UNITED STATES
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Geological Survey

APPLICATION OF HYDRAULIC AND HYDROLOGIC DATA IN URBAN STORMWATER MANAGEMENT

Interpretation of Flood Insurance Study Information to Aid in Urban Stormwater Management Decisions

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CONVERSION FACTORS FOR INCH-POUND UNITS
AND S.I. METRIC UNITS

Inch-Pound units	Conversion factor	S.I. Metric units
inch (in.)	25.4	millimeter (mm)
square mile (mi^2)	2.59	square kilometer (km^2)
foot per mile (ft/mi)	0.189	meter per kilometer (m/km)
cubic foot per second (ft^3/s)	0.0283	cubic meter per second (m^3/s)

Multiply Inch-Pound units by the conversion factor to obtain S.I. metric units. Divide S.I. metric units by the conversion factor to obtain Inch-Pound units.

APPLICATION OF HYDRAULIC AND HYDROLOGIC DATA IN URBAN STORM-WATER MANAGEMENT

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ABSTRACT

Techniques are described for using flood-insurance study information from the Federal Insurance Administration to analyze flood plain management alternatives. A method of developing rating curves which relate flood discharge to flood elevation is explained. Graphical methods of determining urban flood discharges are used in conjunction with rating curves to develop flood profiles resulting from future urban development. The graphical techniques were compared with standard step-backwater computations for two storms and errors were less than 0.5 foot, which are well within acceptable limits.

INTRODUCTION

Management of storm water in urban areas is an essential part of urban planning. The hydraulic and hydrologic information required to make competent decisions is often difficult and expensive to obtain, and is not commonly in a usable form, requiring additional expense in order to make it useful. Therefore, it is important that growing urban communities be aware of existing data and gain some insight into how it can be applied in planning decisions. Urban flood information is generated from the Federal Insurance Administration (FIA) flood insurance studies (National Flood Insurance Act, 1968, Public Law 90-448). Engineering consultants and technical Federal agencies such as the U.S. Geological Survey, U.S. Army Corps of Engineers, and the U.S. Soil Conservation Service have made these flood insurance studies for participating communities. The results of these studies are available to any interested party.

This report discusses the types of hydrologic data collected in a flood insurance study and presents some techniques for applying the data to storm-water management and planning projects that go beyond the scope of the flood insurance program. Approximations made in the study technique which limit its application are discussed, and the results of a typical analysis are presented to illustrate various applications of the technique.

BASIC INFORMATION AVAILABLE

A flood insurance study requires an extensive accumulation of hydraulic and hydrologic data and other related information, costing thousands of dollars per mile of stream channel. The technical contractor providing flood information to the Federal Insurance Administration is required to maintain files of information collected in the course of the flood insurance studies and to make it available to local governments and the public.

Channel geometry of the streams is one of the principal items measured for a flood insurance study. Cross sections are taken at intervals of three to eight per mile of stream channel, depending upon shape and size uniformity throughout the length of the stream. Small irregular streams will have more measurements per mile than large, uniformly shaped streams. These measurements of channel geometry are obtained by field surveying or aerial photography techniques. The data that result are similar in format to that shown in figure 1. The graph in figure 1 is a plot of the distance from the left bank, plotted against the corresponding ground elevations. A table of the plotted points is shown in the upper part of figure 1. The ground elevations for each cross section are measured from a common reference datum, usually mean sea level.

DISTANCE	ELEVATION	DISTANCE	ELEVATION
00	1115.73	160.61	1097.12
4.25	1114.15	168.36	1094.84
37.09	1112.92	170.60	1094.84
52.03	1109.76	186.12	1101.86
82.91	1108.18	223.31	1111.52
113.79	1109.24	255.12	1114.33
129.10	1105.55	260.76	1115.56
152.10	1098.87		

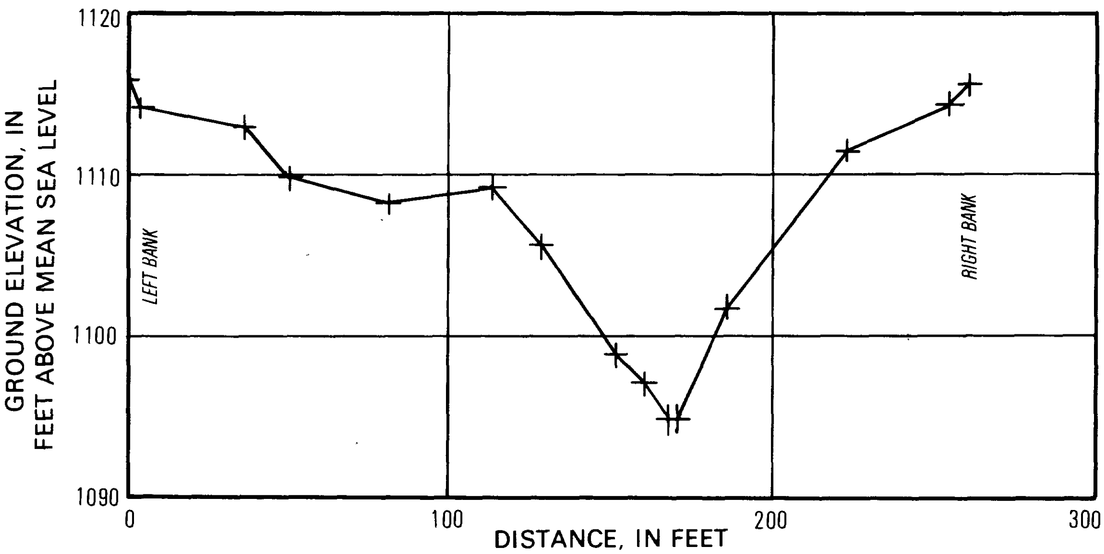


Figure 1.--Example of channel geometry data obtained by field survey or aerial photography.

Dimensions of structures within the flood plain that alter the trend in the channel shape or effect the ability of the channel to convey water are obtained. The most frequent types of structures measured include bridges, culverts, roads, and dams. These structures are measured in the field and surveyed to the common reference datum used for the channel cross sections.

Reference marks are established along the stream channel during the field surveying. These marks are then used as a convenient reference to set the cross sections and structures to a common datum. The locations and elevations of these reference marks are described and are available.

All the above data are used in a hydraulic analysis to develop graphs and maps which describe the flood-flow characteristics of the stream. The analysis includes a graph of the water-surface elevation plotted against the distance along the stream channel for four flood discharges, representing the 10-, 50-, 100-, and 500-year floods. These graphs are the "flood profiles" published in the flood insurance report. Maps of the flood inundation pattern are also prepared and are published in the flood insurance report. Flood boundaries are usually delineated on contour maps, which show ground elevations along the stream channel. Therefore, the depth of flooding can be determined for any point in the flood plain.

INTERPRETATION OF BASIC INFORMATION

Developing channel rating curves.--The discharge corresponding to each flood profile elevation must be determined in establishing a cross-section rating curve. Flood discharge varies with drainage area, slope, and mean annual precipitation for any given stream (Thomas and Corley, 1977). Flood discharges were determined under present conditions for the 500-, 100-, 50-, and 10-year floods in all flood insurance studies at the confluence of major tributaries where major changes in drainage area and discharge occur. A constant discharge was then assumed between tributaries. In the more recent flood insurance studies, routed flood discharges at selected locations such as streets, roads, or intersections are shown in tabular form. Studies done early in the insurance program included a graph of discharges plotted against drainage area. Discharges corresponding to each cross section are obtained from this table or graph, and the four profile elevations are plotted against the corresponding routed discharges on logarithmic plotting paper. The cross-section rating curve is drawn as shown in figure 2. Because each cross section is unique, a rating curve must be defined for each cross section.

Channel shape must be considered in interpolating between the plotted points to obtain a completed rating curve. A curve for a natural channel approximates a series of straight lines with varying slopes when plotted on logarithmic paper. The points where the curve changes slope (transitions) are the points where there is a change in hydraulic control. Changes in slope generally occur near where the channel changes shape or roughness, such as at the low-water bank or where the floodwater spreads

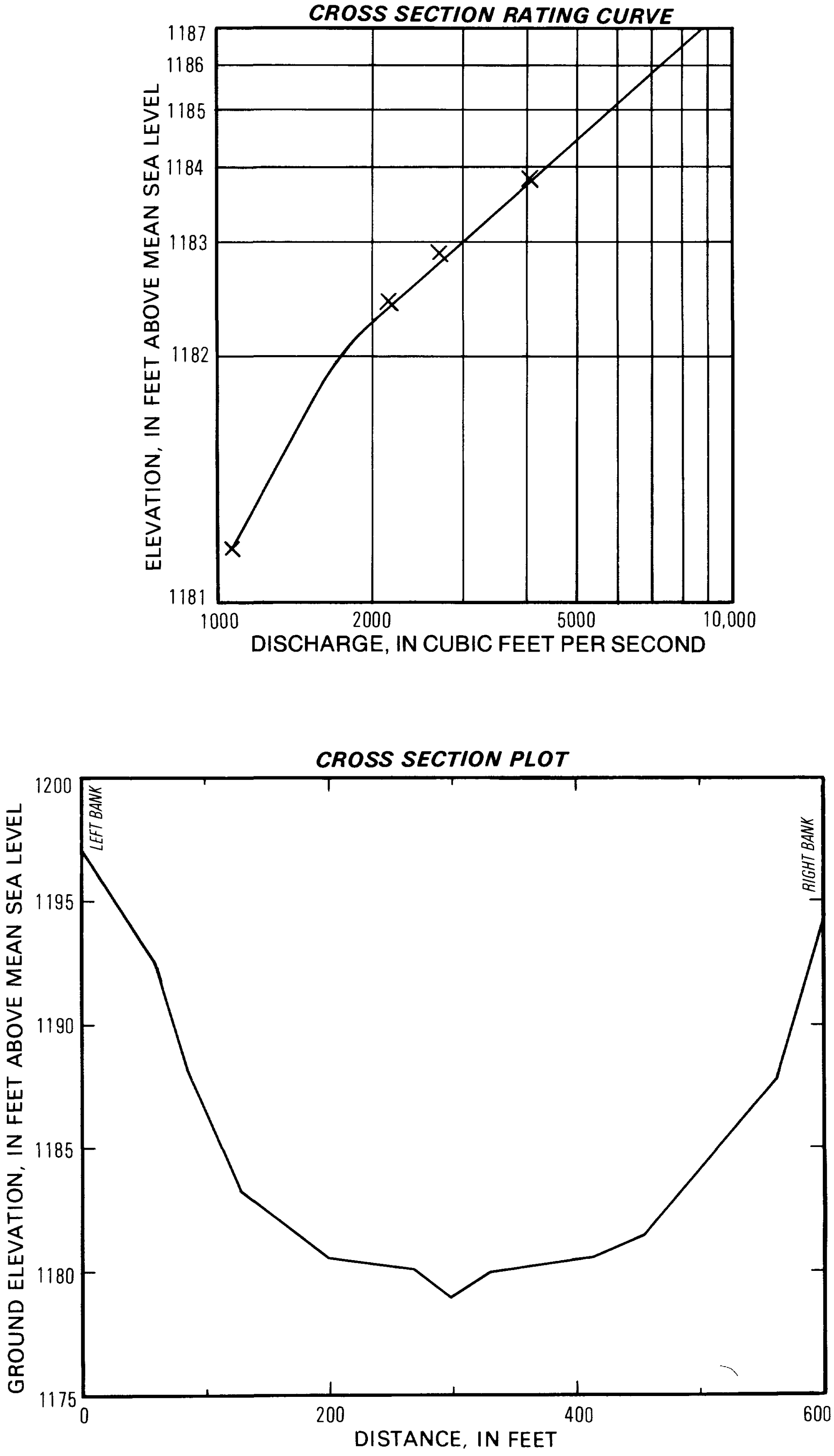


Figure 2.--Example of cross-section plot and cross-section rating curve.

out into the flood plain. Cross sections of a stream having little or no flood plain or no abrupt changes in shape may not have transition points.

The rating curve is drawn through the four plotted points obtained from the flood insurance study, putting the transition or change in slope of the curve at the point where the floodwater breaks out into the flood plain or where there is a change in channel shape. If there are no transitions, a straight line is drawn through the plotted points. Elevations of any discharge may be obtained from the rating curve.

Runoff estimates.--Flood discharges of any given point on a stream depend on the physical and climatalogical characteristics of the area drained by the stream. Those characteristics that are most significant in determining flood discharges in rural Oklahoma streams are drainage area, main-channel slope, and mean annual precipitation (Thomas and Corley, 1977). The drainage area and main-channel slope are obtained from a map or field survey. Drainage area in square miles should be computed as the area of the basin above the point where flood discharge is computed. Slope is computed in feet per mile determined from streambed elevations at points 10 and 85 percent of the distance along the channel from the computation point to the basin divide. The areal distribution of mean annual precipitation, in inches, for Oklahoma is shown in figure 3.

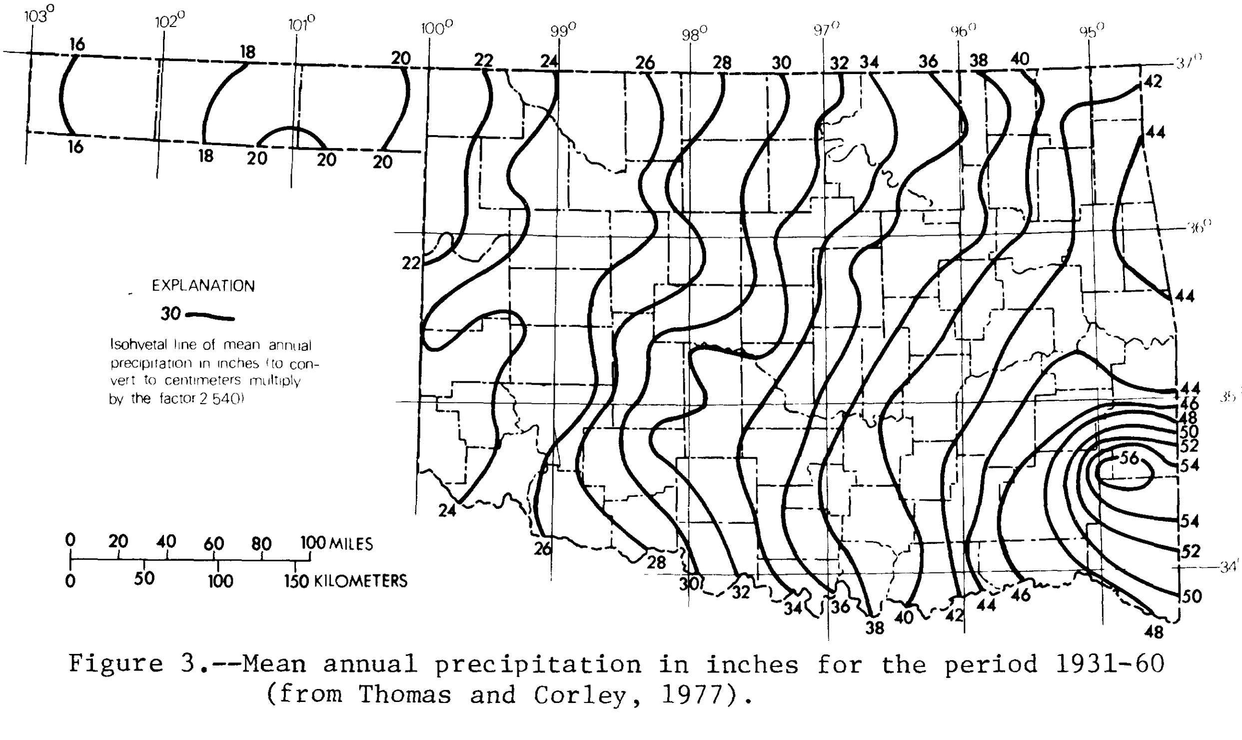


Figure 3.--Mean annual precipitation in inches for the period 1931-60 (from Thomas and Corley, 1977).

Equations developed by Thomas and Corley (1977) relate the peak discharge of floods in rural basins having frequencies of 2-, 5-, 10-, 25-, 50-, 100-, and 500-years to the stream-basin characteristics. These relations are shown in figures 4-10. The peak discharge may be determined graphically for rural basins from figures 4-10 for frequencies of 2-, 5-, 10-, 25-, 50-, 100-, and 500-years. Enter figures 4-10 with drainage area along the top scale and move vertically down to the appropriate main-channel slope curve. Move horizontally across to the appropriate mean annual precipitation curve (determined from figure 3) and downward vertically to the discharge scale to obtain the rural-basin flood discharge. A detailed description of the development of figures 4-10 is described by Thomas and Corley (1977).

Urban-basin peak flood discharges are normally larger than rural-basin peak flood discharges for any given frequency. Any increases in peak discharge depends on the amount and type of urban development in the basin. Urban runoff information for Oklahoma is limited but Sauer (1974) has developed an approach for estimating flood discharge for urban basins. The technique is based upon the assumption that the urban flood-frequency curve can be estimated by interpolating between the rural frequency curve (lower limiting discharges) and the frequency curve for a completely developed basin (upper limiting discharges). This interpolation for intermediate stages of development is based on an urban adjustment factor R_L defined by Leopold (1968) as the ratio of the urban 2-year peak discharge to the rural 2-year peak discharge. Figure 11 illustrates the relationship between the urban adjustment factor R_L and the percentage of the basin impervious and served by storm sewers (adapted from Leopold (1968) by Sauer (1974)). The rural or undeveloped frequency curve ($R_L = 1$) can be estimated by figures 4-10 as noted above. The completely developed frequency curve ($R_L = 7$) is approximated by the rainfall intensity frequency curve assuming 100 percent runoff.

Interpolation of Q_{NU}, the urban peak discharge for frequency N, can be determined for the general equation,

$$\frac{Q_{NU}}{Q_2} = \frac{7\ R_x(R_L-1)}{6} + \frac{(7-R_L)}{6}\ \frac{Q_N}{Q_2}$$

where Q_N is the peak discharge for rural conditions for frequency, N, and the other terms are as previously defined. Sauer (1974) provides more information on the assumptions made and the equations used in developing figures 11-17. The graphical analysis is made using the graphs in figures 12-17 for frequencies of 5, 10, 25, 50, 100, and 500 years. Enter figures 12-17 with the rural-basin flood discharge ratio along the bottom scale and move upward vertically to the appropriate R_L curve. Move horizontally across to the appropriate urban-basin flood discharge ratio. Multiply the urban ratio by the rural-basin 2-year flood to obtain the urban-basin discharge. Figures 3-17 may be used to determine urban flood discharges for any basin in Oklahoma in any present or planned stage of urbanization.

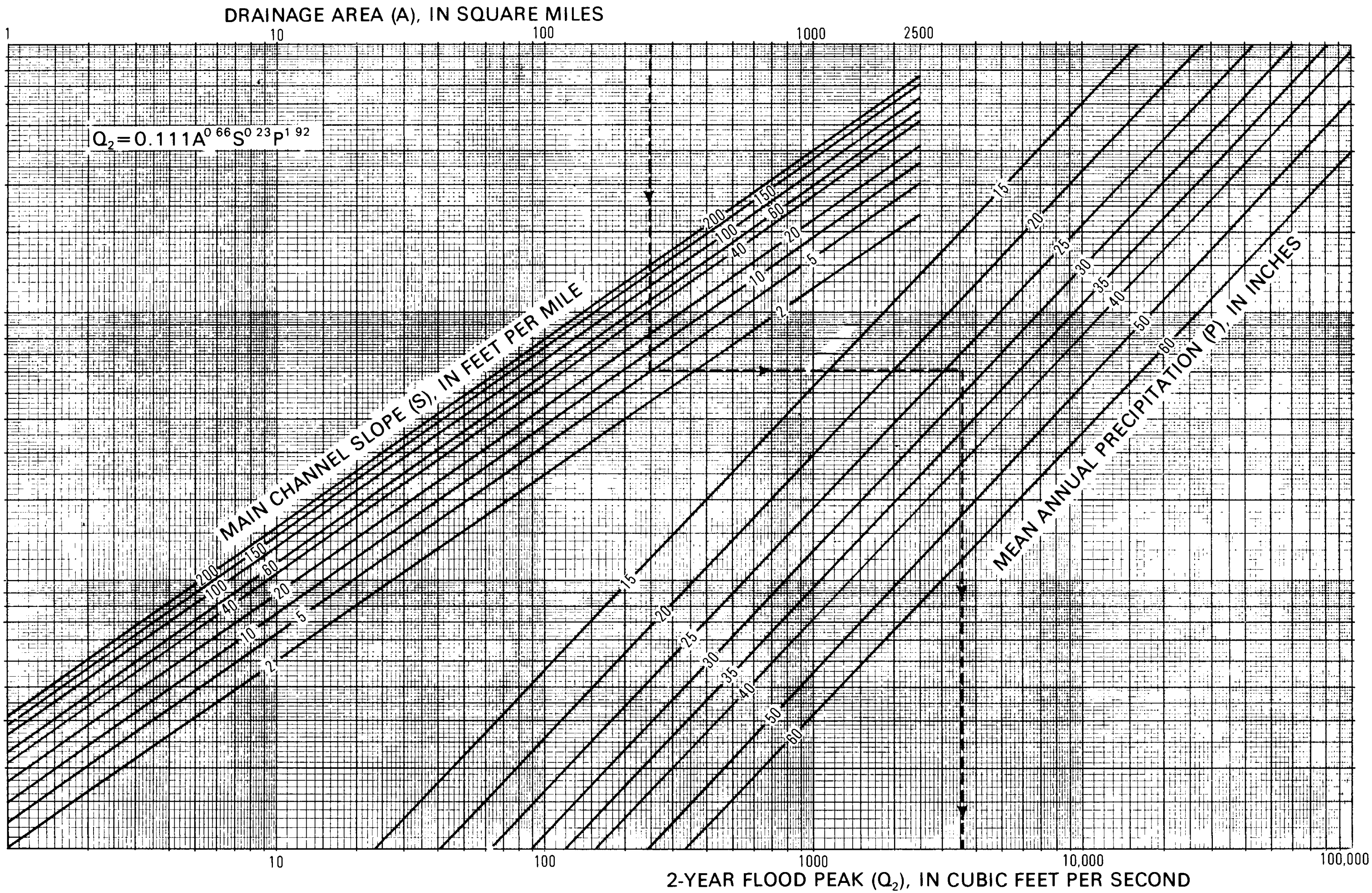


Figure 4.--Relation of 2-year flood peak to drainage area, main channel slope, and mean annual precipitation (from Thomas and Corley, 1977).

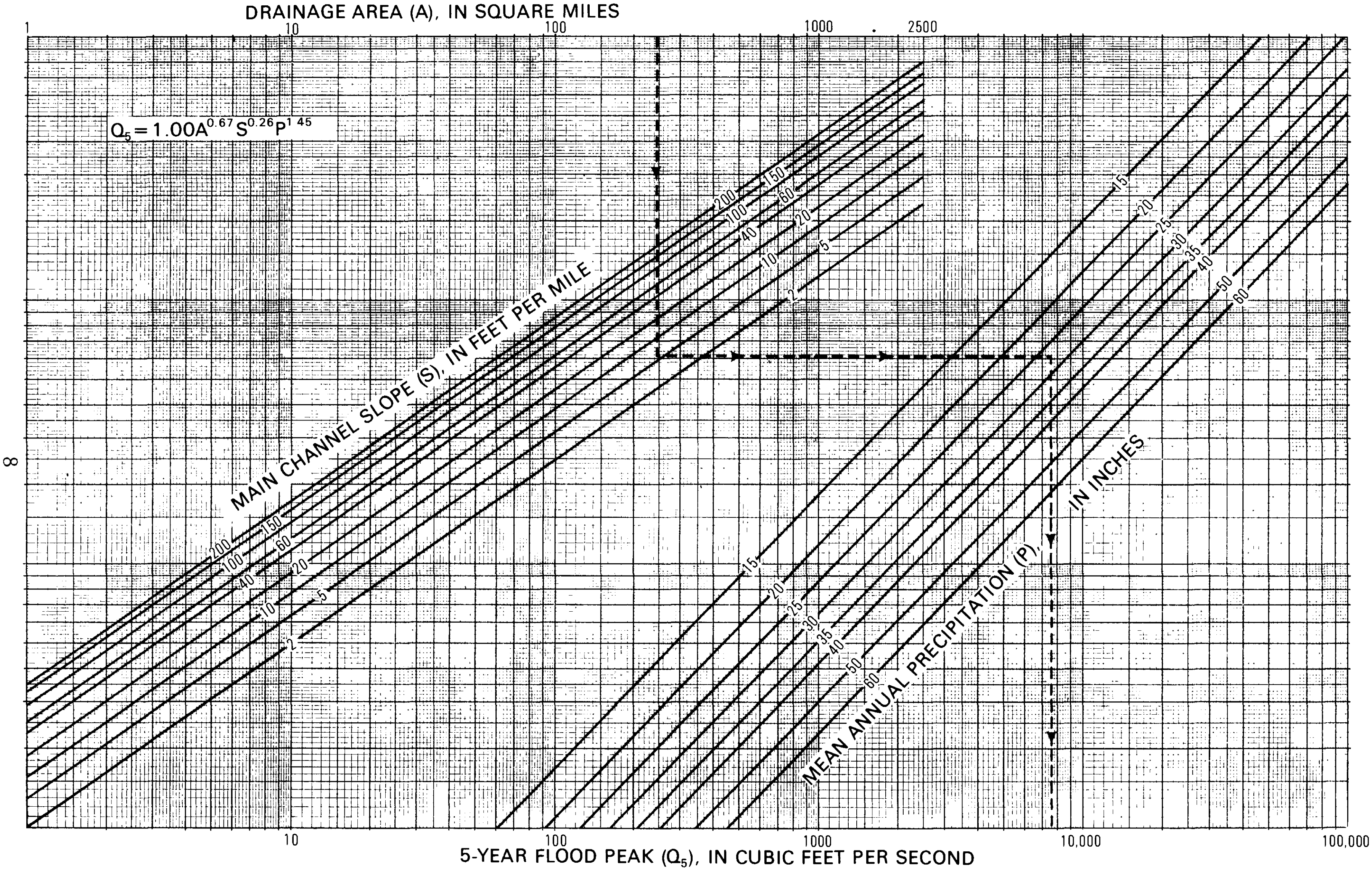


Figure 5.--Relation of 5-year flood peak to drainage area, main channel slope, and mean annual precipitation (from Thomas and Corley, 1977).

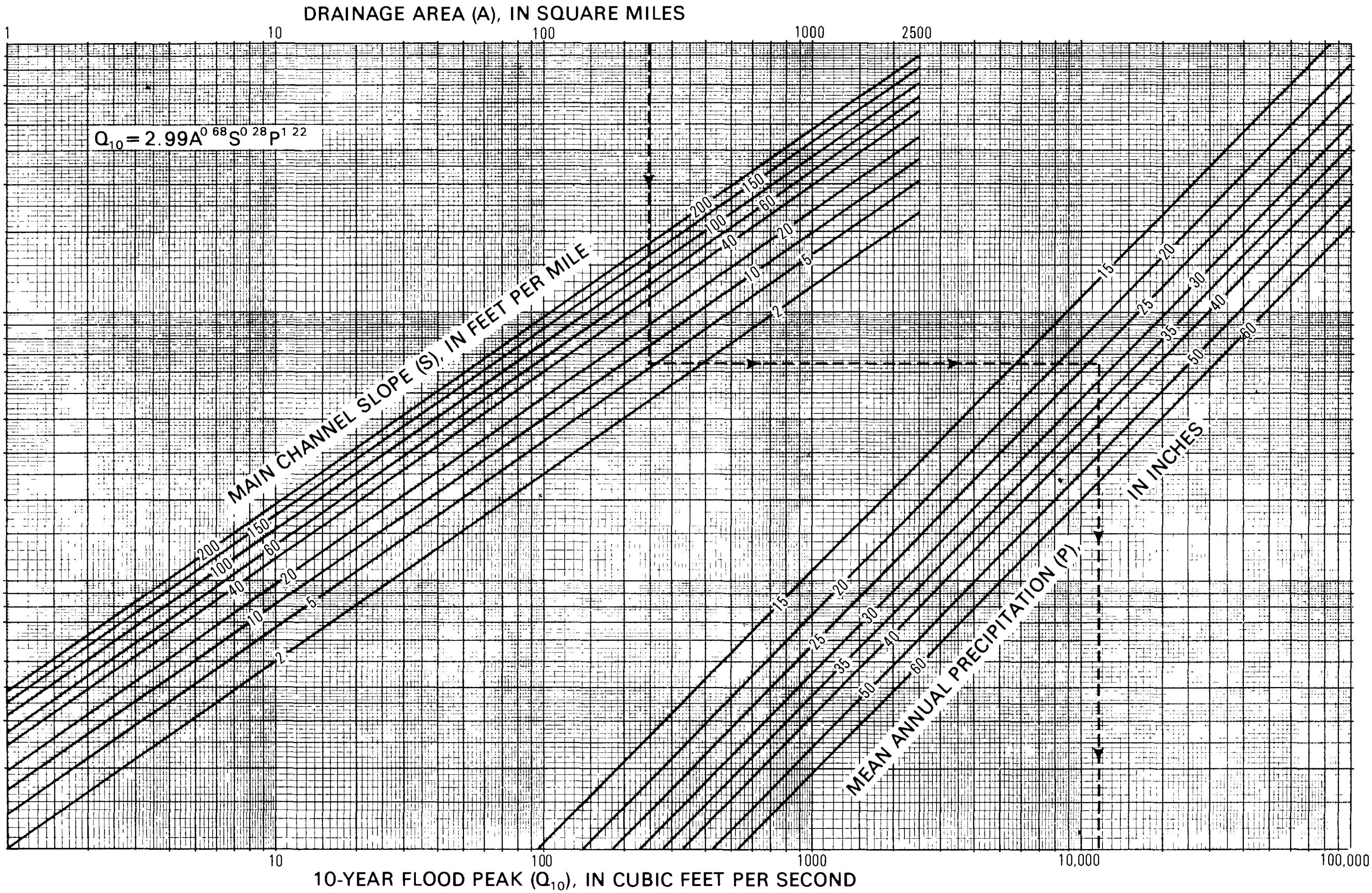


Figure 6.--Relation of 10-year flood peak to drainage area, main-channel slope and mean annual precipitation (from Thomas and Corley, 1977).

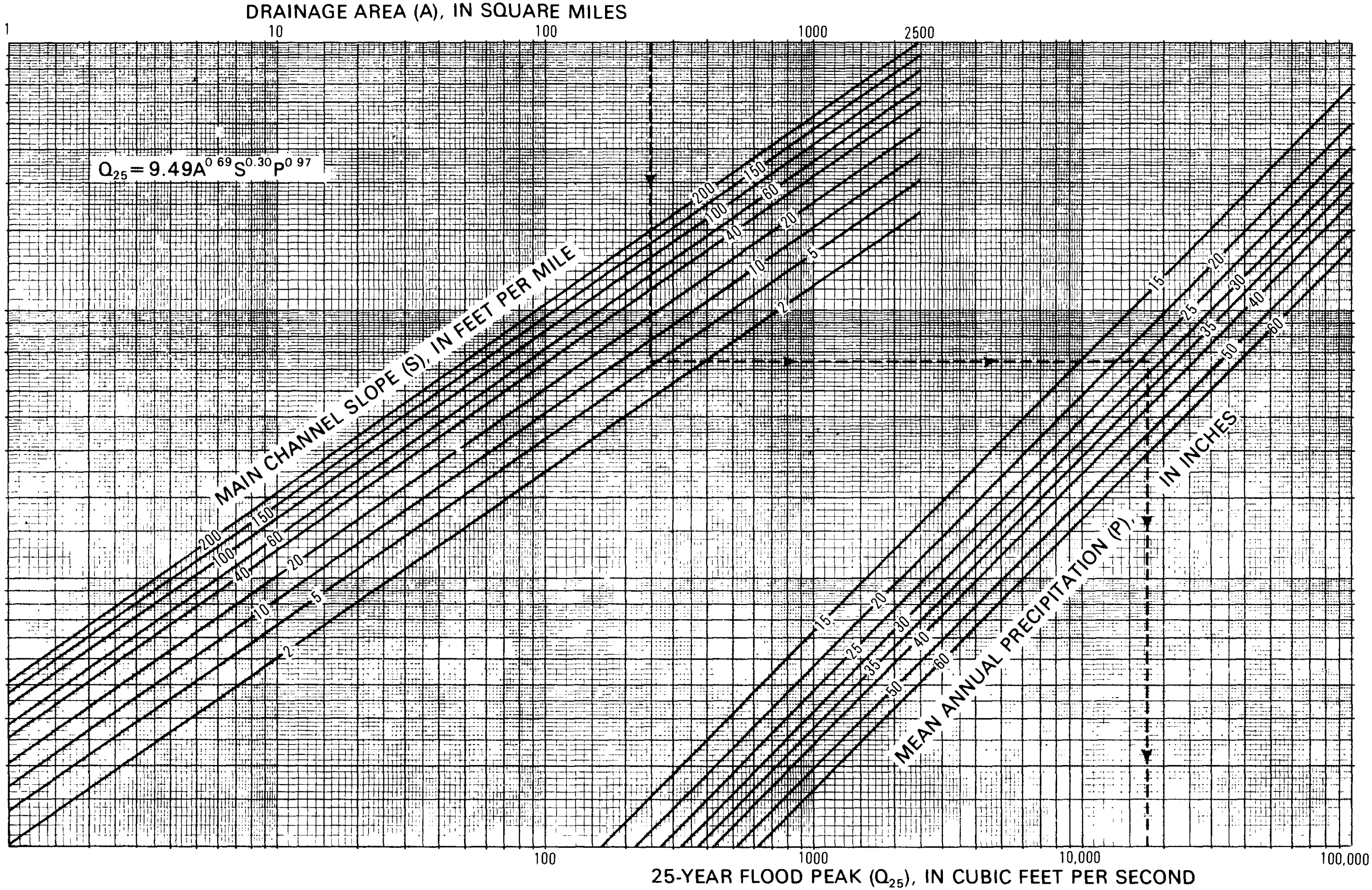


Figure 7.--Relation of 25-year flood peak to drainage area, main-channel slope and mean annual precipitation (from Thomas and Corley, 1977).

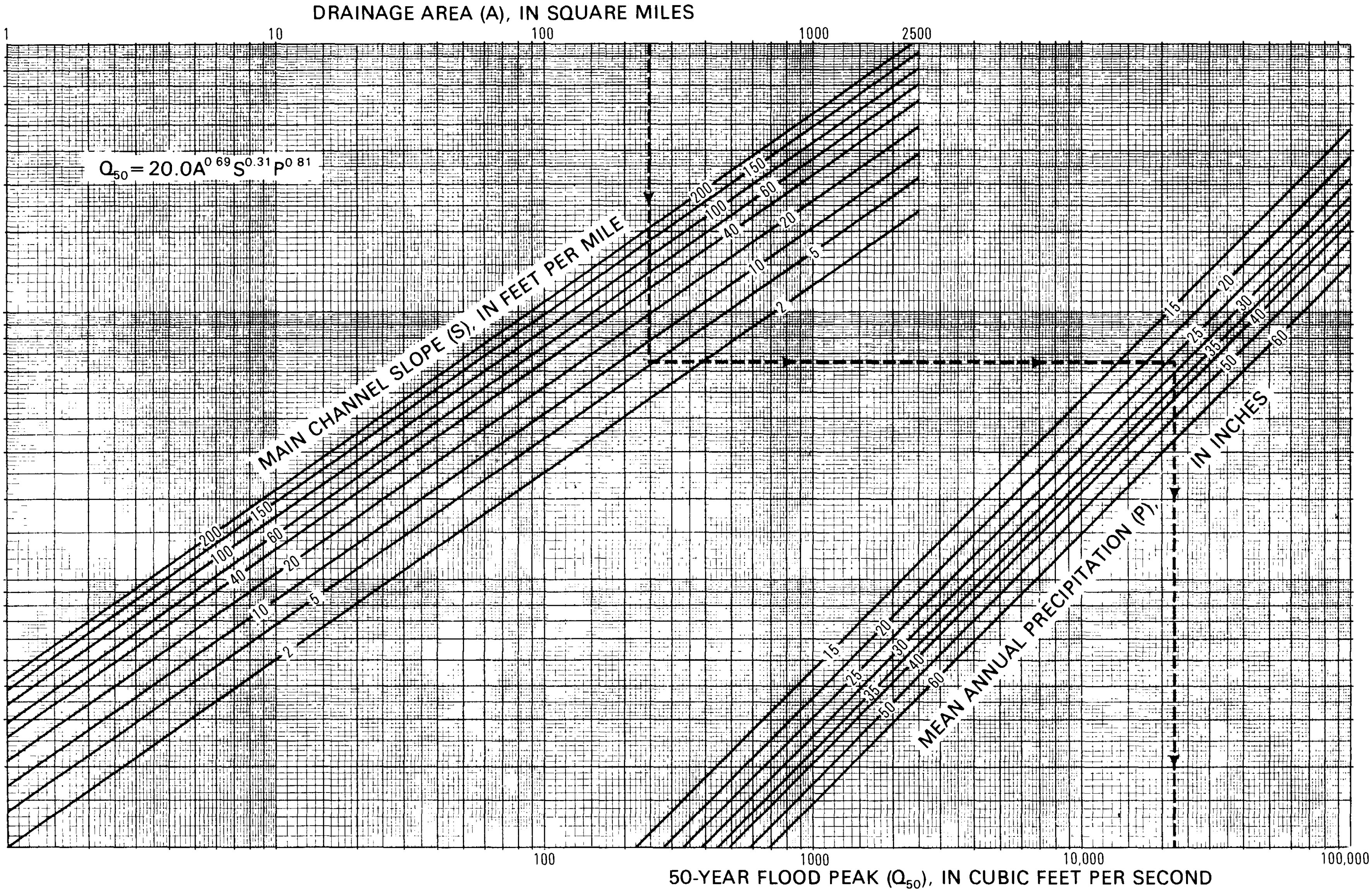


Figure 8.--Relation of 50-year flood peak to drainage area, main-channel slope and mean annual precipitation (from Thomas and Corley, 1977).

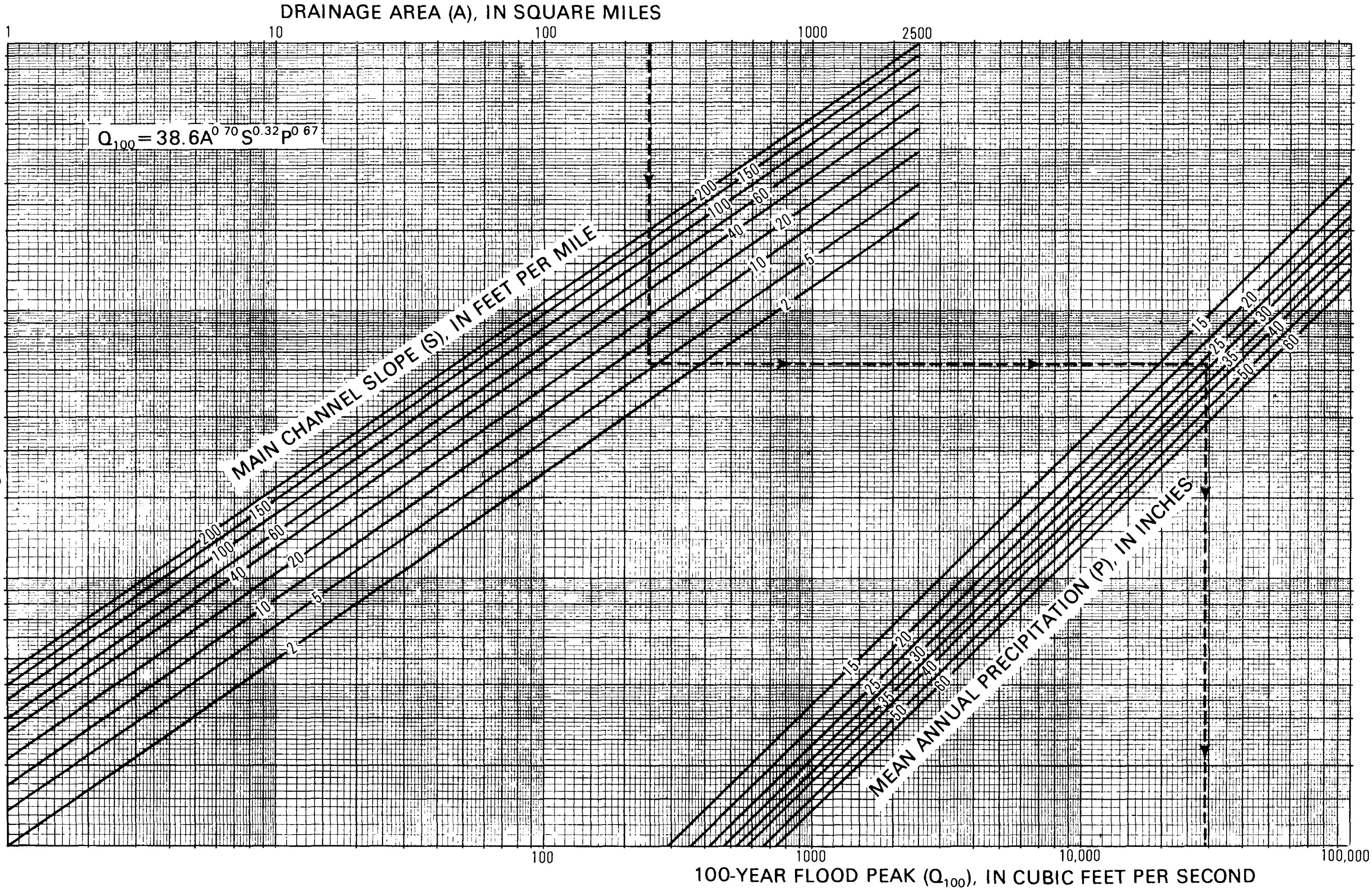


Figure 9.--Relation of 100-year flood peak to drainage area, main-channel slope and mean annual precipitation (from Thomas and Corley, 1977).

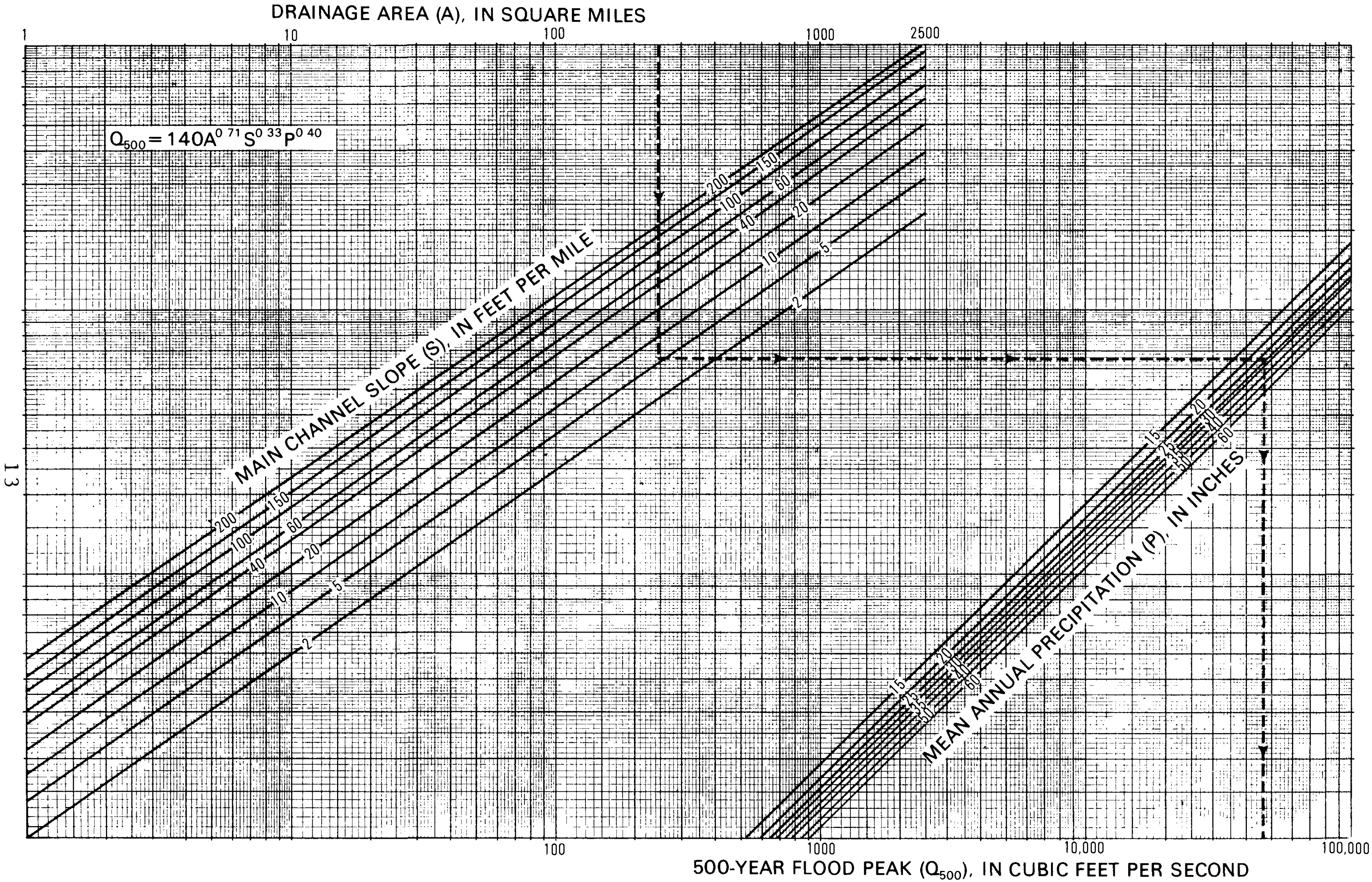


Figure 10.--Relation of 500-year flood peak to drainage area, main-channel slope and mean annual precipitation (from Thomas and Corley, 1977).

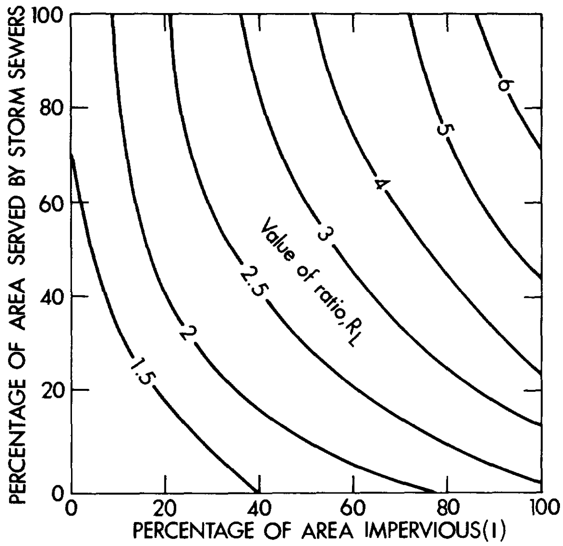


Figure 11.--The relationship of the urban adjustment factor, R_L, to the percentage of the area impervious and served by storm sewer. (Adapted from Leopold, 1963, by Sauer, 1974)

A graphical solution of the above general equation was developed for selected flood frequencies of 5, 10, 25, 50, 100, and 500 years based on rainfall intensities computed by Sauer (1974) from Oklahoma City rainfall data.

Developing profiles and mapping.--The cross-section rating curves and the urban flood discharge relations may be used to define flood profiles and the inundated areas for any urban development plan. First, urban discharges of desired frequencies are computed for the planned urbanized basin above each cross section. The elevation corresponding to each discharge is determined from the rating curve at each cross section. The elevations are plotted against cross-section location along the channel to obtain profiles for the planned urbanization. The plot of the cross section in figure 1 is used to determine the point where the water surface will meet the ground surface on each side of the stream. These two points locate the boundary of the inundation pattern, which can be plotted on a map. Using the contour lines of the map, the inundation pattern may be interpolated between cross sections to show the area inundated by flooding as a result of urban storm runoff.

Limitations.--Techniques described in this report are designed to make optimum use of information previously generated from a flood insurance study. In using this information for an urban study, approximations must be made where available data do not exactly meet the user's requirements. Therefore, the application of the techniques have limitations which are discusssed below.

Any alteration of the hydraulic characteristics of the stream channel such as a change in channel shape, slope, or vegetative cover will change the shape of the rating curves. Most streams in Oklahoma have mild slopes that result in a hydraulic situation whereby the rating curve at each cross section is downstream dependent. This means that anything resulting in rating-curve changes at a particular point along a stream will not affect the rating curve at downstream cross sections but will cause changes in rating curves immediately upstream and may cause changes in all rating curves upstream. The techniques described in this report assume there will be no change in the hydraulic characteristics of the stream channel with urban development.

Figures 3-10 are based upon extensive streamflow data and considerable effort was made to minimize errors; therefore, results from the rural discharge analysis may be used with confidence. An extensive discussion of the rural-basin discharge analysis is given by Thomas and Corley (1977). The urban discharge analysis using figure 11-17 is based upon limited data, none of which was collected in Oklahoma. There have not been sufficient data from urban areas to determine the accuracy of techniques for computation of urban flood discharges for Oklahoma.

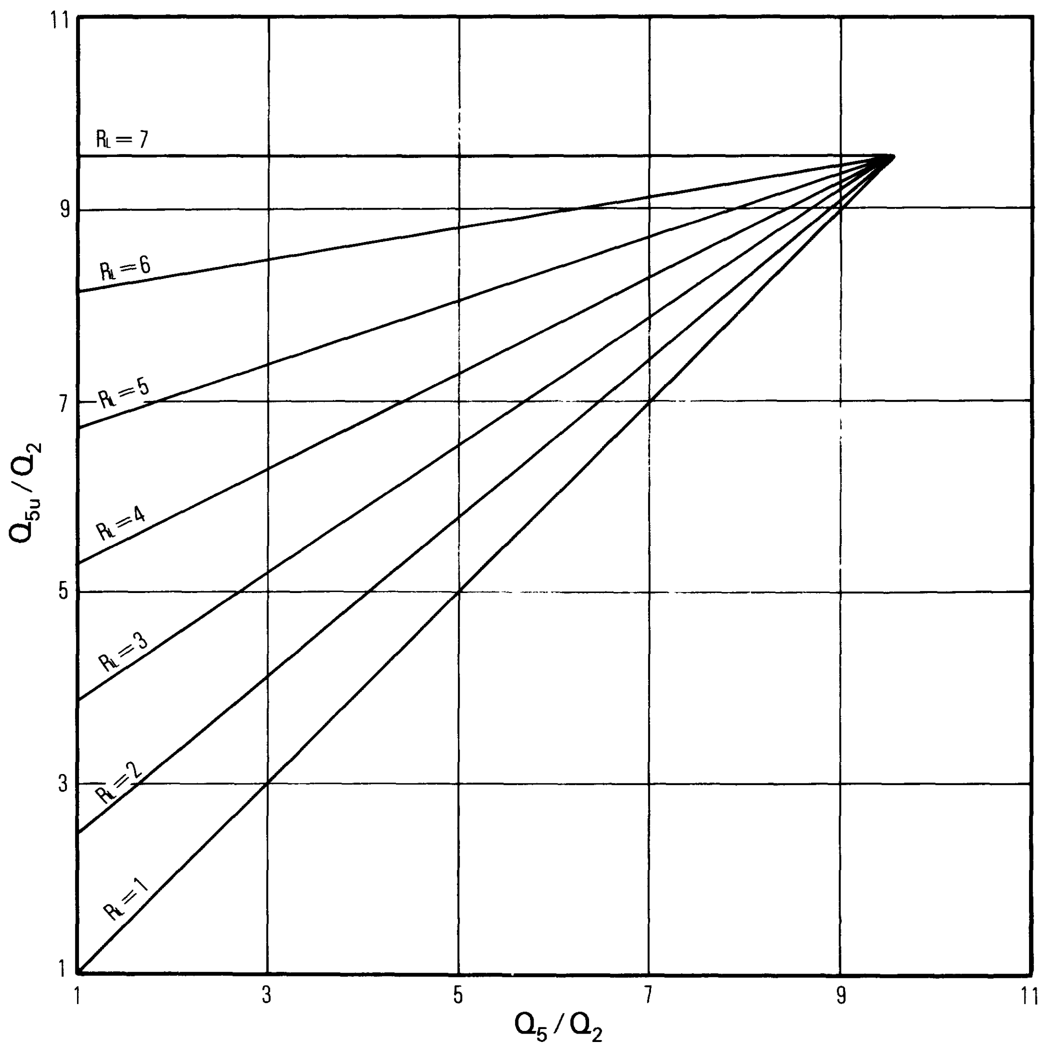


Figure 12.--The relationship of the urban-basin 5-year discharge to the rural-basin 5-year discharge for any R_L.

The graphs in figures 12-17 are limited to streams where the ratio of the rural-basin flood of a desired frequency (Q_N) to the 2-year flood (Q_2) is less than that given in table 1. If the ratio is greater than

Table 1.--Limiting ratio of rural-basin flood frequency to the 2-year flood frequency.

Flood frequency in years	5	10	25	50	100	500
Limiting ratio to 2-year flood	9.59	11.20	13.23	14.77	16.31	23.17

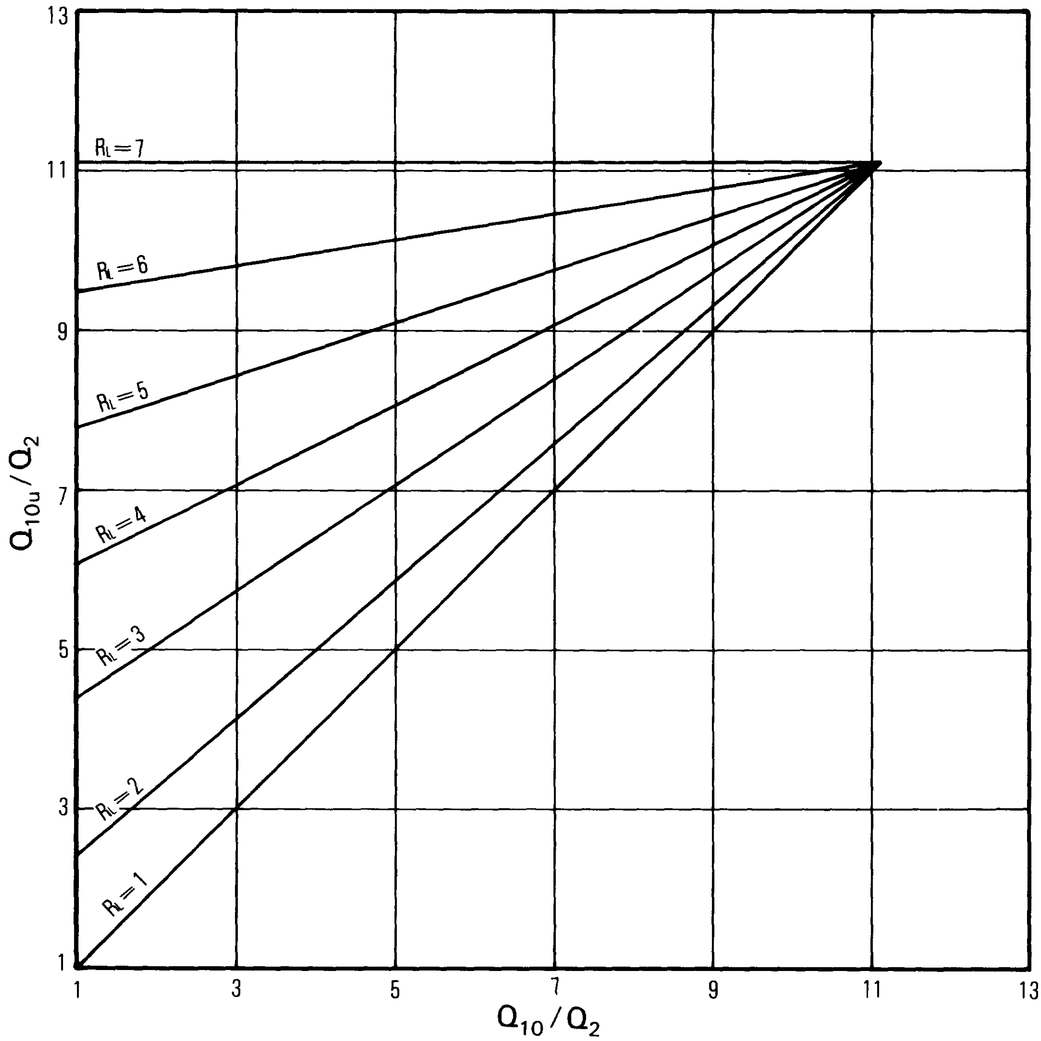


Figure 13.--The relationship of the urban-basin 10-year discharge to the rural-basin 10-year discharge for any R_L.

the table value, urban discharges can be computed that are less than the rural discharges. This situation indicates a bias in the basic data favoring areas with uniform storms of broad areal coverage, and not areas where storms are intense and scattered. Arid regions will have isolated large infrequent floods accompanied by long periods of little or no flooding. This causes the 2-year flood to be low relative to other frequencies, resulting in the ratio of selected flood discharge to the 2-year flood discharge to be large. High discharge ratios probably will not occur in eastern Oklahoma, but discharge ratios exceeding the table values (table 1) will occur in western Oklahoma. The values of the discharge ratios in central Oklahoma will depend on the stream studied. Thus, urban discharges should be used with caution.

Two original assumptions made in the urban analysis are possible contributors to the bias. First, the completely urbanized flood-frequency ratios are

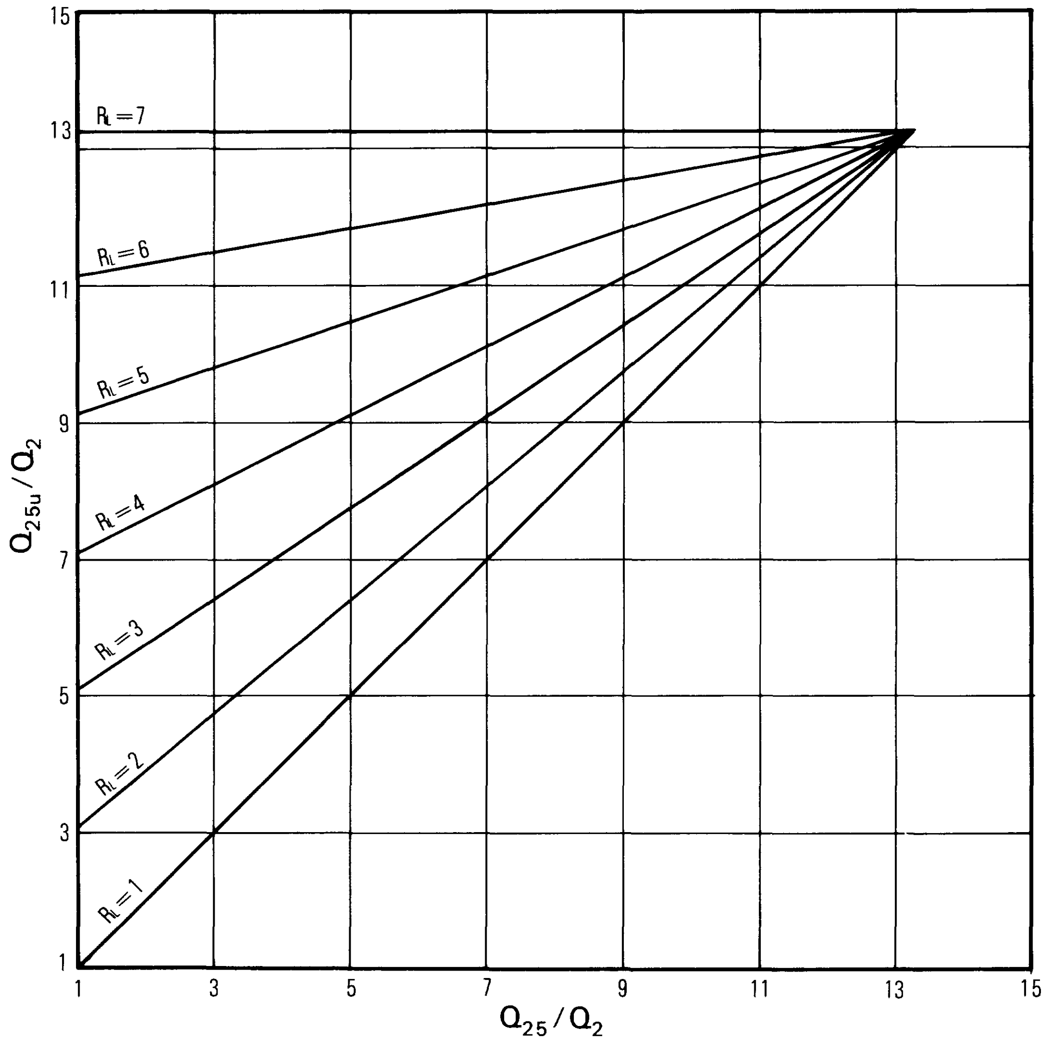


Figure 14.--The relationship of the urban-basin 25-year discharge to the rural-basin 25-year discharge for any R_L.

assumed to be the same as the National Weather Service (NWS) rainfall intensity ratios (R_x). The NWS analysis is the result of averaging several rain gages, eliminating some variability of the data. Also, an urban analysis in an area that is not typical of the Oklahoma City area may not generate accurate results. Using rainfall record that is more representative of the area to compute different R_x values may improve the urban flood analysis. However, some limited investigation in this area was not always successful. The second assumption is that the totally developed 2-year discharge is 7 times the rural 2-year discharge. More storm data than are normally available are needed to determine the validity of this assumption.

Advantages.--The analysis described in this report has several advantages in urban planning. Techniques used require a minimum of technical skill in hydrology and hydraulics. Communities which cannot economically justify extensive technical staff would still be able to perform the computations.

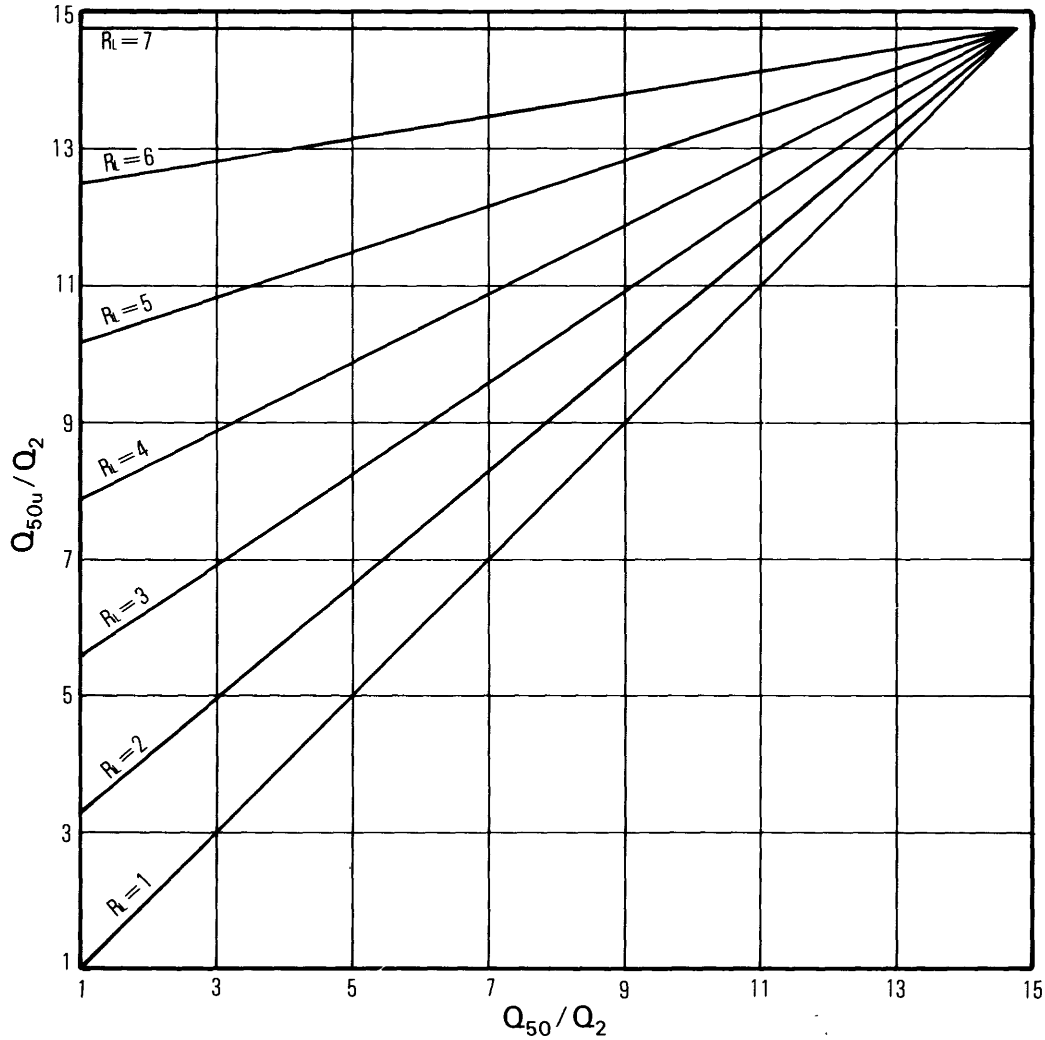


Figure 15.--The relationship of the urban-basin 50-year discharge to the rural-basin 50-year discharge for any R_L.

The number of steps required to obtain results for this analysis is few compared to other more sophisticated techniques. Therefore, flood elevations resulting from any assumed urbanization alternative may be obtained in a shorter time. Many possible alternatives could then be studied. The ability to eliminate unsatisfactory alternatives quickly, and to recognize areas where flooding is not a problem, can save time and money.

Costs involved in urban flood planning may be greatly reduced because existing information is used which was expensive to obtain. These data eliminate the necessity for extensive in-house data collection expense.

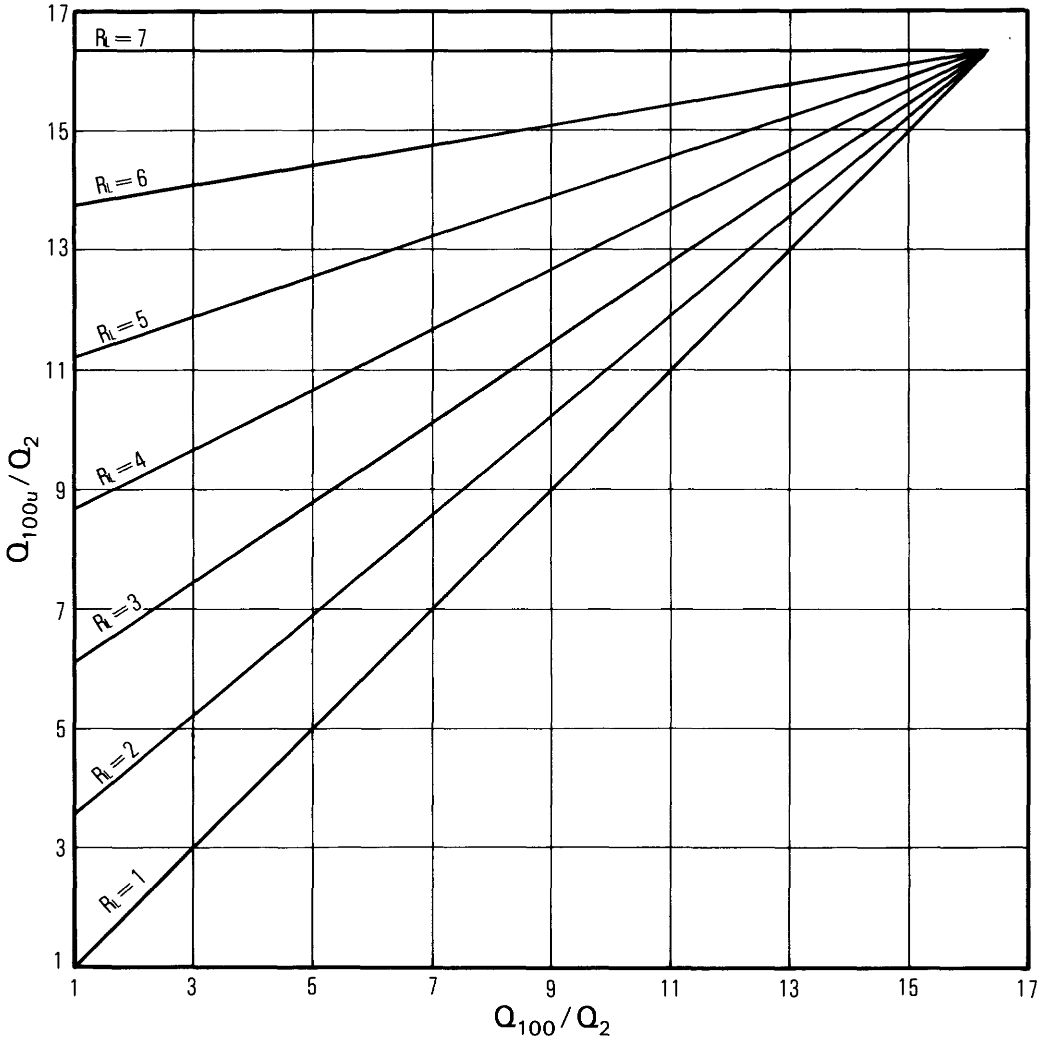


Figure 16.--The relationship of the urban-basin 100-year discharge to the rural-basin 100-year discharge for any R_L.

EXAMPLE APPLICATION

Two reaches of a stream channel were analyzed to illustrate the application of the techniques described in this report. Profiles were computed and flood inundation widths obtained for the natural basin. Comparisons of profiles and flood inundation for increasing stages of urbanization are also shown.

Rating curves.--Rating curves were plotted for selected cross sections on each of two reaches on Choctaw Creek, in the Oklahoma City metropolitan area. The rating curves and corresponding cross-section plots for selected cross sections are shown in figures 18-22. The cross-section numbers increase in an upstream direction.

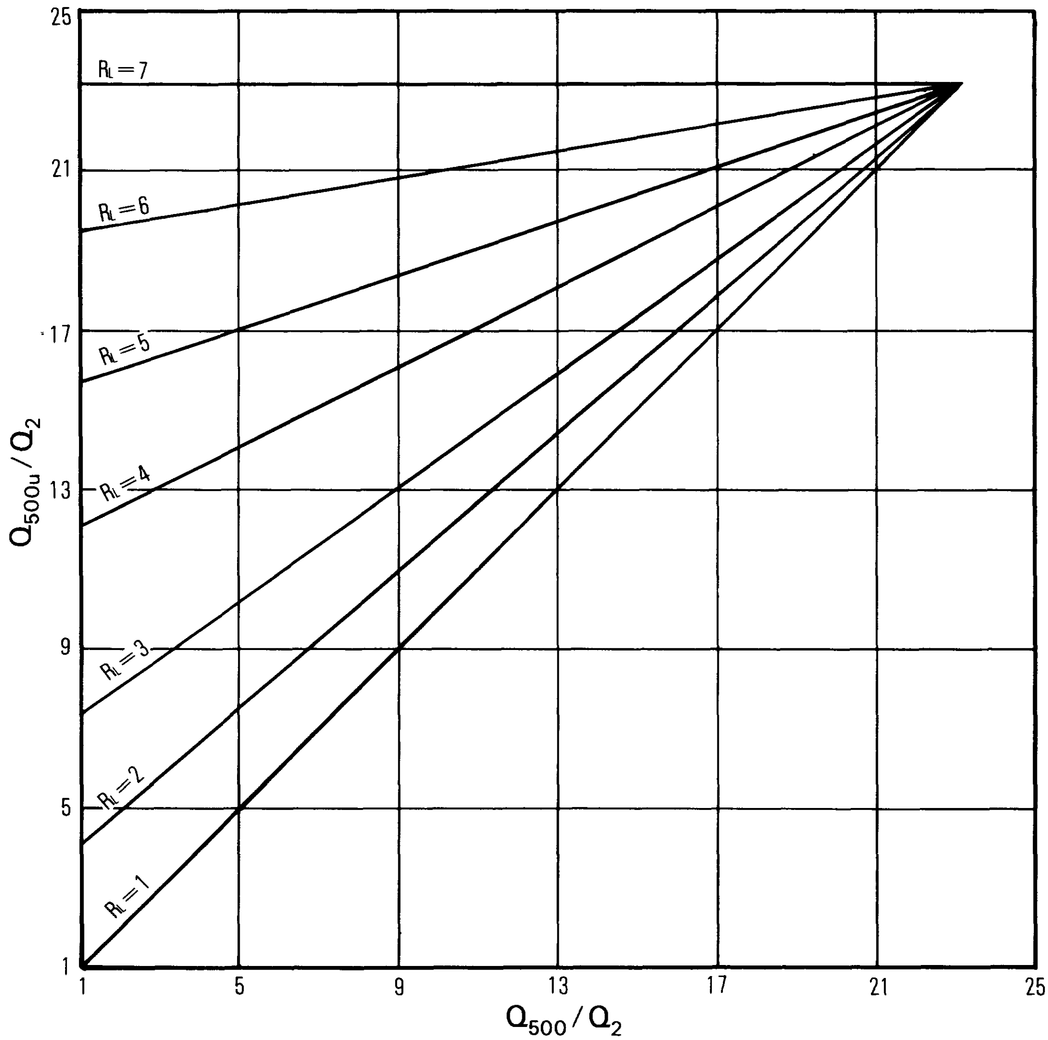
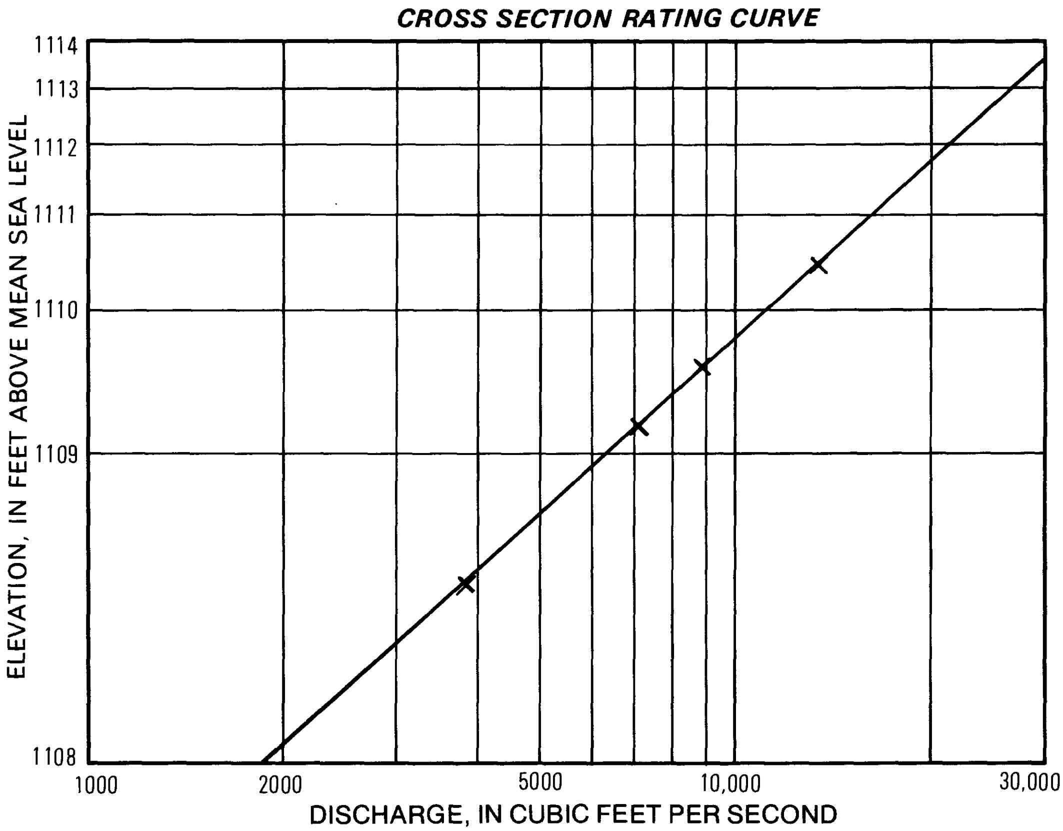


Figure 17.--The relationship of the urban-basin 500-year discharge to the rural-basin 500-year discharge for any R_L.



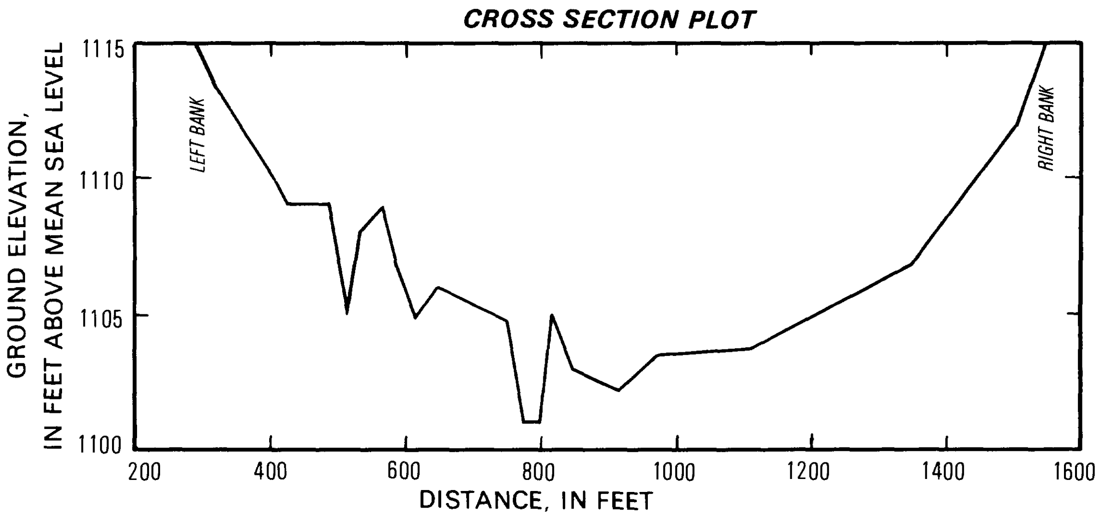
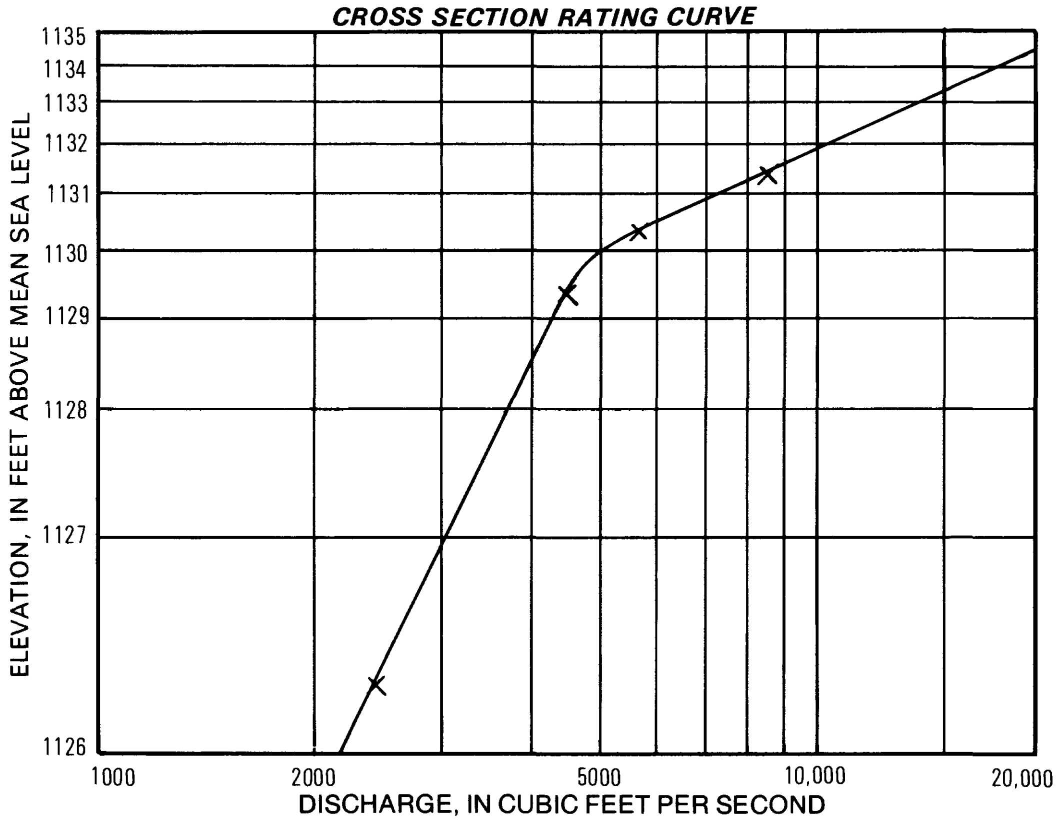


Figure 18.--Choctaw Creek rating curve and plot of cross-section 19.



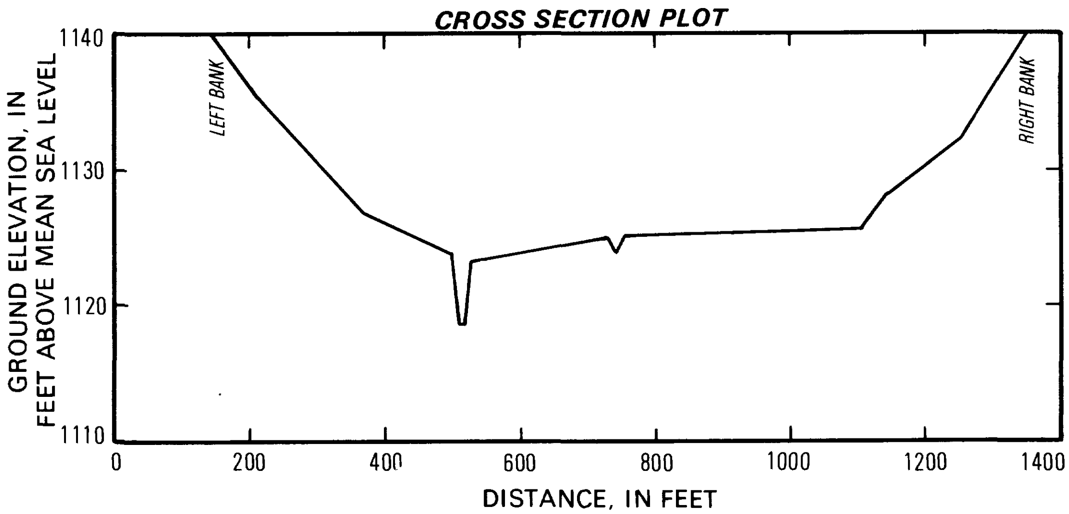
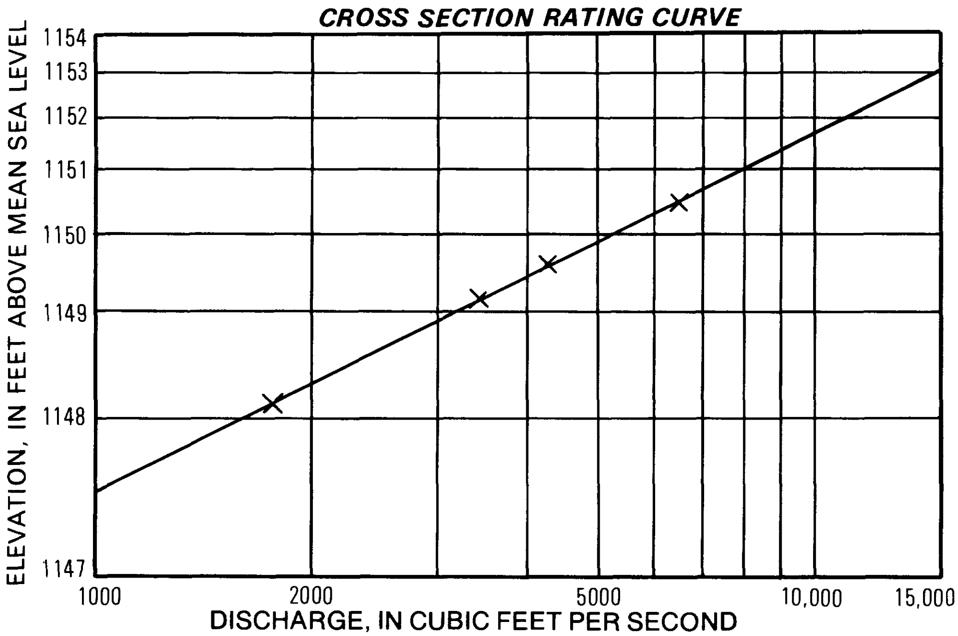


Figure 19.--Choctaw Creek rating curve and plot of cross-section 28.



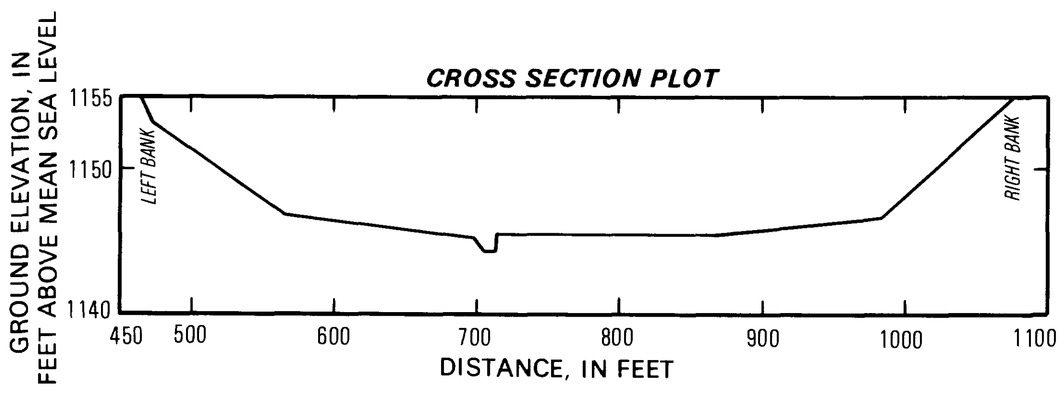
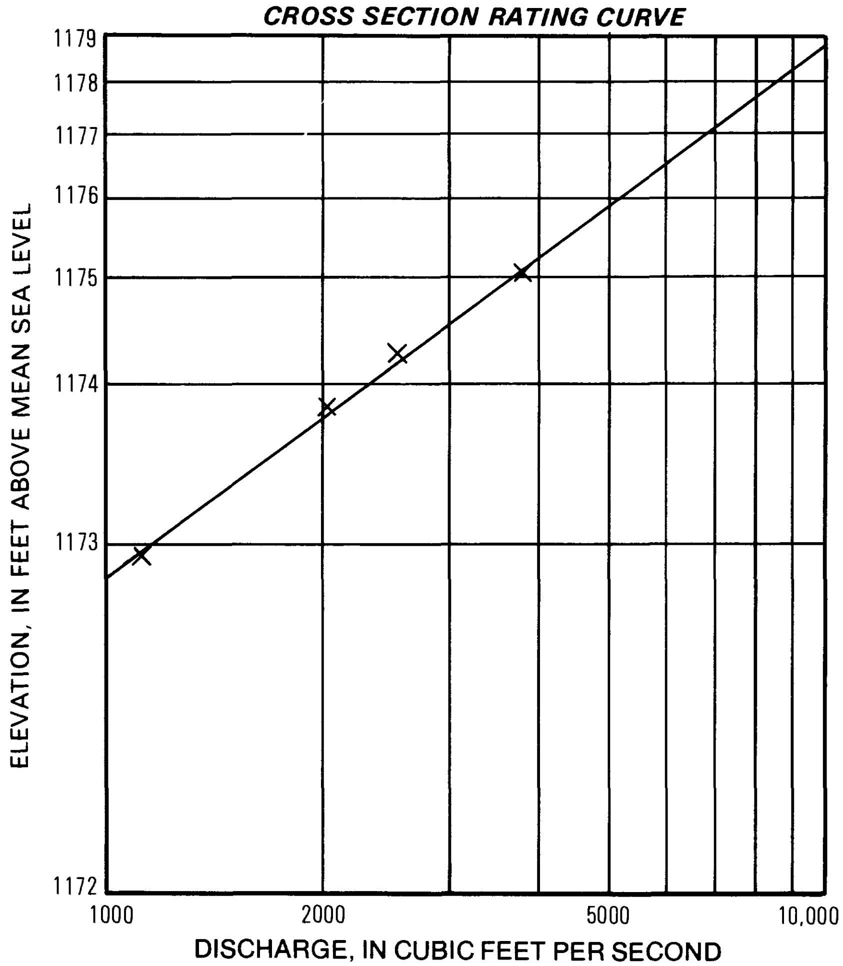


Figure 20.--Choctaw Creek rating curve and plot of cross-section 34.



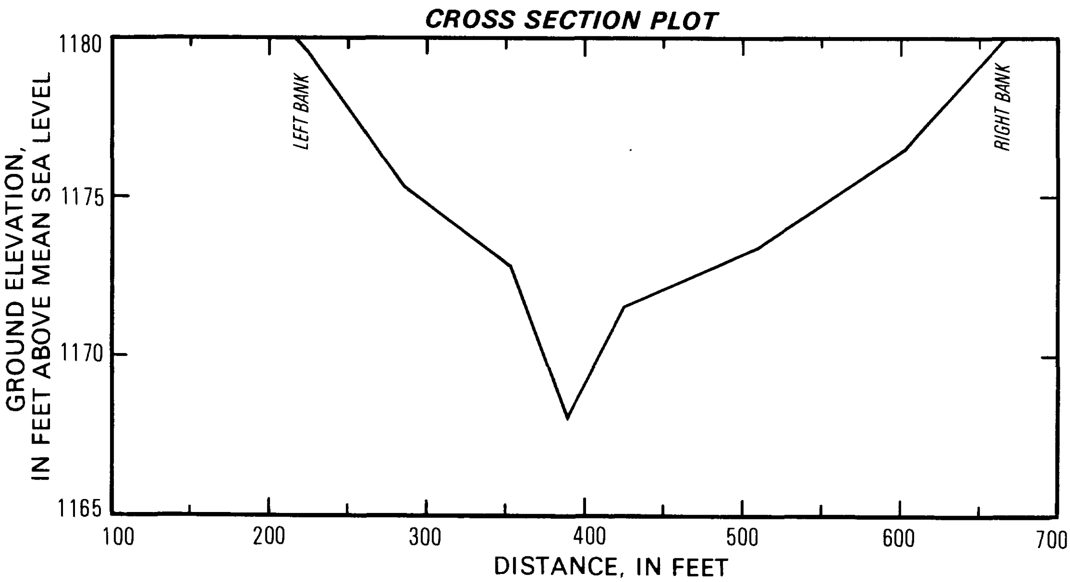


Figure 21.--Choctaw Creek rating curve and plot of cross-section 40.

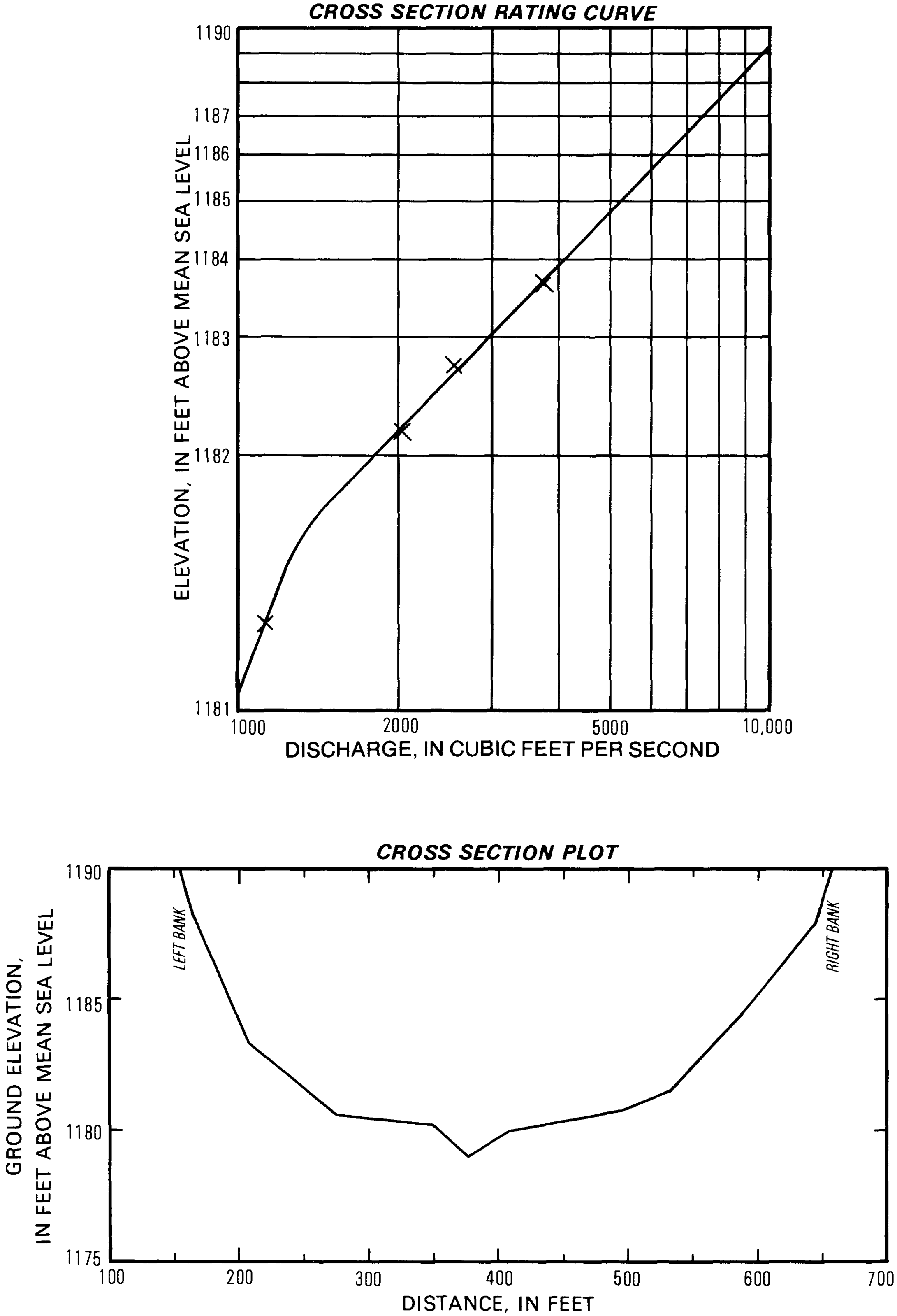


Figure 22.--Choctaw Creek rating curve and plot of cross-section 43.

Urban runoff analysis.--Flood discharges for the 2-, 5-, 10-, 25-, 50-, 100-, and 500-year frequencies were computed for each stream reach for urbanization factors (R_L) of 1, 2, 3, 4, 5, 6, and 7. An urbanization factor of 1 represents no urbanization and a factor of 7 represents complete urbanization with no infiltration of precipitation. The seven flood discharges mentioned above were computed at several cross-section locations along each reach where there were significant increases in tributary inflow. The flood discharges at each of these cross sections were determined graphically from figures 4-17 and are listed in table 2 from downstream to upstream. Discharge was not computed at cross sections not included in table 2, but they were assumed to have the same discharge as the value in the table for the cross section nearest it downstream.

Profiles and flood-plain inundation.--The flood profiles shown in figures 23 and 24 are determined using discharge values from table 2 and the rating curves for the stream cross sections. Flood profiles and flood width were developed for the 100-year flood frequency for urban factors of 1, 2, 3, 4, 5, 6, and 7. Profiles for urban factors of 1, 4, and 7 are plotted for reach 1 and 2 in figures 23 and 24, respectively. The flood-plain width at each cross section for the profiles in figures 23 and 24 are shown in table 3. It also may be shown from table 3 that some areas are more sensitive to discharge changes than other areas. If the increases in flood-plain width in table 3 are computed between the rural-basin flood (R_L=1) and the flood from a completely impervious basin (R_L=7), it becomes obvious which areas are sensitive to development and which are not sensitive. The stream channel at cross section 21 is not significantly affected by increased flood discharge because the increase in flood width is only 4 percent, but cross section 40 is highly sensitive to increased discharge with a 40 percent increase in flood width.

Comparison of analysis.--The techniques described in this report are considered to be an acceptable alternative to the more costly methods of streamflow routing. Some approximations are made and some steps eliminated which may lead to errors in the results. In an attempt to evaluate the significance of these possible errors, comparisons were made between the graphical methods used in this report and the more accurate and costly method of streamflow routing. Three flood discharges for Choctaw Creek were used to obtain flood elevations by the graphical method and also by routing using the step-backwater method (Shearman, 1975).

Table 4 is a summary of the comparisons of the two methods of obtaining flood profiles for Choctaw Creek. The selected discharge, routed elevations, and the graphical elevations are listed for each cross-section in the two stream reaches. Included in the table in addition is the difference between the routed and graphical elevations and the average elevation difference for each reach. The three floods compared were of sizes that covered the range of possible floods to show that errors are not related to flood size.

The graphical method results in differences of less than 0.1 foot from the routing method for most of the Choctaw Creek cross sections. This is an acceptable error in that the original routing techniques used to establish the rating curves have an accuracy of 0.5 foot from the elevation

2.--Choctaw Creek discharge frequency determined at selected cross sections for different urbanization factors.

.s *	Urban :ion factor (R_L)	Flood discharge (ft^3/s) for given frequency in years						
		2	5	10	25	50	100	500
:H 1								
)	1	1304	2603	3845	5623	7019	8864	13407
	2	2607	4259	5648	7576	9067	10947	15509
.=21.1	3	3910	3910	7443	9518	11101	13012	17585
pe=21.4	4	5214	7561	9239	11459	13136	15077	19660
	5	6517	9212	11034	13401	15170	17142	21736
	6	7821	10862	12829	15342	17205	19207	23811
	7	9124	12513	14625	17284	19239	21272	25887
l	1	1219	2433	3591	5249	6552	8267	12493
	2	2438	3982	5278	7076	8469	10218	14466
.=18.9	3	3657	5526	6957	8894	10374	12154	16414
pe=21.8	4	4876	7070	8637	10711	12278	14088	18363
	5	6095	8614	10317	12528	14182	16023	20311
	6	7314	10158	11997	14346	16087	17958	22259
	7	8532	11702	13676	16163	17991	19893	24208
.3	1	985	1962	2888	4211	5259	6616	9968
	2	1970	3214	4253	5692	6814	8203	11583
.=13.5	3	2954	4462	5612	7166	8358	9777	13178
pe=22.8	4	3939	5710	6972	8639	9902	11350	14773
	5	4924	6958	8331	10112	11447	12924	16368
	6	5909	8206	9690	11585	12991	14498	17963
	7	6894	9454	11049	13058	14536	16072	19558
:6	1	838	1670	2456	3579	4475	5620	8452
	2	1676	2735	3618	4840	5797	6971	9831
.=10.2	3	2514	3796	4774	6092	7111	8312	11193
pe=25.4	4	3351	4858	5931	7348	8425	9652	12554
	5	4189	5920	7087	8602	9739	10993	13916
	6	5027	6981	8244	9856	11053	12333	15278
	7	5865	8043	9400	11100	12366	13673	16639
:9	1	643	1280	1879	2732	3419	4280	6416
	2	1286	2098	2772	3703	4437	5323	7486
A.=6.6	3	1930	2914	3661	4668	5449	6358	8544
ope=28.2	4	2573	3729	4550	5633	6460	7393	9601
	5	3216	4544	5439	6599	7471	8428	10659
	6	3859	5360	6328	7564	8483	9463	11717
	7	4503	6175	7217	8529	9494	10497	12774

r cross sections not shown use the discharge for the cross section this table that is nearest it downstream.

Table 2.--Choctaw Creek discharge frequency for selected cross sections and urbanization factors.--Continued

Cross section	Urban factor (R_L)	Flood discharge (ft^3/s) for given frequency in years. 2	5	10	25	50	100	500
REACH 2								
38	1	387	768	1122	1625	2037	2534	3774
	2	773	1260	1660	2211	2652	3168	4432
D.A.=2.8	3	1160	1750	2196	2794	3264	3796	5081
Slope=34.6	4	1547	2241	2732	3378	3875	4425	5731
	5	1934	2731	3267	3961	4486	5054	6381
	6	2230	3222	3803	4545	5097	5682	7030
	7	2707	3712	4339	5128	5708	6311	7680
45	1	218	432	628	906	1139	1406	2080
	2	436	709	932	1238	1486	1767	2458
D.A.=1.1	3	653	985	1234	1567	1832	2124	2831
Slope=45.2	4	871	1262	1536	1897	2177	2481	3204
	5	1089	1538	1839	2227	2523	2839	3578
	6	1307	1814	2141	2557	2868	3196	3951
	7	1524	2090	2443	2887	3214	3554	4325

Table 3.--Comparison of the 100-year flood-plain widths for urban factors of 1, 2, 3, 4, 5, 6, and 7 for Choctaw Creek.

Cross section	Width of flood inundation pattern for given urban factor 1	2	3	4	5	6	7
REACH 1							
19	1015	1032	1055	1082	1108	1136	1145
20	1006	1056	1104	1156	1201	1245	1270
21	831	840	848	856	861	866	872
23	801	816	828	839	849	858	865
24	635	651	670	688	703	718	732
26	783	798	810	821	8-3	844	853
28	897	924	943	957	973	985	994
29	410	430	444	456	466	476	485
31	539	570	597	621	645	667	688
32	487	496	505	514	523	530	537
34	506	517	528	532	540	547	554
REACH 2							
38	591	608	624	639	652	665	679
39	416	423	430	437	443	449	454
40	217	242	263	282	296	308	321
42	532	546	558	570	579	587	587
43	334	355	367	376	384	393	396
44	363	373	385	394	406	417	427
45	244	260	271	283	291	300	307

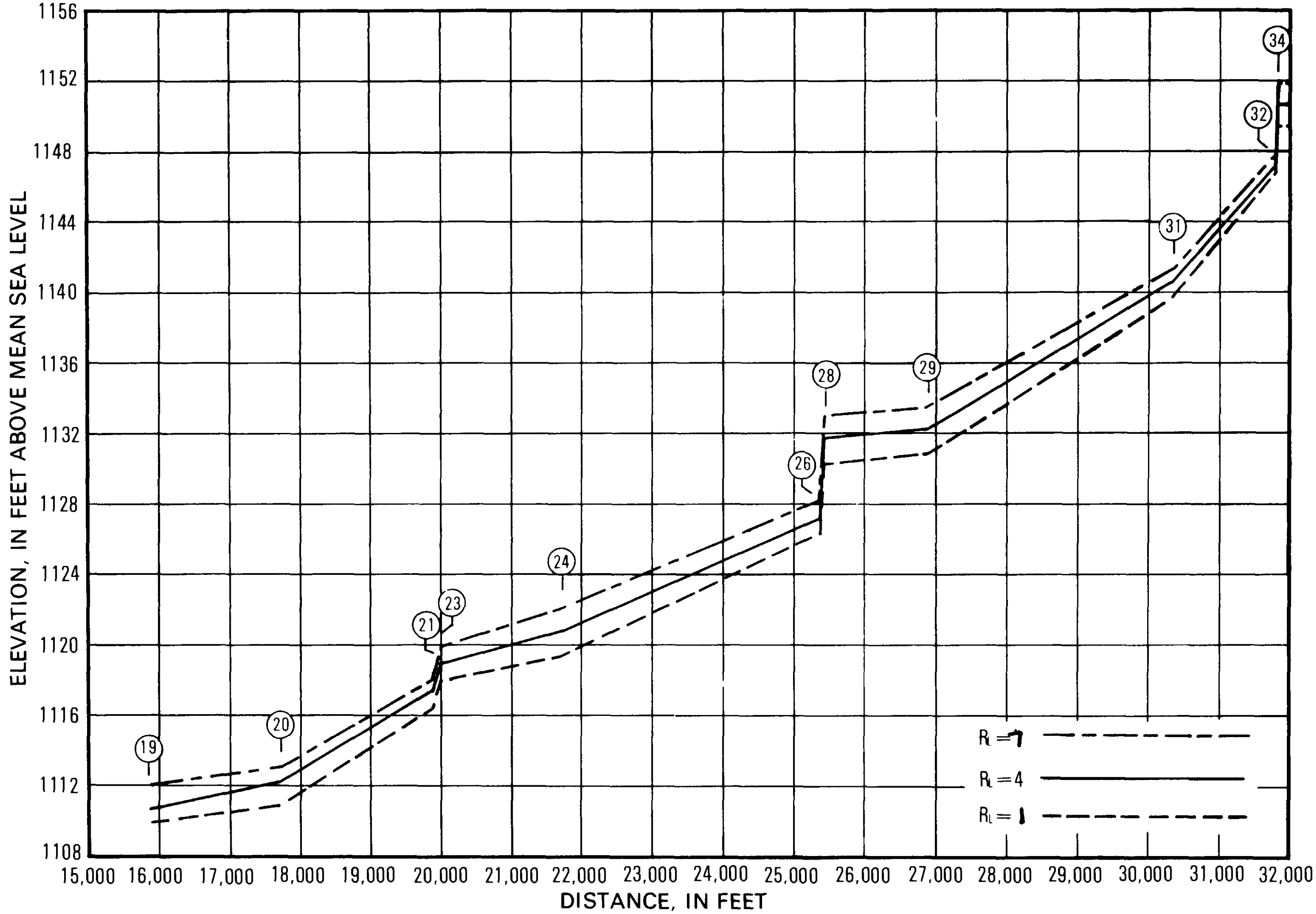


Figure 23.--Choctaw Creek 100-year flood profiles for urban factors of 1, 4, and 7 for Reach 1.

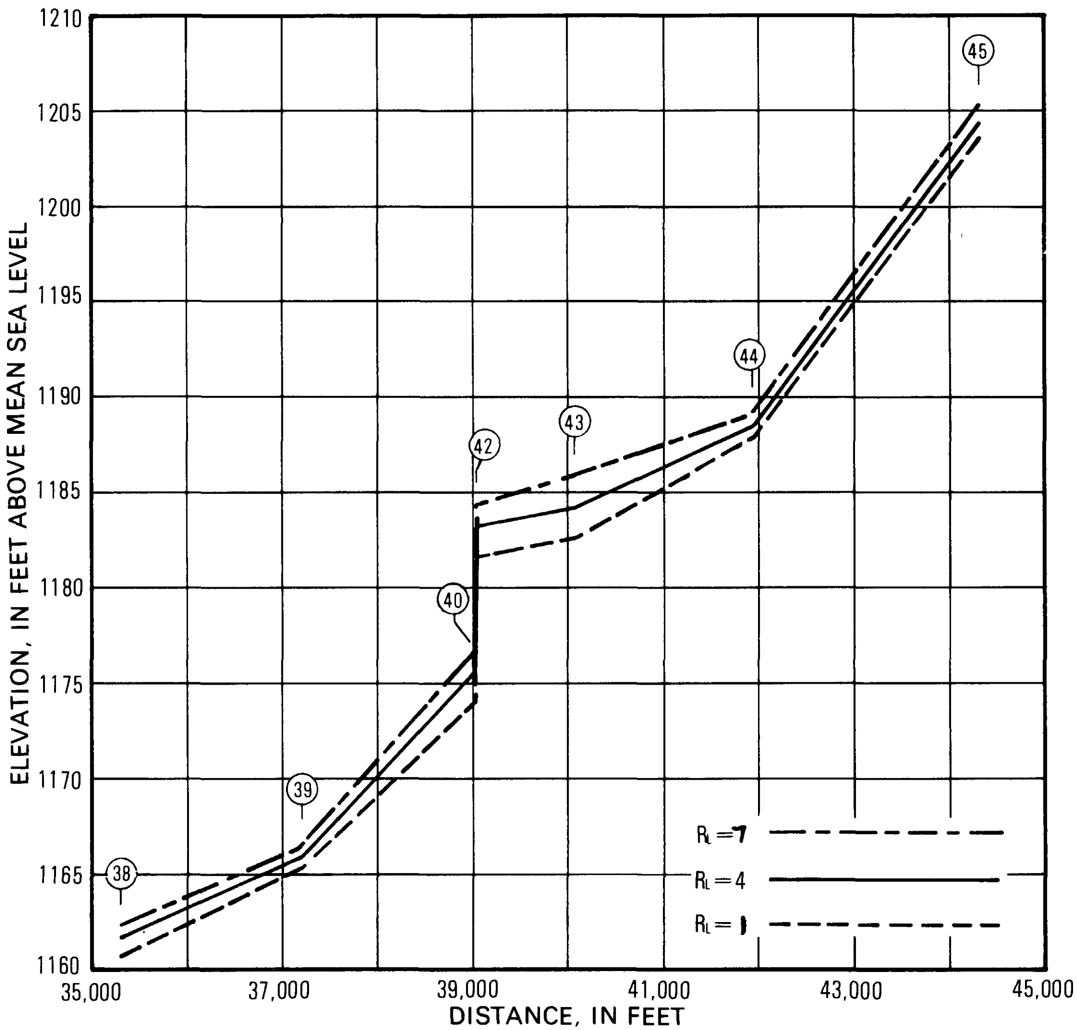


Figure 24.--Choctaw Creek 100-year flood profiles for urban factors of 1, 4, and 7 for Reach 2.

Table 4.--Comparison of selected profile elevations for Choctaw Creek obtained by the graphical and routing methods.

CROSS SECTION	$R_L=1$ Frequency=25 years				$R_L=2$ Frequency=100 years				$R_L=6$ Frequency=100 years			
	Discharge, in ft^3/s	Routed elevation, in feet	Graphical elevation, in feet	Difference, in feet	Discharge, in ft^3/s	Routed elevation, in feet	Graphical elevation, in feet	Difference, in feet	Discharge in ft^3/s	Routed elevation, in feet	Graphical elevation, in feet	Difference, in feet
REACH 1												
19	5623	1108.84	1108.86	+0.02	10947	1109.88	1109.96	+0.08	19207	1111.70	1111.60	-0.10
20	5623	1110.11	1110.10	-.01	10947	1111.36	1111.36	.00	19207	1112.95	1113.00	+.05
21	5249	1115.85	1115.90	+.05	10218	1116.77	1116.75	-.02	17958	1117.63	1117.80	+.17
23	5249	1117.13	1117.07	-.06	10218	1118.30	1118.28	-.02	17958	1119.59	1119.61	+.02
24	4211	1118.52	1118.47	-.05	8203	1119.98	1119.95	-.03	14498	1121.53	1121.85	+.32
26	3579	1125.62	1125.65	+.03	6971	1126.56	1126.54	-.02	12333	1127.76	1127.84	+.08
28	3579	1127.93	1127.80	-.13	6971	1130.90	1130.80	-.10	12333	1132.26	1132.60	+.34
29	2732	1129.50	1129.63	-.13	5323	1131.42	1131.40	-.02	9463	113.282	1133.15	-.67
31	2732	1138.99	1138.98	-.01	5323	1140.18	1140.33	-.15	9463	1141.43	1141.12	-.31
32	2732	1146.62	1146.60	-.02	5323	1147.08	1147-08	.00	9463	1147.77	1147.76	+.01
34	2732	1148.73	1148.74	+.01	5323	1150.03	1150.00	-.03	9463	1151.17	1151.50	+.33
AVERAGE				0.05				0.04				0.22
REACH 2												
38	1625	1160.23	1160.49	+0.26	3168	1160.99	1161.00	+0.01	5682	1162.02	1162.04	+0.02
39	1625	1164.95	1165.02	+.07	3168	1165.53	1165.50	-.03	5682	1166.20	1166.24	+.04
40	1625	1173.50	1173.42	-.08	3168	1174.66	1174.60	-.06	5682	1175.96	1176.30	+.34
42	1625	1181.53	1180.51	-1.03	3160	1182.22	1182.25	+.03	5682	1183.52	1183.60	+.08
43	1625	1182.14	1181.85	-.29	3168	1183.22	1183.18	-.04	5682	1184.62	1185.40	+.78
44	1625	1187.33	1187.64	-.31	3168	1188.06	1188.08	+.02	5682	1188.98	1188.82	-.16
45	906	1203.15	1203.65	-.50	1767	1203.86	1203.80	-.06	3196	1204.70	1205.00	+.30
AVERAGE				0.36				0.03				0.24

of a flood that would occur in the actual stream channel. Differences greater than 0.5 foot may result occasionally when the four plotting points and the channel shape do not readily define the point of transition.

CONCLUSIONS

The analysis described in this report should be useful in planning urban floodwater management programs. Flood profiles may be developed for any desired flood discharge and the inundation patterns mapped. The cost in flood damage in the flood area may also be compared to costs of flood control. The elevations of floodwater to be expected with future urban development may be determined so that structures now safe will be safe in the future.

Sensitivity of the flooded channel to changes in discharge can be determined using the techniques described in this report. Reaches of the channel which drastically increase their inundated area with increases in discharge may be determined as well as reaches where increased discharge causes little or no change in inundated area.

If the elevation is known at which flooding can be tolerated, the corresponding discharge may be determined, and the cost of measures required to reduce the existing flood discharge to the desired discharge can be addressed.

This study outlines low-cost techniques for evaluating flood management alternatives which require a minimum of effort and time. The accuracy of the methods presented in this report is considered acceptable when compared to more sophisticated and costly methods. However, it must be emphasized that the techniques are valid only when management alternatives do not involve changes in channel slope and shape.

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