(200)
WRi
no. 81-34

c.2 in proc.

POTENTIAL EFFECTS OF URBANIZATION ON PEAK FLOWS IN RATTLESNAKE CREEK, MISSOULA COUNTY, MONTANA

U.S. GEOLOGICAL SURVEY

Water-Resources Investigations 81-34

U.S. GEOLOGICAL SURVEY
RESTON, VA
OCT 14 1981
LIBRARY

50272-101

REPORT DOCUMENTATION PAGE	1. REPORT NO.	2.	3. Recipient's Accession No.

4. Title and Subtitle POTENTIAL EFFECTS OF URBANIZATION ON PEAK FLOWS IN RATTLESNAKE CREEK, MISSOULA COUNTY, MONTANA	5. Report Date August 1981 6.
7. Author(s) Charles Parrett	8. Performing Organization Rept. No. USGS/WRI 81-34
9. Performing Organization Name and Address U.S. Geological Survey, Water Resources Division 428 Federal Building, Drawer 10076 Helena, Montana 59626	10. Project/Task/Work Unit No. 11. Contract(C) or Grant(G) No. (C) (G)
12. Sponsoring Organization Name and Address U.S. Geological Survey, Water Resources Division 428 Federal Building, Drawer 10076 Helena, Montana 59626	13. Type of Report & Period Covered Final 14.

15. Supplementary Notes

16. Abstract (Limit: 200 words)

The potential effects of urbanization on the 1-percent-chance flood on Rattlesnake Creek near Missoula, Montana, were assessed using a rainfall-runoff hydrograph model. The model, TR-20 developed by the U.S. Soil Conservation Service, was used to generate a 1-percent-chance flood hydrograph for existing conditions, natural (no-urban-development) conditions, and three different levels of potential future urbanization provided by the Missoula Planning Office.

The model showed no significant change (1 percent or less) in the 1-percent-chance flood magnitude at the mouth of Rattlesnake Creek, which drains an area of 79.7 square miles. The model did show, however, a marked increase of as much as 124 percent in the magnitude of the 1-percent-chance flood peak from the 6.7 square miles of Rattlesnake Creek that is subject to urban development.

17. Document Analysis a. Descriptors

Hydrologic models, urban hydrology, flood peak hydrographs, computer models, Montana

b. Identifiers/Open-Ended Terms

Missoula, Missoula County

c. COSATI Field/Group

18. Availability Statement No restriction on distribution	19. Security Class (This Report)	21. No. of Pages 18
	20. Security Class (This Page)	22. Price

(See ANSI-Z39.18) *See Instructions on Reverse* **OPTIONAL FORM 272 (4-77)** (Formerly NTIS-35) Department of Commerce

Front cover: Aerial photograph of Rattlesnake Creek, Missoula, Mont. Photograph from U.S. Army Corps of Engineers, Seattle District

POTENTIAL EFFECTS OF URBANIZATION ON PEAK FLOWS IN RATTLESNAKE CREEK, MISSOULA COUNTY, MONTANA

By Charles Parrett

U.S. GEOLOGICAL SURVEY

Water-Resources Investigations 81-34

Helena, Montana

August 1981

UNITED STATES DEPARTMENT OF THE INTERIOR

JAMES G. WATT, Secretary

GEOLOGICAL SURVEY

Doyle G. Frederick, Acting Director

For additional information write to:

District Chief
U.S. Geological Survey
428 Federal Building
301 S. Park
Drawer 10076
Helena, MT 59626

For sale by:

National Technical Information Service
U.S. Department of Commerce
5285 Port Royal Road
Springfield, VA 22161
(703) 487-4600

CONTENTS

ILLUSTRATIONS

TABLES

METRIC CONVERSION TABLE

The following factors can be used to convert inch-pound units in this report to the International System (SI) of metric units.

Multiply inch-pound unit	By	To obtain metric unit
acre	0.4047	hectare
cubic foot per second (ft^3/s)	0.02832	cubic meter per second
foot	0.3048	meter
foot per second (ft/s)	0.3048	meter per second
inch	0.02540	meter
mile	1.609	kilometer
square mile (mi^2)	2.590	square kilometer

National Geodetic Vertical Datum of 1929 (NGVD of 1929): A geodetic datum derived from a general adjustment of the first-order level nets of both the United States and Canada, formerly called "mean sea level."

POTENTIAL EFFECTS OF URBANIZATION ON PEAK FLOWS IN RATTLESNAKE CREEK, MISSOULA COUNTY, MONTANA

By

Charles Parrett

ABSTRACT

The potential effects of urbanization on the 1-percent-chance flood in Rattlesnake Creek near Missoula, Montana, were assessed using a rainfall-runoff hydrograph model. The model, TR-20, developed by the U.S. Soil Conservation Service, was used to generate a 1-percent-chance flood hydrograph for existing conditions, natural (no urban development) conditions, and three different levels of potential urbanization provided by the Missoula Planning Office.

The model showed no significant change (1 percent or less) in the 1-percent-chance flood magnitude at the mouth of Rattlesnake Creek, which drains an area of 79.7 square miles. The model did show, however, a marked increase of as much as 124 percent in the magnitude of the 1-percent-chance flood peak from the 6.7 square miles comprising the southern part of Rattlesnake Creek basin that is subject to urban development. Model results are applicable only to rain-caused floods and not to the more common snowmelt-caused floods on Rattlesnake Creek.

INTRODUCTION

Rattlesnake Creek is a perennial stream that drains a mountainous area of 79.7 mi^2 northeast of Missoula, Mont. Rattlesnake Creek flows into the Clark Fork River in the northeast part of the city. Because of its proximity to the urban center of Missoula and its esthetic and scenic qualities, the southern part of the Rattlesnake drainage basin has become a popular residential area. As Missoula is one of the more rapidly growing areas in Montana, pressure is mounting to further develop and urbanize the watershed. Concern has thus arisen that additional urbanization could alter the flow regime of Rattlesnake Creek and thereby cause increased erosion and flooding and impaired water quality.

The purpose of this report is to describe the potential effects of increased urbanization on peak flows in Rattlesnake Creek. Specifically, a rainfall-runoff model was used to simulate the effects of additional urbanization on the 1-percent-chance flood on Rattlesnake Creek. The 1-percent-chance flood is the peak discharge having a 1-percent-chance of occurrence in any given year. The 1-percent-chance flood, which has an average recurrence interval of 100 years, is the accepted standard for flood-plain management and flood insurance purposes. Any change in its magnitude as a result of increased urban development would be of interest to flood-plain managers as well as to local residents and planners.

All information concerning the existing and potential-development levels was provided by the Missoula Planning Office. Soil maps and other general soils and land-cover information were furnished by the U.S. Soil Conservation Service area office in Missoula. An aerial photograph of the southern Rattlesnake Creek drainage basin, stream cross sections, and the 1-percent-chance flood magnitude for Rattlesnake Creek at its mouth were provided by the U.S. Army Corps of Engineers, Seattle, Wash.

DESCRIPTION OF THE AREA

Rattlesnake Creek heads in the steep and rugged mountainous area about 20 river miles north and east of Missoula (fig. 1). The northern headwaters area contains numerous small alpine lakes. Elevations in the headwaters area are as high as 7,600 feet. From the northern headwaters downstream to a point about 3 miles upstream from Missoula, the drainage basin is forested with few rock outcrops or other breaks in forest cover. From about 3 miles upstream from Missoula to the mouth, the Rattlesnake drainage basin is only sparsely forested. The hillsides in the southern part of the drainage basin are predominantly grass covered with some trees at higher elevations.

All residential development is located in the southern 6.7 mi^2 of the basin. Development is concentrated along Rattlesnake Creek from the mouth to river mile 1. Based on an examination of a 1976 aerial photograph, about 20 percent of the southern 6.7 mi^2 of Rattlesnake Creek basin is presently developed, with an estimated 1980 population of 4,500 (D. A. Obermeyer, Missoula Planning Office, written commun., 1980).

RUNOFF CHARACTERISTICS

Streamflow records are available for Rattlesnake Creek for water years 1899 and 1958 through 1967 when a U.S. Geological Survey streamflow-gaging station (012341000) was operated at a site near the mouth. The following generalizations about streamflow are based on the streamflow records.

Flow in Rattlesnake Creek varies seasonally and is typical of most mountain streams in the Rocky Mountains. The largest part of the mean annual flow occurs during the spring and early summer as the result of snowmelt. Conversely, the smallest discharges occur during the winter when most precipitation is stored as snowpack and no melting occurs. Monthly variations in average flow for Rattlesnake Creek are shown in figure 2.

Flooding on Rattlesnake Creek occurs most often as a result of spring snowmelt or snowmelt mixed with rain. Intense rains that occur during the late spring, such as occurred in northwest Montana during June 1964, can also cause flooding in Rattlesnake Creek. The largest known flood discharge on Rattlesnake Creek occurred as a result of snowmelt mixed with rain during May 1948, when a peak discharge of 2,400 ft^3/s was determined by an indirect measurement about 4 miles upstream from the mouth. The 1-percent-chance flood for Rattlesnake Creek at the mouth was determined by the U.S. Army Corps of Engineers (1976) to be 3,000 ft^3/s.

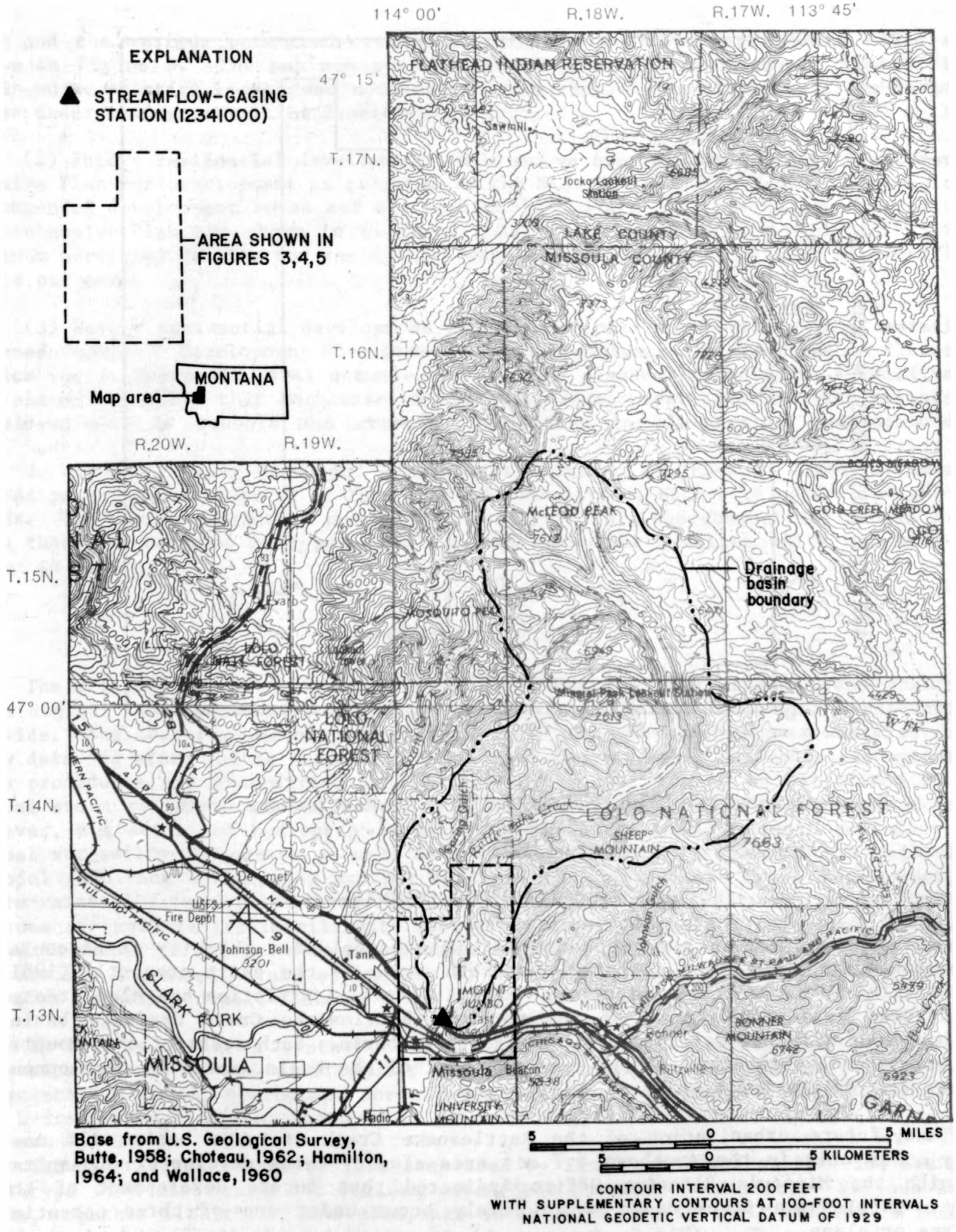

Figure 1.--Location of Rattlesnake Creek drainage basin.

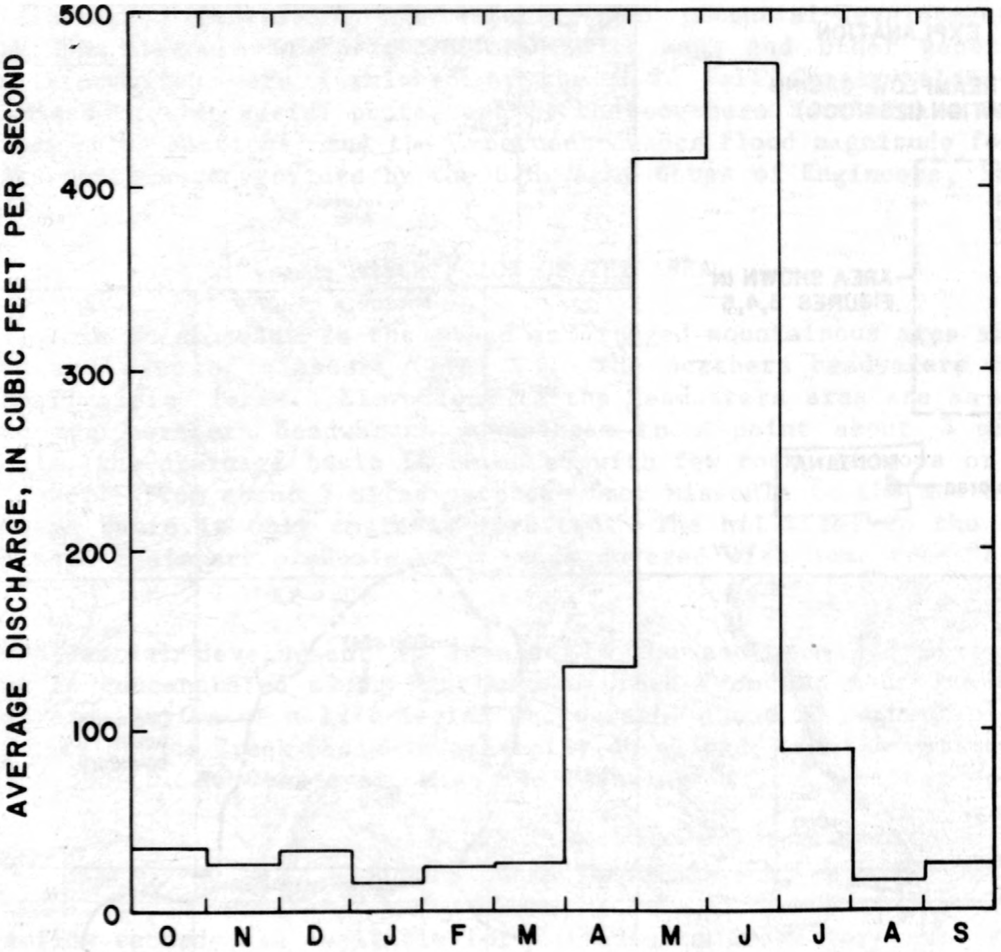

Figure 2.--Monthly distribution of flow in Rattlesnake Creek, water years 1958-67.

FUTURE DEVELOPMENT POTENTIAL

Rattlesnake Creek is a major source of water supply for the city of Missoula. Consequently, access to the forested, northern parts of the basin presently (1981) is restricted to prevent contamination. Recent Federal legislation has also created a wilderness area within part of the northern Rattlesnake Creek drainage basin, thereby limiting future development of the northern basin. Such restrictions, coupled with the natural ruggedness of the northern part of the basin, make any development in that part of the basin unlikely.

Thus, future urbanization of the Rattlesnake Creek drainage basin will most likely occur only in the southern 6.7 mi^2 area already being developed. Consultation with the Missoula Planning Office indicated that future development of the southern Rattlesnake Creek basin would likely occur under one of three potential patterns or plans.

(1) Future residential development could occur in the southern Rattlesnake Creek basin only as allowed under existing zoning regulations. The zoning designa-

tion and the maximum permitted development for the southern part of the basin are shown in figure 3. The maximum possible development in the southern part of the basin under existing zoning was considered to be complete development of the various zones under maximum permitted densities.

(2) Future residential development could occur only as specified in the Comprehensive Plan for Development as prepared by the Missoula Planning Board. The various recommended development zones and the applicable maximum densities allowed under the Comprehensive Plan are shown in figure 4. As noted in the figure explanation, the maximum permitted density for residential development under this plan is six dwelling units per acre.

(3) Future residential development could occur only as specified in a tentative Planned Community Development Plan presently being evaluated by the Missoula Planning Office (D. A. Obermeyer, oral commun., 1980). The planned community is a relatively new planning concept that emphasizes residential development together with attendant services, such as schools and shopping facilities in clusters or neighborhoods.

As presently being discussed by Missoula planners, the Planned Community Development pattern would consist of four planned communities, each with several neighborhoods. The maximum permitted development density within the communities ranges from less than one dwelling unit per acre to more than four dwelling units per acre as shown in figure 5.

RAINFALL-RUNOFF MODEL

The rainfall-runoff simulation model used for the Rattlesnake Creek analysis is a digital-computer model, called TR-20, developed by the U.S. Soil Conservation Service. The model was developed primarily as a design tool for areas where streamflow data and storm-rainfall data were lacking. Consequently, the hydrograph-generation procedures are generalized and the model does not have to be calibrated to an actual storm rainfall for use in a specific drainage basin. As might be expected, however, a generalized hydrograph model such as TR-20 usually cannot reproduce an actual streamflow hydrograph as well as a model calibrated to actual storm rainfall. A model requiring calibration was not applicable to Rattlesnake Creek because actual storm-rainfall data for the basin were not available. An additional limitation on the use of TR-20 is its inability to adequately model snowmelt flood peaks. Because snowmelt runoff is the predominant cause of flooding on Rattlesnake Creek, the modeling results presented herein apply only to the unique, rain-caused floods and not to the more general snowmelt floods.

TR-20 uses either a synthetic or an actual rainfall distribution, generalized loss-rate functions, and a triangular representation of a synthetic unit hydrograph to generate a runoff hydrograph for a basin outlet. A general schematic outlining the hydrograph-generation procedure is shown in figure 6.

The generalized loss-rate functions used by TR-20 are based on the land use and soil type with allowances for various antecedent moisture conditions. Various soil types, together with their land uses, are rated according to their ability to intercept and absorb runoff through a runoff "curve number" (CN). CN ranges from 0 to 100, where 0 represents a soil type/land use that absorbs all precipitation, and 100 represents a completely impervious surface where all precipitation appears as

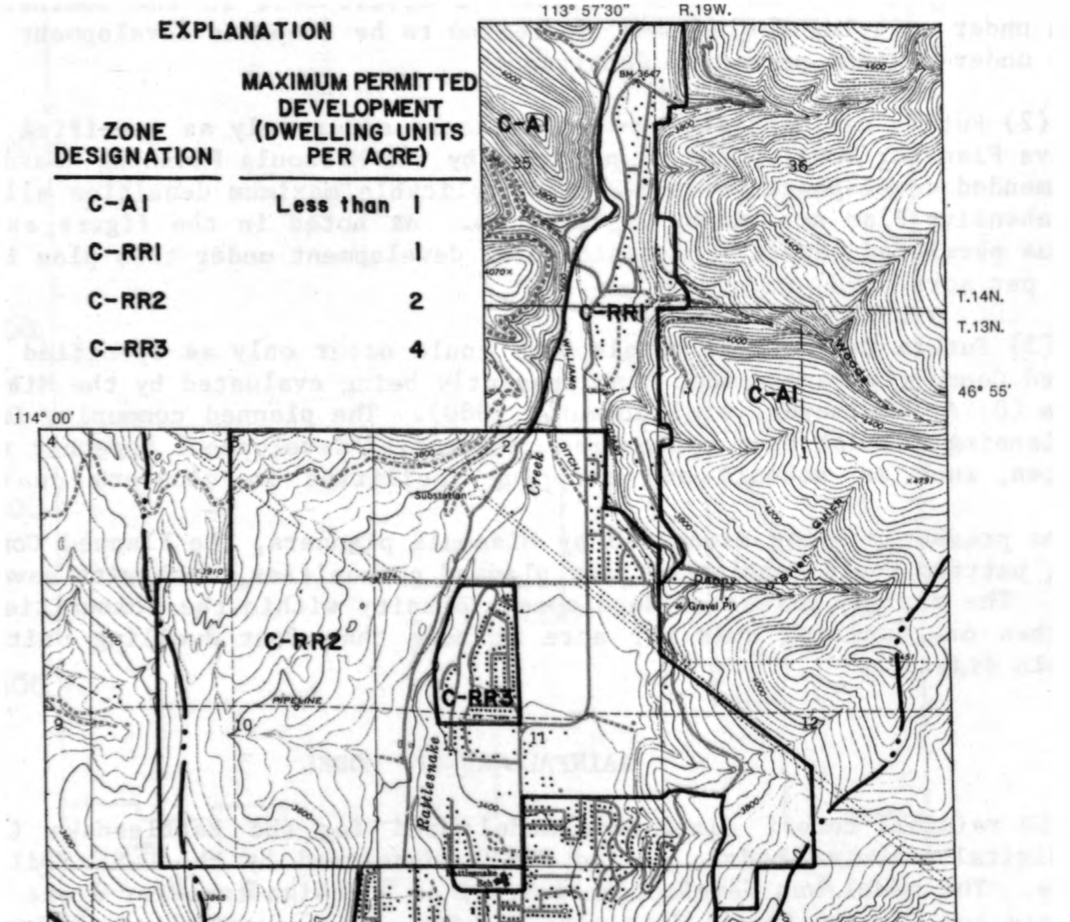

Figure 3.--Future residential development according to existing zoning regulations. Delineations from unofficial zoning map at the Missoula Planning Office.

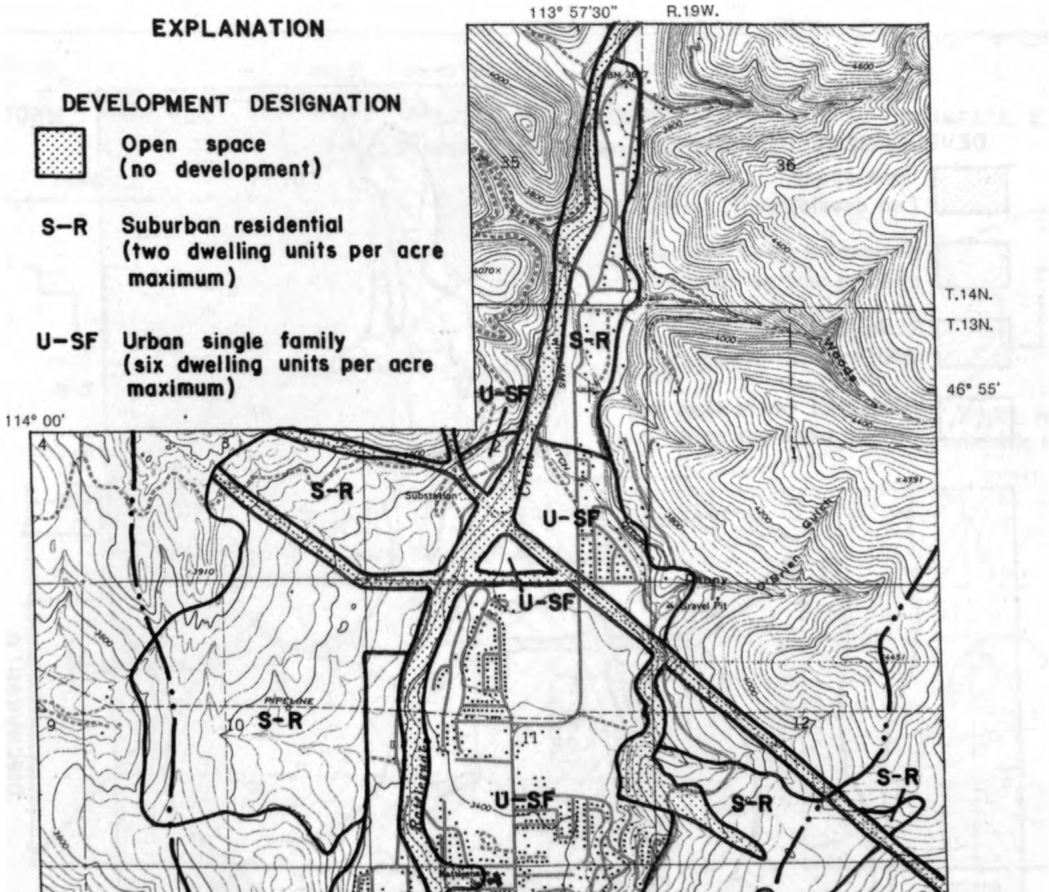

Figure 4.--Future residential development according to the Comprehensive Plan for Development. Delineations from undated map at Missoula Planning Office entitled "Land use: Description and criteria for allocation, Missoula urban area."

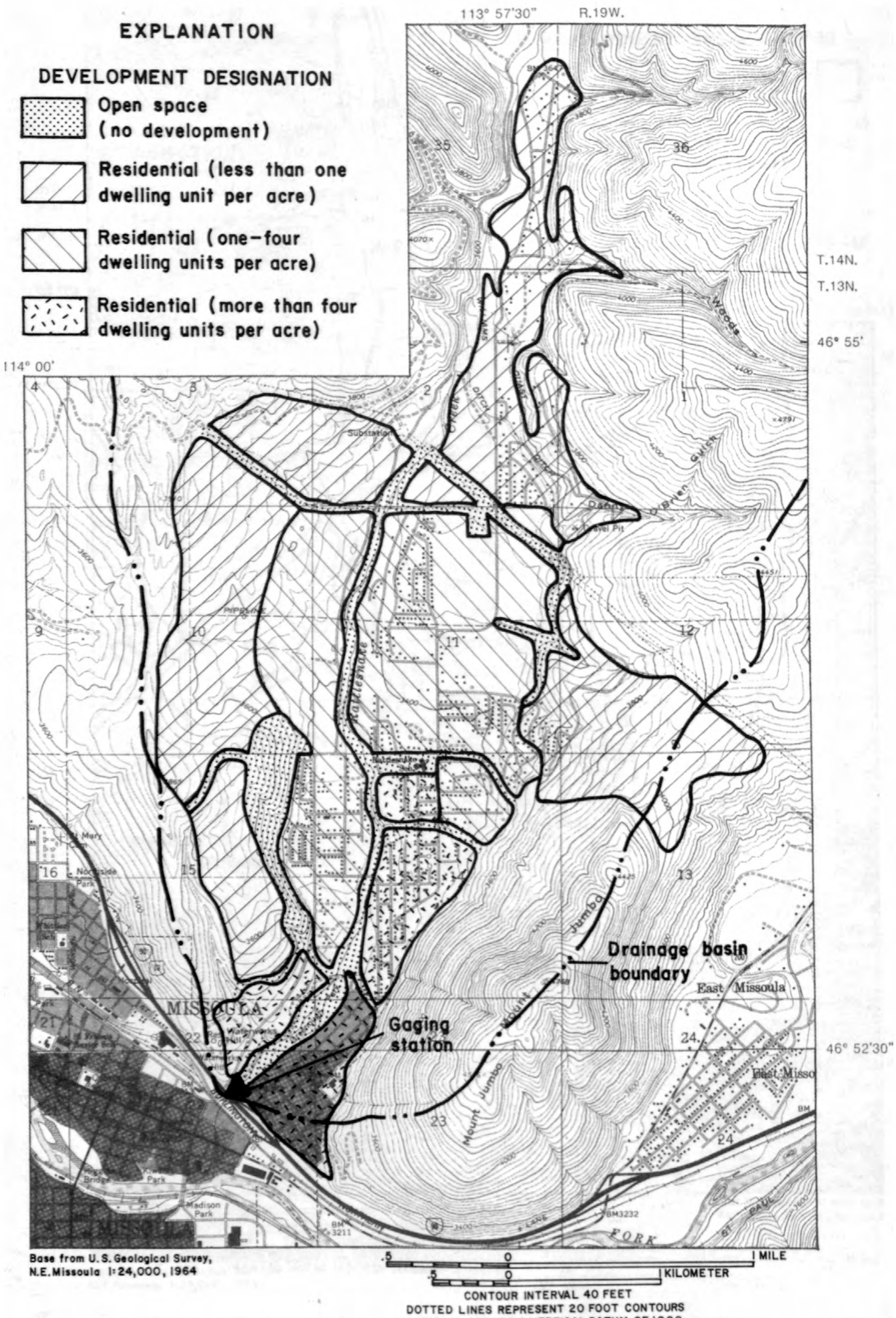

Figure 5.--Future residential development according to the Planned Community Development Plan (tentative). Delineations from D. A. Obermeyer, Missoula Planning Office, written commun., 1980.

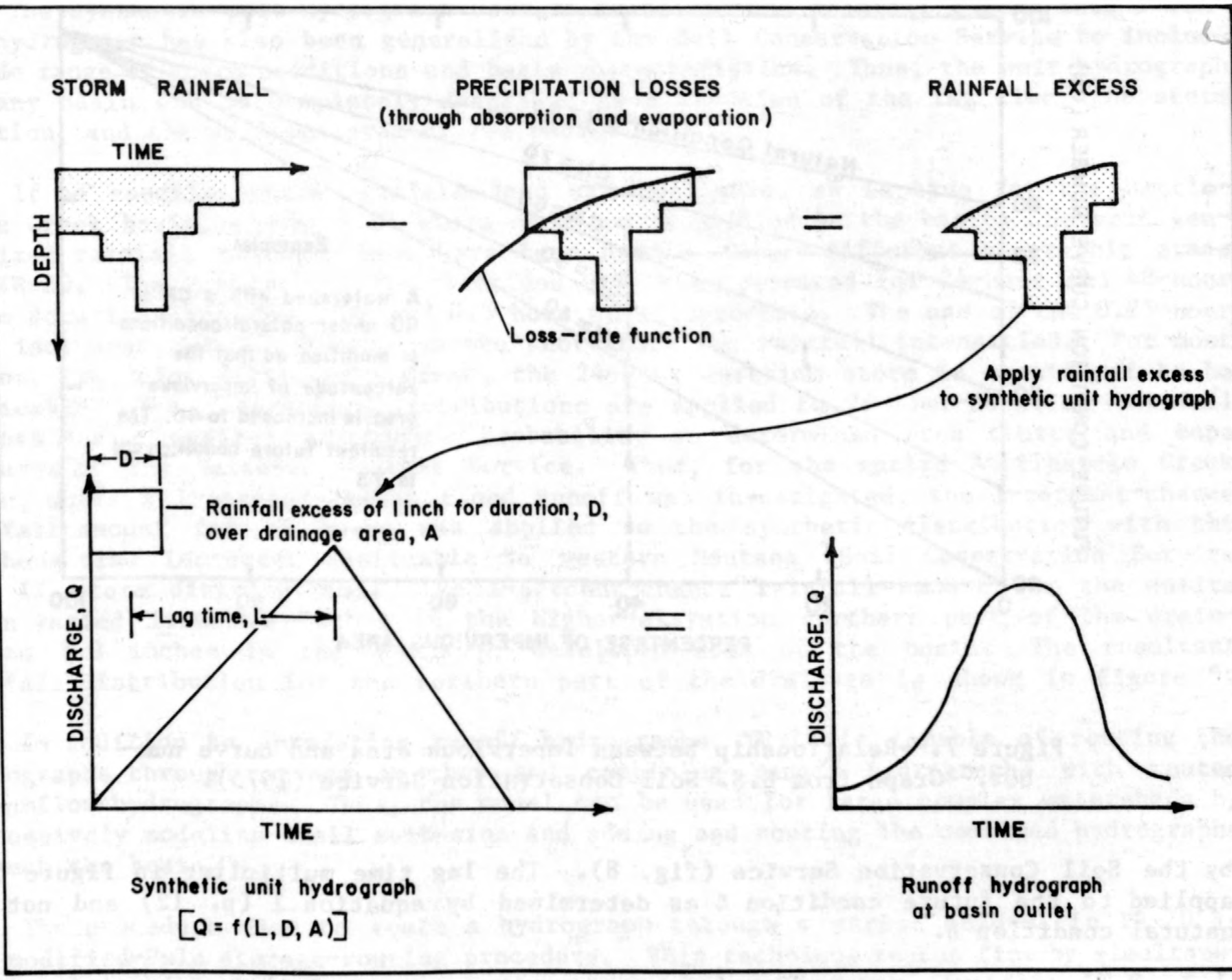

Figure 6.--Schematic of rainfall-runoff model.

runoff. CN is adjusted if the antecedent soil moisture is less than or greater than the average or normal antecedent moisture condition.

The use of the CN concept facilitates modeling conditions where land use changes through urbanization. Thus, as urbanization occurs and previously natural soil with vegetation cover is converted to impervious streets, sidewalks, and buildings, the CN can be expected to increase. The Soil Conservation Service has developed relationships between CN and the percentage of impervious area based on previous urban-area studies. A curve showing the effect of impervious area on CN is shown in figure 7.

Previous studies (Wiitala, 1961; Anderson, 1968) also have shown that urbanization generally decreases the lag time (*L*) in a basin. The *L* is the time from the centroid of the rainfall excess to the peak rate of runoff from the basin. Thus, the conversion of natural soil into impervious surfaces can be expected to shorten flow paths and increase runoff velocities, resulting in a net decrease in *L*. A general relationship between *L* and percentage of impervious area has been developed

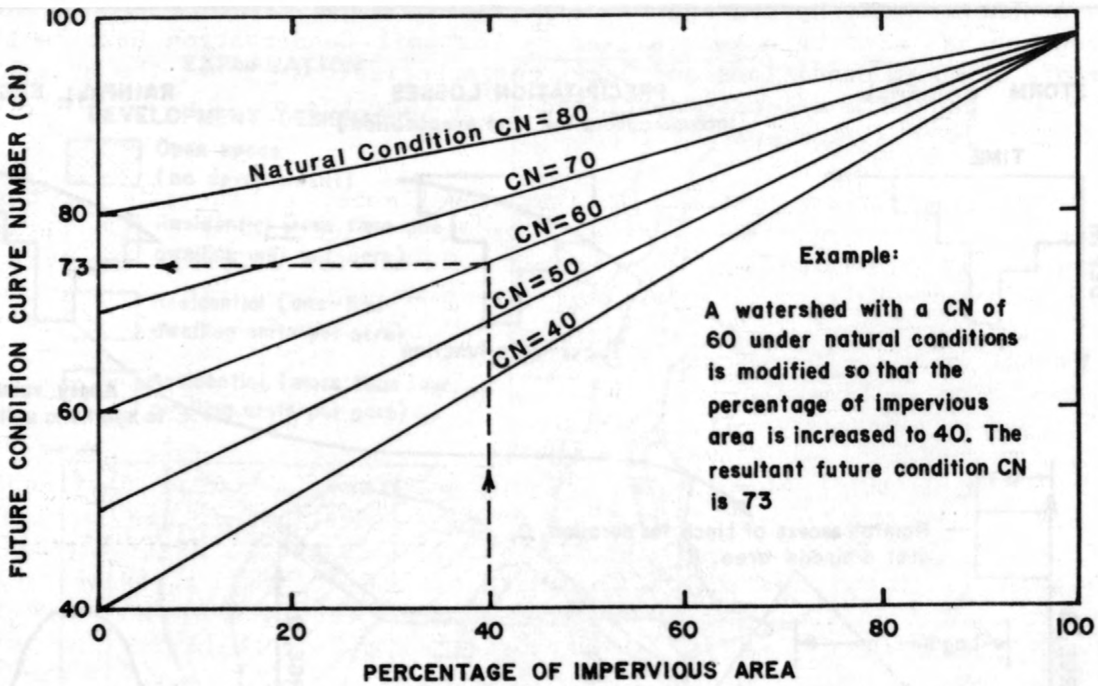

Figure 7.--Relationship between impervious area and curve number. Graph from U.S. Soil Conservation Service (1975).

by the Soil Conservation Service (fig. 8). The lag time multiplier in figure 8 is applied to the future condition *L* as determined by equation 1 (p. 12) and not the natural condition *L*.

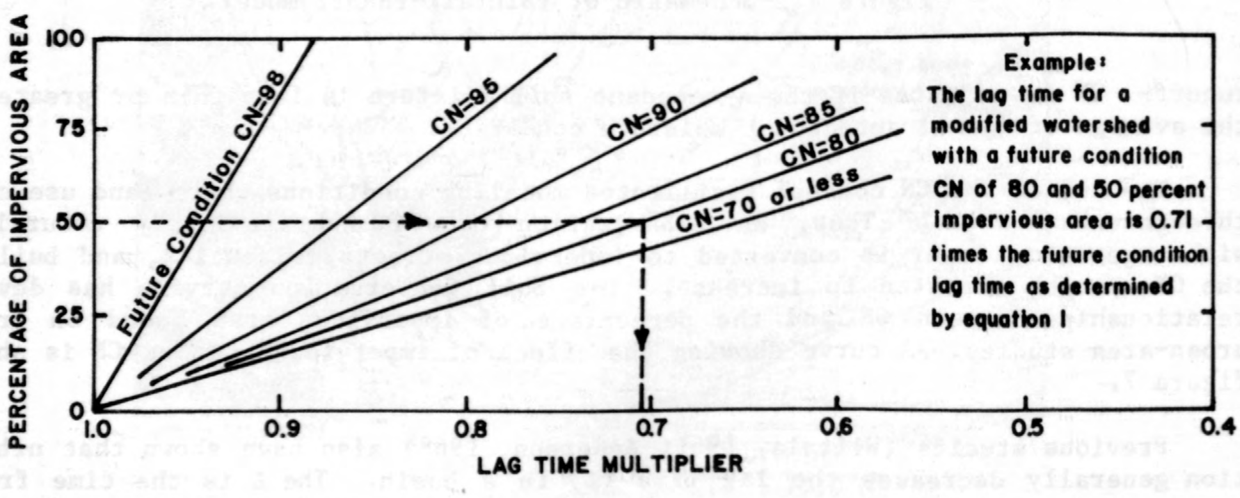

Figure 8.--Relationship between lag time and impervious area. CN is curve number. Graph from U.S. Soil Conservation Service (1975).

The synthetic unit hydrograph used to translate the rainfall excess into a runoff hydrograph has also been generalized by the Soil Conservation Service to include a wide range of storm conditions and basin characteristics. Thus, the unit hydrograph for any basin can be completely described as a function of the lag time, the storm duration, and the drainage area of the basin.

If no specific-storm rainfall data are available, as is true for the Rattlesnake Creek basin, a synthetic storm needs to be applied to the basin. Several generalized rainfall distributions have been developed for different geographic areas for TR-20. The generalized distributions have been prepared for 24-hour and 48-hour storm durations and for 0.25 and 0.5 hour time increments. The use of the 0.25-hour time increment results in more severe short-duration rainfall intensities. For most basins, including Rattlesnake Creek, the 24-hour duration storm is considered to be applicable. The generalized distributions are applied to 24-hour-duration rainfall amounts for a desired exceedance probability as determined from charts and maps prepared by the National Weather Service. Thus, for the entire Rattlesnake Creek basin, where a 1-percent-chance flood runoff was investigated, the 1-percent-chance rainfall amount for 24 hours was applied to the synthetic distribution with the 0.5-hour time increment applicable to western Montana (Soil Conservation Service Type II storm distribution). The 1-percent-chance rainfall amount for the entire basin varied from 4.2 inches in the higher-elevation northern part of the drainage to 3.0 inches in the southern, developed area of the basin. The resultant rainfall distribution for the northern part of the drainage is shown in figure 9.

In addition to generating runoff hydrographs, TR-20 is capable of routing the hydrographs through stream reaches and combining runoff hydrographs with routed streamflow hydrographs. Thus, the model can be used for large complex watersheds by successively modeling small subbasins and adding and routing the combined hydrographs through the basin.

The procedure used to route a hydrograph through a stream channel in TR-20 is the modified-Puls storage-routing procedure. This technique routes flow by simultaneously solving simplified forms of the energy and continuity equations (U.S. Soil Conservation Service, 1965). In practice, storage-outflow curves are required for routing, and the storage-outflow curves in turn are based on the inflow to the routing reach and a routing coefficient. The routing coefficient is a function of the streamflow velocity and is computed from a known discharge-depth relationship at a surveyed stream cross section. If no stream cross-section data are available, the average streamflow velocity through the routing reach must be estimated. For Rattlesnake Creek, cross-section data and discharge-depth data were available only for the southern 5 miles; an estimated streamflow velocity of 5 ft/s was used for routing in the northern part of the basin.

Rattlesnake Creek analysis

To estimate the effects that future urbanization might have on Rattlesnake Creek flood flows, TR-20 was used to develop a 1-percent-chance flood hydrograph for the three potential-development plans described earlier. In addition, TR-20 was used to produce a 1-percent-chance flood hydrograph for natural-flow (that is, no urban development) conditions.

To begin the analysis, the watershed was divided into 20 smaller subbasins as shown in figure 10 with drainage areas ranging from 1.37 to 10.51 mi^2. CN was de-

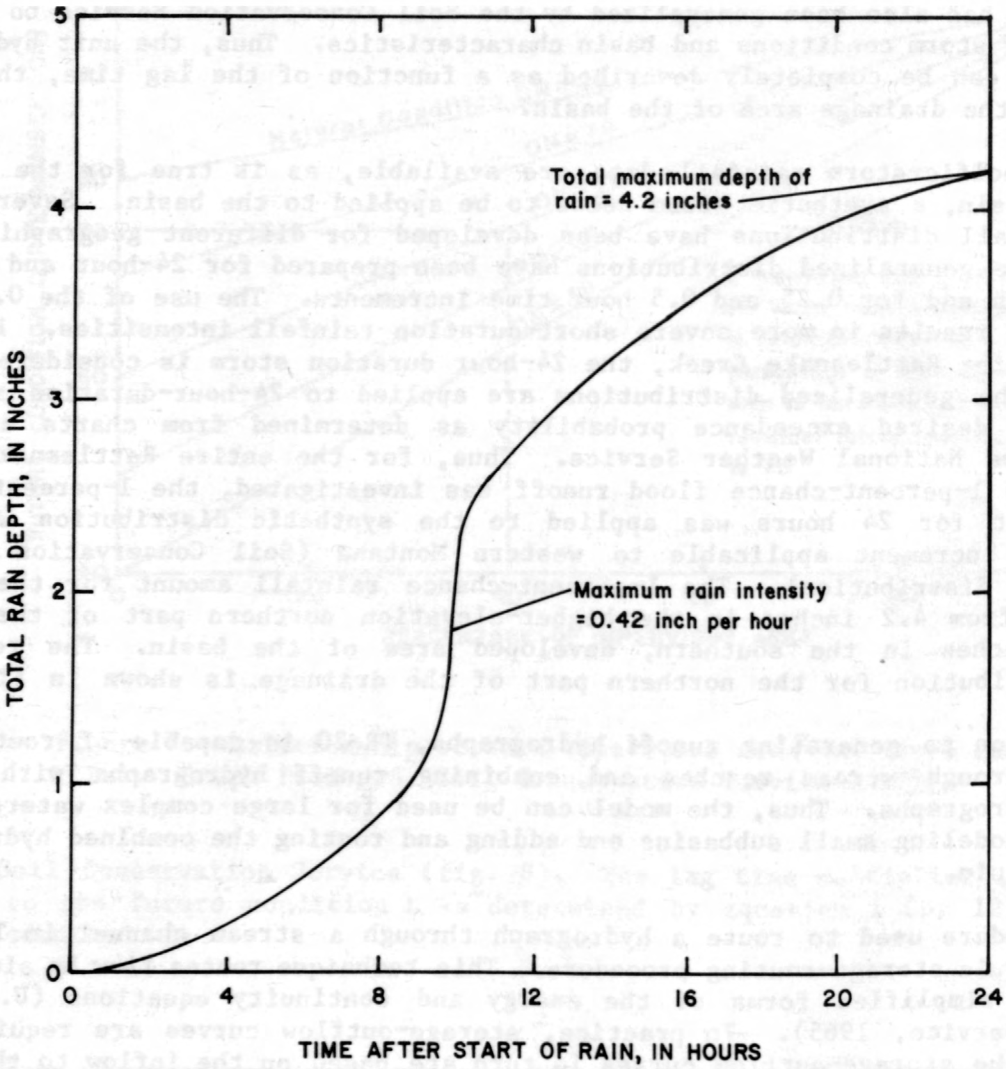

Figure 9.--Synthetic rainfall distribution for 1-percent-chance rainfall on the entire Rattlesnake Creek drainage basin. Distribution data from U.S. Soil Conservation Service (1965).

termined for each subbasin using a soil map of the Rattlesnake drainage prepared by the Soil Conservation Service. The CN for the subbasins ranged from 52 to 69. The *L* for each subbasin was estimated using the following equation (U.S. Soil Conservation Service, 1975, p. 3-6):

$$L = \frac{\ell^{\,0.8}\ (S + 1)^{0.7}}{1{,}900\ y^{\,0.5}} \qquad (1)$$

where *L* is the lag time, in hours; ℓ is the hydraulic length of the subbasin, in feet; *Y* is the average slope of the subbasin, in percent; and *S* is a function of the subbasin CN--that is S = 1000/CN-10. The drainage areas, CN, and *L* for each subbasin under existing development conditions are summarized in table 1.

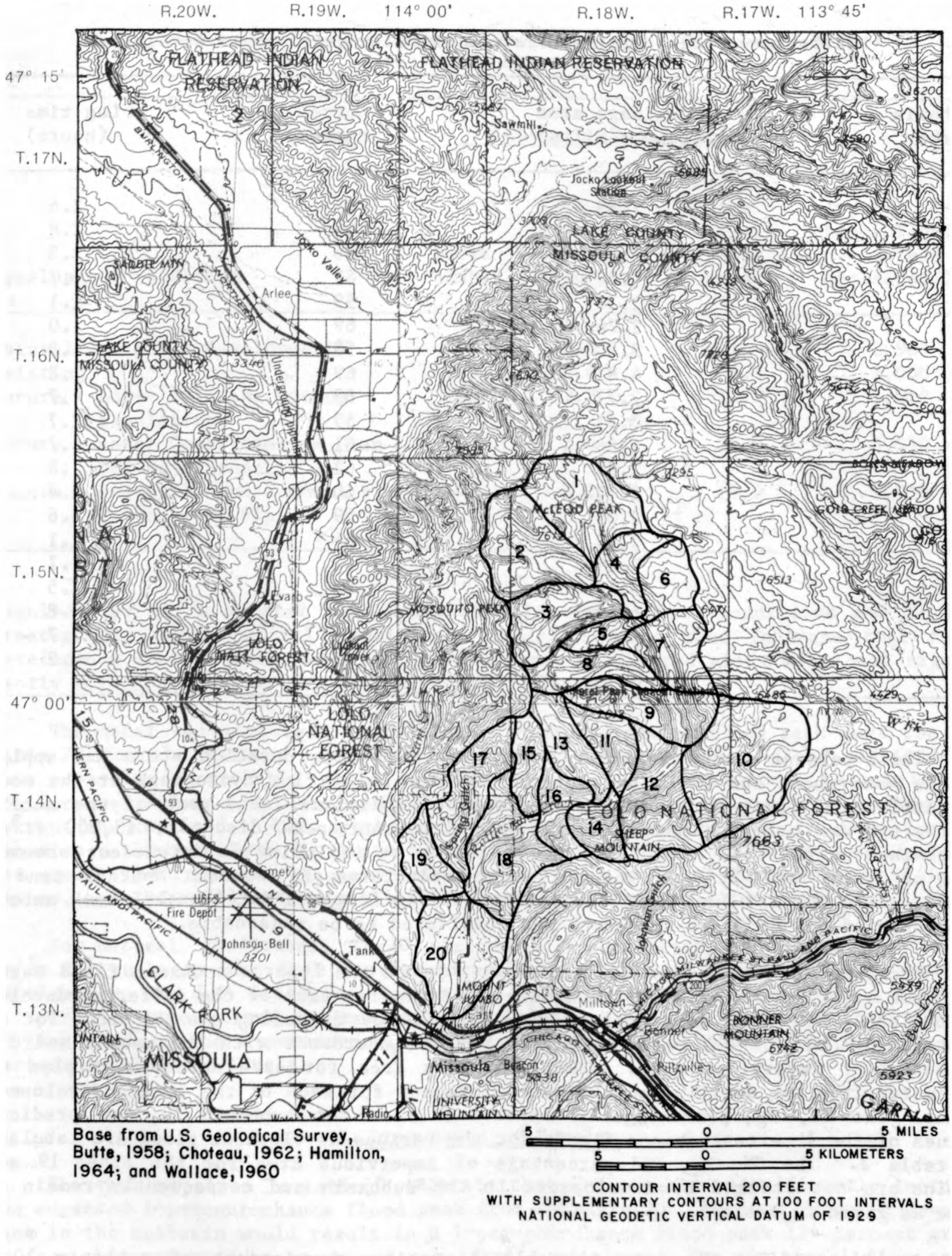

Figure 10.--Rattlesnake Creek subbasin delineation.

Table 1.--*Subbasin parameters for existing development conditions*

Subbasin number	Drainage area (square miles)	Curve number	Lag time (hours)
1	7.53	59	2.6
2	5.69	69	2.8
3	3.93	66	2.3
4	1.88	61	.7
5	1.37	59	1.1
6	2.76	69	1.0
7	3.60	58	.9
8	4.81	69	1.8
9	2.77	63	.7
10	10.51	59	2.7
11	1.86	61	.7
12	2.99	62	.8
13	2.77	60	2.3
14	2.09	59	.6
15	2.01	64	1.1
16	2.29	52	.7
17	5.17	58	2.5
18	6.89	58	2.8
19	2.10	64	1.7
20	6.72	65	2.2

The 1-percent-chance rainfall amount for a 24-hour duration storm was applied to the watershed, and TR-20 was used to develop an outflow hydrograph at the mouth of Rattlesnake Creek for existing development conditions. The peak of the outflow hydrograph was made to match exactly the 1-percent peak discharge (3,000 ft^3/s) determined by the U.S. Army Corps of Engineers by including an antecedent snowmelt flow of about 300 ft^3/s. Because large rainstorms in western Montana tend to occur during May and June when snowmelt runoff is large, a Rattlesnake Creek antecedent flow of 300 ft^3/s at the mouth was considered to be reasonable.

Once the model had been calibrated to produce the 1-percent-chance flood magnitude for existing conditions, the model was rerun for each of the different development plans. The development plans were modeled by adjusting the CN and L for the southern 6.7 mi^2 of the basin (subbasin 20) in accordance with the amount and distribution of impervious area. The impervious area for each development plan was estimated from the dwelling-unit density forecast for each of the future-development plans. The CN, T_C, percentage of impervious area for subbasin 20, and predicted values of the 1-percent-chance floods for the various development plans are tabulated in table 2. The CN, T_C, and percentage of impervious area for the other 19 subbasins are not changed by development in the subbasin and consequently remain the same as given in table 1.

As indicated by the data in table 2, maximum development of subbasin 20 as allowed under the Comprehensive Plan results in a predicted 1-percent-chance flood

Table 2.--*Peak-flow estimates for the entire (79.7 square miles) Rattlesnake Creek basin*

	Subbasin 20 parameters			
Development condition	Curve number	Time of concentration (hours)	Percentage impervious area	1-percent-chance flood (cubic feet per second)
Natural (no urban development)	63	3.9	< 1	2,980
Existing	65	3.6	6.3	3,000
Future - under existing zoning regulations	66	3.2	15.7	3,010
Future - under Comprehensive Plan for Development	69	2.8	20.0	3,030
Future - under Planned Community Development Plan	67	3.1	15.0	3,010

magnitude 30 ft^3/s greater than under existing development conditions and 50 ft^3/s greater than under natural conditions. Model results thus indicate that future development in the basin under any of the three considered plans would not significantly affect peak flows at the mouth of Rattlesnake Creek.

The model was also used to develop a 1-percent-chance flood peak just for subbasin 20 for the various levels of development. The 1-percent flood magnitude for just subbasin 20 probably would be more sensitive to development because of the smaller area being considered and the more intense storm required to produce a 1-percent-chance flood. The synthetic rainfall distribution used in this instance was also a 24-hour Type II distribution, but the shorter 0.25-hour time increment was used. The 1-percent-chance rainfall amount for 24 hours for subbasin 20 is 3.0 inches, and the resultant rainfall distribution is shown in figure 11.

For natural conditions, TR-20 yielded a 1-percent-chance flood peak of 250 ft^3/s for subbasin 20. This result agrees with a regional flood-prediction equation developed by the U.S. Geological Survey (R. J. Omang, written commun., 1981) that gave a 1-percent-chance flood estimate of 270 ft^3/s. Operating the model for subbasin 20 thus yielded the 1-percent-chance peak-flow estimates given in table 3 for the various development levels.

Discussion of results

The results given in table 3 indicate that urbanization significantly increases the expected 1-percent-chance flood peak from subbasin 20. Maximum expected development in the subbasin would result in a 1-percent-chance flood peak 124 percent greater than that expected to occur under natural conditions. The additional flow generated by additional urbanization under any of the plans could be expected to cause increased local flood damage as well as possible increased sediment deposition in

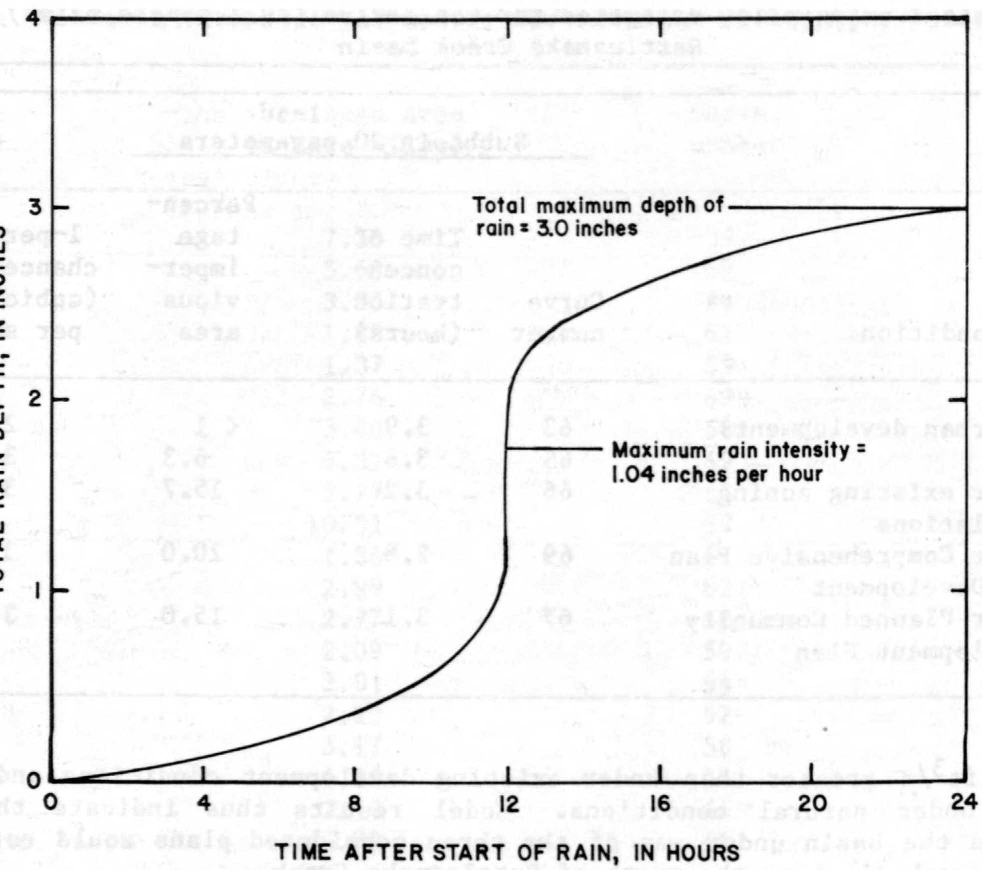

Figure 11.--Synthetic rainfall distribution for 1-percent-chance rainfall on subbasin 20.

the channel of Rattlesnake Creek. The increased peak for the lower basin, however, would still be smaller than the peak from the entire Rattlesnake Creek basin.

At the same time, the model results indicate that increased urbanization has no significant effect on the peak discharge of Rattlesnake Creek itself. Increased urbanization under all development plans thus has only a localized effect on peak flows.

The reader needs to keep in mind that the model results and above discussion are based on a generalized model and that the actual effects of additional urban growth could be markedly different from the modeled effects. In particular, the model is limited to rainfall-runoff prediction and is inappropriate if a 1-percent-chance flood peak on Rattlesnake Creek results from snowmelt runoff or from a combination of rain on melting snow. Other potential model errors are impossible to assess because synthetic rainfall data were used.

The predicted 1-percent-chance flood for natural conditions closely matched the independent results obtained by the U.S. Army Corps of Engineers and the U.S. Geological Survey. This close agreement was considered to provide the most practical test of model applicability and reasonableness. In addition, the model results show the same trends and effects as those obtained in other urban studies (Anderson, 1968; Spencer and Alexander, 1978). Because present data are limited, this modeling

Table 3.--*Peak-flow estimates for subbasin 20*

Development condition	1-percent-chance flood (cubic feet per second)	Percentage impervious area
Natural (no urban development)	250	< 1
Existing	340	6.3
Future - under existing zoning regulations	390	15.7
Future - under Comprehensive Plan for Development	560	20.0
Future - under Planned Community Development Plan	450	15.0

study probably gives the best indications attainable of potential effects of urbanization. Additional monitoring of flow coupled with storm rainfall would improve predictions by allowing better model calibration.

POSSIBLE METHODS TO ELIMINATE ADDITIONAL RUNOFF

To prevent increased flood and erosion damage due to increased urbanization, local planning authorities might impose restraints on new development. In many instances such restraints require that future-condition peak runoff not be allowed to exceed the present-condition peak runoff. Peak-flow reduction in developing areas generally is achieved by constructing storage or retention reservoirs to hold and delay flood runoff. The same result might be achieved by increasing infiltration and lengthening runoff flow paths. Thus, gravel driveways and porous (punctured) pavements might be required rather than impervious concrete or asphalt paving in residential areas. Other measures that could be used to decrease urban runoff include: (1) Storing runoff from roofs in cisterns, (2) installing grassy strips on parking lots, (3) landscaping in contours and with runoff-delaying grasses and shrubs, and (4) directing rooftop runoff to ground-water recharge areas such as dry wells or trenches filled with sand and porous pipes. Regardless of the methods chosen to reduce peak flows from subbasin 20, the results of the TR-20 modeling analysis serve as a guide to the total reduction required under the most likely maximum-development plans.

SUMMARY

The study analyzes the potential effect of three different levels of future urbanization on peak flows in Rattlesnake Creek near Missoula, Mont. The three future-development plans were provided by the Missoula Planning Office and are based on the following possibilities:

1. Future urbanization would occur as allowed under existing zoning regulations,
2. Future urbanization would occur as allowed under the Comprehensive Plan for Development, and
3. Future urbanization would occur as allowed under a Planned Community Development Plan presently under consideration.

Peak-flow runoff hydrographs were developed for Rattlesnake Creek for the three potential-development plans as well as for no-development and existing level of development conditions using the TR-20 rainfall-runoff model developed by the U.S. Soil Conservation Service.

Model results indicated that future development under all the plans would not significantly affect the 1-percent-chance flood magnitude of the entire Rattlesnake Creek basin. The model results did indicate, however, that the 1-percent-chance flood peak for the southern 6.7 mi^2 of the basin that is subject to urbanization (subbasin 20) would be increased by as much as 124 percent over natural (no urban development) conditions.

REFERENCES

Anderson, D. G., 1968, Effects of urban development on floods in northern Virginia: U.S. Geological Survey open-file report, 26 p.

National Weather Service, 1973, Precipitation-frequency atlas of the western United States; Volume 1, Montana: 41 p.

Spencer, D. W., and Alexander, T. W., 1978, Technique for estimating the magnitude and frequency of floods in St. Louis County, Missouri: U.S. Geological Survey Water-Resources Investigations 78-139, 23 p.

U.S. Army Corps of Engineers, 1976, Special Study--Suggested hydraulic floodway, Rattlesnake Creek; vicinity of Missoula, Missoula County, Montana: Seattle District, 5 p.

_____ 1978, Training course on use of HEC-1 to develop discharge-frequency estimates for ungaged areas: Hydrologic Engineering Center, 116 p.

U.S. Geological Survey, 1964, Compilation of records of surface waters of the United States, October 1950 to September 1960, part 12, Upper Columbia River basin: U.S. Geological Survey Water-Supply Paper 1736, 413 p.

_____ 1971, Surface water supply of the United States, 1961-65, part 12, Upper Columbia River basin: U.S. Geological Survey Water-Supply Paper 1933, 685 p.

_____ 1975, Surface water supply of the United States, 1966-70, part 12, Upper Columbia River basin: U.S. Geological Survey Water-Supply Paper 2133, 674 p.

U.S. Soil Conservation Service, 1965, Computer program for project formulation; Hydrology: Technical Release 20, 28 p.

_____ 1972, National Engineering Handbook, Section 4, Hydrology: Chapters 6-10 and 12.

_____ 1975, Urban hydrology for small watersheds: Technical Release 55, 40 p.

Wiitala, S. W., 1961, Some aspects of the effect of urban and suburban development upon runoff: U.S. Geological Survey open-file report, 28 p.

☆ U. S. GOVERNMENT PRINTING OFFICE: 1981—798-727/271 REGION 10

USGS LIBRARY - RESTON
3 1818 00098865 7