{4} = \frac{54}{58} = 1.125$$

$$\text{Slope} = \frac{.43}{50} = .0086$$

$$V = \frac{1.486}{.027} (1.125)^{2/3} (.0086)^{1/2} = 5.52 \text{ fp}$$

$$Q = VA = (5.52)(15.904) = 87.80 \text{ cfs}$$

Q clogged = 58.53

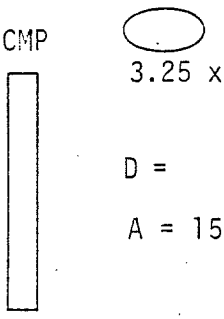
(Pipe Controls)

## HYDROGRAPH POINT #16

Existing Culvert on Broadway at Mulberry

for through pipe

CMP



3.25 x 5.25

D = 54 "

A = 15.904

R = 1.125

Slope = $\frac{4.5'}{60}$ = .0750

$V = \frac{1.486}{.027} (1.125)^{2/3}(.075)^{1/2} = 16.304$ fps

Q = VA = 259.3 cfs

For Gratings & Pipe

$Q = (.6)\ (2)\ (16)\ \sqrt{32}\ \ (2/3)$

Q = 72.407 cfs

Max flow in other pipe = 72.4 cfs

## HYDROGRAPH POINT #17

Existing Culvert at Calvert & Broadway

4' ID CMP
65 LF
4 ft Drop

N = 0.027

Slope = $\frac{(.4)}{(65)}$ (100) = 0.62% = 5

Area = 12.57 $ft^2$

$V_o$ = 1.4860 fps
$Q_o$ = 18.67 cfs

$$\frac{\sqrt{S}}{N} = \frac{\sqrt{.0062}}{.027} = 2.9054$$

V = (1.4860) (2.9054) = 4.32 fps
Q = (18.67) (2.9054) = 54.244 cfs

Method II:

$A = \frac{(\pi)(16)}{4} = 4 = 12.56\ ft^2$

$WP = \pi D = 12.57\ ft^2$

R = 1

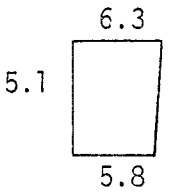
$S = \frac{.4}{65} = .0062$

$V = 14.86\ (1)^{2/3}(.0062)^{1/2} = 4.32$ fps

Q = VA = (4.32)(12.57) = 54.27 cfs OK Check

## HYDROGRAPH POINT #18

Existing Box Culvert at end of Culvert




Drop = 1.75'
L = 35'

$A = \frac{(6.3 + 5.8)}{2} (5.1) = 30.855$ ft

WP = 6.3 = 5.8 + 10.2 = 22.3

$R = \frac{A}{WP} = 1.394$

$V = \frac{1.486}{.013} (1.394)^{2/3} \frac{(1.75)^{1/2}}{35} = 31.75$ fps

$Q = VA = 980$ cfs

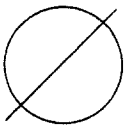
BWTWEEN HYDROGRAPH POINTS #19 & 21

Existing Culverts above 21st Street

$$A = \frac{\pi (36)}{4} = 28.27$$

2 @

$$R = \frac{6}{4} = 1.5$$



6'

60 LF CMP

$$\text{Slope} = \frac{.2}{60} = .0033$$

$$V = \frac{1.486}{.027} (1.5)^{2/3} (.0033)^{1/2}$$

$$V = 4.164 \text{ fps}$$

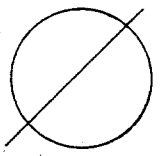
$$Q = VA = 117.7$$

$$\underline{Q_t = 2Q = 235.4 \text{ cfs}}$$

## HYDROGRAPH POINT #21

Existing culverts leading into 21st Street

2 @



7' CMP

160 LF

$$A = \frac{(\pi)\ (49)}{4} = 38.48$$

$$R = \frac{D}{4} = \frac{7}{4} = 1.75$$

$$\text{Slope} = \frac{4.5}{110} = .0409$$

$$V = \frac{1.486}{.027} \quad (1.75)^{2/3}\ (.0490)^{1/2}$$

$$V = 16.165 \text{ fps}$$

$$Q = VA = 622.05 \text{ cfs}$$

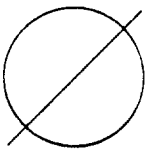
$$Qt = 2Q = 1244 \text{ cfs}$$

Drain Above: 3' x 1.5' A =4.5

$$Q = (.6)(4.5)(32)^{1/2}(2/3)$$

$$\underline{Q = 10.18 \text{ cfs}}$$

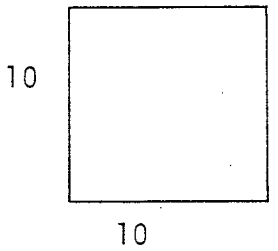
Connecting Pipe:



18" one in both culverts

HYDROGRAPH POINT #22

Existing Box Culvert Under 21st Street




$A = 100\ ft^2$

$WP = 40\ ft$

$R = \frac{10}{4} = 2.5$

Slope = .0409

$$V = \frac{1.486}{.013}(2.5)^{2/3}(.0409)^{1.2}$$

$V = 42.58$ fps

$Q = VA = 4258$ cfs

Existing Culvert Across 26th Street

21" Concrete Pipe Ø

65 LF
N = .013
5.6' Drop

$$\text{Slope} = S = \frac{5.6}{65} = .086$$

$$\text{Area} = \pi \frac{D^2}{4} = (\pi)\ \frac{(\frac{21}{12})^2}{4} = 2.405\ ft^2$$

$$WP = \pi D = (\pi)\ (\frac{21}{12}) = 5.498\ ft$$

$$R = \frac{A}{WP} = \frac{2.405}{5.498} = .437$$

$$V = \frac{1.486}{.013}\ (.437)^{2/3}\ (.086)^{1/2} = \underline{19.317\ fps}$$

$$\underline{Q = VA = 416.458\ cfs}$$

## STREET SYSTEM DATA AND CALCULATIONS

| STREET | FROM/TO | LENGTH (ft) | SLOPE (%) | WIDTH (ft.) | RIGHT OF WAY | ELEV. FR/TO | STREET CAPACITY (V/Q) |
|---|---|---|---|---|---|---|---|
| South | Westend/Langmeyer | 380 | 3.95 | 32 | 60 | 228/213 | 11.4/81.3 |
| South | Langmeyer/Race | 500 | 1.40 | 32 | 60 | 213/206 | 6.8/48.3 |
| Busch | Westend/Langmeyer | 380 | 2.89 | 32 | 60 | 195/184 | 9.8/69.5 |
| Busch | Langmeyer/Race | 100/200/215 | 3.00/2.50/2.33 | 32 | 60 | 184/181 | 9.98/70.9/8.15/57.8/8.8/62.4 |
| Busch | Race/Arch | 810 | 3.70 | 32 | 60 | 181/151 | 11.1/78.6 |
| Busch | Arch/Calvert | 380 | 3.68 | 32 | 60 | 151/137 | 11.0/78.4 |
| Busch | Calvert/Pine | 200/180 | 3.50/+.56 | 32 | 60 | 137/129 | 10.78/76.5/4.3/30.3 |
| Busch | Pine/Mulberry | 380 | .53 | 32 | 60 | 129/127 | 4.2/29.6 |
| Busch | Mulberry/Pecan | 360 | -1.67 | 32 | 60 | 127/133 | 7.43/52.7 |
| Busch | Pecan/21st Street | 380 | -2.89 | 32 | 60 | 133/144 | 9.8/69.5 |
| Wheeler | Westend/Langmeyer | 380 | 4.74 | 32 | 60 | 181/163 | 12.5/89.1 |
| Wheeler | Langmeyer/25th | 380 | 4.21 | 32 | 60 | 163/147 | 11.8/83.9 |
| Wheeler | 25th/Race | 240 | -.42 | 32 | 60 | 147/148 | - |
| Wheeler | Race/Market | 40/330 | -1.25/1.67 | 32 | 60 | 143/143 | 6.4/45.5/7.43/52.7 |
| Wheeler | Market/Arch | 80/280 | -.63/2.68 | 32 | 60 | 143/136 | 4.5/320/9.4/66.9 |
| Wheeler | Arch/Calvert | 380 | 2.89 | 32 | 60 | 136/125 | 9.8/69.5 |
| Wheeler | Calvert/Mulberry | 730 | 2.47 | 32 | 60 | 125/107 | 9.1/64.3 |
| Wheeler | Mulberry/Walnut/Pecan | 380 | -2.37 | 32 | 60 | 107/116 | 8.9/62.9 |
| Wheeler | Walnut/21st | 100/370 | -1.5/1.22 | 32 | 60 | 116/114 | 7.06/50.1/6.3/44.9 |
| Broadway | Westend/Langmeyer | 380 | 4.21 | 50 | 100 | 163/147 | 11.8/83.9 |
| Broadway | Langmeyer/25th | 380 | 3.68 | 50 | 100 | 147/133 | 11.0/78.4 |
| Broadway | 25th/Race | 230 | 3.91 | 50 | 100 | 133/124 | 11.4/80.8 |
| Broadway | Race/Market | 350 | 2.00 | 50 | 100 | 124/117 | 8.15/57.8 |
| Broadway | Market/Arch | 60/320 | -.83/2.34 | 32 | 100 | 117/110 | 5.2/36 8.8/62.5 |
| Broadway | Arch/Calvert | 380 | 3.68 | 32 | 100 | 110/96 | 11.0/78.4 |
| Broadway | Calvert/Mulberry | 730 | 1.78 | 32 | 100 | 96/83 | 7.67/54.4 |
| Broadway | Mulberry/Pecan | 380 | 1.58 | 32 | 100 | 83/77 | 7.23/51.3 |
| Broadway | Walnut/21st | 350 | 3.14 | 32 | 100 | 77/66 | 10.2/72.5 |
| Adams | Westend/Langmeyer | 380 | 5.53 | 36 | 100 | 165/144 | 8.4/97.1 |
| Adams | Langmeyer/Modes | 150 | 2.67 | 36 | 100 | 144/140 | 5.9/67.5 |
| Adams | Modes/25th | 250 | 4.40 | 36 | 100 | 140/129 | 7.5/86.6 |
| Bear Creek | South/Westend | 920 | 6.41 | 32 | 60 | 6240/6181 | 9.1/104.5 |
| Hayes | 26th/25th | 830 | 3.86 | 36 | 60 | 153/121 | 7.1/81.1 |
| Enrich | 26th/25th | 770 | 4.03 | 36 | 60 | 145/114 | 7.2/82.9 |
| Enrich | 25th/Market | 470 | 2.34 | 36 | 60 | 114/103 | 5.5/63.2 |
| Howbert | 26th/25th | 670 | 3.73 | 36 | 60 | 136/111 | 6.9/79.7 |
| Howbert | 25th/Market | 540 | 2.96 | 36 | 60 | 11/95 | 6.2/71.0 |
| Howbert | Market/Arch | 430 | 1.86 | 36 | 60 | 95/87 | 4.9/56.3 |
| Westend | South/Busch | 270 | 12.22 | 36 | 80 | 228/195 | 12.5/144.3 |
| Westend | Busch/Wheeler | 400 | 3.50 | 36 | 80 | 195/181 | 6.7/77.2 |
| Westend | Wheeler/Broadway | 700 | 2.57 | 36 | 80 | 181/163 | 5.8/66.2 |
| Westend | Broadway/Adams | 440 | -0.50 | 36 | 80 | 163/165 | 2.5/29.2 |
| Westend | Adams/26th | 550 | -.91 | 36 | 80 | 165/170 | 3.4/39.4 |
| Langmeyer | South/Busch | 200 | 14.5 | 36 | 60 | 213/184 | 13.7/157.2 |
| Langmeyer | Busch/Wheeler | 400 | 5.25 | 36 | 60 | 184/163 | 8.2/94.6 |
| Langmeyer | Wheeler/Broadway | 700 | 2.29 | 36 | 60 | 163/147 | 5.4/62.5 |

## STREET SYSTEM DATA AND CALCULATIONS
(continued)

| STREET | FROM/TO | LENGTH (ft) | SLOPE (%) | WIDTH (ft.) | RIGHT OF WAY | ELEV. FR/TO | STREET CAPACITY (V/Q) |
|---|---|---|---|---|---|---|---|
| Langmeyer | Broadway/Adams | 430 | .70 | 36 | 60 | 147/144 | 3.0/34.5 |
| Race | South/Busch | 200 | 12.50 | 36 | 60 | 206/181 | 12.7/146.0 |
| Race | Busch/Wheeler | 420 | 8.10 | 36 | 60 | 181/147 | 10.2/117.5 |
| Race | Wheeler/Broadway | 700 | 3.29 | 36 | 60 | 147/124 | 6.5/74.9 |
| 25th | Wheeler/Broadway | 600 | 2.00 | 60 | 80 | 147/133 | 4.3/54.2 |
| 25th | Broadway/Adams | 430 | .93 | 60 | 80 | 133/129 | 3.0/37.0 |
| Market | Wheeler/Broadway | 700 | 3.71 | 36 | 60 | 143/117 | 6.9/79.5 |
| Market | Broadway/Enrich | 700 | 2.00 | 36 | 60 | 117/103 | 5.1/58.4 |
| Arch | Busch/Wheeler | 430 | 3.49 | 36 | 60 | 151/136 | 6.7/77.1 |
| Arch | Wheeler/Broadway | 700 | 3.71 | 36 | 60 | 136/110 | 6.9/79.5 |
| Arch | Broadway/Howbert | 800 | 2.89 | 36 | 60 | 110/87 | 6.1/70.2 |
| 23rd | Howbert/Hagerman | 380 | 2.63 | 36 | 60 | 87/77 | 5.8/67.0 |
| 23rd | Hagerman/Bott | 400 | - | 36 | 60 | 77/- | - |
| Calvert | Busch/Wheeler | 420 | 2.86 | 60 | 100 | 137/125 | 5.2/64.8 |
| Calvert | Wheeler/Broadway | 700 | 4.14 | 60 | 100 | 125/96 | 6.2/78.0 |
| Pine | Busch/Wheeler | 420 | 4.29 | 32 | 60 | 129/111 | 11.9/84.7 |
| 21st | View La./ Bott Ave. | 1300 | 5.85 | 36 | 80 | 246/170 | 8.7/99.9 |
| 21st | Bott Ave./Busch | 400 | 6.50 | 36 | 80 | 170/144 | 9.2/105.3 |
| 21st | Busch/Wheeler | 420 | 7.14 | 36 | 80 | 144/114 | 9.6/110.3 |
| 21st | Wheeler/Broadway | 700 | 6.86 | 36 | 80 | 114/66 | 9.4/108.1 |
| 21st | Broadway/7-11 | 480 | 3.54 | 60 | 100 | 66/49 | 5.8/72.1 |
| Market | Enrich/Howbert | 340 | 2.35 | 36 | 40 & 60 | 103/95 | 5.5/63.3 |
| 24th | Howbert/Haggerman | 400 | 4.00 | 36 | 60 | 95/79 | 7.2/82.6 |
| 24th | Haggerman/Bott | 400 | - | 36 | 60 | - | - |
| South | Bear Creek/Westend | 680 | 1.76 | 32 | 60 | 240/228 | 7.6/54.1 |
| Bott | Arch/Pine | 750 | 2.33 | 32 | 60 | 165/147.5 | 8.8/62.4 |
| Bott | Pine/Mulberry | 220/130 | .23/-.40 | 32 | 60 | 147.5/147.5 | -/3.7/26.5 |
| Bott | Mulberry/Pecan | 350 | -3.00 | 32 | 60 | 147.5/158 | 9.98/70.9 |
| Bott | Pecan/21st | 400 | -.75 | 32 | 60 | 158/161 | 4.9/34.9 |
| South | Arch/Calvert | 250/150 | 3.60/-67 | 32 | 80 | 180/172 | 10.9/77.6/4.7/33.0 |
| South | Calvert/Pine | 200/100/100 | 1.50/-5.09/3.0 | 32 | 80 | 172/171 | 7.06/50.1/12.89/91.5/9.98/70.9 |
| South | Pine/Mulberry | 380 | 0.26 | 32 | 80 | 171/170 | - |
| South | Mulberry/Pecan | 400 | -2.50 | 32 | 80 | 170/180 | 9.11/64.7 |
| South | Pecan/Bott | 300 | 4.67 | 32 | 80 | 180/166 | 12.4/88.4 |
| Pine | Bott/Busch | 400 | 4.63 | 32 | 60 | 147.5/129 | 12.4/88.0 |
| Mulberry | Bott/Busch | 400 | 5.13 | 32 | 60 | 147.5/127 | 13.1/92.6 |
| Pecan | Bott/Busch | 400 | 6.25 | 32 | 60 | 158/133 | 14.3/102.0 |
| Pine | Wheeler/Broadway | 700 | 3.43 | 32 | 60 | 11/87 | 10.7/75.7 |

HYDROGRAPH POINT DATA

| HYDROGRAPH POINT | DROP (ft) | LENGTH (ft) | SLOPE (%) | ACCUM. BASIN AREA (sq.mi.) | Tc (hr) | CN | Q (in) | qp (csm/in) | q TOTAL (cfs) | Tp (hr) | Tb (hr) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 216 | 2800 | 7.71 | .0600 | .157 | 91 | 2.55 | 1150 | 175 | 3.09 | 8.25 |
| 1A | 200 | 2100 | 9.52 | .0282 | .116 | | | 1230 | 88 | 3.07 | 8.20 |
| 1B | 200 | 2100 | 9.52 | .0133 | .116 | | | 1230 | 42 | 3.07 | 8.20 |
| 2 | 270 | 3200 | 8.44 | .0936 | .169 | | | 1120 | 265 | 3.10 | 8.28 |
| 3 | 285 | 3900 | 7.31 | .1354 | .207 | | | 1060 | 365 | 3.12 | 8.34 |
| 4 | 93 | 1100 | 8.50 | .0267 | .074 | | | 1280 | 35 | 3.04 | 8.13 |
| 5 | 316 | 4600 | 6.87 | .1807 | .241 | | | 1000 | 460 | 3.14 | 8.40 |
| 6 | 43 | 800 | 5.37 | .0103 | .069 | | | 1280 | 35 | 3.04 | 8.12 |
| 7 | 335 | 5200 | 6.44 | .2108 | .272 | | | 950 | 510 | 3.16 | 8.44 |
| 8 | 86 | 1500 | 5.73 | .0439 | .109 | | | 1280 | 145 | 3.06 | 8.18 |
| 9 | 350 | 5800 | 5.98 | .2762 | .306 | | | 910 | 640 | 3.18 | 8.50 |
| 10 | 190 | 2900 | 6.55 | .0854 | .172 | | | 1110 | 240 | 3.10 | 8.29 |
| 11 | 153 | 1500 | 10.20 | .0492 | .087 | | | 1280 | 160 | 3.05 | 8.15 |
| 12 | 150 | 1600 | 9.37 | .0390 | .095 | | | 1280 | 125 | 3.06 | 8.16 |
| 13 | 230 | 3700 | 6.22 | .1736 | .212 | | | 1050 | 465 | 3.13 | 8.35 |
| 14 | 248 | 4100 | 6.05 | .1845 | .232 | | | 1005 | 475 | 3.14 | 8.38 |
| 15 | 40 | 800 | 5.00 | .0311 | .071 | | | 1280 | 100 | 3.04 | 8.12 |
| 16 | 276 | 4900 | 5.63 | .2389 | .273 | | | 950 | 580 | 3.16 | 8.45 |
| 17 | 60 | 1200 | 5.00 | .0166 | .097 | | | 1280 | 55 | 3.06 | 8.16 |
| 18 | 365 | 6650 | 5.49 | .3292 | .349 | | | 860 | 720 | 3.21 | 8.57 |
| 19 | 380<br>290 | 7250<br>5500 | 5.24<br>5.27 | .3545<br>.2389 | .380<br>.307 | | | 830<br>910 | 750<br>555 | 3.23<br>3.18 | 8.62<br>8.50 |
| 20 | 200 | 2800 | 7.14 | .0245 | .162 | | | 1140 | 70 | 3.10 | 8.27 |
| 21 | 400 | 7150 | 5.59 | .6330 | .367 | | | 850 | 1300 | 3.22 | 8.60 |
| 22 | 410 | 7200 | 5.69 | .6330 | .367 | | | 850 | 1370 | 3.22 | 8.60 |

## CHANGES IN DEFICIENT EXISTING DRAINAGE STRUCTURES

| LOCATION | EXISTING | CHANGES REQUIRED | ESTIMATED COST |
|---|---|---|---|
| Along Enrich | 2 @ 18" CMP | Remove Culverts | $ 45.00 |
| At Broadway & Calvert | 48" CMP | Remove Culvert | 50.00 |
| At Pine & Wheeler | 3 @ 36"x48" CMP | Remove Culverts<br>Replace with<br>2 @ 53 LF 54" RCP<br>@ 2.00% grade | $ 6,558.98 |
| At Wheeler & Mulberry = | 54" Ø Lowhead CMP | Remove Culvert<br>Replace with 5 LF<br>42" RCP @ 2.00% grade | $ 317.85 |
| At Point #18 | 5'x6' Cinder Block Conduit | Remove Culvert<br>Replace with 35 LF<br>66" RCP | $ 3,306.13 |
| At End of Pecan | 2 @ 72" CMP | Remove and lay to 1.7% grade | $ 175.00 |
| At West end & Wheeler | Dikes | Remove Dikes | $ 275.00 |
| | | TOTAL | $10,727.96 |

## DRAINAGE STRUCTURE INVENTORY

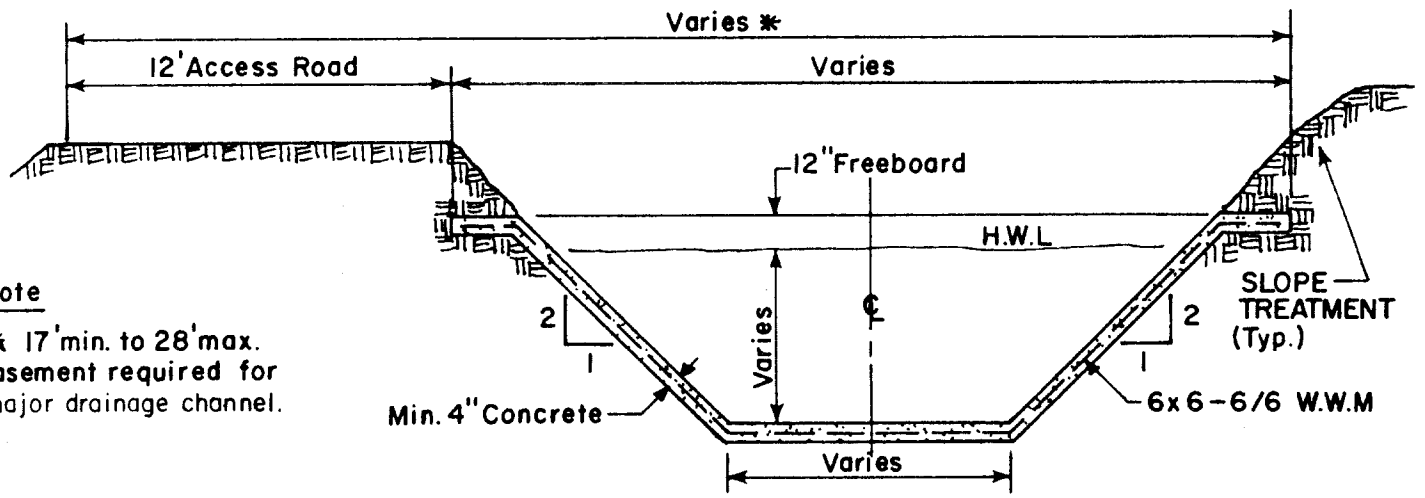
| LOCATION | EXISTING STRUCTURE | $q_p$ EXISTING (cfs) | $q_p$ REQUIRED (cfs) | REQUIRED STRUCTURE |
|---|---|---|---|---|
| Along Bear Creek | - | - | 130 | 2600 L.F. 1.5x2" Lined Channel |
| At Bear Creek & South | - | - | 130 | Flaired Intake Diversion Structures |
| Along South: Bear Creek to Westend | - | - | 130 | 650 L.F. 42" RCP |
| At Westend & South | - | - | 55 | 2@10' - D1OR |
| Along Westend: South to Wheeler | - | - | 175 | 650 L.F. 42" RCP |
| At Westend & Wheeler | Dikes | - | 105 | 3@12' - D1OR |
| Along Westend: Wheeler to Broadway | - | - | 265 | 700 L.F. 54" RCP |
| West of Westend (South) | - | - | 95 | 700 L.F. 2'x2.5' Lined Channel |
| West of Westend (North) | - | - | 85 | 500 L.F. 2'x2.5' Lined Channel |
| At Westend & Broadway | - | - | 25 | 150 L.F. 2'x3' Lined Channel, Flaired Intake 2@ 6'-D1OR |
| Along Broadway: Westend to 25th | - | - | 365 | 750 L.F. 54" RCP |
| At Broadway & Langmeyer | - | - | 40 | 3@ 6'-D1OR |
| At Broadway & 25th | - | - | 30 | 3@ 6'-D1OR |
| At Modes and 25th | - | - | 45 | 2@ 10'-D1OR |
| At Wheeler & 25th | - | - | 85 | 3@ 10'-D1OR |
| Along 25th: Wheeler to Broadway | - | - | 85 | 700 L.F. 36" RCP |
| Along Broadway: 25th to Market | - | - | 465 | 600 L.F. 60" RCP |
| At Wheeler & Market | - | - | 35 | 2@ 6'-D1OR, 1@ 4'-D1OR |
| Along Market: Wheeler to Broadway | - | - | 35 | 700 L.F. 24" RCP |
| At Broadway & Market | 3.5'x40' Grated Inlet | 130 | 35 | - - - - - |
| Along Market: Broadway to Enrich | - | - | 510 | 650 L.F. 58"x91" RCP |
| At 25th & Enrich | - | - | 145 | 4@ 16' - D1OR |
| Along Enrich: 25th to Market | - | - | 145 | 550 L.F. 42" RCP |
| At Arch & Busch | - | - | 125 | 4@ 12' - D1OR |
| Along Busch: Arch to Major Channel | 44"x35' Grated Inlet | 203 | 125 | 550 L.F. 36" RCP |
| On Bott St: Between Mulberry & Pine | - | - | 160 | 1@ 4'x32' Grated Inlet |
| Along Bott St. | - | - | 160 | 350 L.F. 48" RCP |
| At Pine & Wheeler | - | - | 50 | 2@ 8' - D1OR |
| At Broadway & Calvert | - | - | 55 | 4@ 6' - D1OR |
| At 21st & Broadway | 1@4' D1OR | 10 | 40 | 2@ 6' - D1OR |
| At 21st & Above Bott St. | - | - | 30 | 1@ 10' - D1OR |
| Along 21st, Wheeler to Broadway | - | - | 75 | 700 L.F. 24" RCP |
| Along 21st, Between Wheeler & Broadway | - | - | Minimum | 1@4' - D1OR |

DRAINAGE STRUCTURE INVENTORY (continued)

| LOCATION | EXISTING STRUCTURE | qp EXISTING (cfs) | qp REQUIRED (cfs) | REQUIRED STRUCTURE |
|---|---|---|---|---|
| Along 21st, Above Bott St. to Wheeler | - | - | 30-40 | 1350 L.F. 18" RCP |
| At 21st & Busch | - | - | Minimum | 1@4' - D1OR |
| At 21st & Wheeler | - | - | Minimum | 1@4' - D1OR |
| Along Mulberry: Wheeler to Broadway | - | - | 100 | 600 L.F. 2'x3' Lined Channel |
| Along 21st: Broadway to Major Channel | - | - | 70 | 500 L.F. 30" RCP |
| UPPER Major Channel to Point #10 | - | - | 0-240 | 2300 2'x2.5' - 3'x3.75' Lined Channel |
| Major Channel: #10 to #13 | - | - | 240 -350 | 700 L.F. 3'x3.75' Lined Channel |
| Major Channel: #13 to #14 | - | - | 465 | 400 L.F. 3'x4.5" Lined Channel |
| Major Channel: #14 to #16 | - | - | 475 | 850 L.F. 3.5'x4.75' Lined Channel |
| Major Channel: #16 to #19 | - | - | 580 | 500 L.F. 3.5'x5.5' Lined Channel |
| Major Channel: #9 to #18 | - | - | 640 | 750 L.F. 3.5'x5.5' Lined Channel |
| Major Channel: #18 to #19 | - | - | 720 | 800 L.F. 4'x5.75' Lined Channel |
| Major Channel: #19 to #21 | - | - | 1300 | 700 L.F. 5'x7' Lined Channel |
| Along Enrich | 2 @ 18" CMP | Min. | - | Curb & Gutter |
| At Broadway & Calvert | 48" CMP | 54 | 55 | Replace w/ 4@ 6' - D1OR |
| Along Calvert: Broadway to Major Channel | - | - | 55 | 650 L.F. 33" RCP |
| Along Busch: Between Calvert & Pine | 44" x 35' Grated Inlet | 203 | 40 | - |
| Along South: Between Pine & Mulberry | - | - | 100 | 2@ 80L.F. 21" RCP At Ground Grade |
| At Pine and Wheeler | 3 @ 36"x48" CMP | 195 | 475 | 2@ 53 L.F. 54" RCP @ 2.00 % |
| At Wheeler & Mulberry | 4' x 45' Grated Inlet | 400 | 100 | - |
| At Wheeler & Mulberry | 54" Lowhead CMP | 58 | 100 | 5 L.F. 42" RCR @ 2.00% |
| At Broadway & Mulberry | 2 @ 4'x4' Grated Inlet | 75 | 45 | - |
| At Broadway & Mulberry | 2 @ 3.25' x 5.25' Ellipse | 620 | 580 | - |
| At Point #18 | 5'x6' Cinder Block Conduit | 980 | 720 | 35 L.F. 66" RCP |
| At End of Pecan | 2 @ 72" CMP | 235 | 1300 | Increase Grade to 1.7% |
| On West side of 21st Street | 2 @ 84" CMP | 1244 | 1300 | - |
| Under 21st Street | 10'x10' Concrete Conduit | 4250 | 1300 | - |

DRAINAGE BASIN IMPROVEMENTS INVENTORY SUMMARY

| ITEM | DIAMETER (in) | LENGTH (ft) | DIMENSIONS (in) | QUANTITY |
|---|---|---|---|---|
| RCP | 18" | 1400 | - | - |
| RCP | 21" | 160 | - | - |
| RCP | 24" | 1400 | - | - |
| RCP | 27" | 70 | - | - |
| RCP | 30" | 500 | - | - |
| RCP | 33" | 650 | - | - |
| RCP | 36" | 1250 | - | - |
| RCP | 42" | 1900 | - | - |
| RCP | 48" | 325 | - | - |
| RCP | 54" | 1400 | - | - |
| RCP | 60" | 500 | - | - |
| RCP | - | 650 | 58"x91" | - |
| Catch Basins | - | - | 4' DIOR | 5 |
| Catch Basins | - | - | 6' DIOR | 16 |
| Catch Basins | - | - | 8' DIOR | 2 |
| Catch Basins | - | - | 10' DIOR | 11 |
| Catch Basins | - | - | 12' DIOR | 7 |
| Catch Basins | - | - | 16' DIOR | 4 |
| Grated Inlets | - | - | 4'x32' | 1 |
| Lined Channels | - | 2600 | 1.5'x2' | - |
| Lined Channels | - | 1900 | 2'x2.5' | - |
| Lined Channels | - | 750 | 2'x3' | - |
| Lined Channels | - | 2300 | 3'x3.75' | - |
| Lined Channels | - | 1300 | 3.5'x5.5' | - |
| Lined Channels | - | 400 | 3'x4.5' | - |
| Lined Channels | - | 800 | 3.5'x4.75' | - |
| Lined Channels | - | 750 | 5'x7' | - |
| Flaired End Sections | - | - | - | 3 |
| Manholes | - | - | - | 21 |




Note

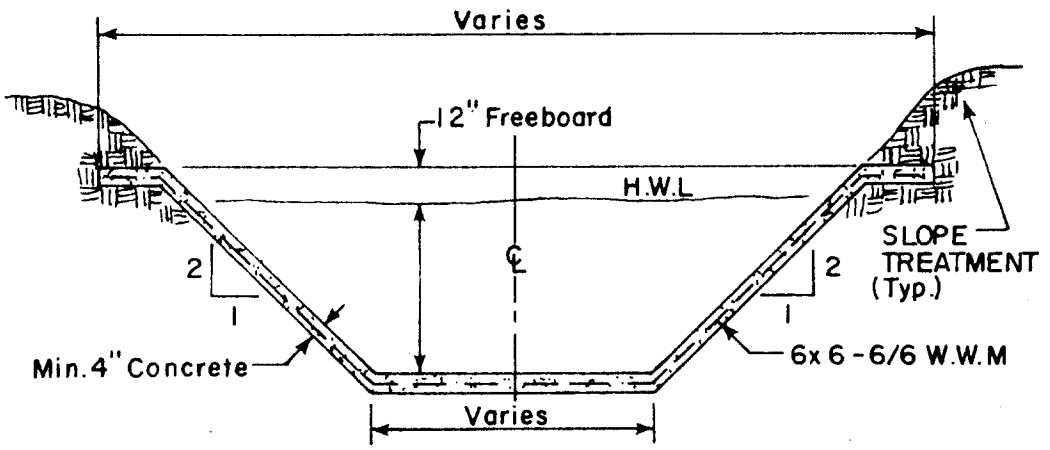
* 17'min. to 28'max. easement required for major drainage channel.

# Major Drainage Channel

r. keith hook & associates, inc.

PHONE 473-5653 2545 E. PLATTE PLACE COLORADO SPRINGS, COLORADO 80909

FIGURE - 1




# Drainage Channel



FIGURE - 2

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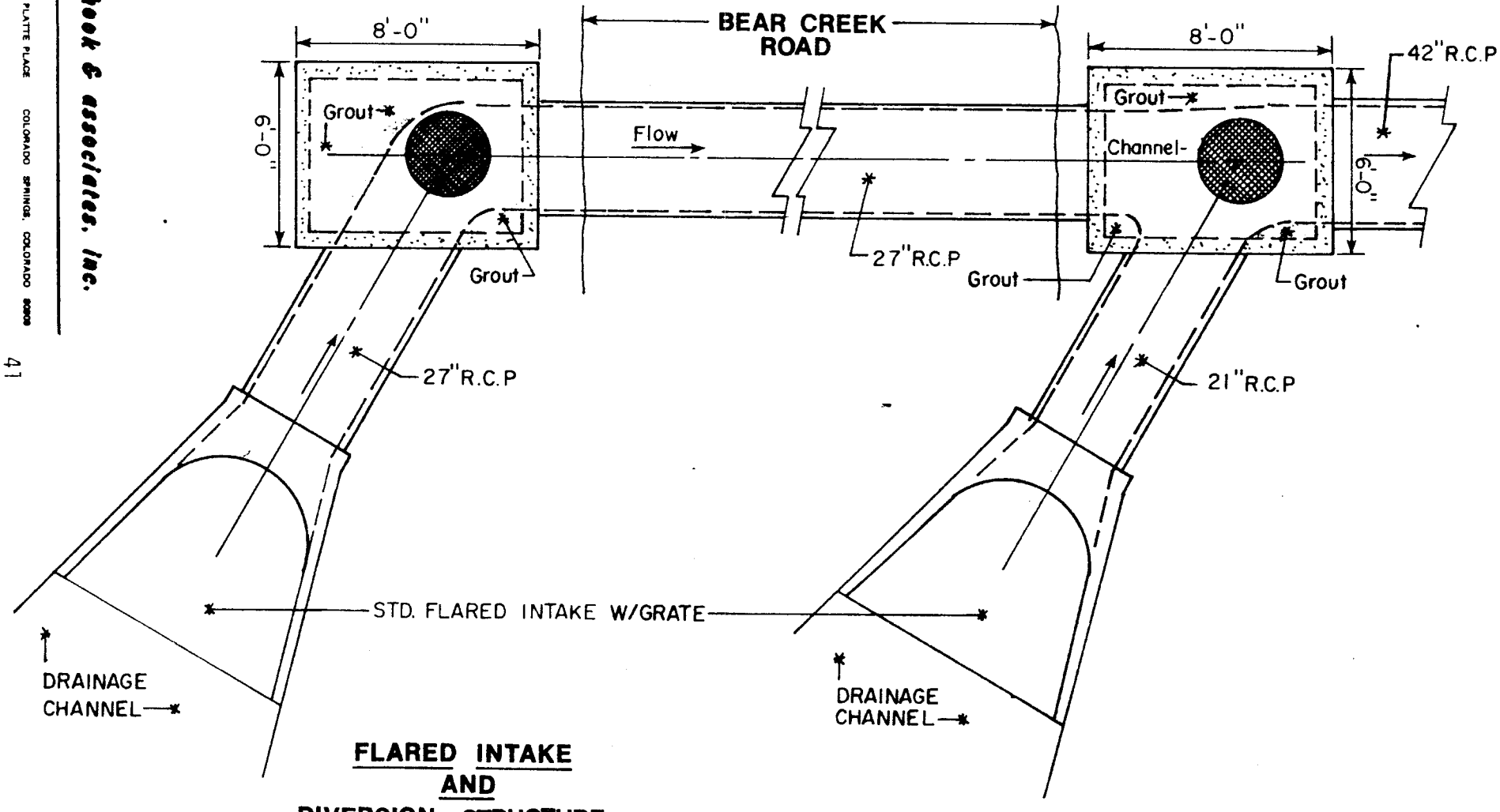
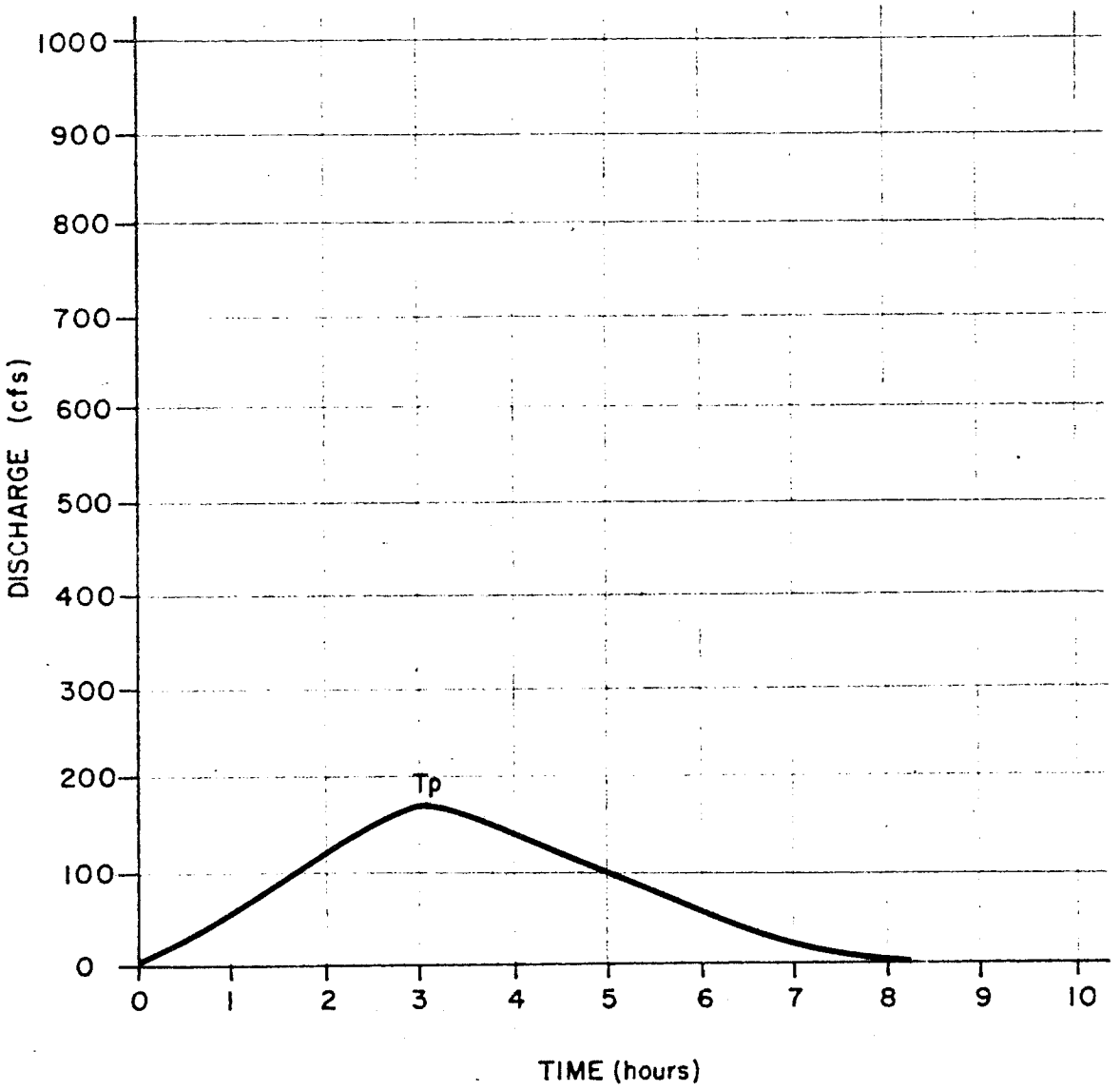



**FLARED INTAKE AND DIVERSION STRUCTURE**

FIGURE-3

# HYDROGRAPH POINT 1




Tp= 3.09 hrs.

Tb= 8.25 hrs.

Qp= 175 cfs

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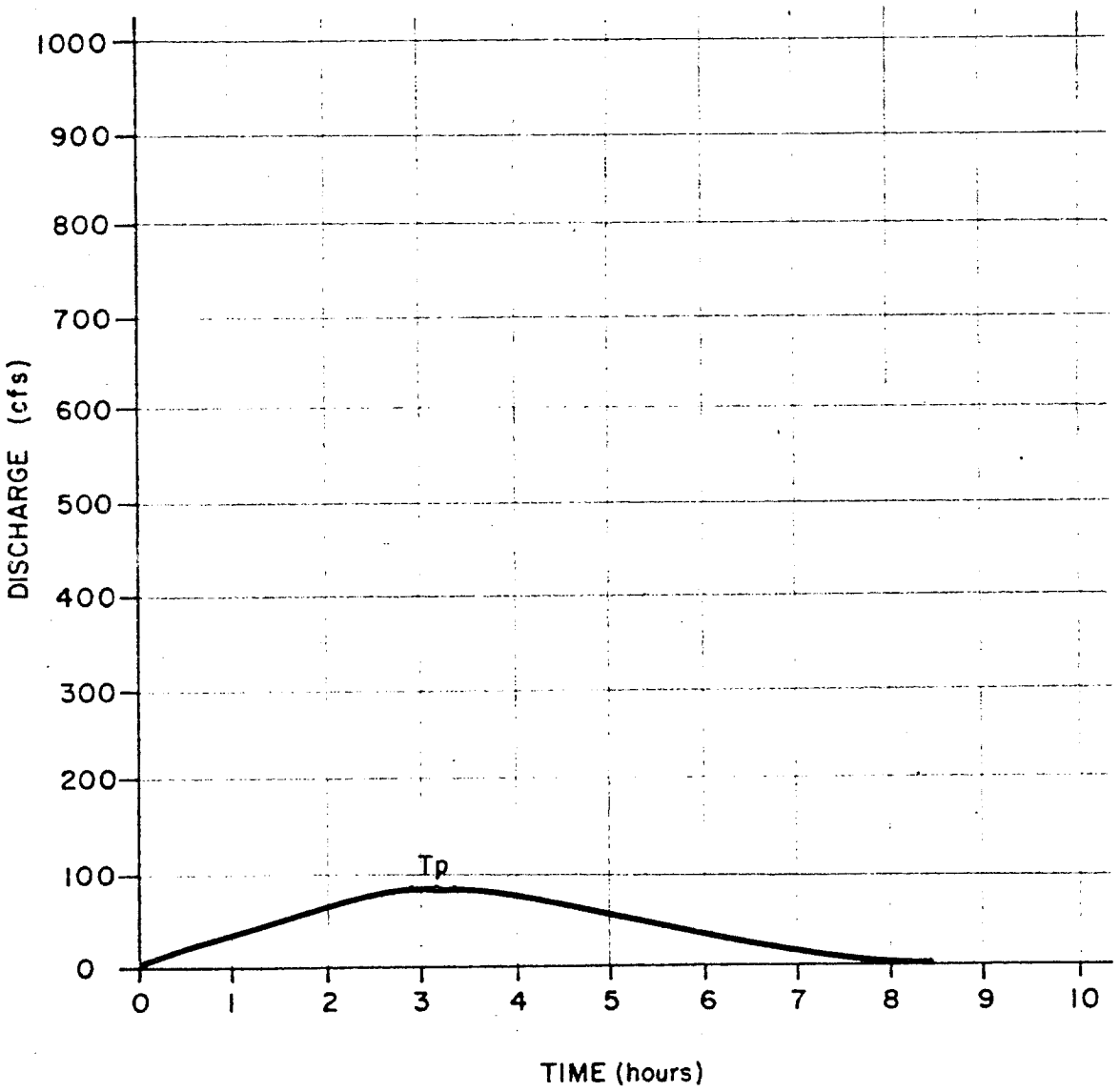
# HYDROGRAPH POINT 1A




Tp= 3.07 hrs.

Tb= 8.20 hrs.

Qp= 88 cfs

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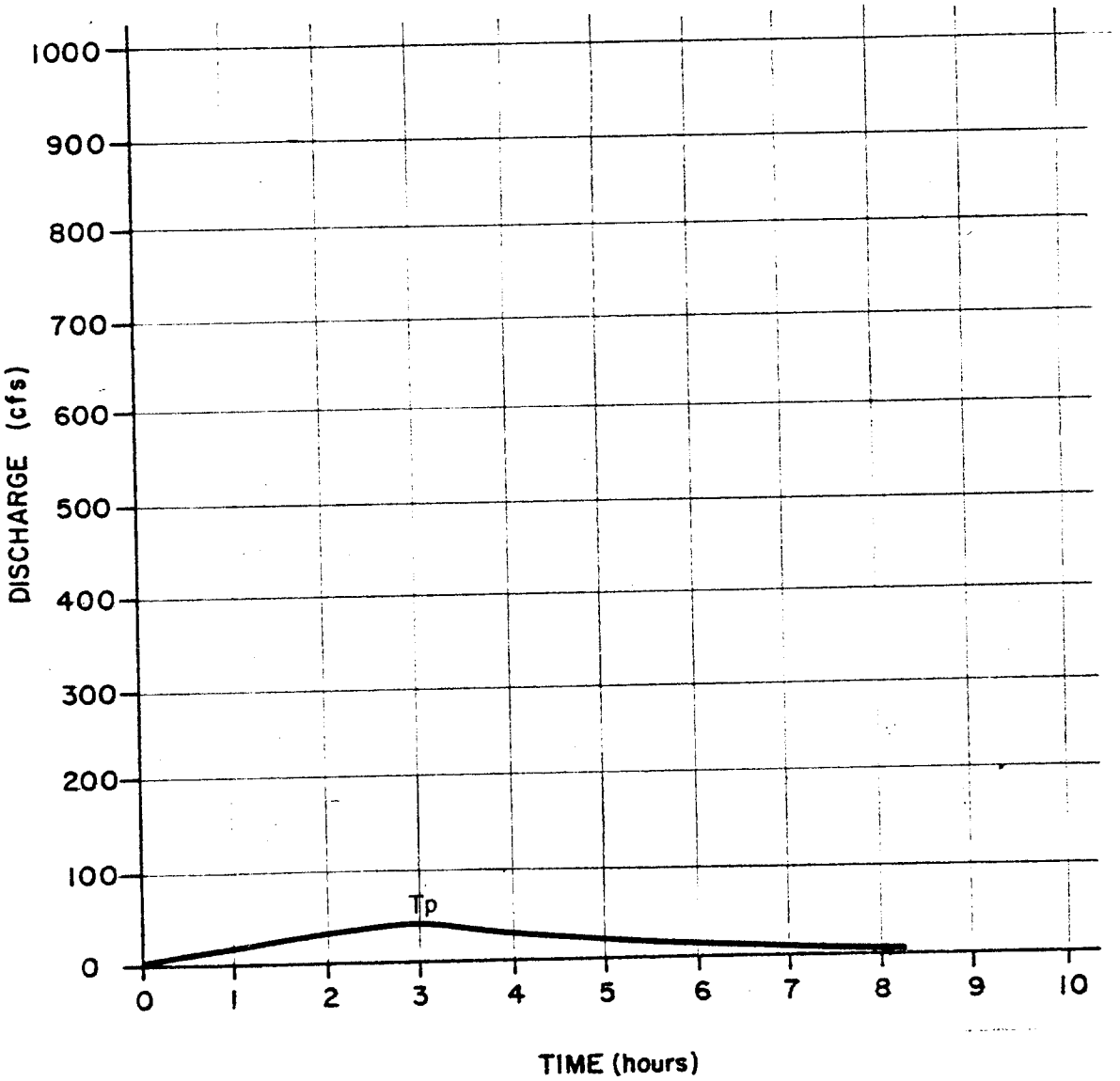
# HYDROGRAPH POINT 1B

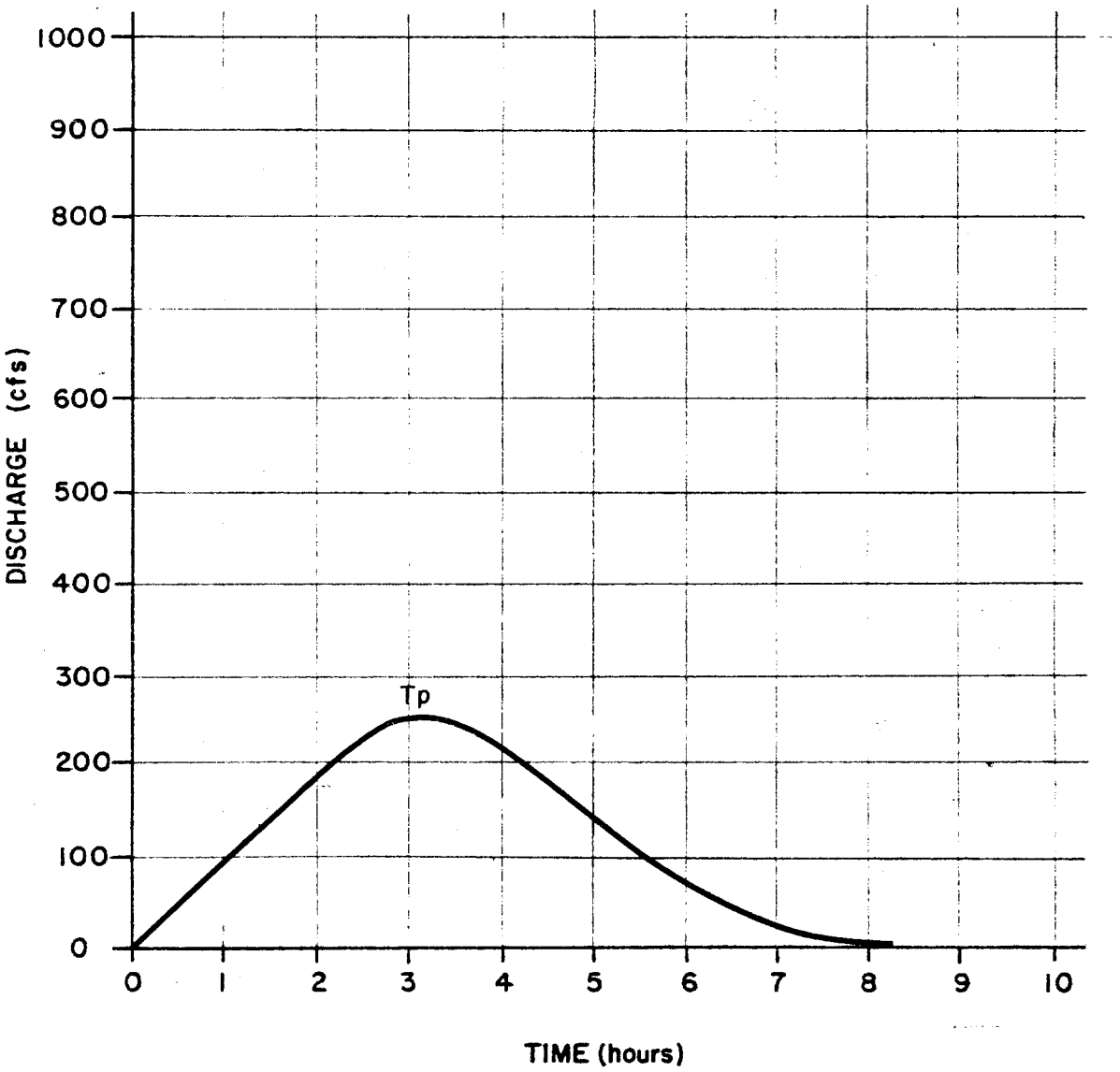



Tp= 3.07 hrs.

Tb= 8.20 hrs.

Qp= 42 cfs

# HYDROGRAPH POINT 2

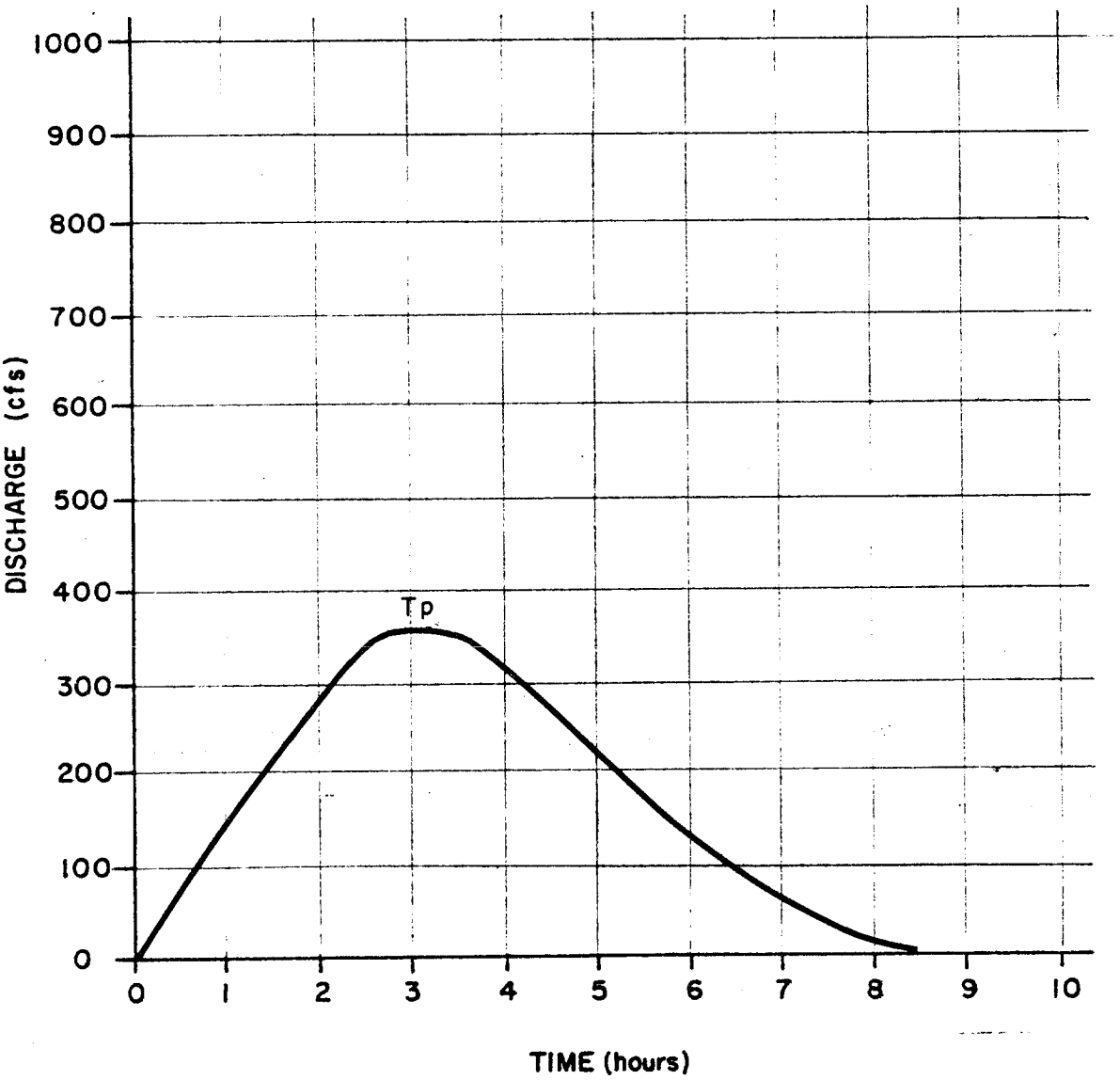



Tp= 3.10 hrs.

Tb= 8.28 hrs.

Qp= 265 cfs

# HYDROGRAPH POINT 3

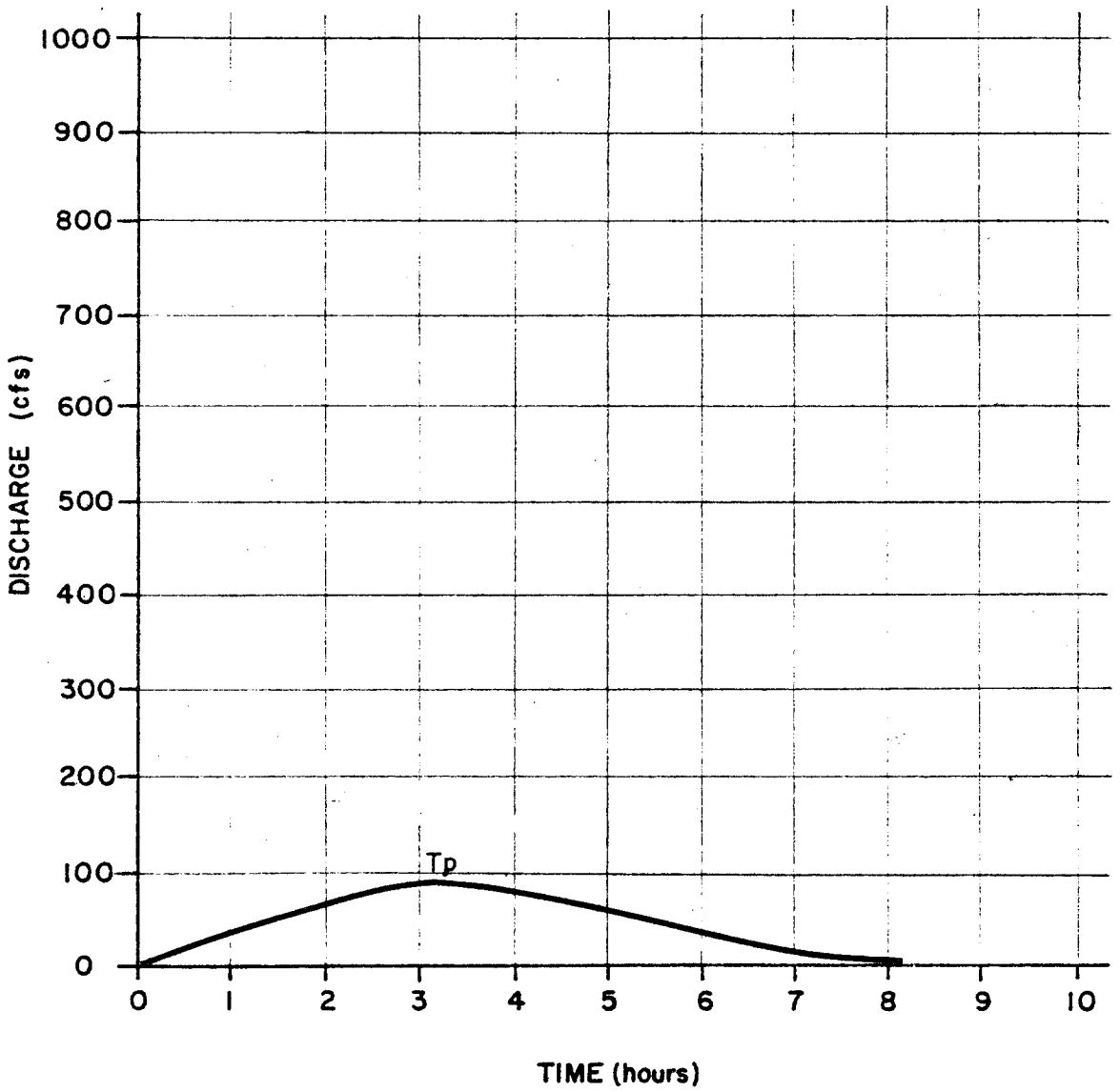



Tp= 3.12 hrs.

Tb= 8.34 hrs.

Qp= 365 cfs

# HYDROGRAPH POINT 4

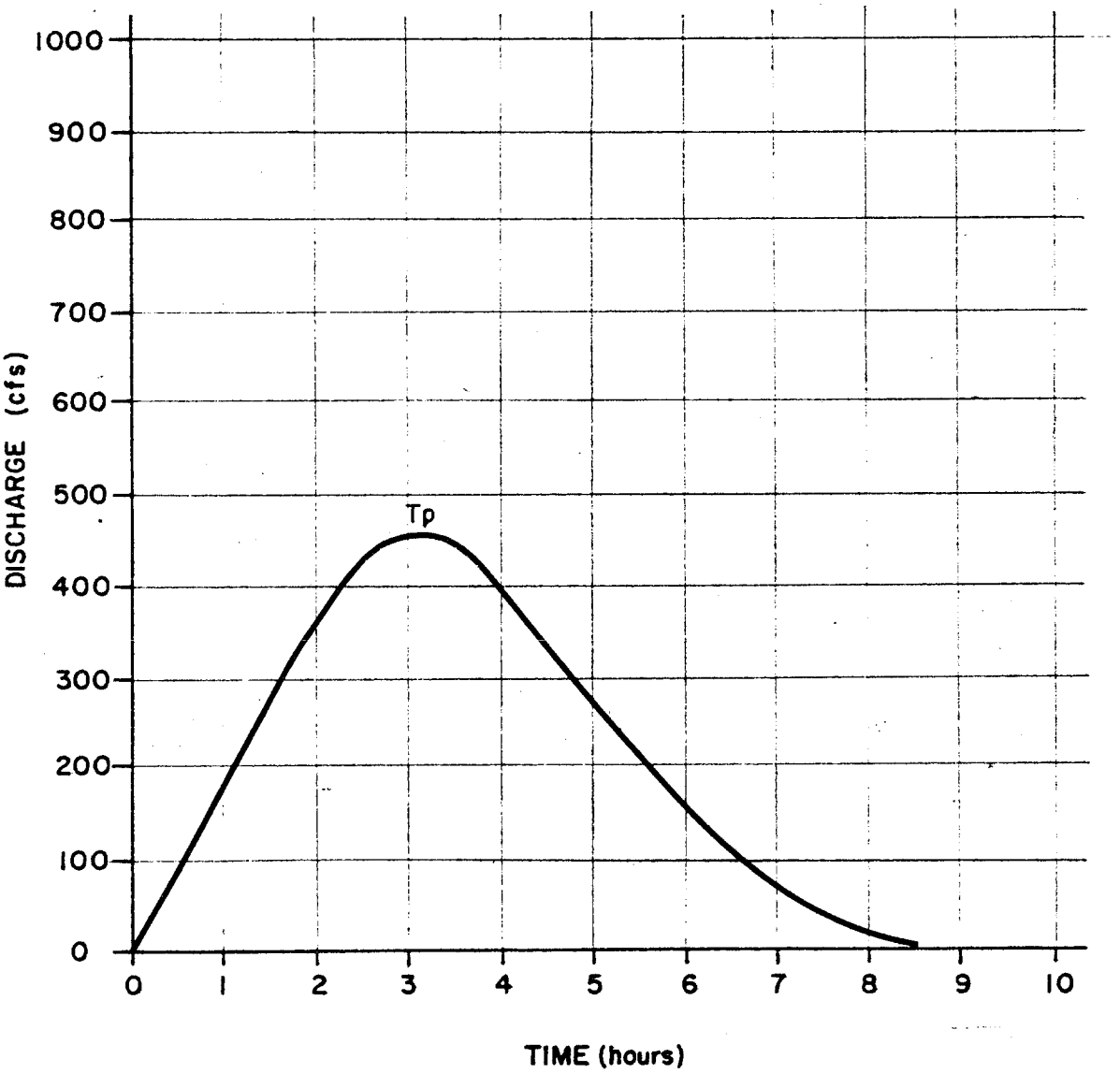



Tp= 3.04 hrs.

Tb= 8.13 hrs.

Qp= 85 cfs

# HYDROGRAPH POINT 5

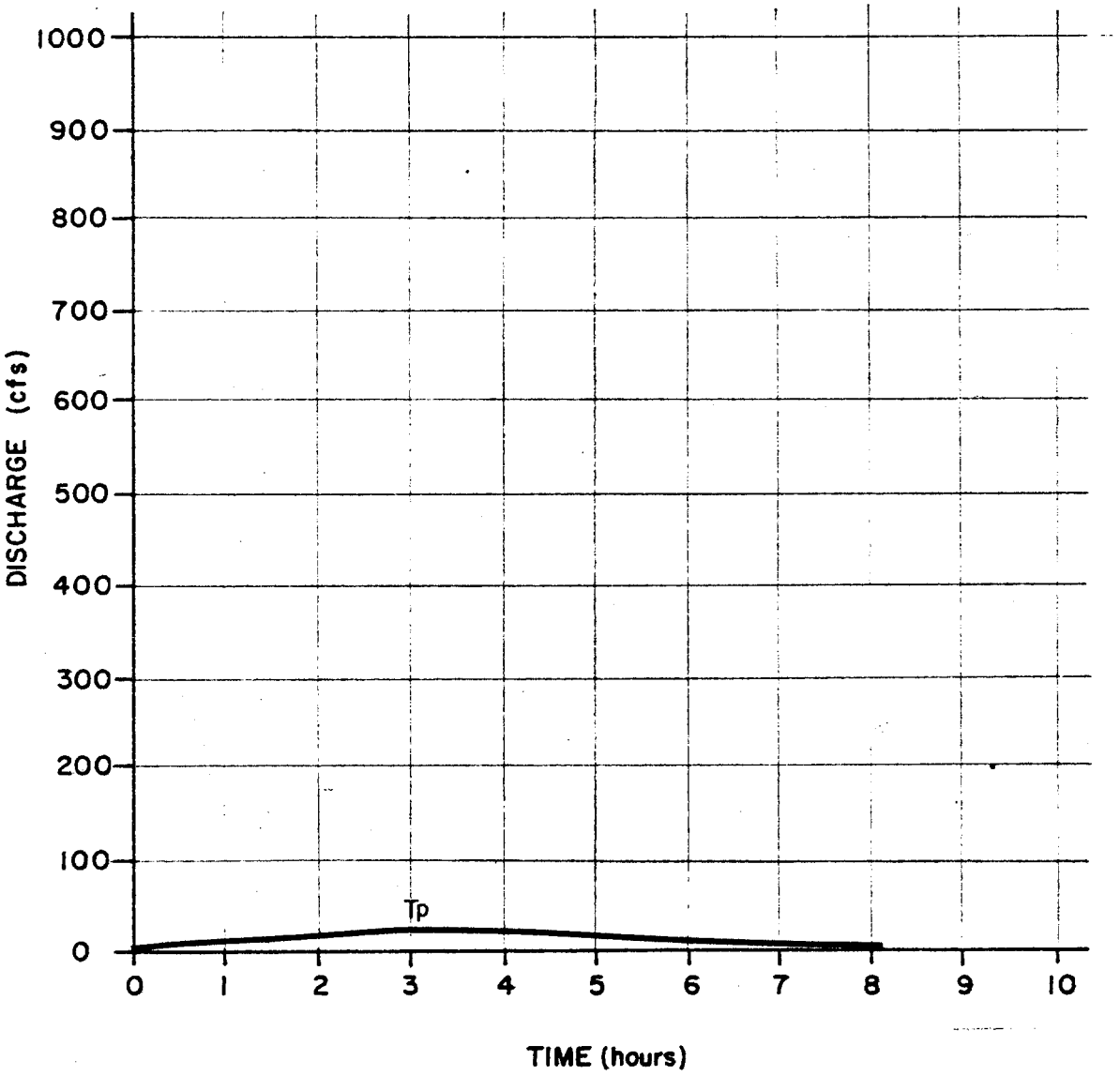



Tp= 3.14 hrs.

Tb= 8.40 hrs.

Qp= 460 cfs

# HYDROGRAPH POINT 6

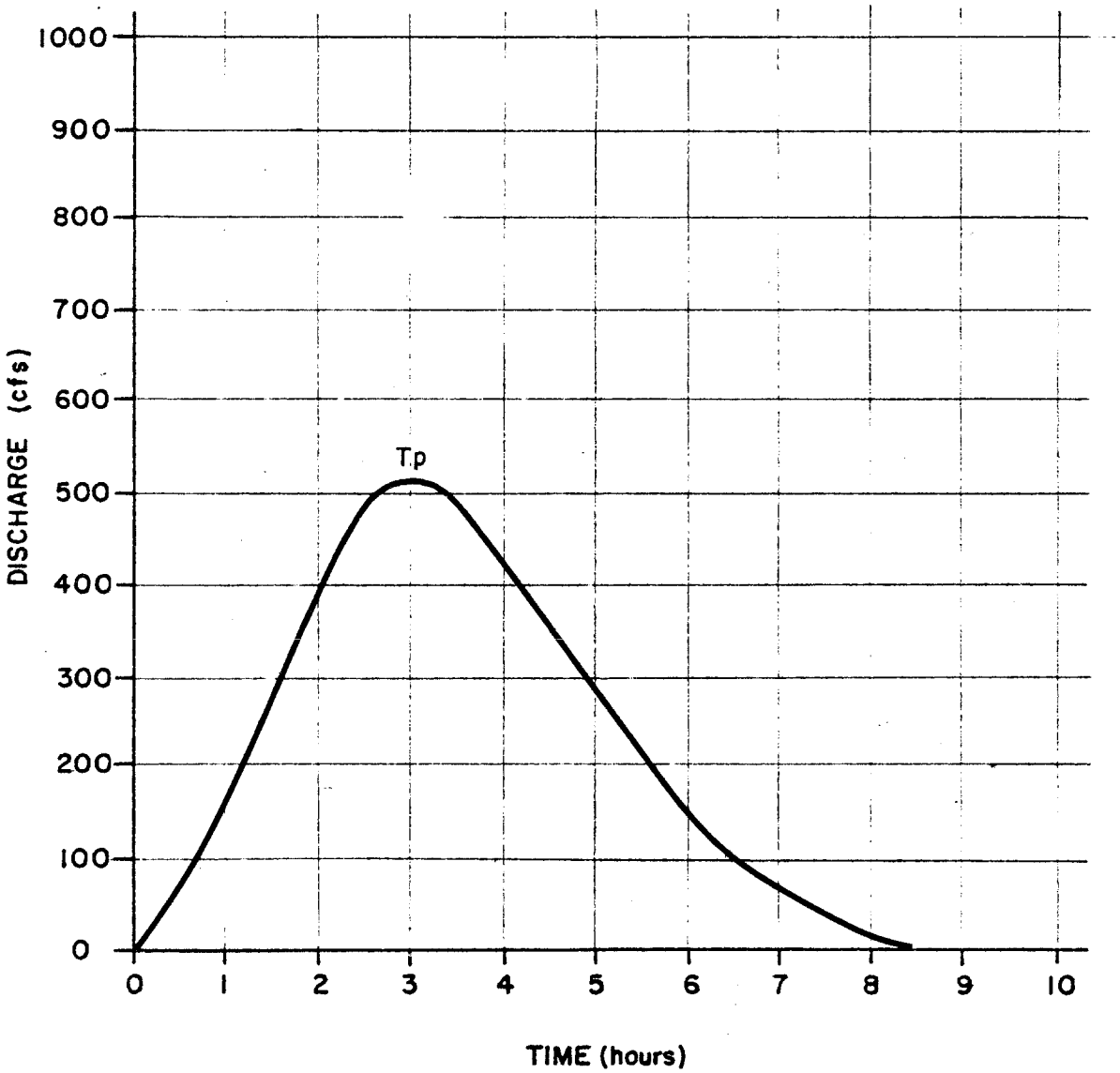



Tp= 3.04 hrs.

Tb= 8.12 hrs.

Qp= 35 cfs

# HYDROGRAPH POINT 7




Tp= 3.16 hrs.

Tb= 8.44 hrs.

Qp= 510 cfs

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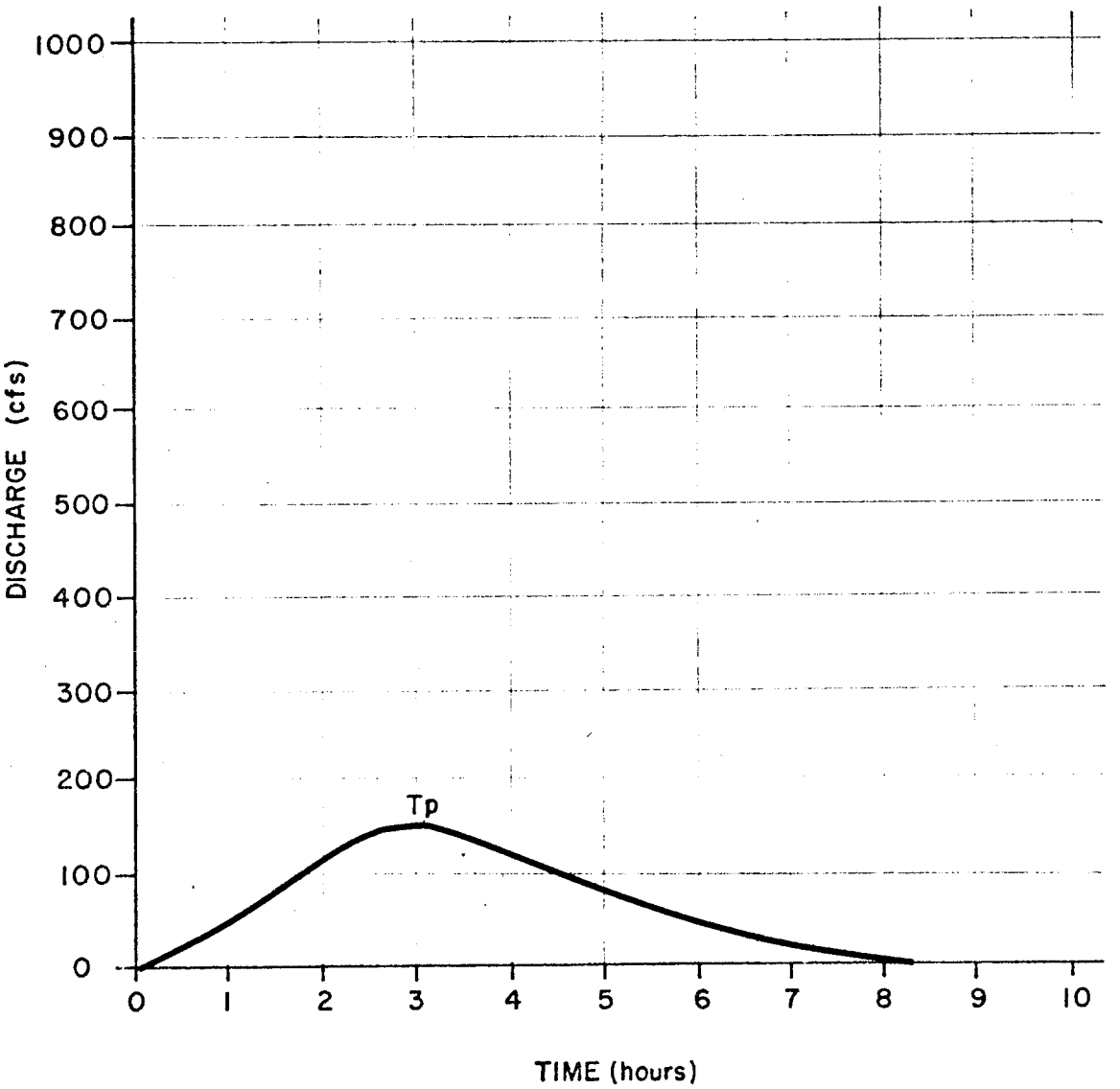
# HYDROGRAPH POINT 8

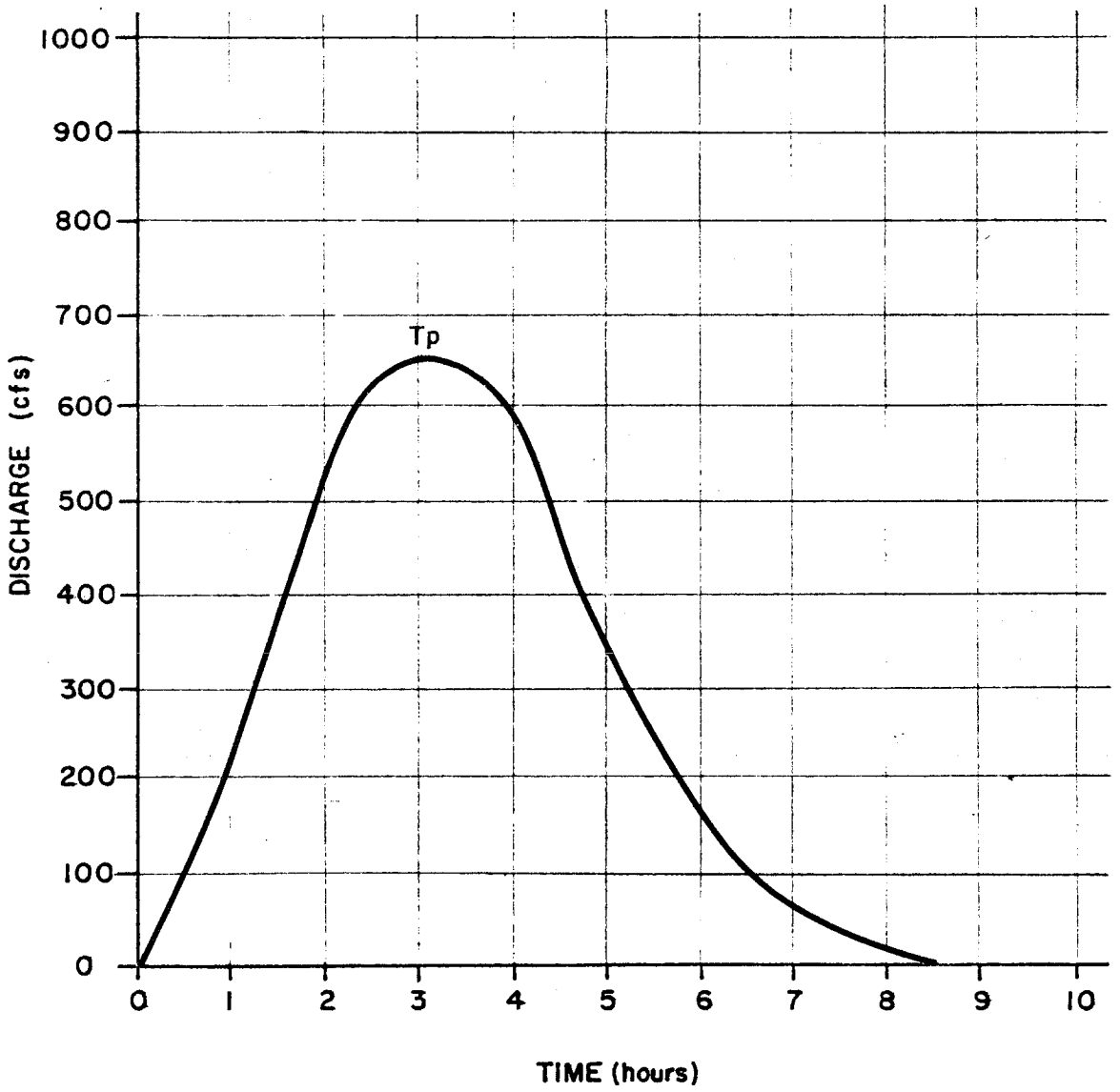



Tp= 3.06 hrs.

Tb= 8.18 hrs.

Qp= 145 cfs

# HYDROGRAPH POINT 9

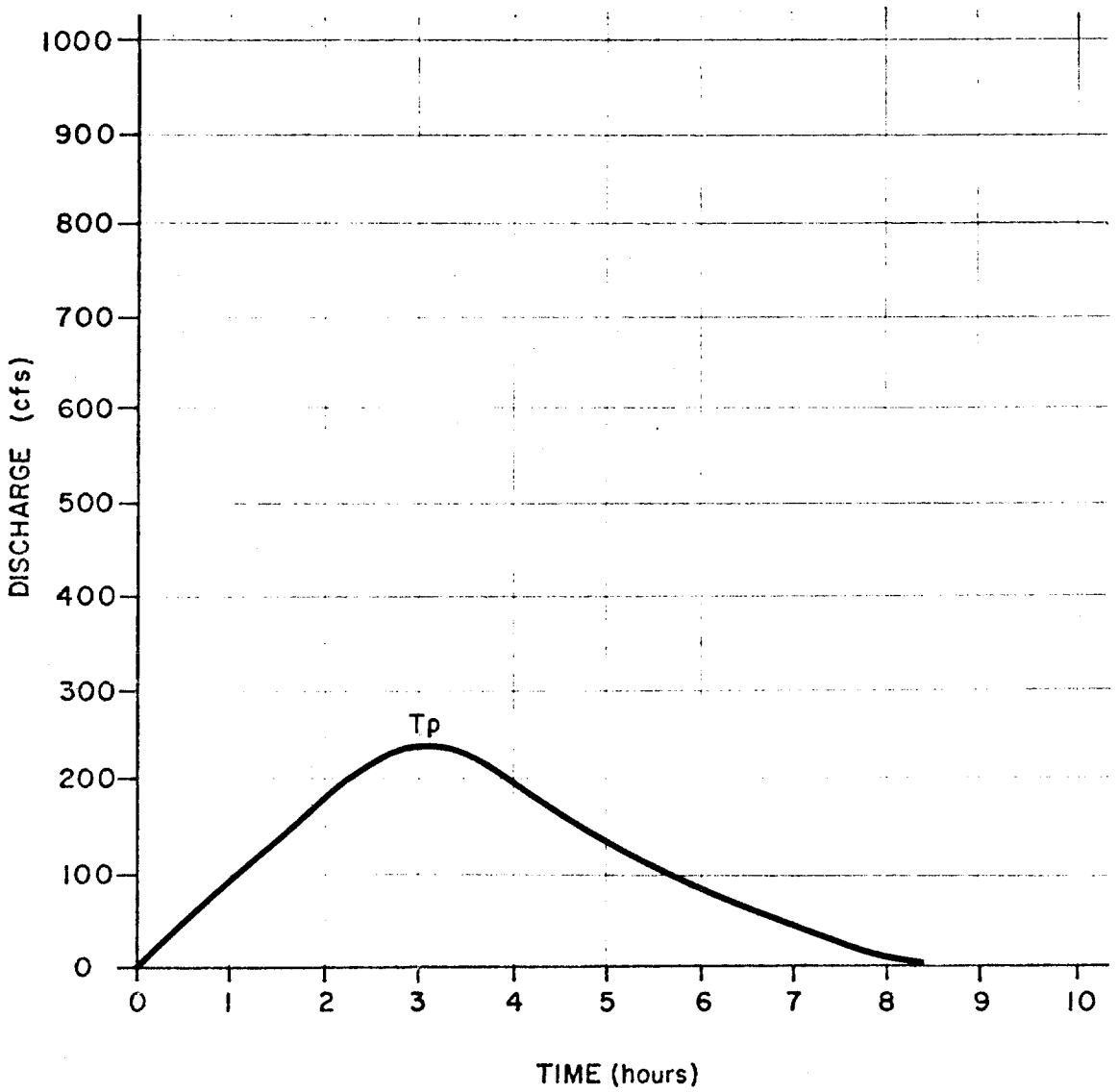



Tp= 3.18 hrs.

Tb= 8.50 hrs.

Qp= 640 cfs

# HYDROGRAPH POINT 10

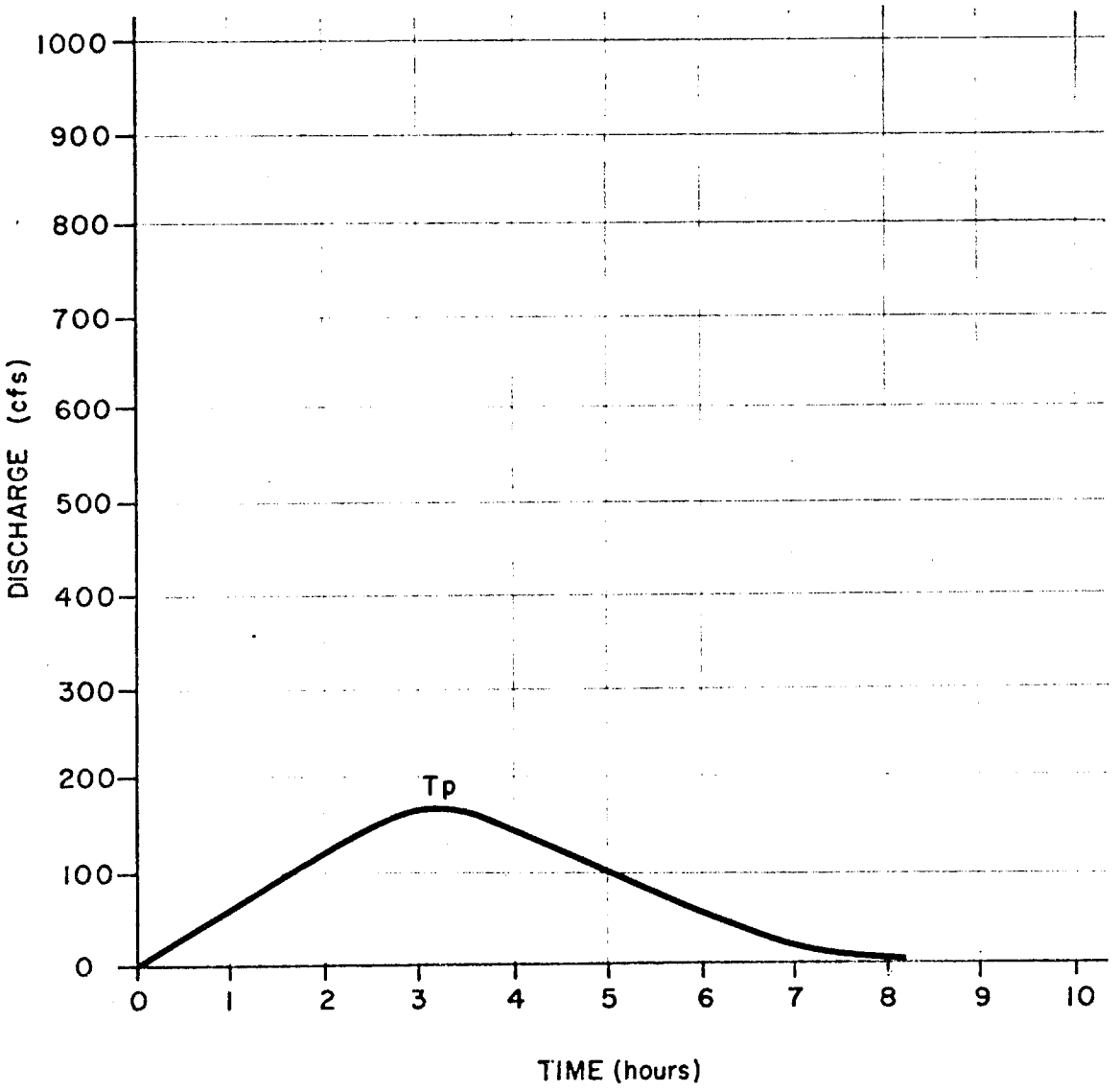



Tp= 3.10 hrs.

Tb= 8.29 hrs.

Qp= 240 cfs

# HYDROGRAPH POINT 11

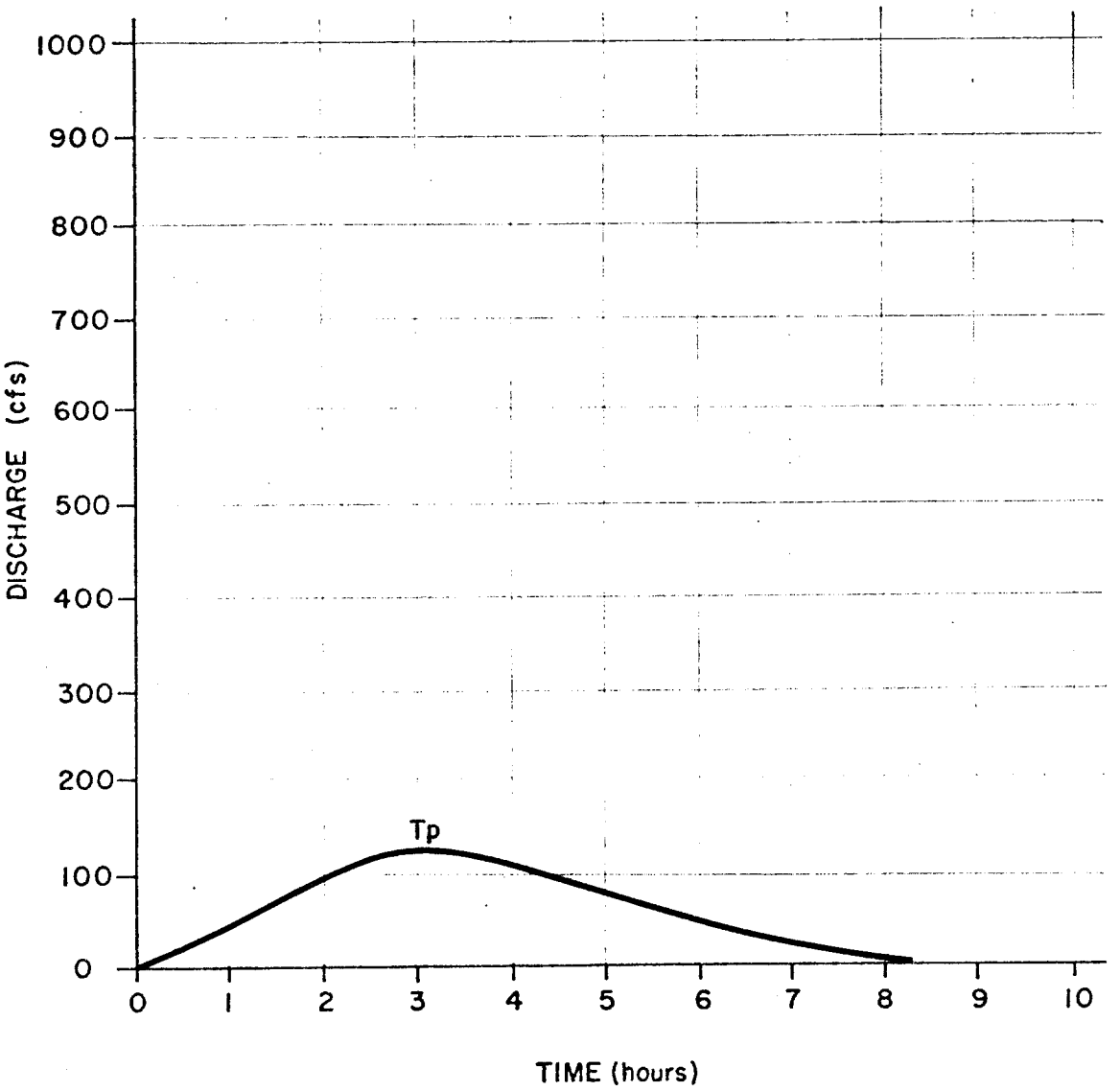



Tp= 3.05 hrs.

Tb= 8.15 hrs.

Qp= 160 cfs

# HYDROGRAPH POINT 12

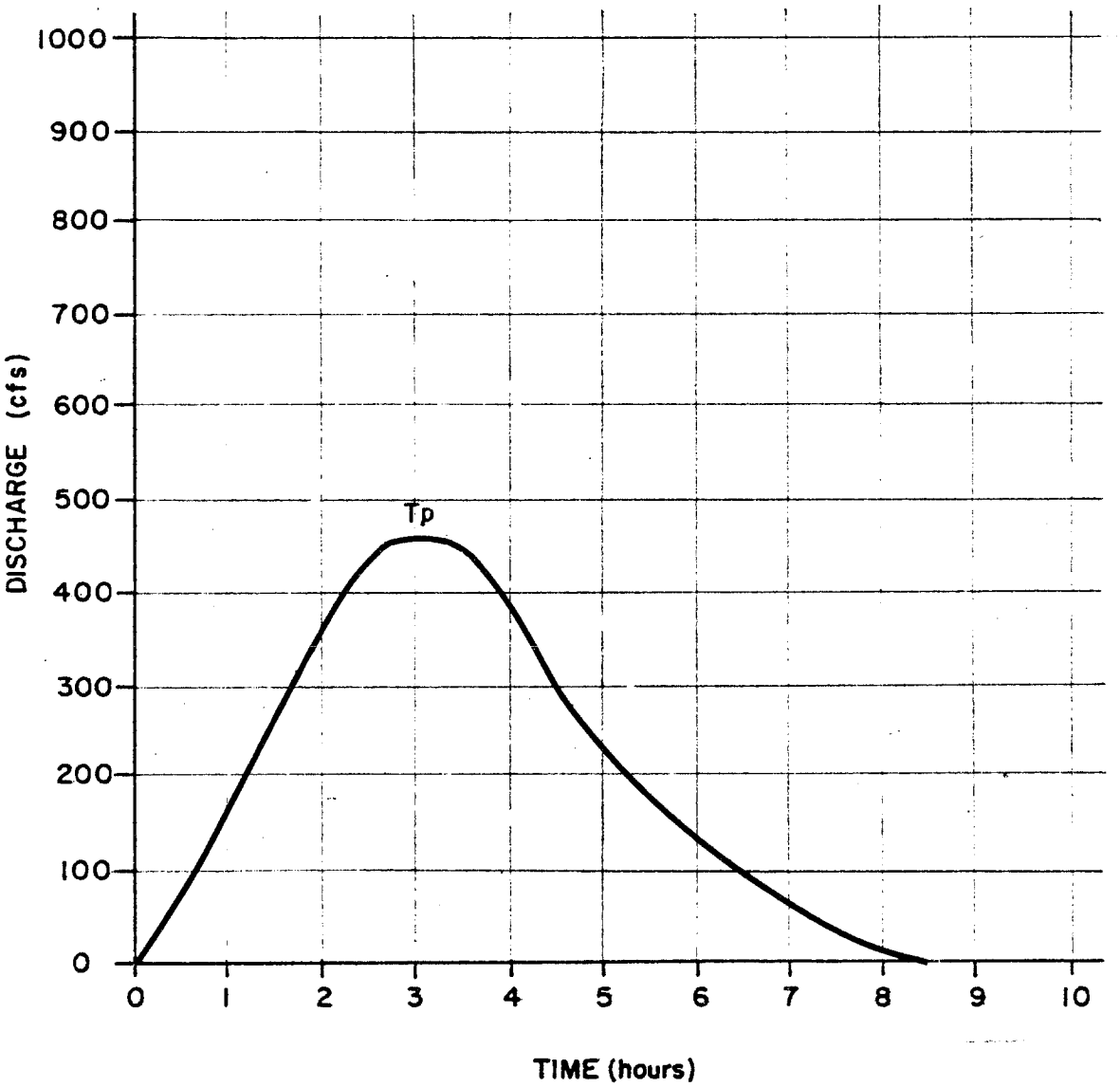



Tp= 3.06 hrs.

Tb= 8.16 hrs.

Qp= 125 cfs

# HYDROGRAPH POINT 13

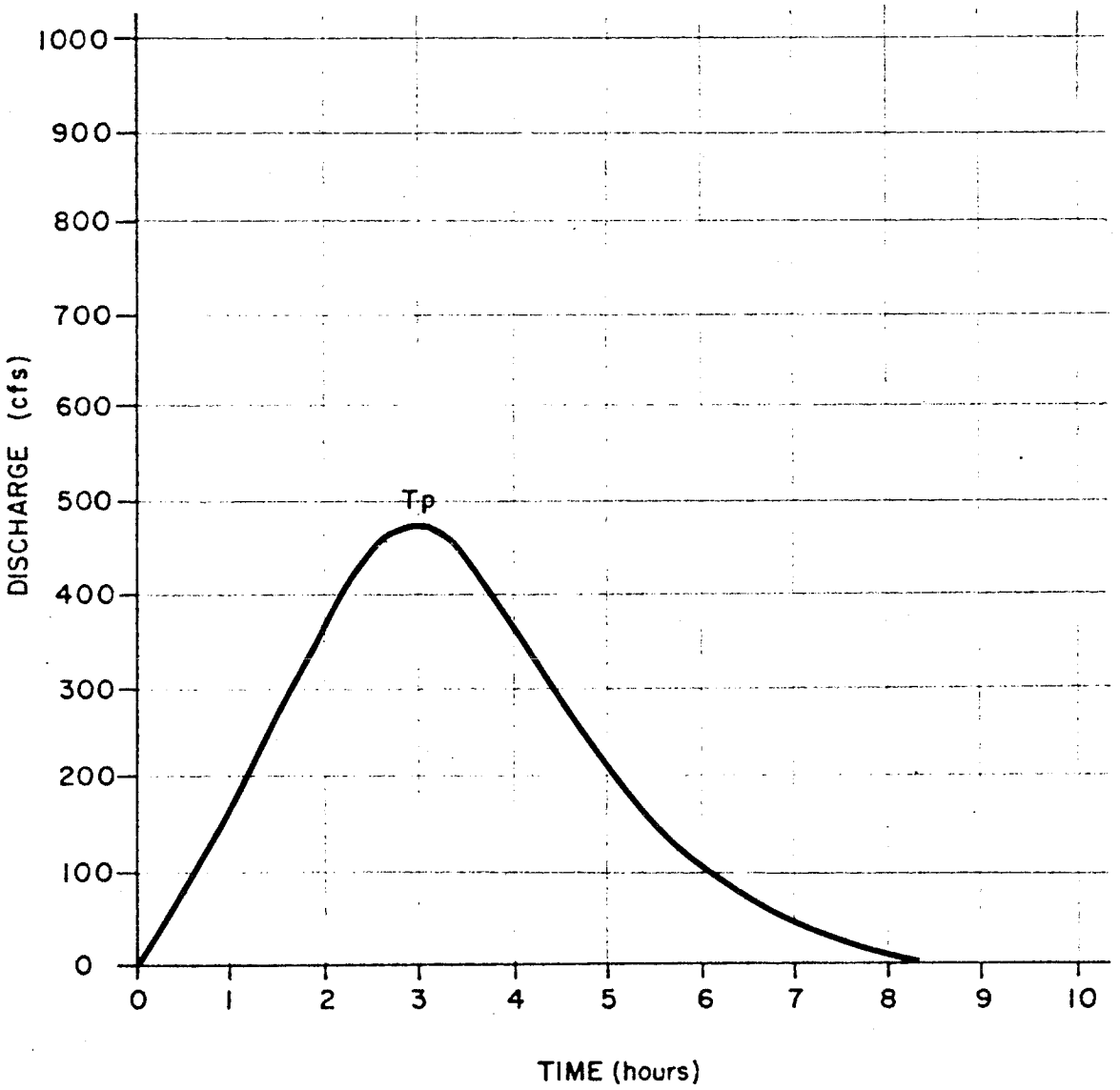



Tp= 3.13 hrs.

Tb= 8.35 hrs.

Qp= 465 cfs

# HYDROGRAPH POINT 14




Tp= 3.14 hrs.

Tb= 8.38hrs.

Qp= 475 cfs

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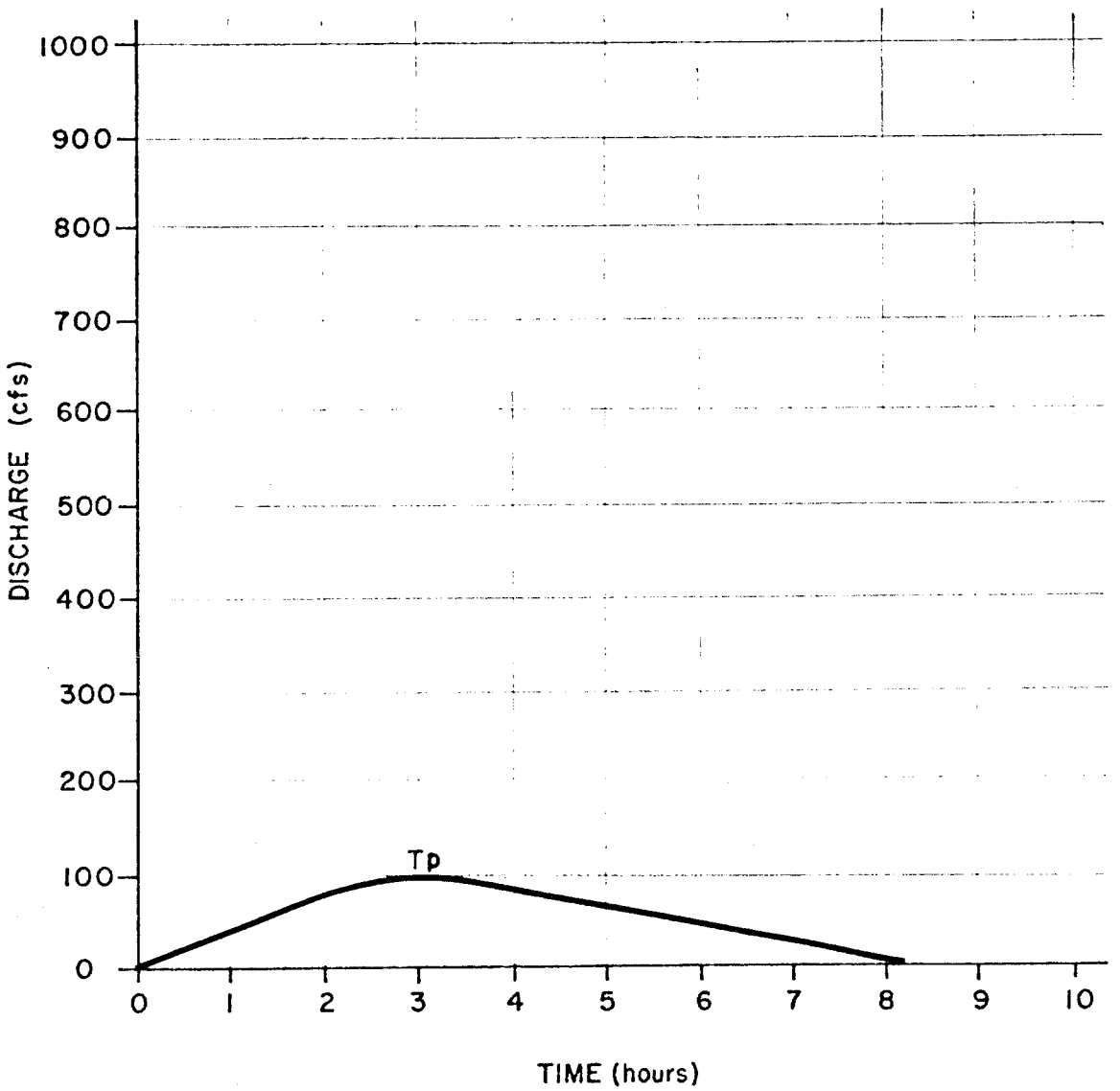
PHONE 473-6653 2545 E. PLATTE PLACE COLORADO SPRINGS, COLORADO 80909

# HYDROGRAPH POINT 15

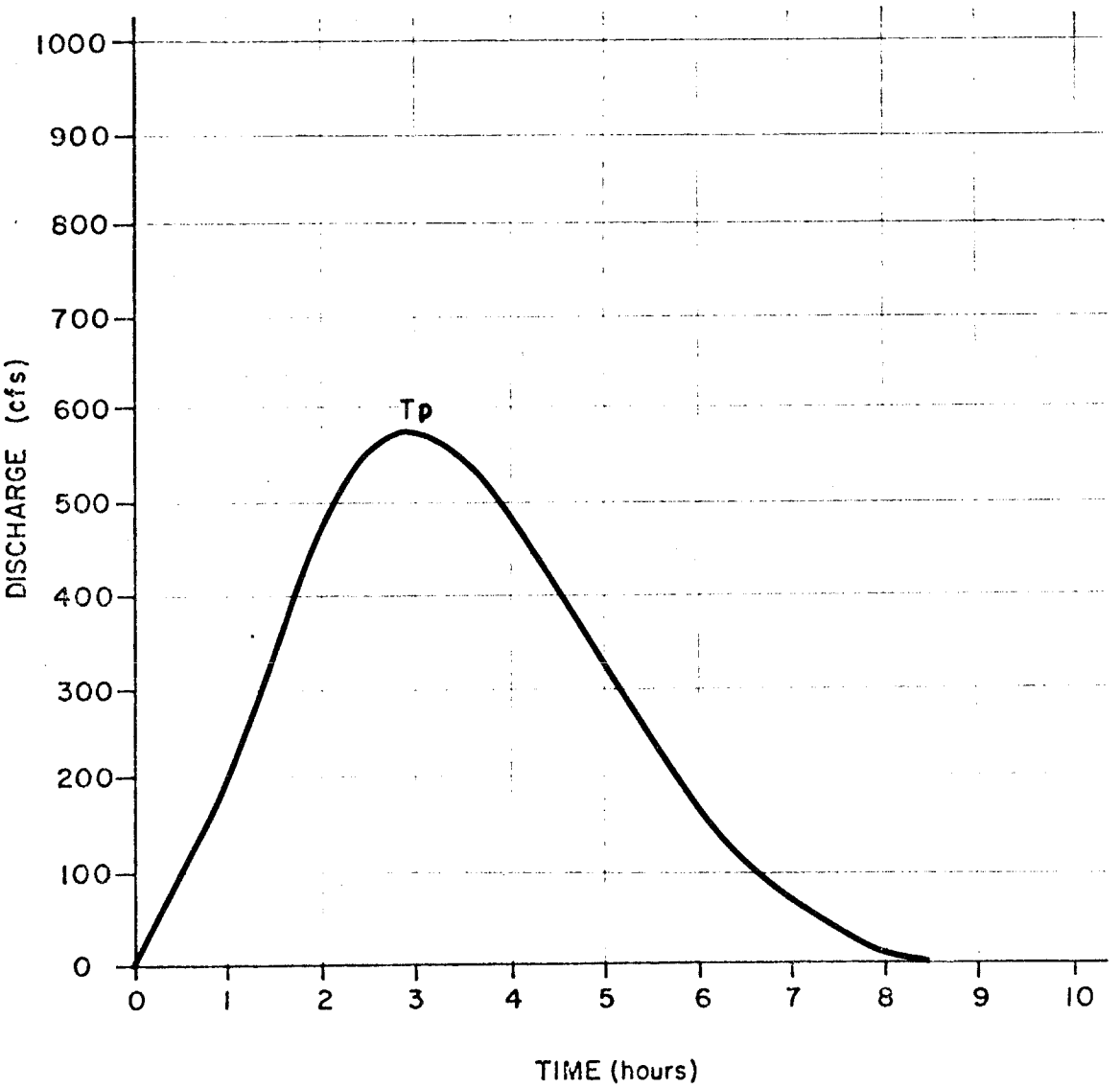



Tp= 3.04 hrs.

Tb= 8.12 hrs.

Qp= 100 cfs

# HYDROGRAPH POINT 16

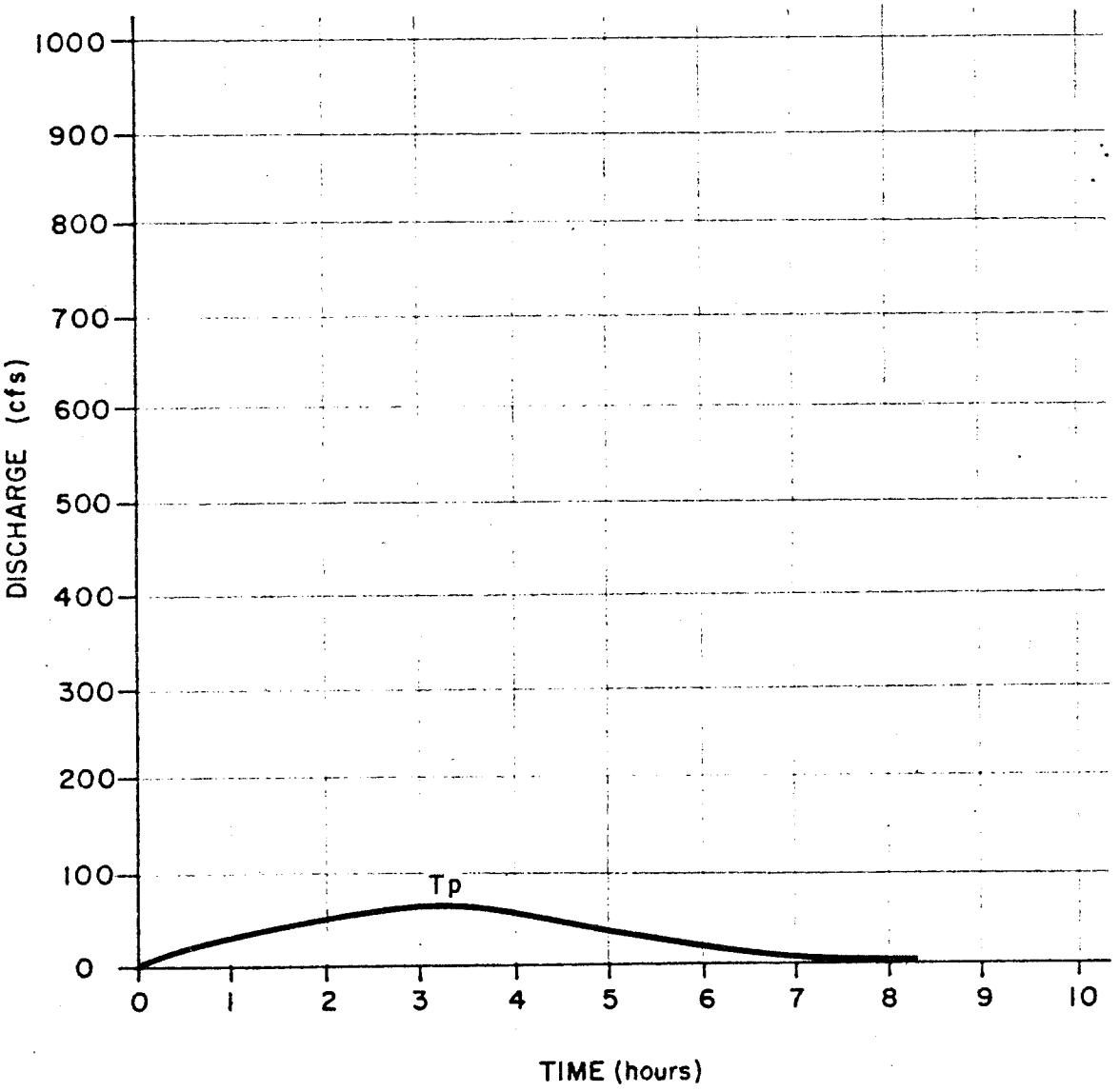



Tp= 3.16 hrs.

Tb= 8.45 hrs.

Qp= 580 cfs

# HYDROGRAPH POINT 17




Tp= 3.06 hrs.

Tb= 8.16 hrs.

Qp= 55 cfs

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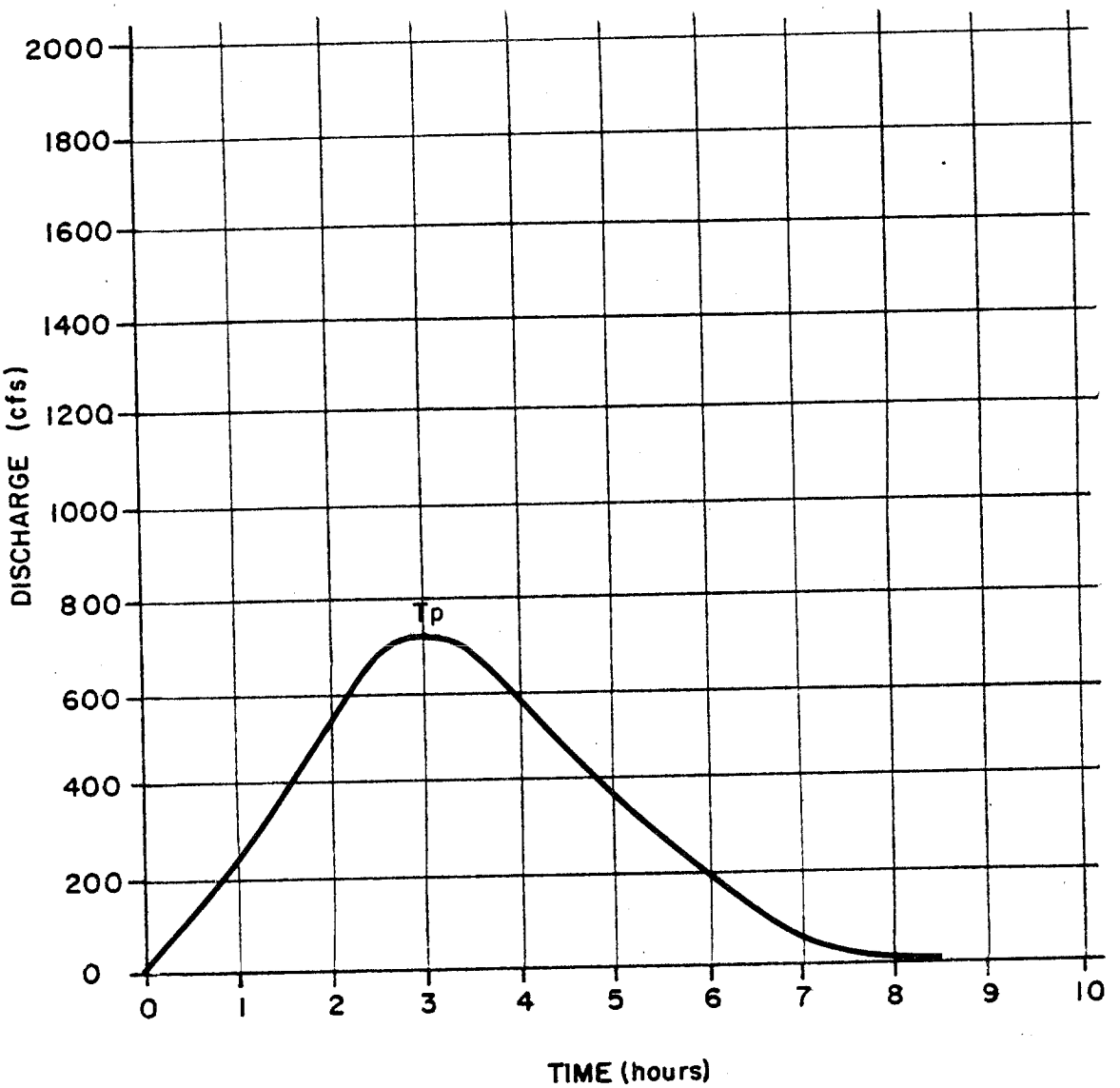
# HYDROGRAPH POINT 18

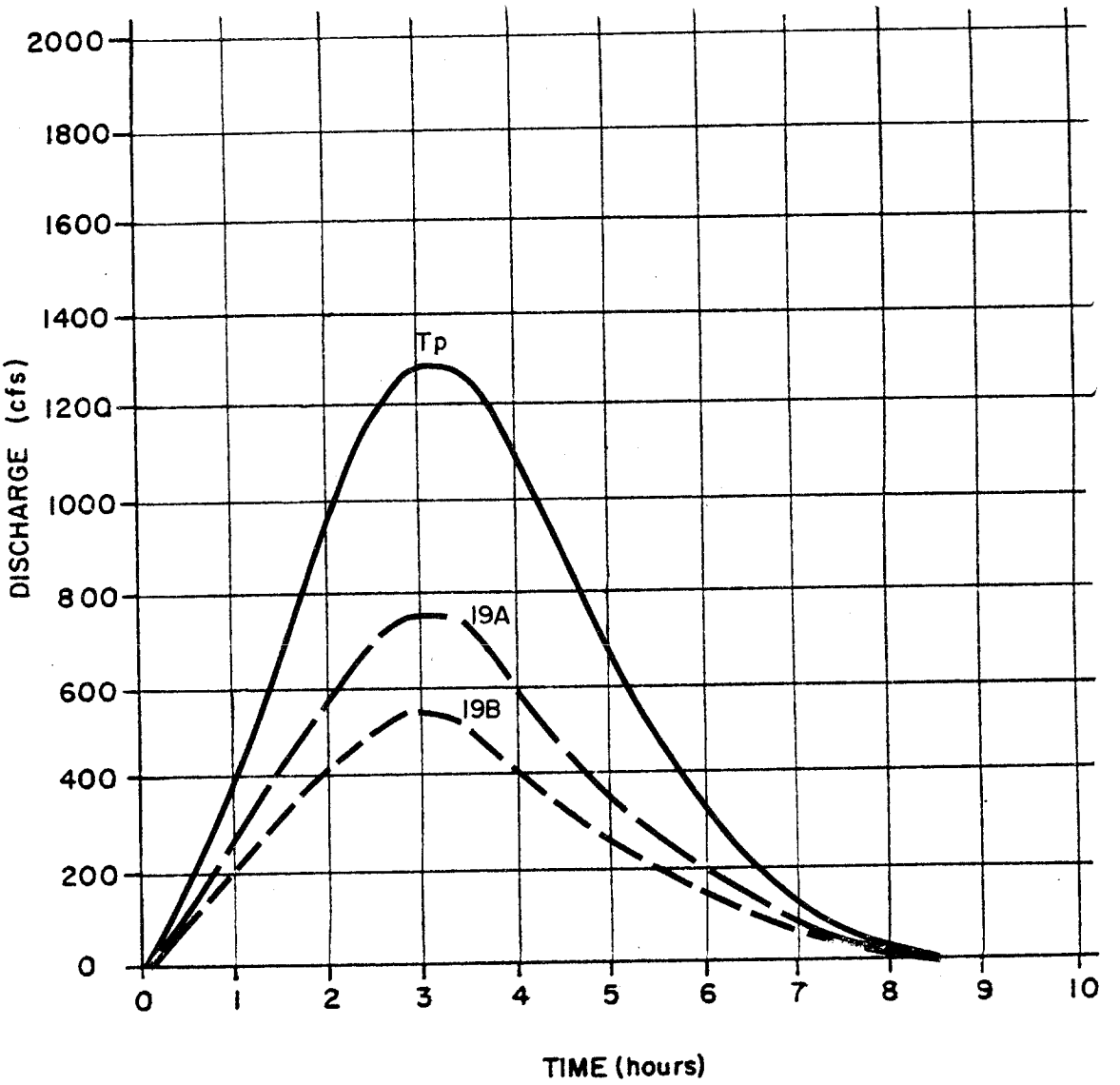



Tp = 3.21 hrs.

Tb = 8.57 hrs.

Qp = 720 cfs

# HYDROGRAPH POINT 19

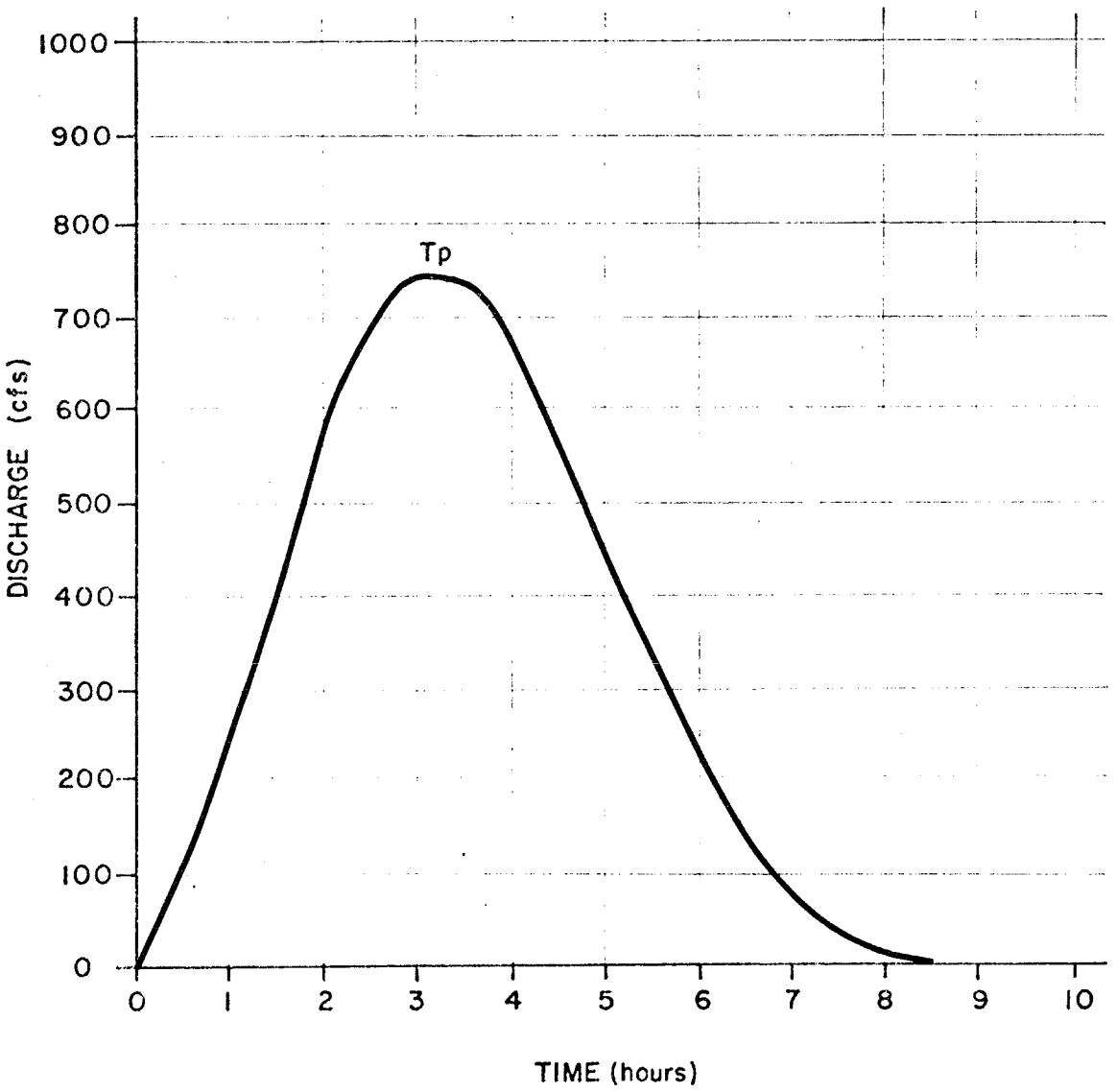



Tp= 3.20 hrs.

Tb= 8.50 hrs.

Qp= 1300 cfs

# HYDROGRAPH POINT 19A

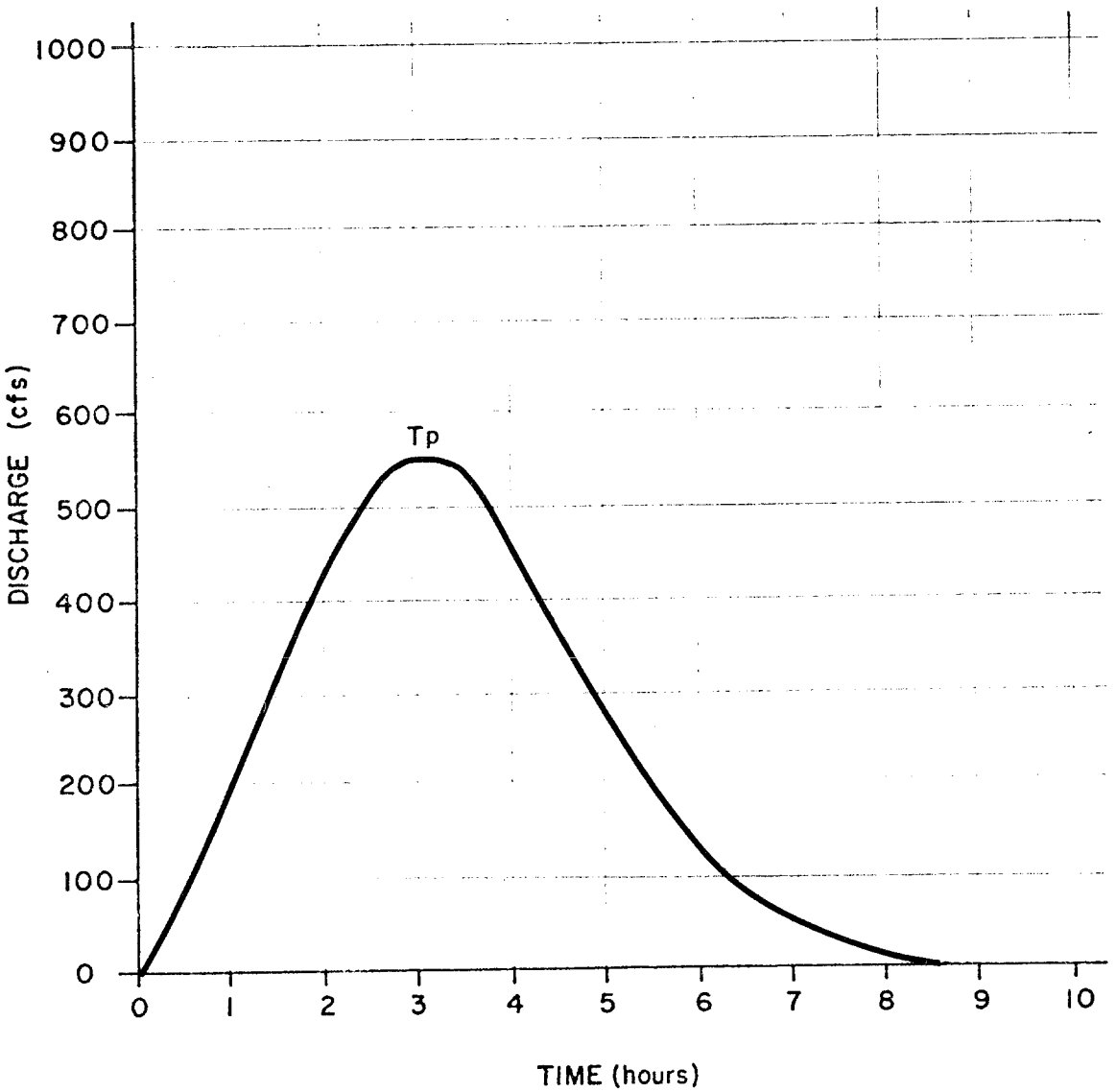



Tp= 3.23 hrs.

Tb= 8.62 hrs.

Qp= 750 cfs

# HYDROGRAPH POINT 19B

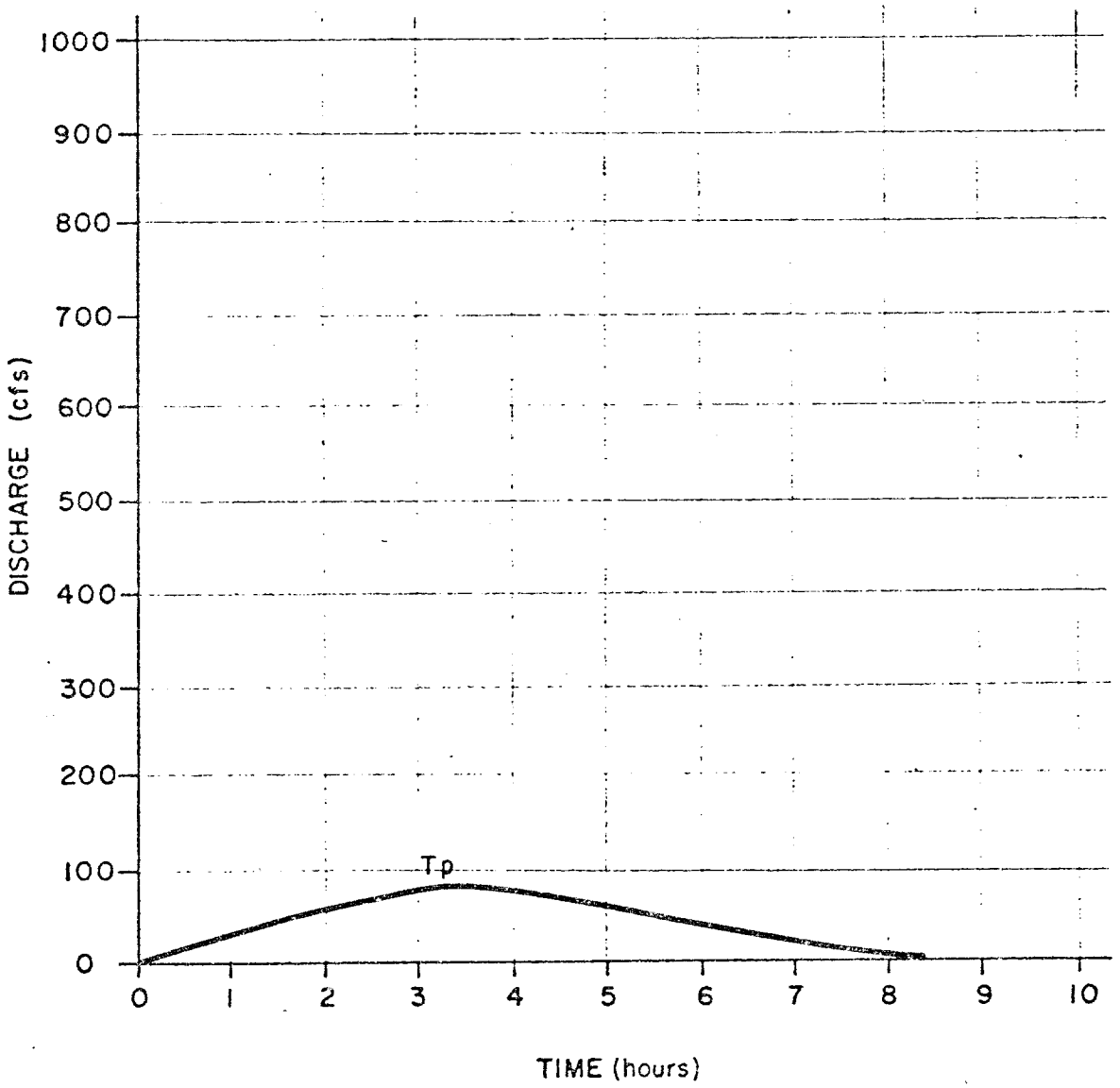



Tp= 3.18 hrs.

Tb= 8.50 hrs.

Qp= 555 cfs

# HYDROGRAPH POINT 20

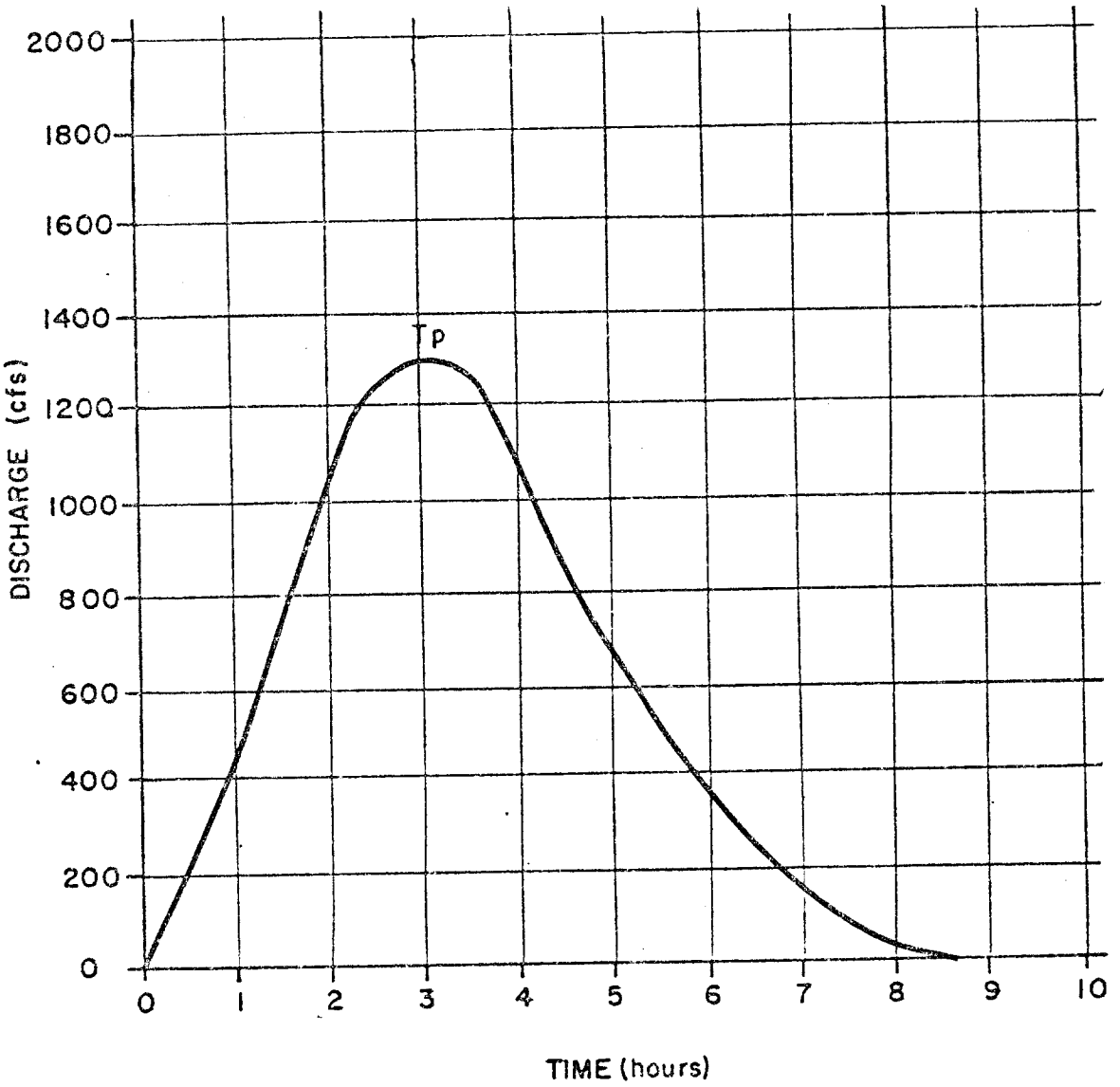



Tp= 3.10 hrs.

Tb= 8.27 hrs.

Qp= 70 cfs

# HYDROGRAPH POINT 21




Tp= 3.22 hrs.

Tb= 8.60hrs.

Qp= 1300 cfs

RECOMMENDED FREEBOARD AND HEIGHT OF BANK OF LINED CHANNELS (U.S. BUREAU OF RECLAMATION) - FROM CHOW, V.T. "OPEN CHANNEL HYDRAULICS", FIGURE 7-1