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I. Executive Summary

A. Introduction

The City of Leavenworth has periodically experienced significant flooding. The City's current drainage systems were constructed using considerably less stringent design standards than those used today. Major flooding was experienced in 1993 and 1995. Largely as a result of the flooding in 1993 and prior years, and because the existing Storm Drainage Plan, which was prepared in 1967, is becoming outdated, the Leavenworth Department of Public Works presented a program for addressing storm drainage and flooding problems to the City Council. On October 11, 1994 the City Manager adopted Policy Report PWD 71-94 and the City engaged the services of Black & Veatch for the Stormwater Master Plan Project #1994-162. The project was steered by the Citizen's Stormwater Committee, a volunteer organization.

The short-range goals of the master plan are to evaluate improvements to existing drainage facilities to prevent street flooding during a 10-year storm, overtopping of major arterials and collector streets during a 50-year storm, and flooding of structures in the two major creeks--Three Mile and Five Mile--during a 100-year storm. The long-range goals are to develop stand-alone documents to aid the City and its engineers design and construct improvements and new facilities in the future.

B. Purpose

The primary objectives of this study were to evaluate the City's stormwater conveyance system and to prepare a master plan report; to develop financing alternatives and recommend a capital improvements implementation plan; and to evaluate the City's existing policies regarding drainage issues and to prepare a Storm Drainage Design Manual and a Subdivision Planning Manual.

The general project goals were to accomplish the following:

1. Involve the public in the development of the Stormwater Master Plan.
2. Develop a Geographic Information System (GIS) and computational model of the storm drainage system based on aerial mapping, storm sewer maps, and field measurements and observations.
3. Evaluate existing drainage system for capability to handle selected design storms under existing and future conditions.

4. Develop improvements or additions, including detention, to the existing drainage system to prevent flooding.
5. Develop cost estimates and priorities for the improvements.
6. Prepare a prioritized capital improvements program with financing plan.
7. Evaluate future NPDES requirements and the existing FEMA flood plain mapping and studies.
8. Prepare a written report giving results and backup information used in the planning.
9. Prepare Design and Planning manuals based on input from the public involvement program and a review of other cities' and agencies' manuals.

C. Findings and Results

The Leavenworth Public Works Department has taken a positive and important step in the development of one of the City's essential, yet often neglected, utilities--the stormwater conveyance system. The system incorporates more than 60 miles of channels, underground pipes, and appurtenant structures and serves a population of more than 30,000. Public involvement programs were implemented, including establishment of the Citizen's Stormwater Committee, distribution of a questionnaire to determine public opinion on several topics, and establishment of a telephone hotline for residents with flooding problems.

Responses noted on the questionnaires indicate that the most extensive storm drainage problems occur in areas with roadside ditches. Many of these ditches have been filled in by property owners. Grass clippings and other yard waste are also frequently dumped in the roadside ditches. Because of this, the City cannot provide adequate maintenance. This causes frequent localized ponding throughout the City.

Many data sources were used in developing this Stormwater Master Plan and associated documents, including the City's files and maps, engineering studies and design drawings, and studies performed by the Federal Emergency Management Agency (FEMA), among others. There were some discrepancies between the ground elevations recorded during the aerial mapping and the invert elevations in Three Mile Creek from the FIA study. The more recently recorded values were assumed to be correct and were used in the analyses. The aerial map and FEMA elevations in Five Mile Creek all agreed within one foot.

A Geographic Information System (GIS) of the subsurface stormwater conveyance system elements was developed by a joint effort of M.J. Harden Associates and Black & Veatch. M.J. Harden was hired by the City to update aerial photography and create the digital base maps for the GIS. The GIS also includes topographic features such as ground contours, streets, and physical structures. Black & Veatch performed quality control on the x-y coordinates and elevation data for the subsurface system, and worked with M.J. Harden to finalize the GIS information. Black & Veatch also added open channel conveyance elements between closed conduits.

Several hydraulic computer models were developed to analyze the response of the City's bridges, culverts, pipes, and open channels to various hydrologic scenarios. Significant effort was expended to delineate subwatersheds, collect and input the many parameters representing the physical storm conveyance elements to the models, trouble-shoot computational instabilities, and verify the accuracy of the input parameters.

Although the capacity and capabilities of the system vary throughout the City, most of the time, it collects and conveys flows with minimal problems. The criteria for determining this, as well as other policy issues, was adopted by the Citizen's Stormwater Committee working with the City and with Black & Veatch.

When larger, less frequent storms occur, flooding results, and the duration, extent, and damage caused by the flooding vary depending on the location. Analyses for the 10-year design storm confirm that severe and repetitive flooding occurs in the Three Mile and Five Mile Creek watersheds while the outlying, or "external," watersheds appear to have fewer problems. The Three Mile and Five Mile Creek watersheds represent extreme conditions. Some of the oldest parts of the City developed along Three Mile Creek, while large agricultural areas and undeveloped plots still exist in much of the Five Mile Creek watershed. Where flooding problems were identified, preliminary improvements, consisting primarily of parallel or replacement conduits, detention facilities, and flood walls, were sized and evaluated.

The preliminary cost projections for the capital improvements projects (CIPs) range from $3,500 to $6,379,000. A priority ranking system based on benefits and costs was adopted. The priority ranking system is based on a system used in Columbus, Ohio, and adapted for Leavenworth based on the staff and Citizen's Advisory Committee input. This system ranks each project on its relative flood severity divided by its relative cost. Thus, the projects with the most severe flood problems and lowest costs are ranked highest. A total of 56 CIPs were ranked according to their prioritization index. Timing of CIP construction is also dependent on the financing plan selected. The priority list is an element of the master plan that must be updated as development proceeds, depending on the extent and the locations of development.

Although the City of Leavenworth is currently exempt from the National Pollutant Discharge Elimination System (NPDES) permit process because its population is less than 100,000, it is anticipated that the U.S. EPA will eventually adopt environmental regulations that will affect smaller communities such as Leavenworth. A long-term rainfall and stream flow monitoring program is recommended.

D. Recommendations

A summary of the recommendations and costs for each of the CIPs is presented in Table I-1.

Table I-1
Stormwater Capital Improvements Projects (CIPs)
Summary of Projects, Prioritization Index Number (PIN), and Cost Estimates

Rank	CIP ID	Project Description	PIN	Cost* $
1	3MC-Main-Broadway	Install new open channel to divert Subsystem 2R flows from Cherokee Street to Broadway bridge (Larkin project)	391	120,000
2	3MC-8L	Metropolitan & 16th to 14th & Kiowa Subsystem 8L with proposed detention pond north of Metropolitan	322	134,404
3	5MC-7L	17th Street & Vilas Street Subsystem 7L	296	358,803
4	3MC-S1L	13th & 14th & Shawnee & Delaware; 3 Mile Creek South Branch Subsystem S1L	265	64,181
5	5MC-5L	10th Avenue & Limit Street Subsystem 5L	261	541,090
6	5MC-Main-10th	Install parallel 8' x 7' RCB at 10th Avenue on 5 Mile Creek	253	40,500
7	5MC-5R	Hughes Road & McDonald Road Subsystem 5R	248	120,285
8	5MC-2L	Santa Fe & 2nd Street Subsystem 2L	242	623,252
9	3MC-5L	Broadway & 3mc Subsystem 5L	231	46,580
10	5MC-4L	West of Shrine Park Road to Goddard Circle Subsystem 4L	228	798,996
11	5MC-Main-Limit	Elevate bridge and road at junction of Limit Street and 2nd Ave. on 5 Mile Creek; install berm around low-lying structure	226	504,200
12	3MC-2R	Ohio to Spruce & 10th Street Subsystem 2R	224	1,208,717

Table I-1
Stormwater Capital Improvements Projects (CIPs)
Summary of Projects, Prioritization Index Number (PIN), and Cost Estimates

Rank	CIP ID	Project Description	PIN	Cost* $
12	3MCSB-Cherokee	Replace existing Cherokee Street arch on 3 Mile Creek South Branch with 2 - 10' x 10' RCBs	224	267,000
12	3MC-Main-6th St.	Remove 6th Street bridge and replace with 4 - 16' x 16' RCBs	224	274,000
15	3MC-7R	Ottawa & 20th Street Subsystem 7R	223	205,469
15	3MC-6R	Shawnee & 20th to 18th & Osage Subsystem 6R	223	1,096,353
17	3MC-Main-13th St.	Replace 13th Street bridge on 3 Mile Creek with 3 - 12' x 12' RCBs and increase deck top elevation	222	216,000
17	5MC-3R	4th Street Subsystem 3R	222	175,801
19	3MC-1R	Ohio to Spruce & Broadway Subsystem 1R	219	885,011
20	3MC-4L	Metropolitan & Broadway Subsystem 4L	214	940,640
21	3MCSB-18th St.	Replace 18th Street arch on 3 Mile Creek South Branch with 10' x 10' RCB	213	65,300
22	5MC-Main-N. Lawrence	Install parallel 8' x 8' RCB at New Lawrence Road on 5 Mile Creek	210	47,000
22	3MC-9L	Metropolitan & 18th Street Subsystem 9L	210	8,612

Table I-1
Stormwater Capital Improvements Projects (CIPs)
Summary of Projects, Prioritization Index Number (PIN), and Cost Estimates

Rank	CIP ID	Project Description	PIN	Cost* $
24	3MC-5R	15th & Osage Street Subsystem 5R	207	18,920
24	5MC-8R	East of 10th Avenue to Parkway Drive Subsystem 8R	207	437,457
26	5MC-4R	Hughes Road & Limit Street Subsystem 4R	203	384,948
27	3MC-S3L	18th & Sherman; 3 Mile Creek South Branch Subsystem S3L	200	26,362
28	5MC-9L	Limit Street to County Hwy. 5 Subsystem 9L	199	13,968
29	3MC-6L	Metropolitan & 9th Street Subsystem 6L	198	221,150
29	3MC-S6R	West Leavenworth Tfwy. to 20th & Spruce; 3 Mile Creek South Branch Subsystem S6R	198	22,246
29	5MC-2R	4th Street to V.A. Entrance Drive Subsystem 2R	198	1,225,170
32	3MCSB-19th St.	Parallel conduits from 19th to 20th Street with new RCBs	197	372,000
32	5MC-10R	West Leavenworth Tfwy. & 5mc Subsystem 10R	197	38,455
32	5MC-6L	14th & Limit Street Subsystem 6L	197	482,553
35	5MC-9R	West of 10th Avenue to 13th Street Subsystem 9R	195	368,846
36	3MC-7L	Metropolitan & 11th Street to 12th Street Subsystem 7L	191	75,568
37	5MC-1L	Marion, Evergreen, Pennsylvania & 4th Street Subsystem 1L	188	522,986

Table I-1
Stormwater Capital Improvements Projects (CIPs)
Summary of Projects, Prioritization Index Number (PIN), and Cost Estimates

Rank	CIP ID	Project Description	PIN	Cost* $
38	3MC-S8R	22nd & Spruce; 3 Mile Creek South Branch Subsystem S8R	185	56,111
39	3MC-Main-Ottawa	Replace Ottawa Street bridge with 4 - 11' x 11' RCBs and increase bridge top elevation	180	455,000
40	5MC-Main-2nd St.	Replace bridge at 2nd Street and elevate top deck of bridge and approach; install new flood wall at WWTP	176	2,137,000
40	3MC-S5R	18th, 19th & Spruce; 3 Mile Creek South Branch Subsystem S5R	176	13,208
42	5MC-1R	Marion Street Subsystem 1R	172	214,078
43	5MC-6R	East of Shrine Park Rd. to Lakeview Drive Subsystem 6R	170	28,200
44	5MC-7R	Deerfield Street & Garland Avenue Subsystem 7R	168	54,870
45	3MC-S1R	10th & Cherokee; 3 Mile Creek South Branch Subsystem S1R	165	17,412
46	5MC-10L	22nd St., Limit Street & Vilas Street Subsystem 10L	162	33,384
47	3MC-S7R	21st & Kenton; 3 Mile Creek South Branch Subsystem S7R	161	42,723
48	3MC-1L	4th Street Subsystem 1L	159	1,278,437
49	5MC-3L	10th Avenue & Thornton Subsystem 3L	158	2,275,594
50	3MC-Main-Osage	Install flood levee for two structures east of 3 Mile Creek	151	5,200

Table I-1
Stormwater Capital Improvements Projects (CIPs)
Summary of Projects, Prioritization Index Number (PIN), and Cost Estimates

Rank	CIP ID	Project Description	PIN	Cost* $
50	3MC-Main-10th	Install flood levee for two structures south of 3 Mile Creek	151	3,500
52	5MC-8L	Candlewood & Tudor Drive Subsystem 8L	136	43,646
53	3MC-8R	20th & Dakota & Ottawa Subsystem 8R	134	9,016
54	5MC-11L	Hebbelin Dr. & 23rd Street Subsystem 11L	115	47,090
55	3MC-S4L	21st & Choctaw; 3 Mile Creek South Branch Subsystem S4L	99	19,385
56	3MC-Main-Outfall	Line 3 Mile Creek from Shawnee St. to mouth of Missouri River with concrete trapezoidal channel	79	6,379,000

*Does not include land acquisition or easement costs.

The following additional recommendations are also presented for the City's consideration.

1. The problems identified, and improvements where given, in the external water-shed subsystems should be evaluated. Cost opinions should be prepared for these improvements. Site visits will probably be necessary where no recommendations were made regarding potential solutions to drainage problems.
2. More stringent zoning and flood plain restrictions should be considered. The City currently prevents construction within the FEMA-designated floodway and should consider extending this policy into tributaries not delineated in FEMA mapping. This can be based on the results of the modeling completed for this study. In the long-term, prevention of construction in the 100-year floodway will eliminate the need for costly improvements to lower water levels after development takes place.
3. The analyses for the Three Mile and Five Mile Creek watersheds should be carried forward to preliminary design and design level analyses. Many improvement configurations are possible, and the cost of additional analyses now will be more than offset by the savings derived from selecting the most cost-effective solution.
4. The Public Works Department should increase the amount and frequency of maintenance of the stormwater conveyance system. Questionnaires indicated flooding occurs throughout the City, not just along major drainageways. This is due primarily to non-functional roadside ditches and driveway culverts that have been filled in by property owners through the years. Present staff do a good job of maintaining the major drainage system and addressing the most critical problem areas. However, resources are not adequate to maintain all of the roadside ditches. Increased maintenance of these systems will allow them to function properly and eliminate many of the perceived flooding problems in the City.
5. The City should finalize and begin using the Drainage Criteria Manual and New Development Planning Manual, both of which were prepared for this project.
6. To properly plan and develop the conveyance system and timing of improvements, the City should consider increasing its technical staff. Present staff appear to lack sufficient time to devote to future needs of the system. Additional personnel should be employed to meet both engineering and GIS needs.
7. Zoning and more restrictive flood plain management are the most cost-effective means of developing the City's watersheds. Preventing development from occurring in flood prone areas will eliminate the need for costly flood control projects in the

future. Although the improvements presented in this report do not reflect these types of measures, it is crucial that the City move forward and study these options now, before the watersheds develop additional problems.

8. A rainfall and streamflow monitoring system to establish peak runoff rates and flood elevations should be installed as time allows. This will allow calibration of the models developed as part of this study.
9. The master plan should be updated on a periodic basis. Depending on the rate of development and timing of improvements, the updates should occur every 5 to 10 years.
10. The City should consider implementation of a stormwater utility to fund capital improvements projects and operation and maintenance of the drainage system.
11. Adopt the policies listed below recommended by the Citizen's Advisory Committee.

- The City of Leavenworth shall maintain roadside ditches and driveway tubes in a more consistent manner as part of an overall plan for stormwater management.
- Curb and gutter streets shall be required in all new developments.
- Property owners with property along open channels and creeks must leave natural drainageways undeveloped to allow for storm runoff from future development upstream.
- The City shall not pursue acquisition of easements or ownerships along open channels unless necessary for a specific project or as part of a new development.
- The City shall not assume maintenance of open channels. The City should consider using the existing "nuisance" ordinances to enforce maintenance needs on open channels.
- The City shall follow federal guidelines for stormwater quality issues without additional City requirements.
- To complete the stormwater model, it is necessary to select a design storm for the sizing of improvements. After discussing the current practice, the extent of known problems areas, and the design standards of surrounding area, the Committee recommends the criteria in Table I-2:

Table I-2
Recommended Design Storm

Residential Street Systems:	10-Year Storm
Arterial/Collector Systems:	50-Year Storm
Arterial/Collector Creek Crossings:	50-Year Storm
Flood Plain/High Value Commercial Property:	100-Year Storm

E. Acknowledgments

The success of the Stormwater Master Plan depends on the direction and input of City staff, the Citizen's Stormwater Committee, and the general public. City staff who assisted with this project included Michael G. McDonald, Director of Public Works and City Engineer; Robert Patzwald, Deputy Director of Public Works; Jerry Geise, City Planner; Dan Williamson, Finance Director; Gary Ortiz, Assistant City Manager; and Mark Pentz, City Manager.

The following are members of the Citizen's Stormwater Committee: Pat Cooper, Dave Davis, Bob Euler, Jim Gillespie, Pauline Graeber, Dave Kaaz, Florence Larkin, Ellie Markle, Pat McQuirk, Bob Needham, Lawrence Schumake, Marvin Stevens, and Pete Zink.

II. Introduction

A. Purpose

The infrastructure of Leavenworth is of concern to its residents as well as to public officials. The more visible and commonly-used elements of the City's infrastructure are the street and highway system, the water distribution system, and the wastewater collection and conveyance system. A vital, yet often forgotten, element is the stormwater conveyance system that winds its way through the City, and provides the essential service of collecting stormwater runoff and ultimately conveying it to the Missouri River. Although the system was designed to operate efficiently and effectively, it is not adequate for today's expectations.

The reasons behind the inadequacies of the present stormwater conveyance system are multifaceted, and include the following:

- Age of the system components.
- Increased flows beyond the system's design capacity.
- Increased runoff resulting from development.
- Sedimentation from construction-related runoff.
- Channel bank erosion.
- Structural failures.
- New policies superseding former design criteria.
- Development in areas where flooding has become a concern as a result of upstream development.
- Improper maintenance of roadside ditches, including complete removal of the ditches.
- Increased maintenance needs of an aging and expanding drainage system.

Many of these aspects are interrelated; therefore, correction of one may result in the elimination of two or more causes.

The deterioration of the stormwater conveyance system has occurred over a long period of time. A stormwater conveyance system typically receives attention only when it fails to operate properly, causing property damage or even loss of life.

As the City has grown and developed, the demands on the stormwater system have increased. Whereas in the past, flooding was often viewed as inevitable and uncontrollable, it can now be controlled and its effects alleviated. As Leavenworth competes with other cities to attract commerce and industry, prevention and control of flooding are becoming increasingly important. The challenge facing the City is to develop, implement, and maintain a stormwater system capable of operating well into the 21st century. Such a system must not only reduce or eliminate stormwater-related damage, inconvenience, and threat to life; but it must also enhance other aspects of the urban system by offering recreational opportunities, complementing the transportation network, and helping to realize development and redevelopment plans.

The Stormwater Master Plan is the initial step towards upgrading the stormwater system. It identifies and examines the flooding problems within Leavenworth, proposes practical planning level improvements, provides a sound, technically-based framework for development of the stormwater conveyance system, and identifies funding mechanisms. The severity of flooding within the City varies. For example, the Three Mile Creek watershed, which contains the most developed and older parts of town, experiences the most severe flooding and has the least amount of land available for improvements. The Five Mile Creek watershed, on the other hand is not fully developed and has an adequate system of open channels and space for construction of improvements, including detention facilities. The extent and types of improvements must be evaluated in light of the associated costs. Therefore, identification of the potential cost-recovery mechanisms is an essential element of this Stormwater Master Plan.

Different kinds of problems are encountered in different parts of the City, and each must be handled by the most appropriate corrective measures. The extent of flooding is equally important as it can indicate the location, or both the location and intensity of the problem. It is also a factor in developing funding sources and in assigning responsibilities and allocating resources for dealing with the problems.

B. Scope of Master Plan Work

The Stormwater Master Plan presents a preliminary assessment of the improvements needed for the Three Mile and Five Mile Creek watersheds as shown on Figure II-1. The scope of the master plan is broad in physical coverage and comprehensive in its assessment of the overall system. The detail provided in the master plan is at planning level, appropriate for this stage in the system's development, and in keeping with available resources and time.

The general appraisal of the watersheds is based on an overview of specific problems encountered throughout the City. Each problem warrants further attention: to prepare plans for capital improvements, to schedule special maintenance, or to postpone action until more pressing needs are met. This study provides a general assessment of the costs of improvements and recommends a capital improvements program, which will enable Leavenworth to plan specific stormwater system projects and maintenance activities in a logical and effective manner.

This master plan describes the general locations, type, and approximate costs of needed improvements. The recommended improvements and costs presented in this Plan are preliminary; final design should not be based solely on these recommendations and analyses.

The Plan includes an appraisal of the City's stormwater management policies and design standards and recommendations for modifications where considered appropriate.

An evaluation of available financing options and identification of the most feasible methods for funding the needed stormwater improvements is also included in the Plan.

III. Public Involvement

A. Purpose

To develop a Stormwater Master Plan that meets the needs of the residents and the businesses, as well as the City, a program was developed that provided the opportunity for city officials and the residents to become actively involved. This involvement was initiated before any field investigations or analyses. Shortly after the start of the project, City officials stated the type and extent of assistance to be solicited from the public.

Public involvement took the form of a Citizen's Stormwater Committee, participation in a written information survey, a telephone hotline, and participation at public information meetings.

B. Citizen's Stormwater Committee

The Citizen's Stormwater Committee was formed specifically for this project. The purpose of the Committee was to review, comment on, and participate in, the development of the Stormwater Master Plan for Leavenworth.

The numbers and types of members were determined by the City, as were the structure and duties of the Committee. Following is a summary list of the duties for which their input was requested:

- Review existing storm drainage ordinances, policies, and design criteria.
- Develop new or modifications to existing storm drainage ordinances, policies, and design criteria.
- Representation at Leavenworth City Commission meetings pertaining to stormwater issues with the City and Black & Veatch.
- Representation at Public Information Meetings pertaining to stormwater issues.
- Verify locations of known historic flooding.
- Develop storm drainage system improvement alternatives.
- Finalize storm drainage system improvement alternatives and develop improvement cost estimates.
- Develop a priority ranking system.
- Develop an Improvements Priority List.
- Develop the Storm Drainage Capital Improvements Program.
- Develop an Implementation Plan.
- Review the draft and final Master Plan Reports.

- Define alternative design criteria, specifications, and details for the new Storm Drainage Design Manual.
- Review the new Subdivision Plan Review procedures.
- Review the draft and final Storm Drainage Design Manual.
- Examine the City's financing policies, objectives, and information resources.
- Identify and evaluate stormwater management funding sources.
- Develop new public information/education program needs.
- Review the draft and final financial reports and related information.

The membership of the Committee consisted of two technical experts, two representatives of institutional complexes, one representative from Fort Leavenworth, one City Planning Commission member, two developers, two representatives of business and industry, and four members "at-large." A list of the members of the Citizen's Stormwater Committee is included in the Executive Summary.

The Committee was active for the duration of the project. Meetings were on the fourth Monday of each month, and were led by the elected chairman Bob Euler. Minutes were not recorded, as input from Committee members was inserted directly into policy documents, onto maps, and other master plan deliverables.

C. Stormwater Questionnaire

A Stormwater Questionnaire was distributed to nearly 1,000 Leavenworth residents. The questionnaire was also printed several times in the two local newspapers, and copies were available for the public at City Hall. The questionnaire requested information on the location, extent, and severity of flooding throughout the city. The intent was to identify and classify known flooding locations (in addition to those identified by City staff) for verifying and assessing the validity of the stormwater model. A second objective was to provide a means for public input, as it is believed that people are generally more supportive of projects of this kind if given an opportunity to participate and voice their opinions.

The Stormwater Questionnaire was developed in response to the need to identify the stormwater flooding issues that are important to residents, City staff, and the overall goals of the project. The questionnaire included a short description of the ongoing Stormwater Master Plan project, the Stormwater Hotline number, explanation of the purpose of the questionnaire and the importance of public participation, and a request for response and comments.

With the incorporation of the City's Geographic Information System (GIS), the questionnaire was designed to elicit responses that could be coded into a database and queried by the GIS. Although this method did not allow residents to expand on their responses, it did serve as a straightforward means of interpreting and displaying the responses consistently with the GIS. Additional comments were requested, but were not necessarily used in the GIS analyses. An example of the Stormwater Questionnaire is presented on Figure III-1.

Questionnaires were mailed out in March/April 1995 and responses were received through June 1995. Recipients of the questionnaire were selected randomly to reach a broad geographical distribution.

To limit costs while maintaining a statistically relevant sample distribution, the Stormwater Questionnaire was mailed to approximately 968 occupants and owners. In addition to generating an address database and the mailing labels, City staff also provided a unique number for each returned questionnaire which, along with the responses, was keyed into the database to eliminate data entry errors for addresses and address matching.

Tables III-1 through III-4 present summaries of responses to the questionnaire. A total of 303 questionnaire responses were received, as indicated in Table III-1. The majority of responses to question No. 7, which involved ranking the severity of various stormwater-related problems, referred to some degree of flooding at their address. The questionnaires were divided into three mutually exclusive groups: according to whether they indicated the following: (a) at least one major flooding problem; (b) at least one minor flooding problem and no major problems; or (c) don't know or no major and no minor flooding problems. Tables III-3, III-4, and III-5 show the responses in each group, to questions 7 through 16. Responses to question No. 10, having to do with the frequency of occurrence of flooding and drainage problems, are shown on Figure III-2. The intent of question 15 was to solicit residents' opinions on stormwater management policies. The results of their responses are indicated graphically on Figures III-3 through III-6. Similarly, Figure III-7 shows the results from question number 16, in which residents were asked to prioritize stormwater improvements.

CITY OF LEAVENWORTH, KANSAS - STORMWATER MASTER PLAN
STORMWATER MANAGEMENT QUESTIONNAIRE

The City of Leavenworth is currently completing a comprehensive, City-wide Stormwater Master Plan, which, when completed, will allow the City to improve storm drainage services City-wide. This questionnaire outlines key issues and information important in the completion of this Stormwater Master Plan. Please complete separate copies for your residence and business locations (photocopy or request 2nd copy).

1. SURVEY NUMBER (official use) > > >	2. DATE > > > > > >
3. NAME (opt.) > > >	4. # YEARS AT THIS LOCATION > >

5. ADDRESS > > > >
(optional: list nearby cross-street intersection) > > >

Is the Above Address Your Home or Business? > > > > _____ Home _____ Business

6. AREA CODE AND PHONE NUMBER (optional) > > > > >

7. To what degree are the following conditions a problem in your area?

	Major Problem	Minor Problem	Not a Problem	Don't Know
a. Basement flooding				
b. Street flooding				
c. Yard flooding				
d. Trash/debris in ditches				
e. Soil erosion				
f. Other				

8. Has rainfall or stormwater entered your home or business at the above address by way of the following in the last 5 years?

	Yes	No	Don't Know
a. Floor drains			
b. Bathtub/toilet/sink			
c. Windows/window wells			
d. Floors or walls			
e. Front yard or back yard			
f. Other			

9. Has flooding caused any of the following damages to your property at the above address?

	Yes	No	Don't Know
a. Erosion of ditches			
b. Flooded yard, little or no damage			
c. Debris deposited by floodwaters			
d. Damage to lawn, trees, or shrubs			
e. Damage to fences or buildings			
f. Extensive damage, loss of property			

10. How often do you have a problem with the flooding or drainage identified in Questions 8 or 9?

a. During every rainfall event	
b. Several times per year, or seasonally	
c. Once a year or so	
d. Once every 5 years or sooner	
e. Longer than 5 years since it occurred	
f. Never/Other	

11. Did you alter or cancel your travel route due to flooding caused by the Missouri River in 1993?

Yes	No	Don't Know

If YES, indicate areas or roadway intersections that were impassable due to flooding:

Figure III-1

STORMWATER MANAGEMENT QUESTIONNAIRE (page 2)

12. Have you ever had to alter or cancel your travel route due to flooding in the last 5 years? (Please do not include flooding caused by the Missouri River in 1993.)

Yes	No	Don't Know

If YES, indicate areas or roadway intersections that were impassable due to flooding, and when the flooding occurred:

13. Have you observed flooding in a street near your property?

If yes, list the street location(s) where you have observed flooding:

Yes	No	Don't Know

14. Have you seen flooding at storm drain inlets or culverts?

If yes, list the location(s) where you have observed flooding:

Yes	No	Don't Know

15. YOUR OPINIONS ON DRAINAGE CRITERIA AND POLICIES

Please indicate your opinion of the following criteria and policy issues:

	Yes	No	Don't Know
a. Street curbs and storm sewer pipes increase the desireability and value of property.			
b. New projects that increase runoff should pay for onsite & offsite drainage improvements.			
c. Those who benefit more from drainage improvements should pay more for them.			
d. Property along open channels should leave open space along the channels for drainage.			
e. Property along open channels should leave extra open space along the channel to allow for increased runoff from future upstream development.			
f. The City should acquire easements along all open channels and piped drainageways.			
g. The City should assume ownership of all open channels and piped drainage systems.			
h. The City should assume maintenance of all open channels and piped drainage systems.			
i. It would be acceptable to "share" the cost of drainage improvements with the City.			
j. Open channels on private property are acceptable vs. piped storm sewers.			
k. Improving water quality in our streams is worth some extra cost to achieve.			
l. It's O.K. to send stormwater runoff to large detention basins to reduce flooding.			
m. It's best to concentrate on reducing many "routine" flooding problems rather than on reducing a few "major" flooding problems.			

16. RANK THE FOLLOWING DRAINAGE IMPROVEMENTS IN ORDER OF IMPORTANCE (1=most important)

____ a. Minimizing or eliminating major soil and streambank erosion due to flooding is important.
____ b. Ensuring personal safety during severe storm events is important.
____ c. The relationship of storm drainage improvement costs vs. the benefit of reduced flooding is important.
____ d. Minimizing or eliminating street flooding during storm events is important.
____ e. Maintaining emergency services (police, ambulance, fire, etc.) during flooding events is important.
____ f. I'm not sure what is most important concerning prioritizing improvements.
____ g. Minimizing or eliminating the potential for extensive property damage/loss from flooding is important.
____ h. Containing flooding and storm runoff within piped systems or under culverts/bridges is important.

17. ADDITIONAL COMMENTS OR CONCERNS (attach separate sheets):

IF YOU HAVE ANY QUESTIONS, PLEASE CALL THE LEAVENWORTH STORMWATER HOTLINE AT 758-0200

Thank you for your time. Please complete the questionnaire by May 1, 1995, if possible, and return by mail, or drop it off at the City Clerk's office in City Hall.

Engineer's Office
ATTN: STORMWATER QUESTIONNAIRE
City Hall, 5th & Shawnee
Leavenworth, KS 66048

Figure III-1

		Table III-1			
		Stormwater Questionnaire Results			
		Response to Question 7			
Question No.	Part	303 TOTAL Respondents	No. of Responses	No. of "Major"	No. of "Minor"
7		To what degree are the following conditions a problem in your area?			
7	A	Basement flooding	272	38	73
7	B	Street flooding	279	50	53
7	C	Yard flooding	280	49	62
7	D	Trash/debris in ditches	269	50	64
7	E	Soil erosion	262	35	62
7	F	Other	19	7	12
			Percent "Major"	Percent "Minor"	% "No Prob"/ "Don't Know"
7		To what degree are the following conditions a problem in your area?			
7	A	Basement flooding	14.0	26.8	59.2
7	B	Street flooding	17.9	19.0	63.1
7	C	Yard flooding	17.5	22.1	60.4
7	D	Trash/debris in ditches	18.6	23.8	57.6
7	E	Soil erosion	13.4	23.7	63.0
7	F	Other	36.8	63.2	0.0

Table III-2
Stormwater Questionnaire Results
Major Problems Group

Question No.	Part	108 Respondents with MAJOR FLOODING PROBLEMS	No. of Responses	No. of "Major"	No. of "Minor"	Percent "Major"	Percent "Minor"
7		To what degree are the following conditions a problem in your area?					
7	A	Basement flooding	86	38	22	44 2	25 6
7	B	Street flooding	94	50	28	53.2	29 8
7	C	Yard flooding	94	49	27	52.1	28 7
7	D	Trash/debris in ditches	85	50	14	58 8	16 5
7	E	Soil erosion	80	35	18	43 8	22 5
7	F	Other	10	7	3	70 0	30 0

Question No.	Part		No. of Responses	No. of "Yes"	Percent "Yes"
8		Has rainfall or stormwater entered your home or business at the above address by way of the following in the last 5 years?			
8	A	Floor drains	74	22	29 7
8	B	Bathtub/toilet/sink	71	6	8 5
8	C	Windows/window wells	72	14	19 4
8	D	Floors or walls	75	31	41.3
8	E	Front yard or back yard	90	50	55 6
8	F	Other	9	9	100.0

Question No.			No. of Responses	No. of "Yes"	Percent "Yes"
9		Has flooding caused any of the following damages to your property at the above address?			
9	A	Erosion of ditches	87	38	43 7
9	B	Flooded yard, little or no damage	96	65	67.7
9	C	Debris deposited by floodwaters	94	54	57 4
9	D	Damage to lawn, trees, or shrubs	85	28	32.9
9	E	Damage to fences or buildings	84	22	26.2
9	F	Extensive damage, loss of property	82	17	20 7

Question No.	Part		No. of Responses
10		How often do you have a problem with the flooding or drainage identified in Questions 8 or 9?	
10	A	During every rainfall event	32
10	B	Several times per year, or seasonally	40
10	C	Once a year or so	12
10	D	Once every 5 years or sooner	13
10	E	Longer than 5 years since it occurred	2
10	F	Never/Other	2

Question No.			No. of Responses	No. of "Yes"	Percent "Yes"
11		Did you alter or cancel your travel route due to flooding caused by the Missouri River in 1993?	94	27	28.7
12		Have you ever had to alter or cancel your travel route due to flooding in the last 5 years?	89	14	15.7
13		Have you observed flooding in a street near your property?	98	68	69.4
14		Have you seen flooding at storm drain inlets or culverts?	96	65	67.7

Question No.	Part		No. of Responses	No. of "Yes"	Percent "Yes"
15		Your opinions on drainage criteria and policies:			
15	A	Street curbs and storm sewer pipes increase the desireability and value of property.	93	82	88.2
15	B	New projects that increase runoff should pay for onsite & offsite drainage improvements.	91	63	69.2
15	C	Those who benefit more from drainage improvements should pay for them.	86	24	27.9
15	D	Property along open channels should leave open space along the channels for drainage.	87	52	59.8
15	E	Property along open channels should leave extra open space along the channel to allow for increased runoff from future upstream development.	88	43	48.9
15	F	The City should acquire easements along all open channels and piped drainageways.	87	40	46.0
15	G	The City should assume ownership of all open channels and piped drainage systems.	87	46	52.9
15	H	The City should assume maintenance of all open channels and piped drainage systems.	84	58	69.0
15	I	It would be acceptable to "share" the cost of drainage improvements with the City.	86	29	33.7
15	J	Open channels on private property are acceptable vs. piped storm sewers.	86	24	27.9
15	K	Improving water quality in our streams is worth some extra cost to achieve.	87	46	52.9
15	L	It's O.K. to send stormwater runoff to large detention basins to reduce flooding.	89	48	53.9
15	M	It's best to concentrate on reducing many "routine" flooding problems rather than on reducing a few "major" flooding problems.	85	44	51.8

Question No.	Part		No. of Responses	Sum	Average	Rank
16		Rank the following drainage improvements in order of importance (1 = most important).				
16	A	Minimizing or eliminating major soil and streambank erosion due to flooding is important.	65	287	4.4	6
16	B	Ensuring personal safety during severe storm events is important.	72	137	1.9	1
16	C	The relationship of drainage improvement costs vs. the benefit of reduced flooding is important.	65	291	4.5	7
16	D	Minimizing or eliminating street flooding during storm events is important.	71	225	3.2	4
16	E	Maintaining emergency services (police, ambulance, etc.) during flooding events is important.	74	163	2.2	2
16	F	I'm not sure what is most important concerning prioritizing improvements.	45	237	5.3	8
16	G	Minimizing or eliminating the potential for property damage/loss from flooding is important.	72	205	2.8	3
16	H	Containing flooding & storm runoff within piped systems or under culverts/bridges is important.	67	281	4.2	5

Table III-3
Stormwater Questionnaire Results
Minor Problems Group

Question No.	Part	109 Respondents with MINOR FLOODING PROBLEMS	No. of Responses	No. of "Major"	No. of "Minor"	Percent "Major"	Percent "Minor"
7		To what degree are the following conditions a problem in your area?					
7	A	Basement flooding	105	0	51	0.0	48.6
7	B	Street flooding	103	0	25	0.0	24.3
7	C	Yard flooding	105	0	35	0.0	33.3
7	D	Trash/debris in ditches	102	0	50	0.0	49.0
7	E	Soil erosion	100	0	44	0.0	44.0
7	F	Other	9	0	9	0.0	100.0

Question No.	Part		No. of Responses	No. of "Yes"	Percent "Yes"
8		Has rainfall or stormwater entered your home or business at the above address by way of the following in the last 5 years?			
8	A	Floor drains	102	6	5.9
8	B	Bathtub/toilet/sink	101	1	1.0
8	C	Windows/window wells	104	17	16.3
8	D	Floors or walls	101	31	30.7
8	E	Front yard or back yard	102	27	26.5
8	F	Other	2	2	100.0

Question No.			No. of Responses	No. of "Yes"	Percent "Yes"
9		Has flooding caused any of the following damages to your property at the above address?			
9	A	Erosion of ditches	104	20	19.2
9	B	Flooded yard, little or no damage	106	32	30.2
9	C	Debris deposited by floodwaters	104	17	16.3
9	D	Damage to lawn, trees, or shrubs	103	12	11.7
9	E	Damage to fences or buildings	104	6	5.8
9	F	Extensive damage, loss of property	102	1	1.0

Question No.	Part		No. of Responses
10		How often do you have a problem with the flooding or drainage identified in Questions 8 or 9?	
10	A	During every rainfall event	6
10	B	Several times per year, or seasonally	21
10	C	Once a year or so	32
10	D	Once every 5 years or sooner	11
10	E	Longer than 5 years since it occurred	1
10	F	Never/Other	30

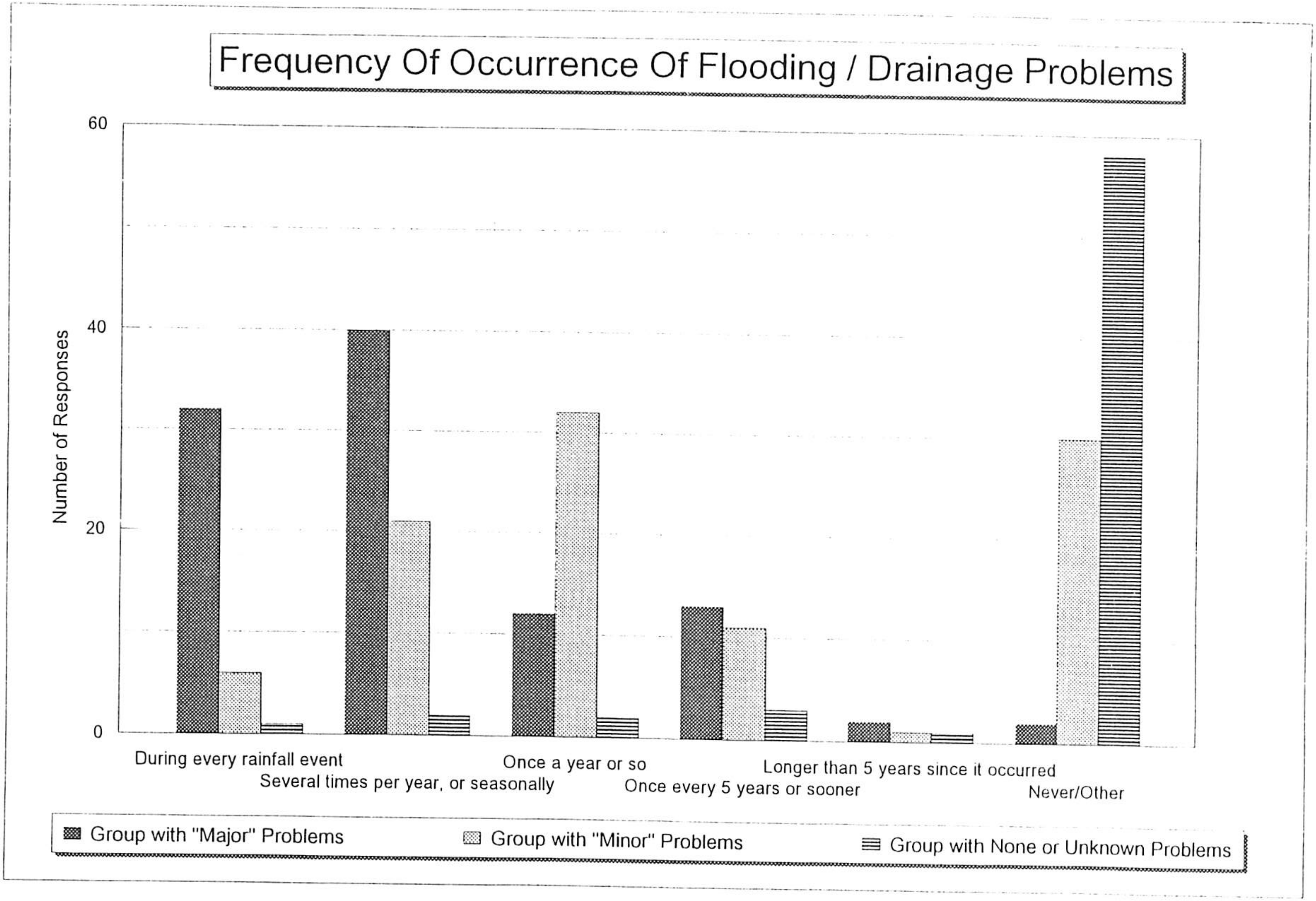
Question No.			No. of Responses	No. of "Yes"	Percent "Yes"
11		Did you alter or cancel your travel route due to flooding caused by the Missouri River in 1993?	109	26	23.9
12		Have you ever had to alter or cancel your travel route due to flooding in the last 5 years?	107	17	15.9
13		Have you observed flooding in a street near your property?	107	27	25.2
14		Have you seen flooding at storm drain inlets or culverts?	104	40	38.5

Question No.	Part		No. of Responses	No. of "Yes"	Percent "Yes"
15		Your opinions on drainage criteria and policies:			
15	A	Street curbs and storm sewer pipes increase the desireability and value of property.	105	91	86.7
15	B	New projects that increase runoff should pay for onsite & offsite drainage improvements.	103	80	77.7
15	C	Those who benefit more from drainage improvements should pay for them.	105	46	43.8
15	D	Property along open channels should leave open space along the channels for drainage.	105	79	75.2
15	E	Property along open channels should leave extra open space along the channel to allow for increased runoff from future upstream development.	104	62	59.6
15	F	The City should acquire easements along all open channels and piped drainageways.	101	52	51.5
15	G	The City should assume ownership of all open channels and piped drainage systems.	104	53	51.0
15	H	The City should assume maintenance of all open channels and piped drainage systems.	103	66	64.1
15	I	It would be acceptable to "share" the cost of drainage improvements with the City.	104	55	52.9
15	J	Open channels on private property are acceptable vs. piped storm sewers.	104	44	42.3
15	K	Improving water quality in our streams is worth some extra cost to achieve.	104	79	76.0
15	L	It's O.K. to send stormwater runoff to large detention basins to reduce flooding.	103	73	70.9
15	M	It's best to concentrate on reducing many "routine" flooding problems rather than on reducing a few "major" flooding problems.	105	49	46.7

Question No.	Part		No. of Responses	Sum	Average	Rank
16		Rank the following drainage improvements in order of importance (1 = most important).				
16	A	Minimizing or eliminating major soil and streambank erosion due to flooding is important.	87	396	4.6	6
16	B	Ensuring personal safety during severe storm events is important.	96	169	1.8	1
16	C	The relationship of drainage improvement costs vs. the benefit of reduced flooding is important.	88	394	4.5	5
16	D	Minimizing or eliminating street flooding during storm events is important.	91	363	4.0	4
16	E	Maintaining emergency services (police, ambulance, etc.) during flooding events is important.	99	196	2.0	2
16	F	I'm not sure what is most important concerning prioritizing improvements.	66	419	6.3	8
16	G	Minimizing or eliminating the potential for property damage/loss from flooding is important.	91	340	3.7	3
16	H	Containing flooding & storm runoff within piped systems or under culverts/bridges is important.	92	435	4.7	7

Table III-4
Stormwater Questionnaire Results
No Problems Group

Question No.	Part	86 Respondents with NO FLOODING PROBLEMS, or "don't know"	No. of Responses	No. of "Major"	No. of "Minor"	Percent "Major"	Percent "Minor"
7		To what degree are the following conditions a problem in your area?					
7	A	Basement flooding	81	0	0	0.0	0.0
7	B	Street flooding	82	0	0	0.0	0.0
7	C	Yard flooding	81	0	0	0.0	0.0
7	D	Trash/debris in ditches	82	0	0	0.0	0.0
7	E	Soil erosion	82	0	0	0.0	0.0
7	F	Other	0	0	0	0.0	0.0
Question No.	**Part**		**No. of Responses**	**No. of "Yes"**		**Percent "Yes"**	
8		Has rainfall or stormwater entered your home or business at the above address by way of the following in the last 5 years?					
8	A	Floor drains	82	2		2.4	
8	B	Bathtub/toilet/sink	82	1		1.2	
8	C	Windows/window wells	82	4		4.9	
8	D	Floors or walls	82	5		6.1	
8	E	Front yard or back yard	82	2		2.4	
8	F	Other	0	0		0.0	
Question No.			**No. of Responses**	**No. of "Yes"**		**Percent "Yes"**	
9		Has flooding caused any of the following damages to your property at the above address?					
9	A	Erosion of ditches	81	1		1.2	
9	B	Flooded yard, little or no damage	81	1		1.2	
9	C	Debris deposited by floodwaters	81	0		0.0	
9	D	Damage to lawn, trees, or shrubs	82	2		2.4	
9	E	Damage to fences or buildings	80	0		0.0	
9	F	Extensive damage, loss of property	80	0		0.0	
Question No.	**Part**		**No. of Responses**				
10		How often do you have a problem with the flooding or drainage identified in Questions 8 or 9?					
10	A	During every rainfall event	1				
10	B	Several times per year, or seasonally	2				
10	C	Once a year or so	2				
10	D	Once every 5 years or sooner	3				
10	E	Longer than 5 years since it occurred	1				
10	F	Never/Other	58				
Question No.			**No. of Responses**	**No. of "Yes"**		**Percent "Yes"**	
11		Did you alter or cancel your travel route due to flooding caused by the Missouri River in 1993?	79	10		12.7	
12		Have you ever had to alter or cancel your travel route due to flooding in the last 5 years?	79	4		5.1	
13		Have you observed flooding in a street near your property?	82	6		7.3	
14		Have you seen flooding at storm drain inlets or culverts?	79	15		19.0	
Question No.	**Part**		**No. of Responses**	**No. of "Yes"**		**Percent "Yes"**	
15		Your opinions on drainage criteria and policies:					
15	A	Street curbs and storm sewer pipes increase the desireability and value of property.	76	52		68.4	
15	B	New projects that increase runoff should pay for onsite & offsite drainage improvements.	73	51		69.9	
15	C	Those who benefit more from drainage improvements should pay for them.	74	43		58.1	
15	D	Property along open channels should leave open space along the channels for drainage.	75	50		66.7	
15	E	Property along open channels should leave extra open space along the channel to allow for increased runoff from future upstream development.	72	45		62.5	
15	F	The City should acquire easements along all open channels and piped drainageways.	73	35		47.9	
15	G	The City should assume ownership of all open channels and piped drainage systems.	75	32		42.7	
15	H	The City should assume maintenance of all open channels and piped drainage systems.	77	46		59.7	
15	I	It would be acceptable to "share" the cost of drainage improvements with the City.	71	23		32.4	
15	J	Open channels on private property are acceptable vs. piped storm sewers.	73	20		27.4	
15	K	Improving water quality in our streams is worth some extra cost to achieve.	74	46		62.2	
15	L	It's O.K. to send stormwater runoff to large detention basins to reduce flooding.	74	39		52.7	
15	M	It's best to concentrate on reducing many "routine" flooding problems rather than on reducing a few "major" flooding problems.	71	34		47.9	
Question No.	**Part**		**No. of Responses**	**Sum**		**Average**	**Rank**
16		Rank the following drainage improvements in order of importance (1 = most important).					
16	A	Minimizing or eliminating major soil and streambank erosion due to flooding is important.	53	208		3.9	5
16	B	Ensuring personal safety during severe storm events is important.	60	112		1.9	1
16	C	The relationship of drainage improvement costs vs. the benefit of reduced flooding is important.	52	237		4.6	7
16	D	Minimizing or eliminating street flooding during storm events is important.	59	209		3.5	3
16	E	Maintaining emergency services (police, ambulance, etc.) during flooding events is important.	62	127		2.0	2
16	F	I'm not sure what is most important concerning prioritizing improvements.	52	284		5.5	8
16	G	Minimizing or eliminating the potential for property damage/loss from flooding is important.	53	200		3.8	4
16	H	Containing flooding & storm runoff within piped systems or under culverts/bridges is important.	56	253		4.5	6



Frequency Of Occurrence Of Flooding / Drainage Problems
Number of Responses
60
40
20
0
During every rainfall event
Several times per year, or seasonally
Once a year or so
Once every 5 years or sooner
Longer than 5 years since it occurred
Never/Other
Group with "Major" Problems
Group with "Minor" Problems
Group with None or Unknown Problems

Figure III-2

OPINIONS ON COSTS RELATED TO DRAINAGE IMPROVEMENTS

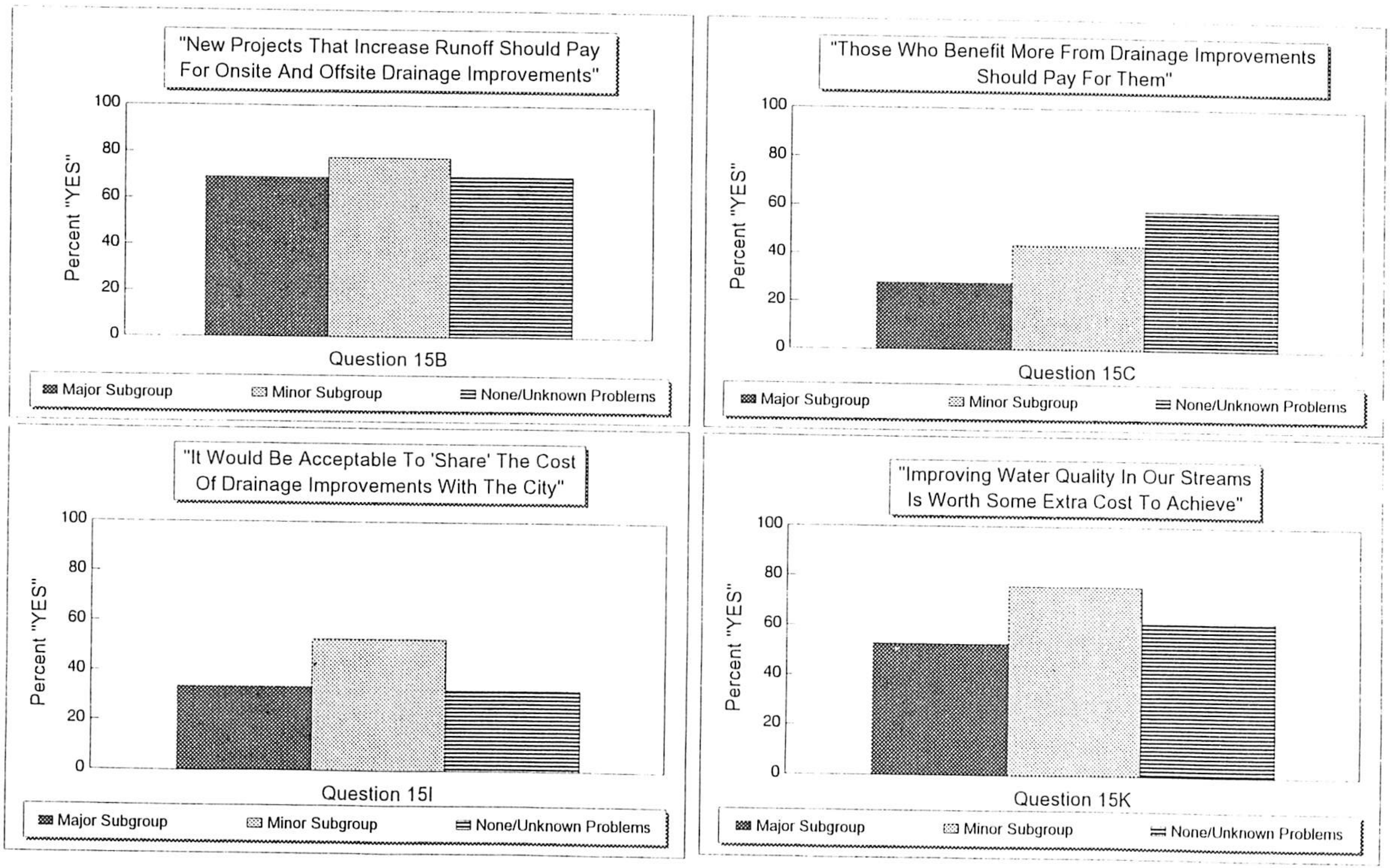
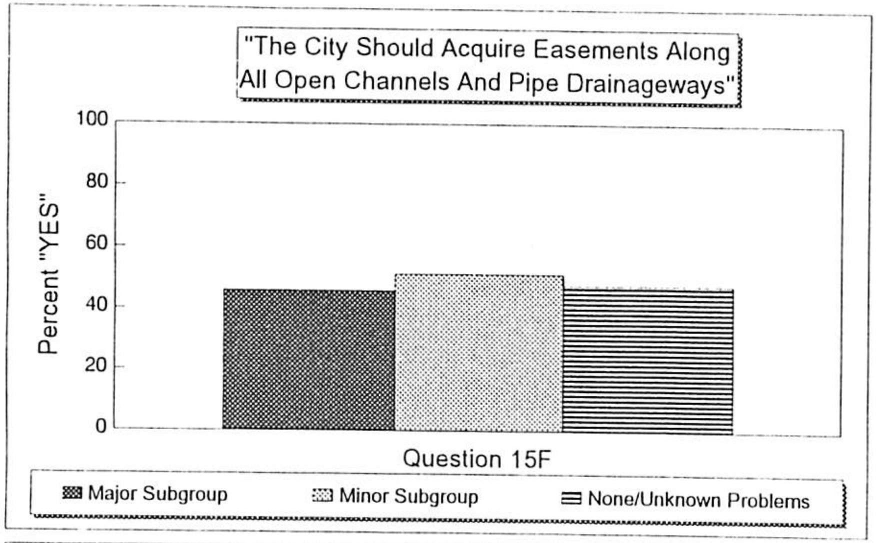
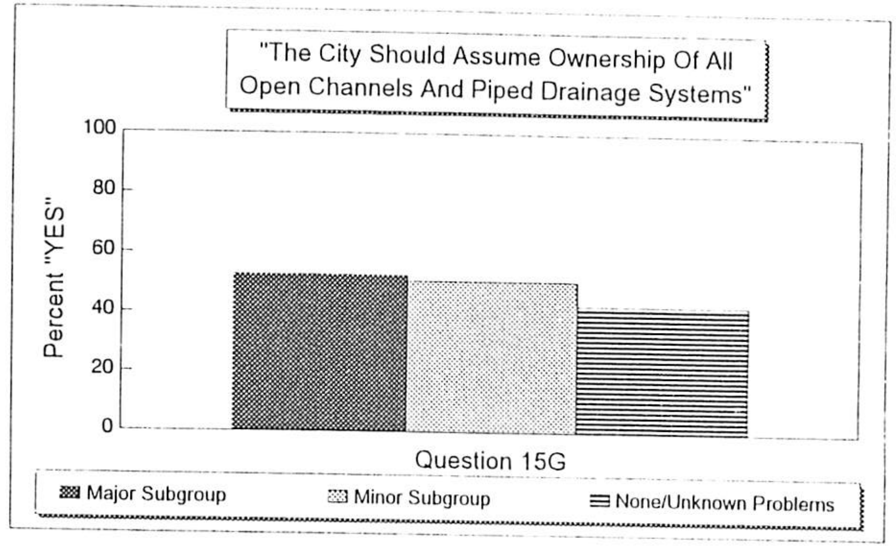


Figure III-3

OPINIONS ON CITY OWNERSHIP / MAINTENANCE OF STORMWATER CONVEYANCE FACILITIES





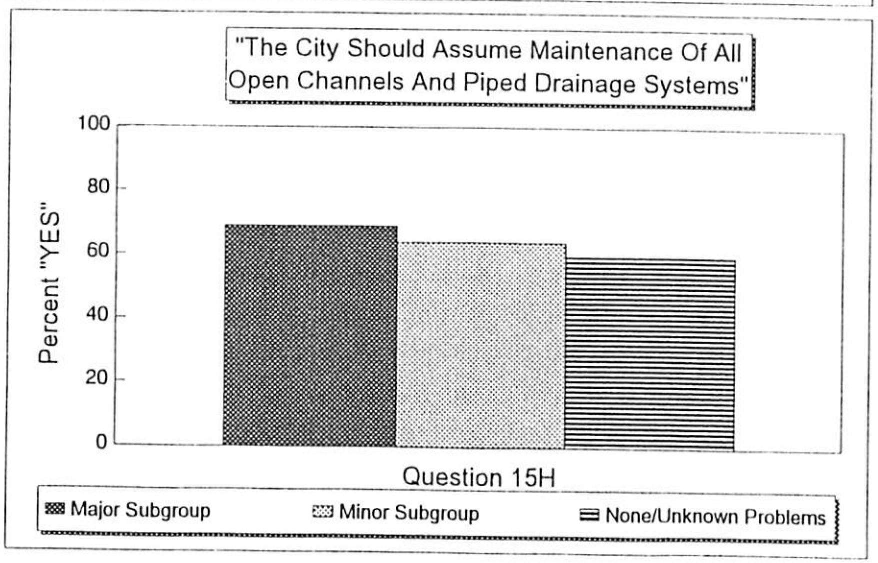
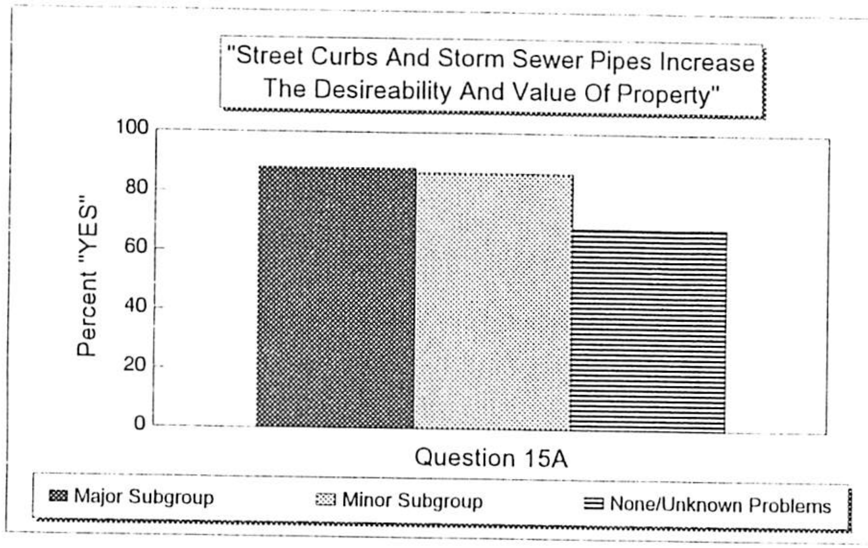
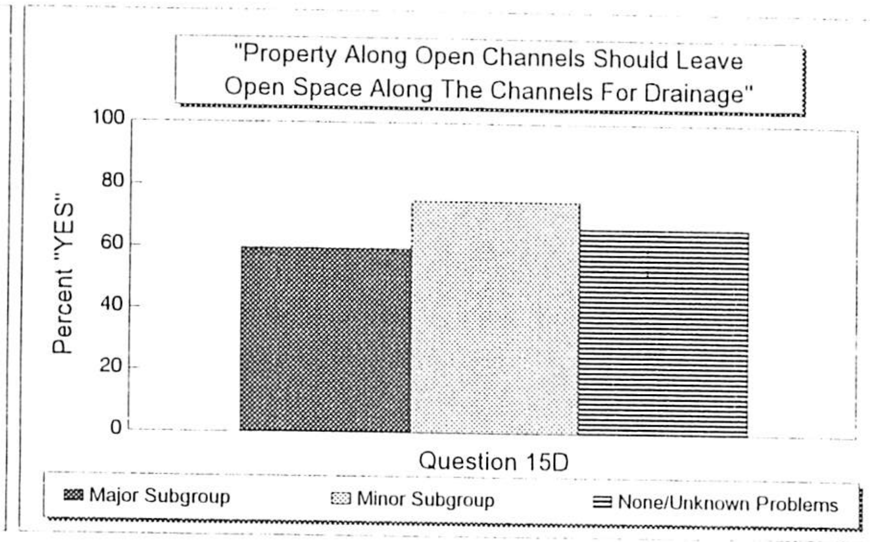
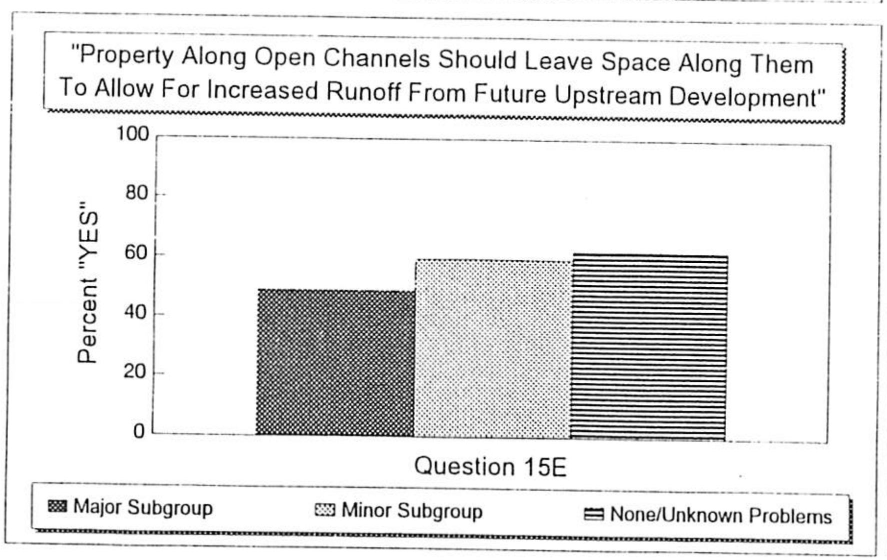


Figure III-4

OPINIONS ON AESTHETICS AND EFFECT OF DRAINAGE IMPROVEMENTS ON PROPERTY VALUES







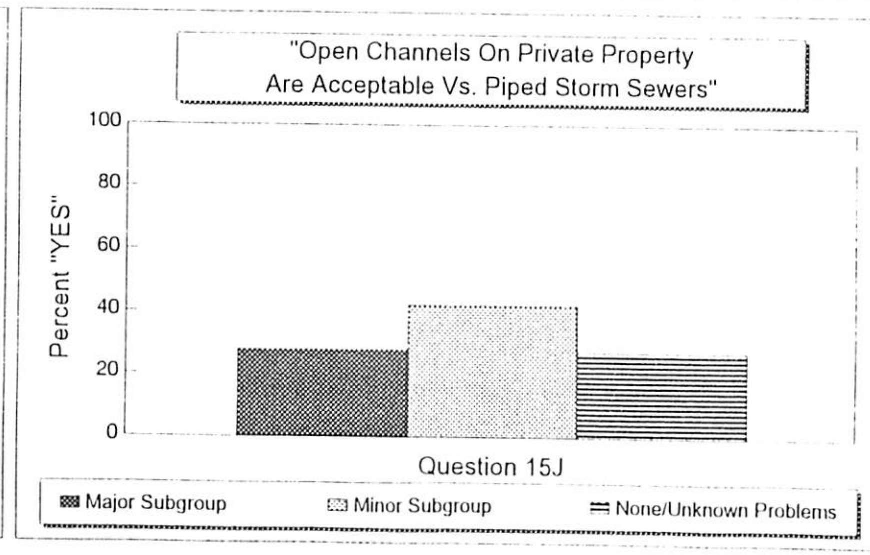
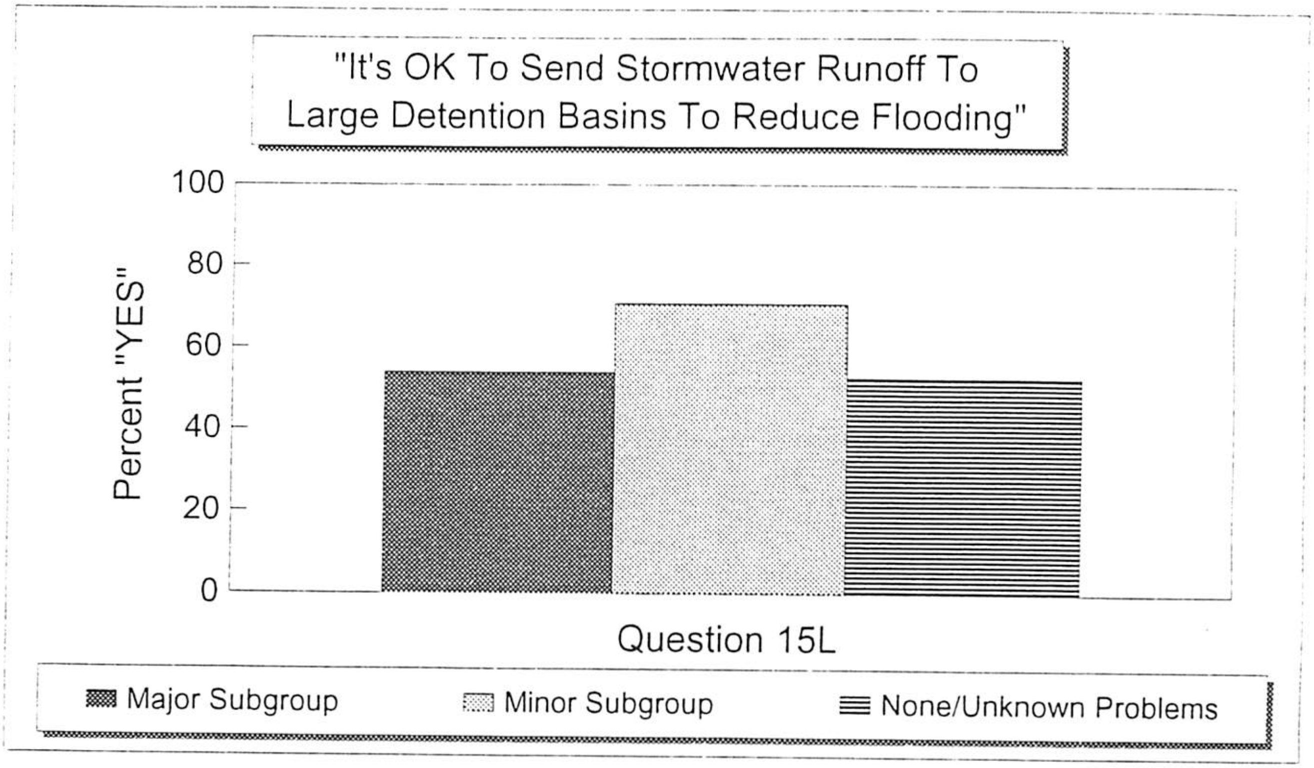


Figure III-5


"It's OK To Send Stormwater Runoff To Large Detention Basins To Reduce Flooding"
100
80
60
40
20
0
Percent "YES"
Question 15L
Major Subgroup
Minor Subgroup
None/Unknown Problems

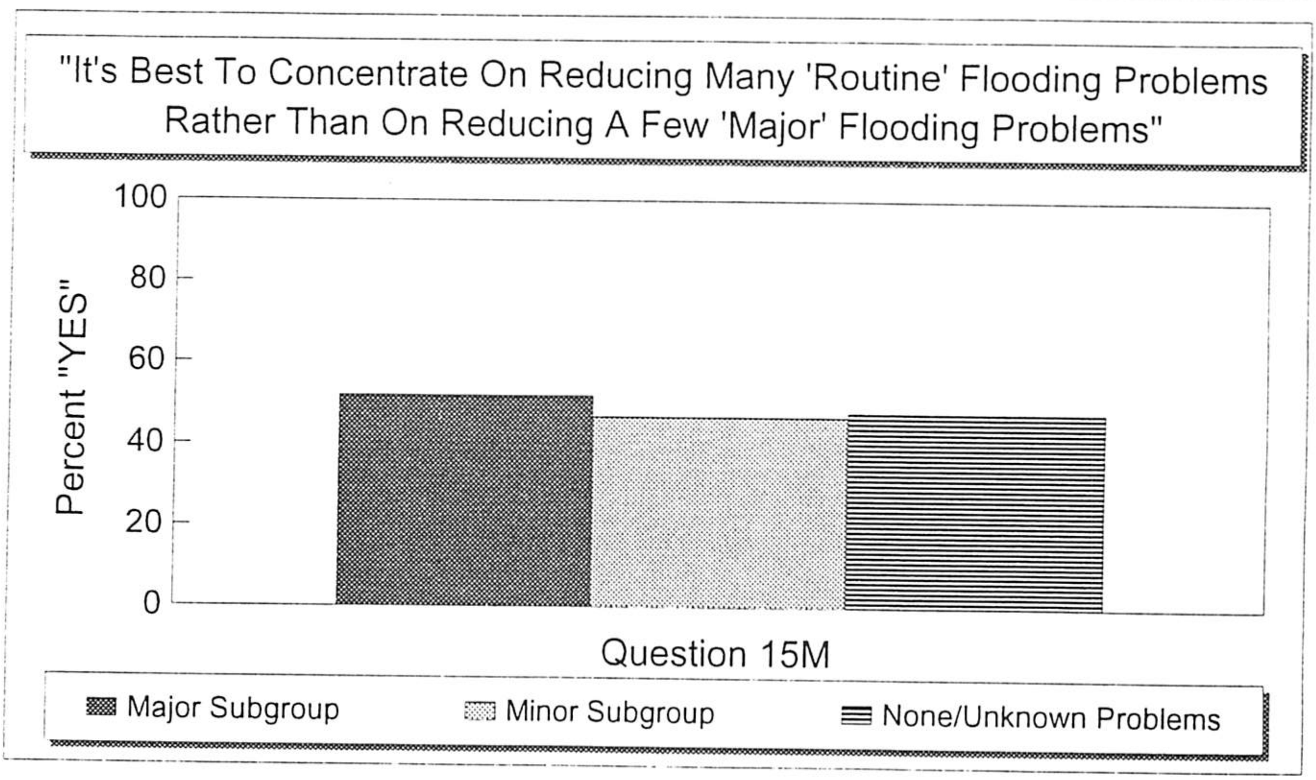

"It's Best To Concentrate On Reducing Many 'Routine' Flooding Problems Rather Than On Reducing A Few 'Major' Flooding Problems"
100
80
60
40
20
0
Percent "YES"
Question 15M
Major Subgroup
Minor Subgroup
None/Unknown Problems

Figure III-6

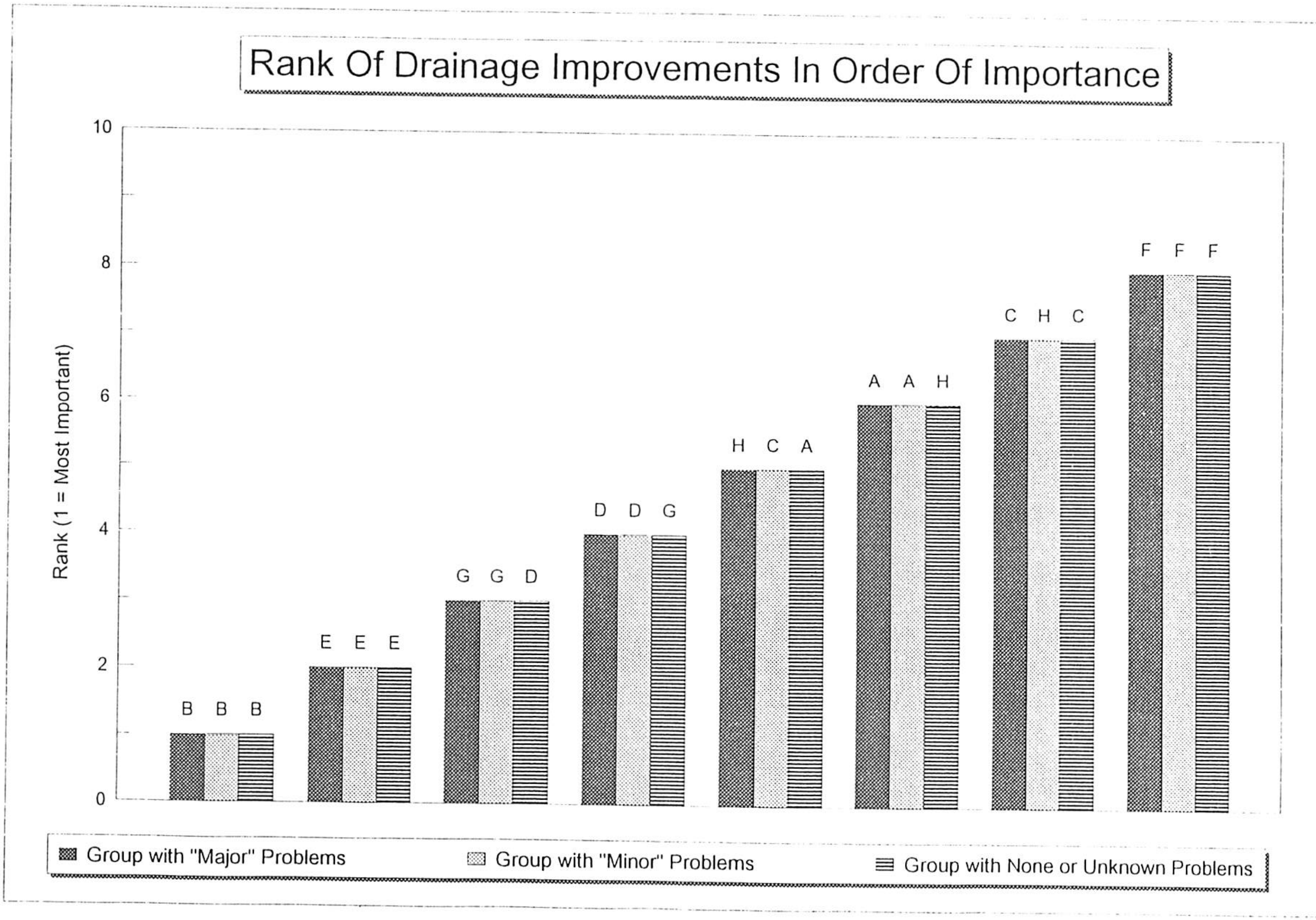

Rank Of Drainage Improvements In Order Of Importance
Rank (1 = Most Important)
10
8
6
4
2
0
B B B
E E E
G G D
D D G
H C A
A A H
C H C
F F F
Group with "Major" Problems
Group with "Minor" Problems
Group with None or Unknown Problems

Figure III-7

Figures VI-11 and VI-12 (Chapter VI) indicate a good correlation between the questionnaire responses and the system inadequacies identified by computer modeling. Responses that are a measurable distance away from the conveyance system are most likely on smaller system components that drain to the analyzed system. These flooding problems may be alleviated by correcting the identified inadequacies since the surcharging will be significantly reduced. Additionally, inadequacies may be identified where flooding presently has no adverse impact on residents or where no complaint has been registered. This approach of combining questionnaire responses with model results provides the opportunity to react to existing system inadequacies, as well as proactively address potential flooding locations before they actually occur.

D. Stormwater Hotline

A telephone hotline was established for reporting drainage problems during storm events. Black & Veatch answered the calls, recorded the pertinent information for database entry, and forwarded calls pertaining to sanitary sewer backups, street maintenance, etc., to the City. Some calls warranted site visits by City or Black & Veatch personnel. Publicity regarding the establishment of the hotline was provided through local news media. To provide the service at no cost to residents of Leavenworth, a local service was established, using a local call-in phone number which, in turn, was transferred long-distance to the Black & Veatch office. The Stormwater Hotline was set up in January 1995 and operated through to the end of the project in 1996. During the 24-month period, 25 telephone calls were recorded.

E. Public Information Meetings

The public was invited to attend the presentation of project information at Public Information Meetings. Two Public Information Meetings were held. The first meeting, held on May 17, 1995, was attended by approximately 20 citizens in addition to City and Black & Veatch personnel.

The final public presentation of the study was made by the City, Black & Veatch, and the Citizen's Stormwater Committee on June 15, 1999. Black & Veatch prepared visual aids for these meetings and assisted with answering questions.

IV. Existing Stormwater System Data

A. Data and Information Sources

As shown in Table IV-1, data is available to help Leavenworth manage its stormwater conveyance system. However, as the system develops, additional types of information will become available, and its management will become increasingly important. The Public Works Department must decide not only how data will be collected, processed, organized, and distributed, but also what information is necessary to properly plan, regulate, design, build, and maintain the physical system.

The foresight of Leavenworth's Public Works Department in developing a city-wide Geographic Information System (GIS) has proven very beneficial to the completion of this master plan and the inclusion of a data management component. The use of GIS has made it possible to develop this master plan and to initiate the data management strategy for the stormwater conveyance system. The data entered and stored in the GIS include historic flooding locations, questionnaire responses, and hydrologic and hydraulic modeling data.

Table IV-1 presents a summary of data collected and used in this study. A brief description of the contents of each piece of information is provided in Appendix C.

B. Stormwater Ordinances and Design Criteria Assessment

The City of Leavenworth regulates its stormwater system through the following documents:

- Zoning Ordinance 1985 as Amended through July 1992, City of Leavenworth.
    - Article II. District Regulations, Section 21.212 Flood Plain.
    - Article V. Site Plan Review.
- "Report on Stormwater Drainage, Leavenworth, Kansas," 1967, Black & Veatch.
- Memo to City Public Works Department from City Attorney, May 1995.

Table IV-1 Summary of Data Collected	
Number	Title of Document
Utility Maps	
1	Stormwater Sewer Maps (M.J. Harden) Sections 1, 2, 3, 4 (SE), 6 (SW), 7 (NW,SW), 9(NE), 10, 11, 12, 13 (NE,NW), 14 (NE,NW), 15 (NE), 18 (NW), 25 (SE,SW,NW), 26, 27, 34, 35, 36
2	Leavenworth, Kansas Scale: 1 inch = 500 feet
Data on Recent Improvement Projects	
3	Storm Drainage Improvements 17th St. & Vilas St. Leavenworth, Kansas Storm Drainage Improvements 5th Ave. & South St. Leavenworth, Kansas
4	4th Street at the Veteran's Hospital Access Road Leavenworth, Kansas
5	Hometown Village P.U.D. Phase I
6	Storm Sewer Line 1 As-Built Plans Leavenworth Plaza Shop Center
7	Grading Plan - WalMart Storm Sewer Profiles
Development Plans	
8	State of Kansas Department of Transportation Kansas Project West Leavenworth Trafficway Leavenworth County City of Leavenworth
9	West Leavenworth Annexation Plan Future Land Use Existing Land Use
10	City of Leavenworth, Kansas 760 Cherokee Drainage Improvements

Table IV-1 Summary of Data Collected	
Number	Title of Document
Aerial Photos	
11	Aerial photos of the Leavenworth area: T.8.S., R.22.E; Sections: 20, 21, 22, 23, 24, 25, 26, 27, 28, 29, 32, 33, 34, 35, 36 T.9.S., R.22.E; Sections: 1, 2, 3, 4, 5, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 20, 21, 22, 23, 24, 25, 26, 27, 28, 29 T.9.S., R.23.E; Sections: 6, 7, 18, 19, 30 T.8.S., R.23.E; Section 31
FEMA Flood Plain Studies and Maps	
12	Flood Insurance Study, County of Leavenworth, Kansas Unincorporated Areas
13	Flood Insurance Study City of Leavenworth, Kansas
Complaint Files and Reports	
14	Stormwater Management Questionnaire
15	Telephone Memorandum
City Design Standards for Storm Sewers	
16	Shawnee Steel & Welding, Inc. 6" Steel Inlet Frame-Welded
17	City of Leavenworth, Kansas Office of the City Engineer Type "A" Curb Inlet Detail
18	City of Leavenworth, Kansas Asphaltic Concrete Paving C. & G. Details
City Ordinances/Codes	
19	Zoning Ordinance 1985 as Amended through July 1992, City of Leavenworth

Table IV-1
Summary of Data Collected

Number	Title of Document
Soils Reports	
20	State Soil Geographic Data Base (STATSGO)
Corps of Engineers Studies	
21	Flood Plain Information Five Mile Creek Leavenworth, Kansas
22	Flood Plain Information Three Mile Creek Leavenworth, Kansas
USGS Maps and Studies	
23	Leavenworth Quadrangle Map
Other Past Studies	
24	Report on Stormwater Drainage Leavenworth, Kansas
25	City of Leavenworth FEMA Damage Report, Site 1 through 33
Street and Bridge Data	
26	City of Leavenworth, Kansas Bridges (20 or more feet in length)
27	Map of Leavenworth, Kansas Wards & Precincts
28	Shopping Guide and Membership Directory
29	Figure 16 Arterial and Collector Streets
30	Report on 1993, Biennial Bridge Inspection
31	Bridge Reports and Inventory System for Kansas (BRISK) diskette, Version 2, Release 3
32	Construction Layout, Bridge over Three Mile Creek
33	7th Street Bridge over Three Mile Creek, Construction Layout
34	Construction Layout, Bridge over Three Mile Creek
35	Construction Layout & Geology, Bridge over Three Mile Creek

Table IV-1 Summary of Data Collected	
Number	Title of Document
36	Construction Project 1961-54
37	Construction Project 1964-75
38	Construction Project 1964-75
39	Ottawa Street Bridge and Approach at Three Mile Creek, Sheets 1 & 2 of 10
40	Project No. 52U-0807-01, 083-164, Sheet 3 of 14
41	Project 1967-10
42	5th Street Bridge over Three Mile Creek
43	6th Street Bridge and Approach at Three Mile Creek
44	Construction Layout, 10th Street Bridge
45	Construction Layout, Bridge over Five Mile Creek
46	Construction Layout, U.S.-73 over Five Mile Creek
47	Limit Street Bridge over Five Mile Creek
48	Shrine Park Road Bridge over Five Mile Creek Construction Layout
Hydrologic Data	
49	Rainfall Intensity Tables for Counties in Kansas
50	Final Report K-TRAN Research Project KU-93-5 Rainfall Inputs for Simulation of Design Floods in Kansas
Historical Flooding Data	
51	Historic Flooding Locations, B&V Memorandum
References	
52	Stormwater Management Model, Version 4, User's Manual
53	XP-SWMM User's Manual, Version 2
Other	
54	Missouri River Gauge Data

These documents provide authority for the City to control the quality and conveyance of stormwater, and the technical criteria to design and operate a stormwater conveyance system.

Article II. District Regulations, Section 21.212 Flood Plain, of the zoning ordinance, addresses development in the flood plain and outlines the limitations on development in the flood plain for different types of structures and land uses. According to this source, the provisions for flood plain protection are adopted pursuant to the authorization contained in Kansas Statutes Annotated, Sections 12-705, 12-707, 12-710, and 12-734-735.

The intent of Article V. Site Plan Review of the zoning ordinance is to provide the City with sufficient information to review all development proposals and assure compliance with the requirements established in these regulations.

Storm sewer design criteria are based on the following recommendations in the 1967 Black & Veatch study:

- Calculation of peak flow rates using the Rational Method.
- The level of protection in residential areas should be for a five-year return period storm, a 10-year return period storm in commercial and high value areas, and a 100-year return period storm where topography would cause deep water in commercial and high value areas.
- Calculation of conveyance system capacities using Manning's equation.

A new storm drainage design manual was prepared concurrently with this master plan report. This document specifies the design criteria for a storm sewer system. Information provided includes capacity requirements; channel and sewer pipe sizes, grades, materials, depths and locations; sewer manholes, inlets, extraneous connections; and provisions for siltation/soil erosion control and stormwater retention/detention. A separate subdivision manual contains requirements related to construction documents.

In May of 1995, the Leavenworth City Attorney presented to the Public Works Department a summary of the City's legal responsibilities regarding storm drainage. The presentation focused on legal issues for municipalities in Kansas. A list of specific questions was developed jointly by the Citizen's Stormwater Committee, Public Works staff, and Black & Veatch staff, and the attorney's responses have been incorporated into the General Policy, as indicated in Chapter VII of this report.

In general, the City's stormwater ordinances are adequate but not in an easily retrievable form. Each city has its own method for analysis, design, and enforcement of stormwater-related policies. There is no single correct method or policy--the policies that are in line with the City's philosophy for stormwater management are best and most appropriate for the City officials and the residents. Policies/regulations that are not included in the new storm drainage design manual, but which the City may wish to review, include the following:

- Other Design Tools

  The Rational Formula is the hydrologic design method stipulated in the new Storm Drainage Design manual. It is a widely used and appropriate method for estimating flows for the design of stormwater conveyance systems. With the development of this master plan, the City may want to consider expanding the hydrology section to include XP-SWMM as a basis for the analysis and design of conveyance system components for subcatchments larger than a stipulated area.

- More Stringent Flood Plain Regulations

  Although not generally favored by developers and land owners, stringent flood plain regulations, in addition to those adopted by FEMA, can prove beneficial in the future. The City may consider restricting construction in the flood plain to minimum elevation above the 100-year floodwater level.

- Include Property Acquisition as a Standard Improvement Alternative

  Although purchase of properties is detrimental to the City's tax base, property acquisition can be a cost-effective method of reducing the extent of flood damage, and redevelopment of the property to a park or open space (designed to allow flooding), can produce recreational and aesthetic benefits that far outweigh the loss of tax revenue.

V. Geographic Information System (GIS) Development

A. Mapping/Data

M.J. Harden provided the base mapping for the City of Leavenworth which included planimetric, contour, and storm sewer maps. The storm sewer maps were converted from hard copy maps provided by the City. In addition to the storm sewer mapping, database information was provided which was linked to the storm sewer entities. This information included x, y, and z coordinates and pipe sizes.

The information provided by M.J. Harden was further developed into a GIS by adding the remaining drainage structures, i.e., open channels, connectivity information, and additional information on the conveyance system. The information added into the database on the drainage structures includes: slope, roughness, upstream/downstream nodes, length, upstream/downstream invert elevations, and loss coefficients.

The purpose of incorporating a GIS for the Stormwater Master Plan project included developing a GIS for the City, while providing a tool in which to assist in the development of stormwater modeling files. The stormwater management software utilized in the analysis of the stormwater drainage system is XP-Extran software. This software requires hydrologic and hydraulic information on the drainage areas and storm sewer system. The development of the database was patterned from the requirements of the input for the XP-Extran software. The mapping for the stormwater project is divided into three areas: watershed maps (hydrologic information), storm sewer maps (hydraulic information), and a questionnaire map.

The watershed maps contain the watershed boundary for Three Mile Creek and Five Mile Creek drainage basins, as well as the boundary of the individual subarea boundaries.

The storm sewer maps contain the conveyance system which includes the drainage structures, open channels, and cross section markers.

The questionnaire map contains location markers for return stormwater questionnaires which were distributed to residents in the watershed. The location markers are color-coded depending on the severity of the flooding problem. A detailed listing of the GIS structure is provided in Appendix M.

As the next section discusses, the GIS is not a complete, stand-alone system and several additional tasks are recommended.

B. Preliminary GIS Recommendations

The development of the Stormwater Master Plan has initiated the development of an AM/FM/GIS for the Public Works Department. With the completion and delivery of the Stormwater Master Plan, the following recommendations should be considered by and addressed by Public Works staff:

- Develop master storm sewer system Intergraph design files and relational database. Necessary information from the original storm sewer system graphic design files provided by M.J. Harden were incorporated into the Stormwater Master Plan design files. To meet the needs of the master plan project, the information obtained from the original storm sewer system design files was modified and enhanced. Additionally, the design files were linked to a relational database to provide basic AM/FM/GIS capabilities and aid in the development of the hydrologic and hydraulic models.

  At this time, not all of the data from the original storm sewer system design files has been incorporated into the Stormwater Master Plan design files and relational database and changes have been made to both databases. It is recommended that before any additional work is performed on the graphic files or relational database, the information from the original storm sewer system design files and master plan database be made consistent. This requires adequate hardware, software, and personnel.

- Confirm selection of GIS software and identify GIS needs. The selection of Intergraph as the AM/FM/GIS platform was based on delivery of digital data from M.J. Harden in an Intergraph format and the CAD and plotting capabilities of Intergraph for use by Public Works staff. It is recommended that as the Public Works Department moves forward with GIS, a needs assessment be completed to verify the use of Intergraph as the AM/FM/GIS platform, or to identify the new GIS platform and to identify, plan, and budget for future GIS needs.

- Develop a map maintenance application. The completion of the Stormwater Master Plan represents a significant investment by Public Works into the storm sewer system infrastructure. Incorporation of GIS into the project represents an added value deliverable to Public Works. The GIS plan data is, and will continue to be a valuable asset to Public Works if it is properly maintained and updated. It is recommended that Public Works invest in software to maintain, update, and enhance the storm sewer system data that exists in GIS.

- Train staff. It is recommended that Public Works train staff in the use of the GIS software and applications.

- Add GIS staff. It is recommended that the City hire a GIS specialist to maintain, update, and extend the GIS system. In addition to the items listed above, the GIS should be extended to include the sewer, water distribution, and transportation systems as time and resources allow.

VI. Model Development

A. Purpose

The primary purpose of choosing one computer model for the master planning evaluation of the Three Mile Creek and Five Mile Creek watersheds in Leavenworth, Kansas, is to help assure consistency of the hydrologic and hydraulic modeling. The model selected will serve as the basis for the following: estimating flows at various locations in the watershed; identifying inadequate underground systems, bridges, open channels and culverts; locating existing and potential future flooding areas; estimating the necessary detention volumes for curtailing peak flows; identifying locations for detention basins; quantifying the effects of potential improvements; and developing planning level costs to improve the conveyance system.

B. Criteria and Evaluation

Several models were evaluated for applicability: the Penn State Urban Runoff Model (PSRM); the U.S. Army Corps of Engineers' HEC-1 and HEC-2; the Soil Conservation Service's (SCS) TR-20 and TR-55; the US EPA Stormwater Management Model (SWMM); XP Software's XP-SWMM; and the P8 Urban Catchment Model. The two key factors considered were the ability to model both open channel/culvert systems and underground systems, and the ability to model the hydraulics to account for backwater effects. A secondary factor was the model's ability to perform water quality modeling. Modeling the water quality has become necessary for some systems as a result of the EPA's 1990 enactment of the National Pollutant Discharge Elimination System (NPDES) regulations. These regulations require monitoring the quality of stormwater runoff being discharged to "waterways of the United States." The communities initially affected by the regulations were those with a population of 250,000 or greater. Thus, Leavenworth is presently not subject to this regulation. In the ever-changing regulatory environment however, the City could one day be required to monitor and evaluate its water quality constituents. Based on these factors, the list of applicable models was reduced to HEC-1 and HEC-2, SWMM, XP-SWMM, and P8. A brief description of each model is presented below:

1. **XP-SWMM**

XP-SWMM was developed by XP Software and is an enhancement of EPA's SWMM model. XP-SWMM is supported by XP Software, is very flexible, provides the capability to model open channel/culvert systems and underground conveyance systems, takes into account backwater effects and models water quality in the same "block" (routine), serves as a graphical interface to the EPA SWMM computational engine, and is user-friendly. In addition, the graphical locations of the structures in the model can be referenced to county or state plane coordinates, thus providing a properly scaled plan view of the network. However, XP-SWMM is new to the modeling arena, and is not public domain software.

2. **EPA Stormwater Management Model (SWMM)**

The SWMM model was developed and is supported by the US EPA, is public domain software, is accepted by FEMA for the hydrologic analyses conducted during flood insurance studies, is very flexible; can be used to model open channel/culvert systems and underground conveyance systems; takes into account backwater effects; and models water quality. However, the backwater effects and water quality are modeled using separate "blocks" (routines) requiring separate data files, and the SWMM model can be very difficult and cumbersome to set up and use.

3. **HEC-1 and HEC-2**

In the HEC-1 and HEC-2 combination, HEC-1 performs the hydrologic modeling to be used as input to HEC-2 for the hydraulic modeling. HEC-1 and HEC-2 were developed and are supported by the US Army Corps of Engineers, are public domain software, are accepted by the Federal Emergency Management Agency (FEMA) for flood insurance studies; and can be used to model open channel/culvert systems; and take into account backwater effects. However, they cannot be used for direct modeling of underground conveyance systems or for modeling water quality.

4. **P8 Urban Catchment Model**

The "Program for Predicting Polluting Particle Passage through Pits, Puddles, and Ponds" (P8) was developed by William Walker, Jr., PhD, for IEP, Inc. P8 is a water quality model, with its routines based on the algorithms from the EPA SWMM model. Although it performs the basic hydrologic analyses of rainfall and runoff, for practical purposes it performs no hydraulic analyses. The strengths of the P8 model for water quality modeling are that the quality data are based on the Nationwide Urban Runoff Program and it models structural Best Management Practices (BMPs) such as wet and dry detention basins, infiltration basins, and infiltration swales. P8 would, therefore, be used for water quality modeling only.

The results of the evaluation and the considerations discussed above indicate that EPA SWMM and XP-SWMM are the most appropriate models for this and future studies. XP-SWMM was selected for the Stormwater Master Plan. The controlling factors in the selection of XP-SWMM over the other models, particularly EPA SWMM, were its overall user-friendliness, graphics capabilities, and the ability to import and export data to and from the model.

C. Project Description

Existing and future Geographic Information System (GIS) requirements related to this project were identified. Work for this project was completed to benefit the development of the City's GIS. Other data, e.g., maintenance data, may be collected by the City in the future. Appropriate methods and formats for storing the data were identified. A brief memorandum summarizing the recommended level of effort and the tasks that should be implemented by the City to ensure that all work done on this project will be compatible for inclusion into the future GIS had been previously submitted to the City and is included in Appendix M. Where practical, to facilitate future use in the GIS, the data collected and developed under this project were stored in digital form.

Using the information from the stormwater questionnaires; a review of existing data; and during meetings with the City staff, the Citizen's Stormwater Committee, and other residents, locations of known historic flooding were identified for more detailed modeling. A map was prepared, depicting known flooding problems and the portions of the stormwater conveyance system requiring detailed evaluation. The majority of the development and storm sewer systems in the Leavenworth city limits lie within one of two major watersheds--Three Mile Creek and Five Mile Creek. According to the Corps of Engineers' Flood Plain Information report, the names of these two streams signify their distance from the famous flagpole at Ft. Leavenworth to the north. Since Three Mile and Five Mile Creeks discharge separately to the Missouri River, a separate computer model was developed for each watershed to simulate storm events and the response of the stormwater conveyance network. In addition to the storm sewer networks and drainage channels in these two watersheds, there are two subsystems which drain directly to the Missouri River between the Three Mile and Five Mile Creek outlets; four subsystems in the northeast corner of the City; and eight subsystems within the Leavenworth city limits which drain south of the Five Mile Creek watershed toward Lansing. Computer models were developed for the larger of these external watersheds. Stormwater conveyance systems in these areas consist of single cross-road culverts and were evaluated by manual methods.

Based on input from City staff and the data reviewed, a schematic identifying the extent of the conveyance system to be modeled was developed. All mapping and data pertinent to the storm drainage system, including digital mapping from M.J. Harden, and pertinent storm system information such as top-of-structure elevations and depth-to-flowline for most structures, numbering system, x-y coordinates, and pipe sizes and types, was provided by the City. This information was incorporated into the GIS from which a large part of the model data was extracted.

Representative elements of the existing storm drainage system, both open channel and closed conduit, were visually examined to define typical system operating and maintenance conditions.

Based on the selection of the XP-SWMM model and the data collected, input data files were developed for the surface characteristics and schematic stormwater conveyance systems in the Three Mile and Five Mile Creek watersheds. All 24 inch and larger diameter pipe and pipe-equivalent elements were modeled. Selected 18 inch diameter pipes were included if they were downstream from larger pipes in the same subsystem or located adjacent to historical flooding problem areas identified from City records, the stormwater questionnaire, stormwater hotline calls, other complaint calls, or other records. The Three Mile and Five Mile Creek models were configured to simulate typical storm events over the stormwater conveyance system. These model runs were verified using historic flow data and by comparing to other computational methods, as described in Section G of this chapter. The verified models were used with additional design storm events to quantify flooding problem areas, and to identify and evaluate conveyance system improvements, as described in Chapter VIII of this report.

1. Three Mile Creek Watershed

Three Mile Creek, a right-bank tributary, joins the Missouri River near river mile 396.5, at approximately two-thirds of the distance between St. Joseph and Kansas City. At Kansas City, the Missouri River has collected flows from approximately 485,200 square miles of its 529,000 square mile watershed. The majority of the Three Mile Creek watershed, which covers approximately 3,970 acres, or 6.2 square miles, is within the city limits, except for tributary areas west of 22nd Street and north of Metropolitan Avenue. Three Mile Creek originates in the northwest portion of the basin and flows eastward and southeastward. Ten tributaries and storm sewer subsystems discharge to Three Mile Creek on the left bank and nine on the right bank, including a major tributary named South Branch. The South Branch originates in the southwest portion of the basin and joins the main branch of Three Mile Creek about 250 feet upstream from the 10th Street bridge.

Current land use in the Three Mile Creek watershed ranges from undeveloped land in the western portions, to low-density residential in the west-central areas, to medium- and high-density residential in the eastern third surrounding the City's central business district. Development is expected to continue westward, with the same general land use distribution. Parks and pockets of open areas are scattered throughout the developed watershed. The surface topography is dominated by hills and the natural valleys of tributary streams. The high bluffs along the Missouri River's right bank protect the watershed, except for the Three Mile Creek flood plain, from extreme high water on the Missouri River.

It is believed that flooding problems in the older areas in the Three Mile Creek watershed are attributed to inadequate maintenance of drainageways and failing conveyance structures, and to development in or near historic drainageways. In other areas, inadequate bridges and driveway drainage tubes are causing localized flooding and back-up of storm flows.

2. Five Mile Creek Watershed

Five Mile Creek, a right-bank tributary originates in the northwest portion of the basin, joins the Missouri River near river mile 395.5, south and slightly east of the Three Mile Creek outlet. The main stream of Five Mile Creek is more than 5.5 miles long (the length of the main branch of Three Mile Creek is 3.1 miles).

The Five Mile Creek watershed covers 5,934 acres, or 9.3 square miles, and is located directly south of the Three Mile Creek watershed. Except for small pockets in external watersheds, nearly all of the City of Leavenworth is within the Three Mile and Five Mile Creek watersheds. The western third of the Five Mile Creek watershed is currently outside the city limits, but with the implementation of the West Leavenworth Annexation Plan, it will be incorporated by the City.

Development in the Five Mile Creek watershed is less dense and widespread than in the Three Mile Creek watershed. Land use ranges from undeveloped in the west to low-density residential in the central and eastern portions, with large parks and open areas, and institutions such as schools, hospitals, a college, and business establishments. Growth is proceeding to the south and west, especially along the proposed West Leavenworth Trafficway right-of-way. High-intensity commercial and industrial development has been projected for the southernmost strip along Eisenhower Road. Surface topography is similar to that of the Three Mile Creek watershed, with elevations ranging from more than 1,100 feet to approximately 760 feet above mean sea level in the Missouri River flood plain.

As in the Three Mile Creek watershed, high bluffs along the east side protect Leavenworth from flooding on the Missouri River, except at the outlet to the river. The wastewater treatment plant is located in this flood plain, and is likely to be affected by high water caused by a major storm event. It is believed that flooding in older areas is caused by inadequate, or the lack of, culvert inlets, whereas areas of new growth are experiencing problems due to greater expectations than supported by current design standards.

3. External Watersheds

Two storm sewer subsystems within the small right-bank tributary watershed between Three Mile and Five Mile Creeks discharge directly to the Missouri River. Many of the responses to the stormwater questionnaires received from this watershed refer to minor driveway tube problems. The constructed facilities follow the natural drainageways.

The infrastructure facilities in the northeast corner of the City, situated on the high bluffs overlooking the river, also discharge directly to the Missouri River.

South of the Five Mile Creek watershed, eight subsystems within the city limits discharge to the south. All of these subsystems are at the headwaters of tributaries to Seven Mile Creek. No complaints or historical flooding records were received for these subsystems.

The single-conduit subsystems in these external watersheds were not incorporated into any computer models, but were reviewed and evaluated by manual methods. The larger and/or more complex subsystems were evaluated by XP-SWMM.

D. Hydrology

1. Introduction

The hydrologic modeling for Leavenworth was conducted by the Runoff block of XP-SWMM. The Runoff block was originally developed in EPA SWMM to simulate both the generation of rainfall runoff from a drainage basin, and the routing of flows and contaminants to the sewer lines, according to the reference manual. The drainage basin is represented by an aggregate of idealized subcatchments and gutters. The program accepts a rainfall or snowfall hyetograph and makes a step-by-step accounting of snowmelt, infiltration losses in pervious areas, surface detention, overland flow, channel flow, and the constituents washed into inlets, leading to the calculation of a number of inlet hydrographs and pollutographs. The Runoff block generates surface and subsurface runoff based on hyetographs, antecedent conditions, land use, and topography.

The Runoff block may be run for periods ranging from minutes to years. Precipitation may be entered at constant or variable time intervals, for single events less than a few weeks' duration, or may be read from the National Weather Service (NWS) or other rainfall records for continuous simulation.

The drainage basin may be divided into a maximum of 5,000 subcatchments and 1,000 inlets. Each subcatchment is assigned surface and subsurface parameters. Infiltration is computed using the Horton, Green-Ampt, or SCS method, with optional subsurface routing.

Overland flow hydrographs are generated by the non-linear reservoir routing method using Manning's equation and lumped continuity and depression storage. Inlet flows and pollutographs are stored on the interface file for input to the subsequent routing block. Other hydrograph generation techniques available in the Runoff block include the Kinematic wave method, Laurenson Non-Linear method, SCS Unit Hydrograph method, Other Unit Hydrographs, and the Rational formula.

2. Hydrologic Data Requirements

The Three Mile and Five Mile Creek watersheds were divided into subareas, or subcatchments, which served as the basic unit of land for the hydrologic analysis. To provide the necessary detail while keeping the mapping to a minimum, the subareas were delineated on 1 inch = 100 feet topographic maps with 2-foot contour intervals, which were provided by M.J. Harden & Associates, Inc., and were based on spring 1992 aerial photography.

The requirements of the subarea boundary delineation on the maps included identifying a reasonably-sized tributary area draining to the major structures; keeping the size of each subarea manageable; and assuring that each subarea had a defined drainage system to convey flows to the major conveyance system. Therefore, the subarea delineation ended at a storm sewer inlet, at a major structure on the channel, or at a minor drainage system (swales and smaller channels). Based on these criteria, there are 342 subareas in the Three Mile Creek basin averaging approximately 12 acres; the smallest is 0.5 acre and the largest, 684 acres. There are 472 subcatchments in the Five Mile Creek watershed, with the smallest, average, and largest sizes of 0.2 acre, 13 acres, and 1,007 acres.

The hydrologic data requirements for the subareas are listed below:

- *Size.* The size of each subarea, in acres, was determined based on topography (from GIS) and the layout of the conveyance system being modeled.
- *Width.* The width of each subarea, in feet, was determined from its general shape. The model idealizes each subarea as a rectangle; therefore, estimating a subarea's width enables the model to calculate its length. The length is used by the model as the length of overland flow in calculating the surface runoff, and thus, the time of concentration. The XP-SWMM and EPA SWMM manuals present discussions on estimating the width of the subareas.
- *Percent Imperviousness.* The percent imperviousness for each subarea was estimated based on land use. Information on existing and future land uses was provided by the City Planning Department and incorporated into the GIS, as indicated on Figures VI-1 and VI-2. A composite value was determined from the combination of land uses within each subarea. Table VI-1 presents the value for percent of imperviousness by land use. The reference for these values is Urban Hydrology for Small Watersheds, Soil Conservation Service, 1986.
- *Average Drainage Area Ground Slope.* The ground slope was calculated by averaging the ground slopes at several separate and representative locations in each subarea from the contours generated in GIS.

Table VI-1 Imperviousness by Land Use	
Land Use/Zoning	Imperviousness (percent)
Business	
downtown	95
neighborhood	85
Residential	
single-family	35
multi-family	60
apartments	60
churches and schools	75
Industrial	
heavy	80
light	60
Other	
impervious: asphalt concrete, roofs	100
railroad yard	25
parks, cemeteries	10
pervious: turfed, agricultural, undeveloped	0

- *Manning's Roughness Coefficients.* Values of Manning's roughness coefficient are not as well known for overland flow as for channel flow because of the considerable variability in ground cover, very shallow depths, etc. Estimates of these values are available in textbooks.

  Impervious Area Overland Flow Roughness Coefficient (Manning's "n"). In the absence of field data, the impervious area roughness coefficient value presented in Table VI-2 was used.

Pervious Area Overland Flow Roughness Coefficient (Manning's "n"). In the absence of field data, the pervious area roughness coefficient value presented in Table VI-2 was used.

Table VI-2 Hydrologic Parameters	
Variable	Value
1. Manning's Overland Flow Roughness Coefficients	
pervious areas	0.3
impervious areas	0.02
2. Depression Storage, inches	
pervious areas	0.2
impervious areas	0.06
3. Percent Zero Detention	25

- *Depression Storage.* The depth in inches, to which small surface depressions must be filled before runoff will occur. It represents the loss caused by phenomena such as surface ponding, interception, and evaporation.
  Impervious Area Depression Storage. In the absence of field data, the impervious area depression storage value presented in Table VI-2 was used.
  Pervious Area Depression Storage. In the absence of field data, the pervious area depression storage value presented in Table VI-2 was used.
- *Zero Detention.* The percentage of the subcatchment impervious area with immediate runoff, 0-100 percent. The term "zero detention" is equivalent to "immediate runoff." In the absence of field data, the percent zero detention value presented in Table VI-2 was used.
- *Infiltration.* The infiltration routines available in XP-SWMM include the Horton and the Green-Ampt methods. Because the Horton method is older and better established than Green-Ampt, and data for it are more readily available, it was selected as more applicable. Data was extracted from the State Soil Geographic Data Base (STATSGO) and merged with the GIS so that the Horton parameters, including the Maximum and Asymptotic Infiltration Rate and Decay Rate, could be retrieved for each subcatchment.

Max Infiltration Rate (F_o). This parameter depends primarily on soil type, initial moisture content, and surface vegetation. A composite value was determined from the combination of soil types within each subarea. The values range from 1.34 in/hr to 1.90 in/hr.

Min (Asymptotic) Infiltration Rate (F_c). This parameter is essentially the saturated hydraulic conductivity, or permeability, of soils. A composite value was determined from the combination of soil types within each subarea. The values range from 0.41 in/hr to 0.57 in/hr.

Decay Rate of Infiltration (OC). This parameter is the rate of decrease of infiltration capacity, and is independent of initial moisture content. According to the XP-SWMM manual, most reported values are in the range 3-6 cycles/hour. In the absence of field data, an average decay rate of 0.00115 cycles/second was used.

3. Rainfall

Because reliable recent rain gauge data were not available for this study, historical recorded data were evaluated. The average rainfall intensity values in inches per hour from "Rainfall Frequency-Duration-Intensity for Leavenworth, Kansas," Table 1 in the 1967 Black & Veatch study, were compared with the values in "Rainfall Intensity Tables for Counties in Kansas," Kansas Department of Transportation, 1991. As indicated on Figures VI-3 and VI-4 for the 5-year and 10-year storms, respectively, the average of absolute values of the percent difference between the two intensity tables was approximately 5 percent. The KDOT rainfall intensity tables were used in this study because they are based on more recent data, and because they cover other return periods in addition to the 5-year and 10-year storms.

Three computation methods were evaluated for a storm duration of 24 hours, a rainfall interval of 15 minutes, and for return periods of 10, 100, and 500 years. Graphical results of the comparison are presented on Figures VI-5 through VI-7. The time distribution of an actual storm can be irregular. Nevertheless, the hydrologist must compute rainfall amounts from historical recorded rainfall intensity tables for that region and rearrange the incremental values to represent a reasonable storm pattern. Specific arrangements have been adopted by certain firms and agencies. The composite design storm is generated so that the maximum rainfall over any time span centered around the storm peak equals the design storm depth indicated for the corresponding duration in the rainfall intensity table. The U.S. Soil Conservation Service uses one distribution for storms west of the Sierra Nevada and Cascade Mountains (SCS Type 1) and another for

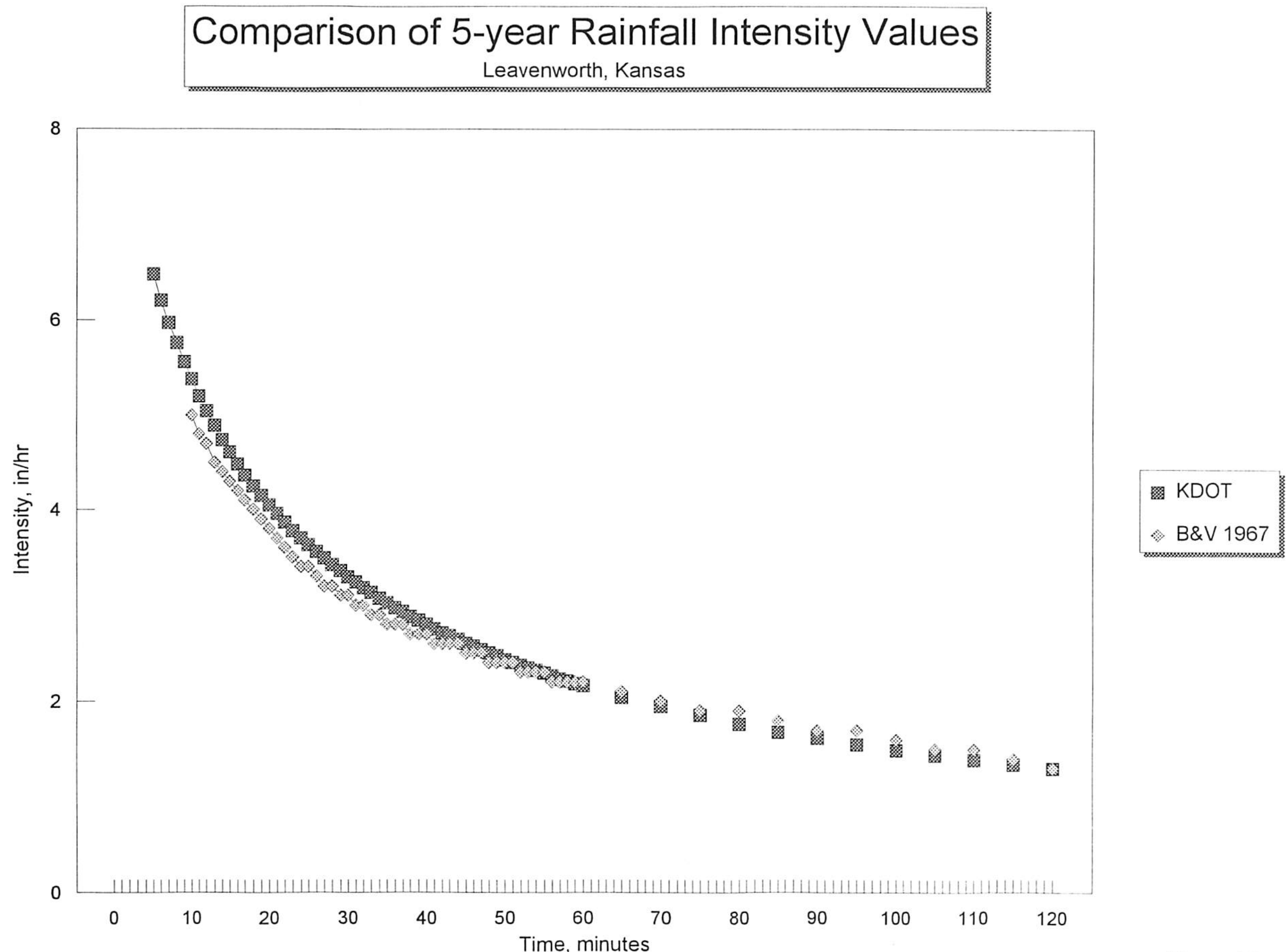

Comparison of 5-year Rainfall Intensity Values
Leavenworth, Kansas
Intensity, in/hr
8
6
4
2
0
0
10
20
30
40
50
60
70
80
90
100
110
120
Time, minutes
KDOT
B&V 1967

Figure VI-3

Comparison of 10-year Rainfall Intensity Values

Leavenworth, Kansas

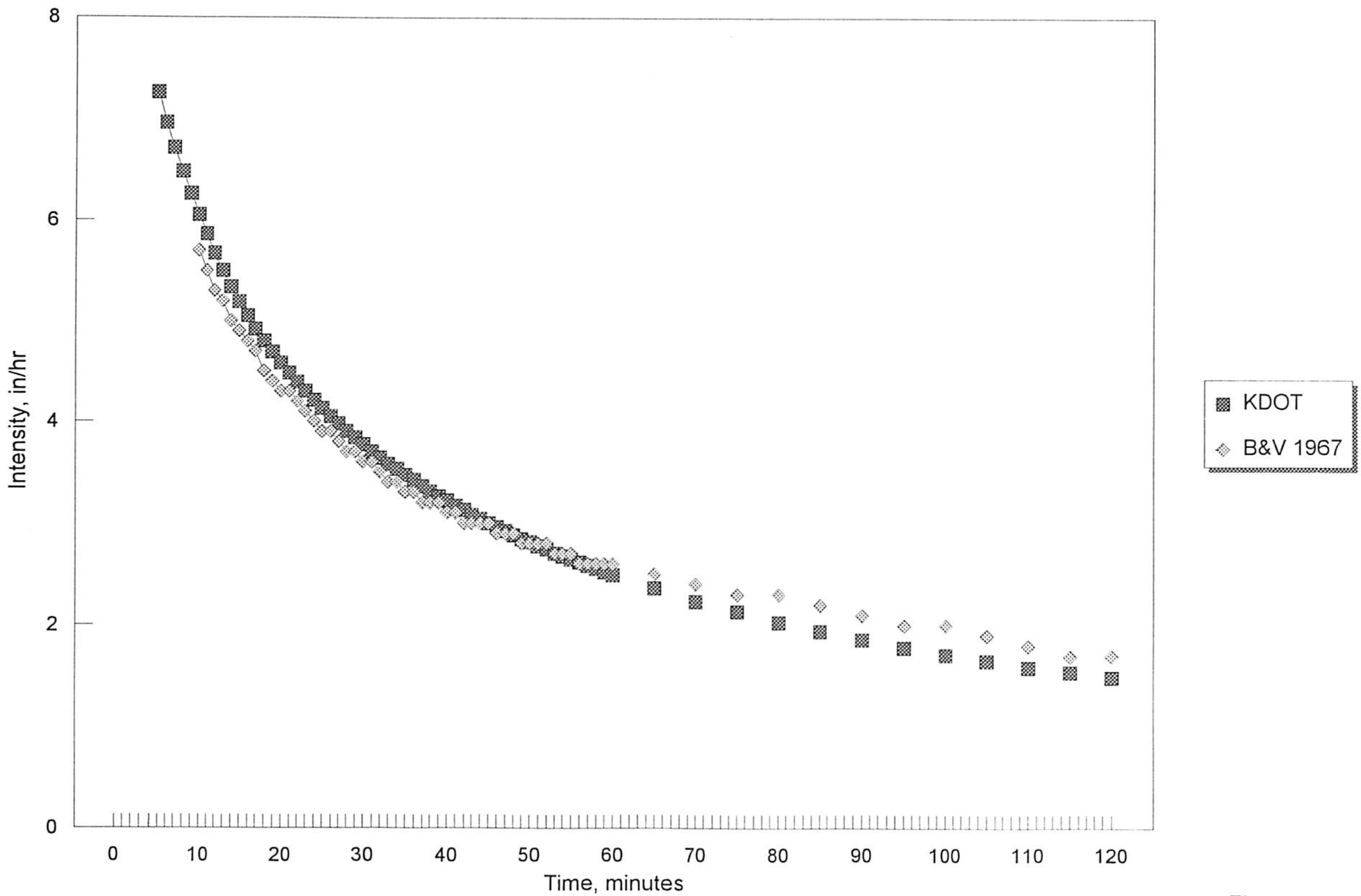


Figure VI-4

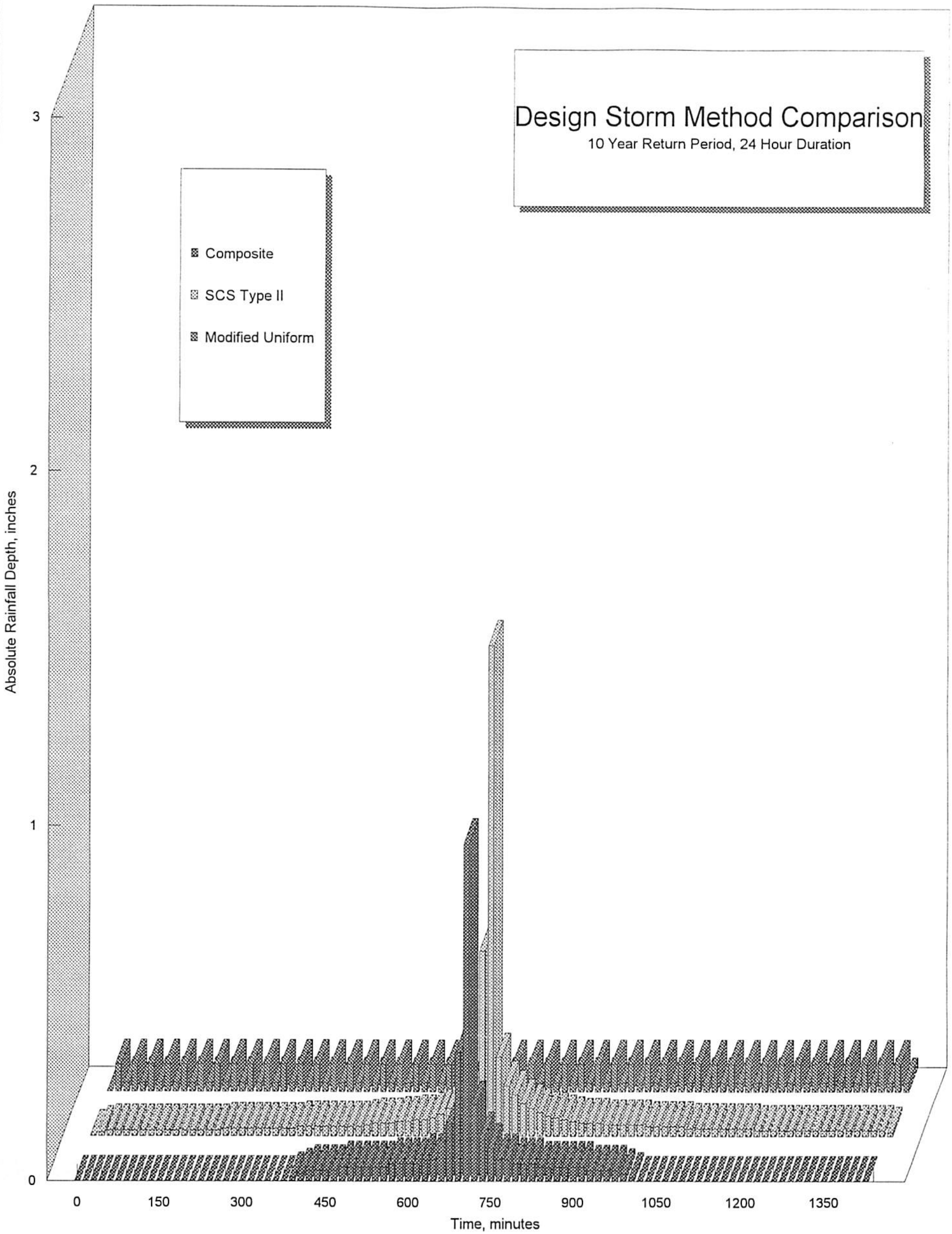
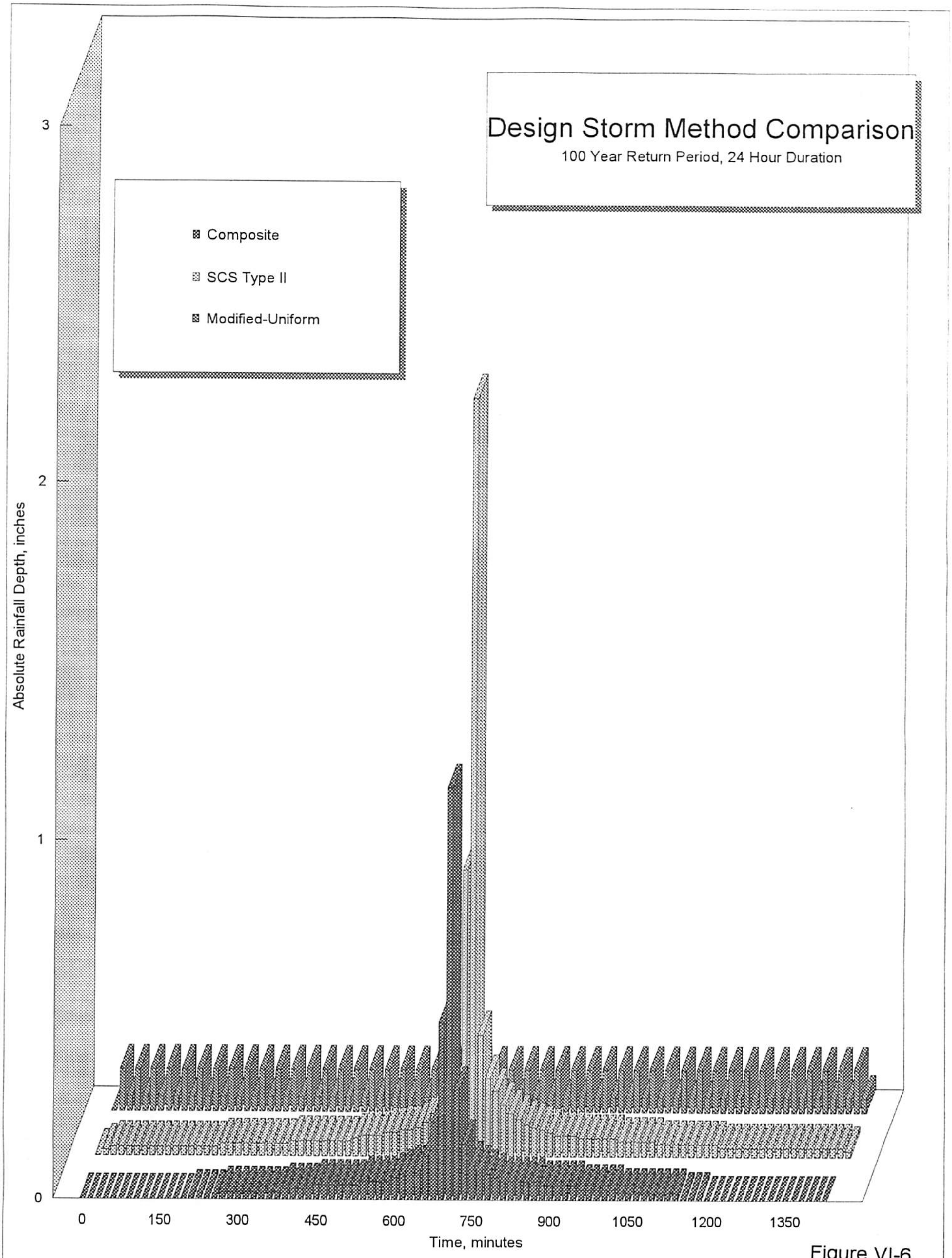

Design Storm Method Comparison
10 Year Return Period, 24 Hour Duration
Composite
SCS Type II
Modified Uniform
Absolute Rainfall Depth, inches
3
2
1
0
0
150
300
450
600
750
900
1050
1200
1350
Time, minutes

Figure VI-5



Design Storm Method Comparison
100 Year Return Period, 24 Hour Duration
Composite
SCS Type II
Modified-Uniform
Absolute Rainfall Depth, inches
0
1
2
3
0
150
300
450
600
750
900
1050
1200
1350
Time, minutes

Figure VI-6

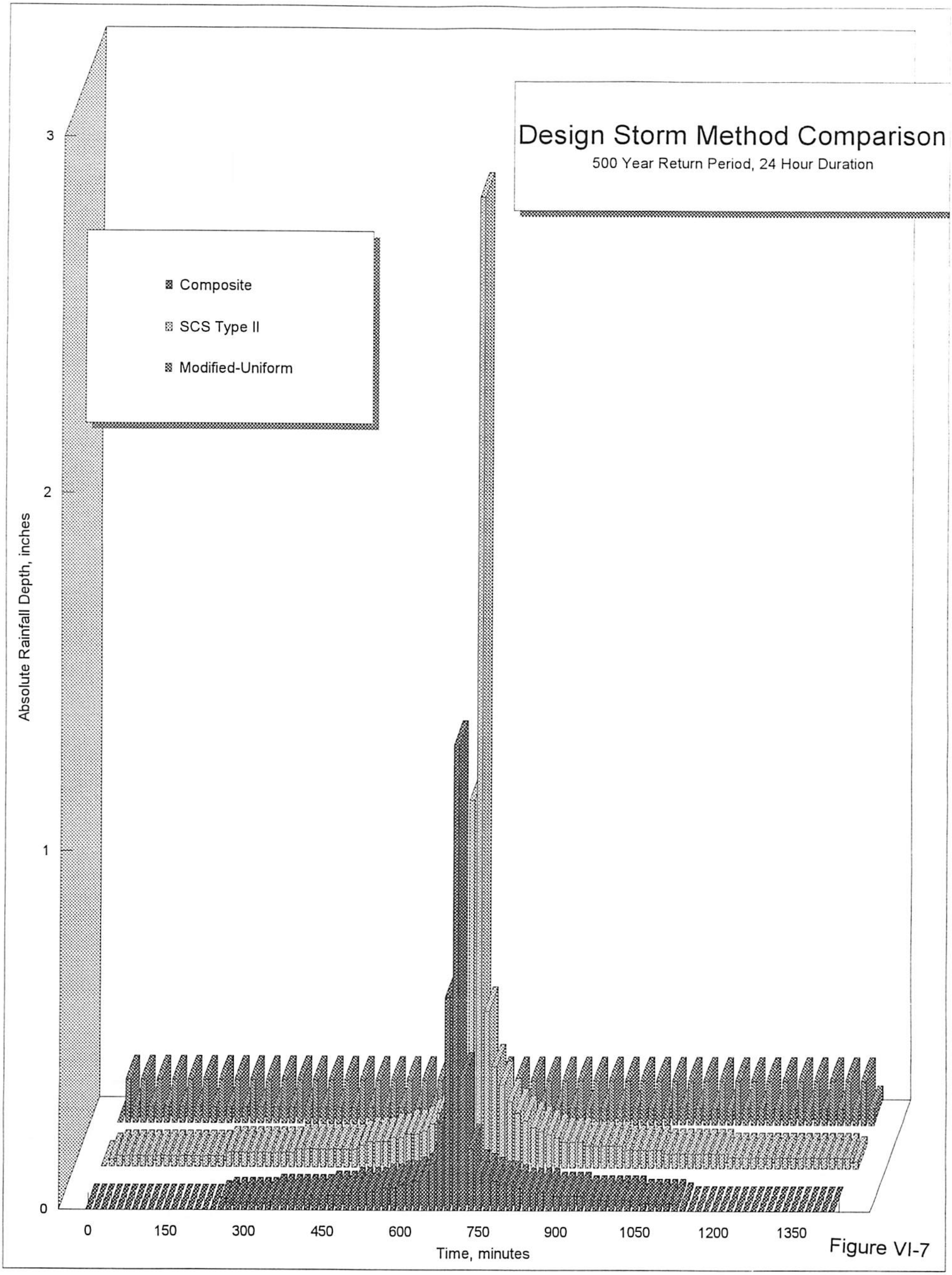

Design Storm Method Comparison
500 Year Return Period, 24 Hour Duration
Composite
SCS Type II
Modified-Uniform
Absolute Rainfall Depth, inches
0
1
2
3
0
150
300
450
600
750
900
1050
1200
1350
Time, minutes

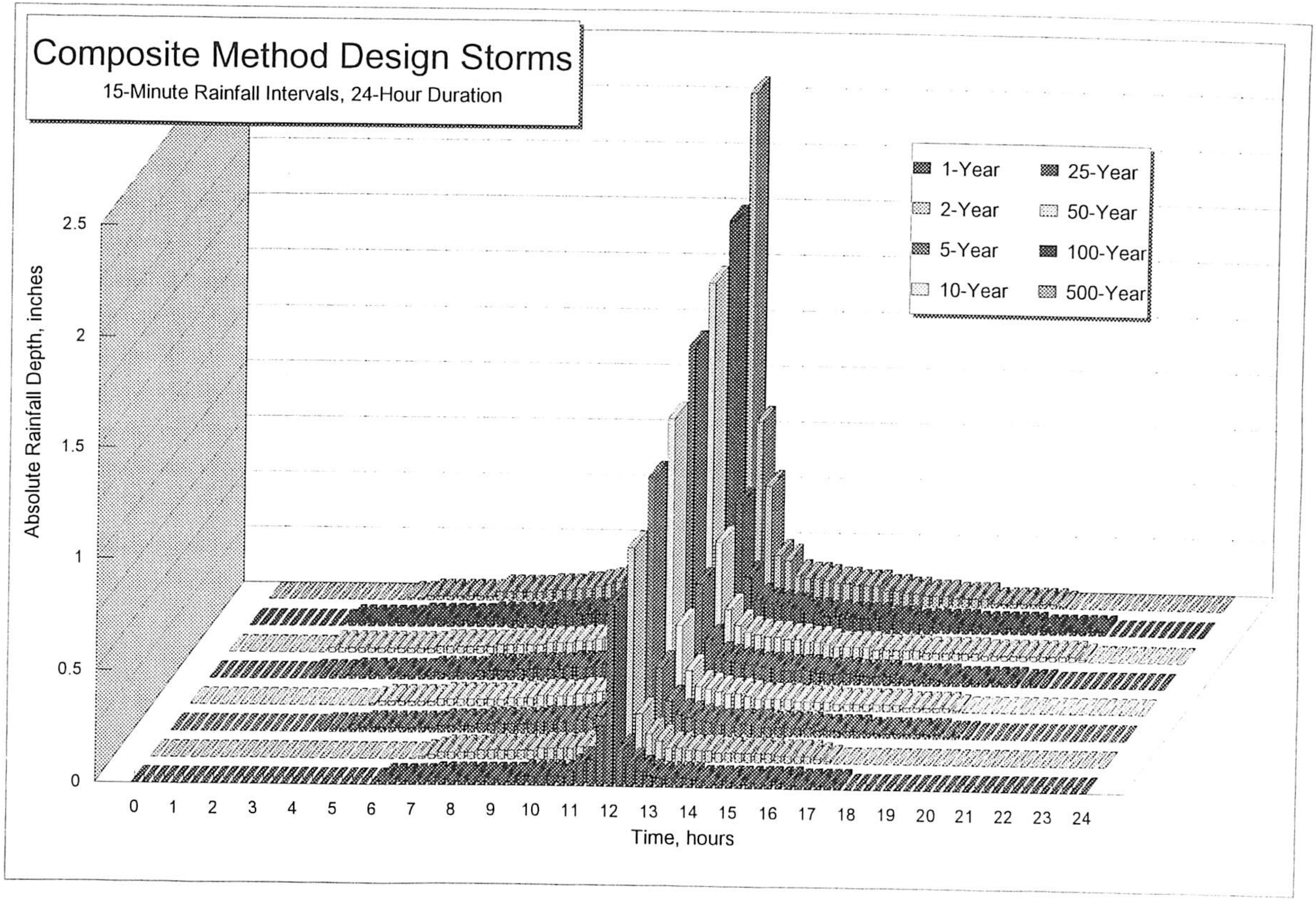
Figure VI-7

storms in other parts of the country (SCS Type 2). In the modified-uniform design storm, developed for the Kansas Department of Transportation by Dr. Bruce M. McEnroe and Ke Zhao, rainfall is distributed in a uniform temporal pattern with a periodic step function. The rainfall intensity is constant over the long term, but over the short term, it fluctuates between 50 and 150 percent of the average intensity. According to Dr. McEnroe's study, the period of the fluctuations is unimportant as long as it is much shorter than the watershed's time of concentration. In this study, the period of the fluctuations was about 2 percent of the storm duration. Calculations for the three design storm methods are presented in Appendix H.

Flood studies are typically conducted using a peaked, fixed-shape hyetograph. Because of the lack of a storm peak, the modified-uniform method was eliminated. The shapes of the design storms generated by the composite and SCS Type 2 methods were similar. The peak of the SCS Type 2 storm, however, was higher than that for the composite storm, and would probably have resulted in higher peak runoff. Since this could lead to overly-conservative design of improvements, the SCS Type 2 storm was eliminated. Therefore, the composite design storm method was selected. Rainfall distributions for the 1-, 2-, 5-, 10-, 25-, 50-, 100-, and 500-year return period storms were prepared as indicated on Figure VI-8. The total rainfall depths, in inches, were computed as indicated in Table VI-3. The design storms were entered into the XP-SWMM models.

Table VI-3
Total Rainfall Depths

Design Storm Return Period in Years	24-Hour Duration Rainfall Depth in Inches
1	2.88
2	3.36
5	4.56
10	5.04
25	6.24
50	6.96
100	7.68
500	9.84



Composite Method Design Storms
15-Minute Rainfall Intervals, 24-Hour Duration
Absolute Rainfall Depth, inches
0
0.5
1
1.5
2
2.5
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24
Time, hours
1-Year
2-Year
5-Year
10-Year
25-Year
50-Year
100-Year
500-Year

Figure VI-8

4. Land Use

Two land use scenarios were considered for the modeling--present conditions and ultimate conditions. Data for present conditions was obtained from the City Planning Department's existing land use map, and information for the ultimate conditions, from the future land use map, as indicated on Figures VI-1 and VI-2. From a modeling standpoint, the difference between the present and ultimate conditions is the percent imperviousness in each subarea. This is important, since an increase in percent impervious area increases both peak runoff flow and total runoff volume. The present land use conditions were modeled first to estimate peak flows and total runoff volumes and to identify inadequate structures. Verification consisted of comparing these values to those computed by another method. In addition, the existing inadequate conduits were plotted on a map, with the historical flooding locations and questionnaire responses superimposed, for the 5-year and 10-year events, as described in Section G of this chapter.

The purpose of modeling the ultimate land use condition was to estimate the future peak flows that can be expected when Leavenworth has reached full development. Additionally, total runoff volumes were determined and structures that may become inadequate in the future as the land uses change were identified. Therefore, improvements were sized based on future land use conditions. Land use planning and zoning can be effective flood plain management tools. Altering land use plans to require more open spaces and detention storage can limit runoff and lower the magnitude of required improvements. Also, preventing development in flood prone areas prevents flood damages from occurring.

5. Assumptions

The following assumptions were made to simplify the hydrologic modeling and to provide the accuracy necessary for planning level analyses.

- In general, small detention ponds throughout the City have no storage capacity.
- Manning's roughness coefficients for pervious and impervious areas are constant and of areal extent.
- Pervious and impervious depression storage values are constant and of areal extent.
- The average slopes, widths, Manning's coefficients, depression storage values, infiltration parameters, and rainfall hyetographs are the same for present and future conditions.

- The main structures on Five Mile Creek, Three Mile Creek, and Three Mile Creek South Branch were evaluated based on the frequency mixing concept in the Texas Department of Highways Hydraulic manual. The 100-year flood event was simulated over the watershed with tailwater at the outlet due to the 2-year event on the Missouri River. In addition, the 2-year flood event was applied to the watershed, and combined with the 100-year Missouri River flood backwater.
- Not all of the nodes in the models had contributing drainage areas. Of the nodes with contributing drainage areas, some had more than one subcatchment area draining to it. Lists of the drainage nodes and their contributing subcatchments for the Three Mile and Five Mile Creek basin models are provided in Appendix H.
- The processes of snowfall/snowmelt, erosion, groundwater movement, and pollutant buildup/washoff were not simulated.
- Duration of rainfall simulation time was 24 hours for all conditions and models. Computational time step was 5 minutes during rainfall and 15 minutes during the wet-dry transition.

E. Hydraulics

1. Introduction

The hydraulic modeling was performed using the Extran block of XP-SWMM. The Extran block performs hydraulic analyses, including accounting for backwater effects, in calculating water surface profiles. The purpose of the hydraulic modeling is to analyze the major culverts, bridges, channels, and enclosed stormwater conveyance system components for present and future conditions; locate system deficiencies and inadequacies; and recommend practical and cost-effective improvements to alleviate flooding.

The Three Mile and Five Mile Creek models each included the following conveyance system elements: the local storm sewer subsystems consisting of underground conduits, cross-road culverts, and small open channels; and the major conveyance system consisting of 36 inch and larger (or equivalent) enclosed system conduits, large open channels, culverts, and bridges.

Because of the unmanageably large number of conveyance system elements in the first-cut aerial mapping data received, it was decided to model only 24 inch and larger (or equivalent) conduits, unless there were smaller pipes in areas of known flooding or locations of questionnaire responses/complaints. If an underground system contained 15-24 inch pipes between larger pipes, the smaller pipes were retained.

The Three Mile and Five Mile Creek models were used to identify flooding locations throughout the tributaries and to evaluate the performance of the main channel structures. After improvements of the main channel bridges and culverts were sized for the 100-year design storm, the 10-year and 50-year storms were applied to the system to determine the two design tailwater elevations at the outlets of all the tributary storm sewer subsystems on the main channel. Following establishment of the 10-year and 50-year tailwater elevations, individual subsystem models were created by extracting these tributaries from the main models. The subsystem names and descriptions for the Three Mile and Five Mile Creek watersheds are listed in Tables VI-4 and VI-5 and the locations are shown on Figure II-1. The subsystem models were used to evaluate the local tributary systems; and improvements were sized for the 10-year storm, for underground pipes and open channels and culverts; and for the 50-year storm, for structures under collectors and major arterial streets.

2. Data Requirements

Data used in the hydraulic modeling were collected for the local and major conveyance systems. Data on the open channels, the enclosed system, and most culverts were obtained from the City's Stormwater Sewer Maps, and have been incorporated into the City's GIS. A copy of the data will be presented to the City in the format requested.

Data on culverts and bridges on Three Mile and Five Mile Creeks and Three Mile Creek South Branch were obtained from the KDOT bridge assessment disk, the FEMA Flood Insurance Study, the Bucher Willis 1993 Bridge Inspection Report, and numerous construction drawings and maps provided by the City. Where flowline elevations in these documents conflicted, elevations from the Stormwater Sewer Maps were used.

Table VI-4
Three-Mile Creek Watershed
Storm Sewer Subsystem Descriptions

Subsystem	Description	Node # on 3mc	10-Year Max Elev.	50-Year Max Elev.
1L	4th Street	92756	768.46	769.41
2L	6th Street	92197	771.52	772.65
		86197	771.59	772.73
3L	7th Street	92711	772.69	773.85
4L	Metropolitan & Broadway	92707	773.57	774.71
1R	Ohio to Spruce & Broadway	92707	773.57	774.71
5L	Broadway & 3mc	86369	775.47	776.74
		86368	776.15	777.42
2R	Ohio to Spruce & 10th Street	92702	776.7	777.97
3R	Cherokee & Sherman Avenue	92699	777.89	779.13
		92696	779.31	780.51
6L	Metropolitan & 9th Street	92618	786.92	788.7
4R	10th & Shawnee	92608	789.76	790.47
7L	Metropolitan & 11th to 12th Streets	92613	800.12	802.57
5R	15th & Osage	92305	803.59	805.42
6R	Shawnee & 20th to 18th to Osage	92303	804.51	806.92
8L	Metropolitan & 16th to 14th & Kiowa	92299	805.75	808.35
9L	Metropolitan & 18th	92018	820.72	822.89
10L	Metropolitan & 20th	86831	835.57	836.94
7R	Ottawa & 20th	86831	835.57	836.94
8R	20th & Dakota & Ottawa	92628	843.25	844.34
S1R	10th & Cherokee	92695	795.85	797.69
		92694	796.99	798.51
S1L	13th & 14th & Shawnee & Delaware	86468	807.6	808.68
S2R	14th & High	92657	808.56	809.46
S3R	15th & Spruce & Olive	92656	818.64	819.57
S2L	17th & Cherokee	92653	820.58	821.7
S3L	18th & Sherman	92654	826.1	827.03
S4R	16th & Spruce	92655	833.26	834.23
S5R	18th & 19th & Spruce	92648	844.1	847.48
		92647	844.57	847.63
S6R	West Leavenworth Tfwy to 20th & Spruce	92646	847.63	850.39
S4L	21st & Choctaw	92635	864.76	867.23
S7R	21st & Kenton	92636	864.62	867.14
S8R	22nd & Spruce	92002	870.75	871.88

Table VI-5
Five-Mile Creek Watershed
Storm Sewer Subsystem Descriptions

Subsystem	Description	Node # on 3mc	10-Year Max Elev.	50-Year Max Elev.
1L	Pennsylvania to Evergreen & 4th Streets	92251	771.66	774.72
		85855	774.52	777.09
1R	Marion Street	92250	772.51	776.45
2R	4th Street to V.A. entrance drive	92294	774.31	776.73
3R	4th Street	85855	774.52	777.09
2L	Santa Fe & 2nd Streets	92323	776.27	777.97
4R	Hughes Road & Limit Street	92328	779.61	781.56
3L	10th Avenue & Thornton	92220	781.2	783.19
		92330	782.15	785.15
5R	Hughes Road & McDonald	92507	782.39	785.28
6R	East of Shrine Park Rd to Lakeview Rd	92509	784.46	786.35
4L	West of Shrine Park Rd & Goddard Circle	92504	787.44	788.86
		84936	787.24	788.48
5L	10th Avenue & Limit Street	92505	790.18	791.62
7R	Deerfield and Garland	92502	797.09	798.96
8R	East of 10th Avenue to Parkway Drive	92496	804.56	806.22
6L	14th & Limit Street	92485	807.39	808.3
9R	West of 10th Avenue to 13th Street	92485	807.39	808.3
		92487	812.58	815.35
7L	17th Street & Vilas Street	92061	827.24	829.18
		92450	828.71	831.27
8L	Candlewood & Tudor Drive	92449	833.5	835.07
		92448	835.26	837.26
10R	West Leavenworth Tfwy & Five Mi Creek	92447	835.9	837.77
		92466	837.65	839.23
11R	County Hwy 5 & Five Mile Creek	92434	841.7	843.22
9L	Limit Street to County Hwy 5	92020	846.3	847.93
		92433	852.72	854.45
10L	Limit & 22nd Street and Vilas	92430	861	862.47
		92424	871.45	872.47
11L	Hebbelin Drive & 23rd Street	92416	877.8	879.01
		92822	891.25	892.19

The following hydraulic data were used for modeling the various elements:

Open Channels

- Channel length and slope.
- Upstream flowline elevation.
- Downstream flowline elevation.
- Manning's "n" value for channel.
- Manning's "n" value for overbank.
- Channel cross-section.
- Main channel definition.
- Contraction loss coefficient.

Enclosed system, culverts, and bridges

- Conduit length.
- Structure depth and width or diameter.
- Structure type.
- Manning's "n" value.
- Upstream flowline elevation.
- Downstream flowline elevation.
- Expansion loss coefficient.
- Number of barrels.

Manholes

- Rim, top of structure, or ground surface elevation.
- Invert elevation.
- Outfall data.

For modeling, the channels, culverts, and bridges were separated by "nodes." In a system of open channels and culverts, a node is synonymous with a manhole in an underground conveyance system. The nodes are for modeling purposes only, and do not have any physical representation. In the model, they represent locations where a channel or culvert changes size or slope; serve as an interface between the culverts and channels; and indicate where runoff from tributary areas can enter the conveyance system and can be routed downstream.

3. Assumptions

The following assumptions were made to simplify the hydraulic modeling:

- Invert elevations for open channels, bridges, and culverts were estimated from the contours on the Stormwater Sewer Maps. In general, the Three Mile Creek main channel and south branch inverts were 1-3 feet higher than the stream bed elevations indicated in the 1977 FEMA report. Since no provision was made to collect survey data, the Stormwater Sewer Map inverts are retained in the models. This situation is being investigated as part of the FEMA map update study. Also, final designs will require detailed surveying of structures and channel cross-sections to establish horizontal and vertical control.
- Manning's roughness coefficients ("n") include the following:

- Corrugated metal pipe (CMP)	0.024
- Reinforced concrete pipe (RCP)	0.015
- Horizontal elliptical concrete pipe (HERCP)	0.015
- Reinforced concrete box (RCB)	0.011
- Arch culvert, stone (A)	0.025
- Arch culvert, corrugated metal (MAC)	0.025
- Arch culvert, bolted steel plates	0.012
- Vitrified clay pipe (VCP)	0.013
- Advanced drainage system (ADS)	0.010
- Natural channel, main channel	0.030
- Natural channel, overbank	0.050

- The dimensions of culverts on the Stormwater Sewer Maps adhere to the following convention: width (feet or inches) by height (feet or inches).
- Existing lakes and detention ponds are full and, therefore, have no storage capacity or effect on hydraulics of system.
- In developed areas, the controlling high elevation for open channel cross-sections is at the ground floor flooding depth of the lowest building in the vicinity. In the downstream portions of the main channels, where Missouri River backwater for large storm events can be higher than the existing topography, cross-sections are extended to include higher ground elevations. Where there is permanent water in the main channels and where no below-water level contour lines are indicated on the Stormwater Sewer Maps, channel invert elevations were taken from the Flood Insurance Study Flood Profiles.

- Open channels conveying flow to culverts or underground pipe inlets have a contraction loss coefficient of 0.6. Culverts, bridges, or pipes daylighting to open channels have an expansion loss coefficient of 0.8.
- Flooded water does not pond at manholes, but escapes the system instead of waiting for the downstream conduit to convey the excess.
- Backwater elevations from the Missouri River at the confluences with Three Mile and Five Mile Creeks for the 10-, 50-, 100-, and 500-year floods are from the Flood Insurance Study Flood Profiles. The 1- and 2-year elevations were determined by regression analysis on the Flood Insurance Study data, as indicated on Figures VI-9 and VI-10. Calculations are provided in Appendix H. Detailed analyses of Missouri river flood elevations are beyond the scope of this study.
- HERCP, MAC, and CMAP can be modeled as circular pipes. The equivalent diameter can be calculated from the known dimensions of the non-circular conduits.
- Stone arches and bolted steel arches are equivalent to the "modified basket-handle" conduit type in XP-SWMM.
- All bridges are modeled as reinforced concrete box culverts with the clear space dimensions approximated by the culvert depth, width, and number of cells.
- All structures are modeled as though there were no obstructions due to debris, structure failure, or siltation.
- Where the lengths of bridges and culverts are not available, they are estimated from the Stormwater Sewer Maps, which is consistent with the level of detail used in master planning.
- Stormwater conveyance facilities proposed as part of the West Leavenworth Trafficway project are included in the models.

F. Model Verification

The purpose of model verification is to provide a level of accuracy in the computation consistent with the level of detail required for master planning. Model verification assures that the values obtained are reasonable for the data used and the level of detail assumed. Model calibration, on the other hand, consists of incorporating measured rainfall data into the model, and comparing the flows generated by the model with those measured in the field at stream gauges for the same event. The rainfall input would be obtained from rain gauge information obtained throughout the watershed. Once calibrated, the design events could be run to determine the appropriate design flows. Since no measured rainfall or streamflow data were available for calibration, verification

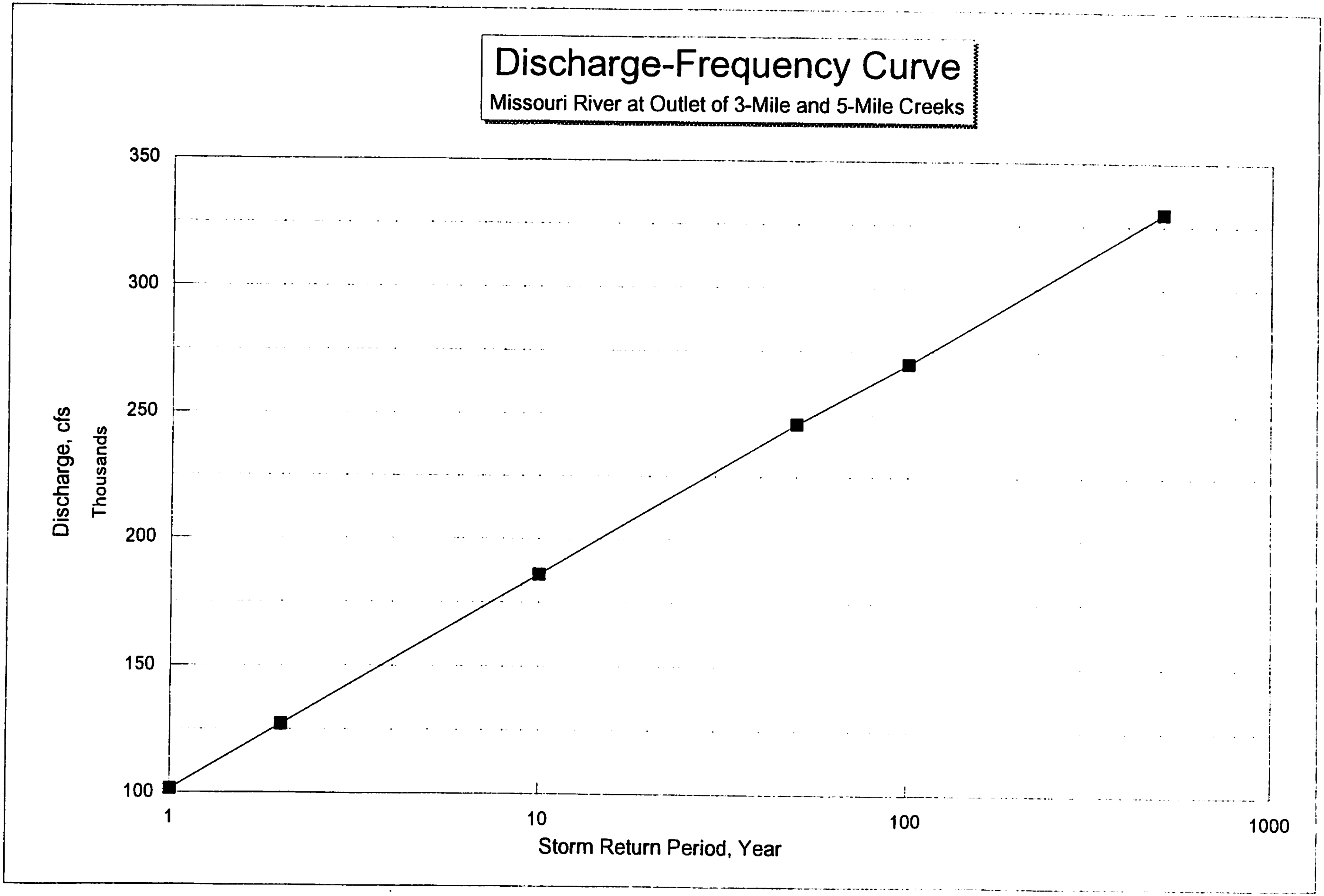

Discharge-Frequency Curve
Missouri River at Outlet of 3-Mile and 5-Mile Creeks
350
300
250
200
150
100
Discharge, cfs
Thousands
1
10
100
1000
Storm Return Period, Year

Figure VI-9

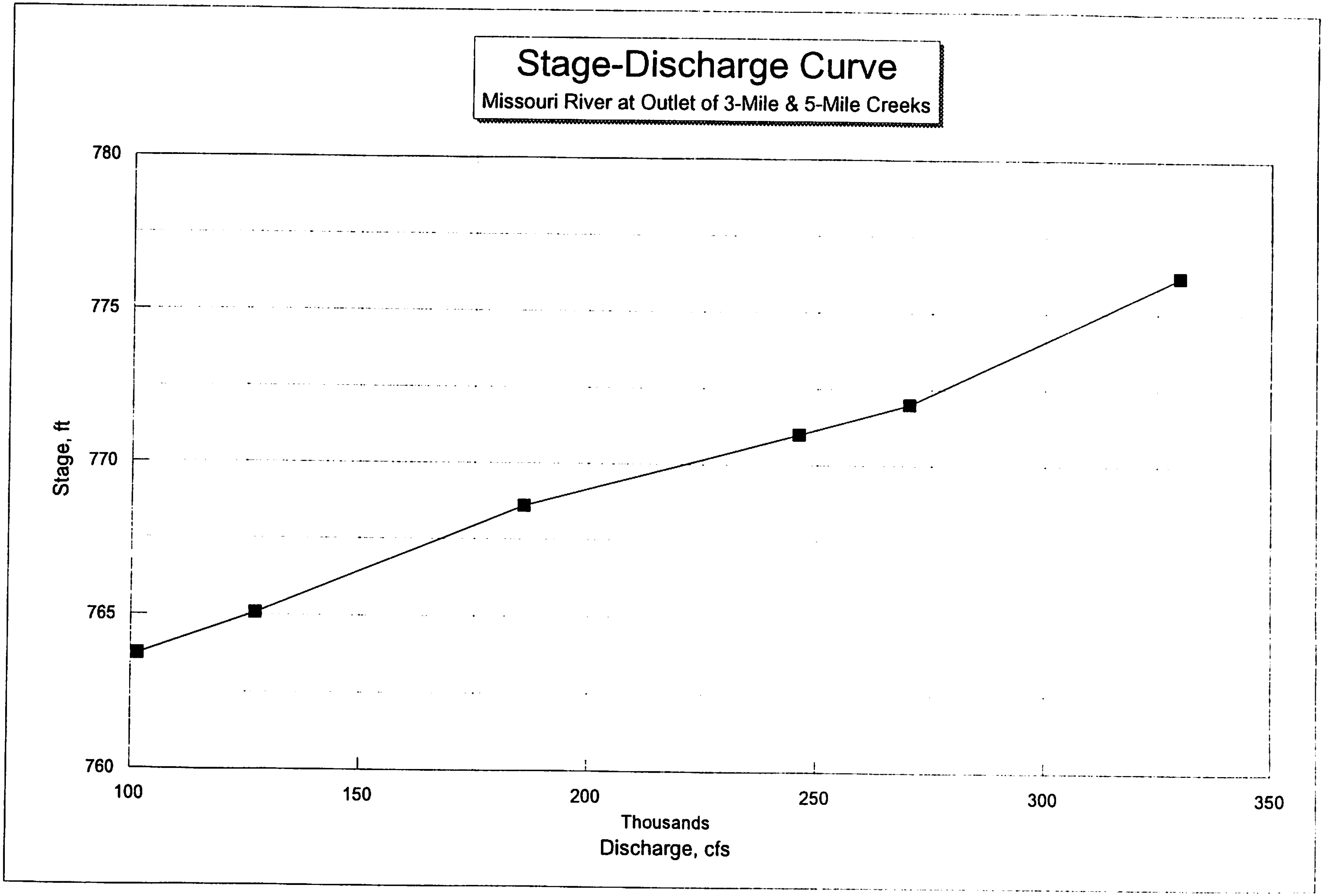

Stage-Discharge Curve
Missouri River at Outlet of 3-Mile & 5-Mile Creeks
780
775
770
765
760
Stage, ft
100
150
200
250
300
350
Thousands
Discharge, cfs

Figure VI-10

was considered the most appropriate method of checking the model. The flow verification was performed at three levels: peak runoff from each subarea; visual comparison of historical flooding areas to inadequate conduits causing flooding identified by the model; and peak discharge at basin outlet.

When resources permit, the City should implement a rainfall and stream gauge monitoring system to calibrate the models. Also, as improvements are made to the drainage system, the models should be updated. Depending on the growth in the City and the timing of implementation of the recommended improvements, the master plan should be updated every 5 to 10 years.

1. Peak Runoff

Verification of the subarea peak runoff consisted of comparing the runoff from XP-SWMM with the runoff (Q) calculated with the Rational formula, $Q = C \times i \times A$. The runoff coefficients used in the Rational formula were converted from the percent imperviousness values in the model based on an empirical formula. The runoff coefficients were calculated as follows:

$$C = (\%\ imp/100 \times 0.90) + (\%\ perv/100 \times 0.30)$$

where:

C = Rational formula runoff coefficient

% imp = percent imperviousness of the subarea

% perv = 1 - % imp/100 = percent perviousness of the subarea

0.90 = runoff coefficient for entirely impervious area

0.30 = runoff coefficient for entirely pervious area

The intensity, i, taken from the KDOT "Rainfall Intensity Tables for Counties in Kansas," was based on a duration equal to the time of concentration (T_c). The time of concentration was calculated as follows:

$$T_c > 5 \text{ minutes, and}$$

$$T_c = T_i + T_t$$

where:

$$T_i = \text{overland flow time}$$

$$= \frac{1.8 \times (1.1 - C) \times (\text{overland flow distance})^{1/2}}{(\text{subcatchment slope})^{1/3}}$$

and where:

$$T_t = \text{pipe and gutter travel time}$$

$$= \frac{\text{pipe length}}{\text{pipe velocity}} + \frac{\text{gutter length}}{_{10}\wedge\ ((\log \text{slope} + .602)/2)}$$

and:

overland flow distance ≤ 300 ft
for pipe slope <2%, pipe velocity = 7 ft/sec
for 2<slope <5%, pipe velocity = 10 ft/sec
for slope >5%, pipe velocity = 15 ft/sec

The Area (A) in the Rational formula was equal to the subcatchment area in the model.

The peak runoff verification was performed for existing and future land use conditions using the 10-year return period. Spreadsheets with the subarea peak flows for XP-SWMM and the computation of subarea peak flows using the Rational formula are provided in Appendix H. In general, there was about a 20 percent difference between the results of the two methods. The Three Mile Creek spreadsheets indicate XP-SWMM produces approximately 24 percent higher runoff values than the Rational formula. In the Five Mile Creek watershed, however, XP-SWMM produces approximately 21 percent lower values overall.

2. Historic Flooding Problem Areas

The stormwater conveyance system was modeled for typical storm events to identify inadequate conduits and quantify the magnitude of flooding. The results of the preliminary design storm simulations were plotted on maps of the watersheds. Adequate conveyance elements were shown in black line, while inadequate conduits, that is, those with flooding at their upstream manholes, were highlighted in red. The stormwater questionnaire results, color-coded to indicate major and minor problems at a given address, were superimposed on the maps. In addition, locations of known flooding problems, provided by the City, were superimposed as blue triangles. The Three Mile Creek watershed is shown on Figure VI-11, and the Five Mile Creek watershed on Figure VI-12. The City, the Citizen's Stormwater Committee, and Black & Veatch concurred that there was good correlation. However, some minor changes to the model were required to better represent the actual conveyance elements at 18th and Osage Streets; 13th, 14th, Shawnee, and Cherokee Streets; and 16th, 17th, and Vilas Streets.

3. FEMA Discharge

Peak flow verification for the Three Mile and Five Mile Creek watersheds was completed using the 1977 Flood Insurance Study (FIS). Although the study was completed nearly 20 years ago, the data were determined to be suitable for flow verification. Because of development in the watersheds, peak discharge at the basin outlet estimated with XP-SWMM for present conditions was expected to be higher than the value given in the 1977 FIS report. Table VI-6 presents the results of the basin flow comparisons for the design storm events. Overall, the peak flows for both watersheds were approximately 12 percent higher than those from the 1977 FIS report. This result is attributed to differences in hydraulic methods used in the studies.

Table VI-6
Basin Outlet Peak Discharge Comparison

Watershed	FEMA 1977 (cfs)	XP-SWMM Future (cfs)	Percent Difference %
	10-Year Event		
Three Mile Creek	3,450	5,040	46.1
South Branch	1,300	1,230	-5.4
Five Mile Creek	4,500	4,930	9.6
	50-Year Event		
Three Mile Creek	6,000	6,940	15.7
South Branch	2,300	1,870	-18.7
Five Mile Creek	8,000	8,040	0.5
	100-Year Event		
Three Mile Creek	7,500	7,770	3.6
South Branch	2,850	2,020	-29.1
Five Mile Creek	9,500	8,840	-7.0

In XP-SWMM, the flow in the channel is attenuated as a result of the timing of the peak flow and the runoff from the tributary areas downstream from the location of peak flow and storage in the conveyance system. By the time the peak flows from the upper portions reach the lower portion of the watershed, the peak runoff from the tributary areas to the lower portion of the system has already passed. As the peak flow travels downstream, it is attenuated, since the runoff contributions from tributary areas are minimal. The model is a dynamic simulation, with thousands of calculations per second extending through the hydraulic system. The system modeled is a complex dendritic network, with several hundred junction, pipe, and channel components.

The FEMA study, conversely, was based on a steady-state, step-backwater program much like HEC-2. The conveyance components consist of a single, linear system of bridges/culverts and open channel reaches. With this method, the user inputs the discharge first and the water surface profile is calculated. The FEMA discharges were determined using a synthetic unit hydrograph method for which the calculations were not available for comparison to the hydrologic parameters for this study.

The differences in peak flow rates reported in the FEMA study versus those calculated in this study are related primarily to the different models. Normally, it is expected that peak flows would increase as development occurs over a 20-year period. In general, the peak flows shown in Table VI-6 show little increase and, in some cases, decreases between the 1977 FEMA study and this master plan. The results are in large part due to different model techniques. XP-SWMM accounts for channel storage behind culverts which reduces peak flows; whereas, the models used in 1977 did not.

4. Conclusions

Three different procedures from three separate sources were used for flow verification. Although some discrepancies were identified in the comparisons of subcatchment peak flows, the verification process in general provided assurance that the flow values are reasonable and within the degree of accuracy necessary for master planning. The preferred procedure for checking flow calculations from a computer model is model calibration using measured rainfall data and streamflow field information. However, this procedure is both time-consuming and expensive, and is outside the scope of this project.

VII. Policy Development

A. Goals and Objectives

Policies were developed to assure that the stormwater management program would proceed in an organized and professional fashion. The policies are a starting point for the City to implement the Stormwater Management Plan. The policies have been developed with flexibility to accommodate the changing needs of the City. To assure that the policies would address as many of the perceived needs as possible, the recommendations received internal review from the City staff and Black & Veatch, public review from the Stormwater Committee, and management review from the City Commission.

B. General Policy

This section provides guidelines for planning and management of the stormwater conveyance system. The City Commission has reviewed the policies finalized by the Citizen's Stormwater Committee, which were developed from Stormwater Questionnaire responses, legal advice, and input from the City staff and the public. The guidelines supplement the Storm Drainage Design Manual. A Subdivision Planning Manual also has been developed for later adoption as part of this study.

<u>Drainage System Issues</u>

The following items were resolved by the Citizen's Stormwater Committee and reviewed by the City Commission.

- The City of Leavenworth shall maintain roadside ditches and driveway tubes in a more consistent manner as part of an overall plan for stormwater management.
- Curb and gutter streets shall be required in all new developments.
- Property owners with property along open channels and creeks must leave natural drainageways undeveloped to allow for storm runoff from future development upstream.
- The City shall not pursue acquisition of easements or ownerships along open channels unless necessary for a specific project or as part of a new development.
- The City shall not assume maintenance of open channels. The City should consider using the existing "nuisance" ordinances to enforce maintenance needs on open channels.

- The City shall follow federal guidelines for stormwater quality issues without additional City requirements.
- To complete the stormwater model, it is necessary to select a design storm for the sizing of improvements. After discussing the current practice, the extent of known problems areas, and the design standards of surrounding area, the Committee recommends the criteria in Table VII-1:

Table VII-1
Recommended Design Storm

Residential Street Systems:	10-Year Storm
Arterial/Collector Systems:	50-Year Storm
Arterial/Collector Creek Crossings:	50-Year Storm
Flood Plain/High Value Commercial Property:	100-Year Storm

<u>Legal Issues</u>

- By Kansas law, a municipality has no legal obligation to provide drainage systems on private property. A City has the authority to construct them, but not an obligation. A City does have liability to maintain the improvements it has constructed.
- The City is responsible for drainage systems, both drainage swales and piped systems on easements, if the City installed the system. Also, if the City has agreed to maintain a system that was installed by others, it has responsibility.
- There is precedent that drainage should follow natural drainage patterns. Any changes in flow patterns may create liabilities.
- The courts have also established that a City is not responsible for upgrading systems and increasing their capacity to keep up with urban growth. In other words, if a City installs a pipe to convey design peak flow rates based on current development conditions, it is not responsible for upgrading the pipe in the future to meet increases in peak flow rates from urban growth.
- A City may create an ordinance prohibiting a property owner from making changes to his property which would cause drainage problems for his neighbor. If an ordinance is in place, then the City can enforce the ordinance by levying fines or other measures, but the City is not responsible for correcting the problem.

- If the City forms a drainage utility, it may acquire existing drainage facilities through eminent domain proceedings, but must compensate the owner. The facilities may also be donated to the City.
- If there is an applicable ordinance, the City can require individual property owners to maintain the drainage systems on their property. Drainage may fall under the broad category of "nuisance," for which there is a City ordinance.
- On private property, the City has no power to prevent someone from building a structure over a storm drainage pipeline that is not in a right-of-way or an easement. Through the building permit process the City can discourage this, but has no authority to prevent it.
- With the consent of the Owner, the City can legally perform maintenance on drainage facilities located on private property.
- A legitimate storm drainage operation/utility plan is to do nothing on private property. If it can be proven that the City has accepted responsibility by giving advice to citizens regarding problems on private property, then a legal responsibility exists.
- The courts have established no standard of care for drainage facilities. The standard of care, i.e., the capacity to convey the five-year storm versus the 10-year storm, etc., is a political and economic decision, not a legal one.

<u>Stormwater Management Issues</u>

- Stormwater management guidelines have been included in this report for alleviating problems associated with stormwater runoff, including flooding, erosion, and water quality deterioration. The guidelines present methods beyond the conventional procedures of increasing conveyance capacity and providing detention storage, such as best management practices, erosion and sediment control, and conveyance system maintenance. Although the capital improvements program projects will most likely not address all of the issues presented in this document, these guidelines should be considered where possible and followed during the design, and particularly during the construction phase of the project. Storm drainage system and flood plain management are discussed in Chapter VIII, Section D, and water quality issues are covered in Chapter XII, Section E.

- The stormwater conveyance system is a part of the City's infrastructure. The planning of these systems must, therefore, be an integral part of the urbanization process. Provisions for adequate drainage promote the general health, welfare, and economic well-being of an urban area. Stormwater conveyance systems consist of two parts--the local drainage system and the major drainage system. The local drainage system collects and conveys the runoff from individual sites, drainage areas, and subwatersheds to the major drainage system. Examples of local drainage systems are catch basins, drains, pumps, curbs and gutters, swales, storm sewers, and small open channels. Although the local drainage system is sized to eliminate flooding caused by design events, the overall intent of the system is to convey stormwater runoff away from the area and to eliminate long-term ponding. For rainfall events greater than the design storm, provisions must be included to assure that stormwater flow in excess of the capacity of local conveyance systems has a general path to follow without producing widespread flooding and ponding. Design issues are covered in the Storm Drainage Design Manual.
- Detention storage is required in developing areas if the peak flows resulting from the design storm would be larger than those provided for in the master plan. When an area is developed, large portions of vegetation and pervious areas are replaced with pavement and buildings. The increase in impervious areas causes higher runoff rates for a given design storm, which can cause or increase flood damage. The detention storage must be sized to store the higher runoff rate and limit peak discharge to the amount projected for that portion of the system in the master plan. This requirement helps to limit the amount of flood damage at particular locations as development continues. The construction of the detention basins, however, must be coordinated to assure that they complement one another and that they do not create worse conditions further downstream.

C. Procedure Manuals

City-wide ordinances, codes, standards, specifications, and details for streets, parks, subdivisions, zoning, and commercial developments were reviewed for consistency with storm drainage management needs. Other cities' and agencies' design criteria were also reviewed. The City and the Citizen's Stormwater Committee helped define alternative design criteria, specifications, and details. The desired storm drainage design goals and needs for future development were determined, and the alternative design information was evaluated on the basis of construction cost impact, maintenance requirements, and overall effectiveness. The final criteria were included in the Storm Drainage Design Manual bound separately as Appendix A. These criteria should be followed for the design of storm drainage system components, whether they are part of a capital improvement project or a new development.

The procedures in the Subdivision Planning Manual should be observed by developers before and during construction of new developments. The Subdivision Planning Manual was compiled from a list of plan review policies and procedures, and reviewed by the City. This manual is bound separately as Appendix B.

Drainage Criteria Manual, City of Leavenworth, Kansas

I. **General Design Criteria**

I.1. General. The following design criteria are the minimum standards to be used in the design and construction of drainage system improvements for the City of Leavenworth.

I.2. Policies. The drainage design criteria are based on the following policies adopted by the City and developed as part of the Stormwater Master Plan completed in 1999.

I.2.1. A drainage report must be submitted by a professional engineer registered in the State of Kansas. The report shall be signed and sealed.

I.2.2. Subdivision plans shall include plans for the conveyance of stormwater and shall be signed and sealed by a professional engineer registered in the State of Kansas. The stormwater facilities shall be designed in accordance with design criteria set forth in "Drainage Criteria Manual, City of Leavenworth, Kansas," (Design Criteria) developed as part of the Stormwater Master Plan.

I.2.3. Easements shall be granted to the City for access to underground drainage improvements and along open channels where the flow is greater than what could be contained in a 72 inch diameter pipe. Minimum easement requirements are listed in the Design Criteria.

I.2.4. Curb and gutter shall be provided on all new roadways.

I.2.5. Off-site drainage improvements shall be provided if peak flow rates are greater than those shown in the Stormwater Master Plan.

I.2.6. Underground drainage systems shall be installed in all areas where the flow can be contained in a 72 inch diameter pipe.

I.2.7. Systems shall be designed to address State and Federal regulations regarding stormwater quality.

I.2.8. Runoff resulting from a 100 year design storm shall be routed through the major drainage system, which consists of the drainage system designed to pass the design storm plus surface routing such as swales, open channels, and roadways. The 100 year design storm shall be routed through the major system without causing structural flooding.

Section II. Design Requirements

II.1. Runoff Calculations. Peak runoff rates shall be calculated using the Rational method for areas smaller than 300 acres. For areas greater than or equal to 300 acres and where detention/retention storage will affect peak runoff rates, a hydrograph method shall be used to calculate peak flow rates.

II.1.1. Rational method. The Rational equation consists of the following formula:

$$Q=k*C*i*A$$ where,

Q = Peak rate of runoff in cubic feet per second
k = Antecedent precipitation coefficient
C = Runoff coefficient
i = Rainfall intensity in inches per hour
A = Tributary area in acres

II.1.1.1. Antecedent precipitation coefficient (k). The antecedent precipitation coefficient is used to adjust the runoff coefficient (C) for less frequent design storms. The following k factors shall be used:

Antecedent Precipitation Factor, k	
Return Period Design Storm, Years	k Factor
10 and less	1.0
25	1.1
50	1.2
100	1.25

The product of C and k shall not exceed 1.0.

II.1.1.2. Runoff coefficient (C). The runoff coefficient is a ratio of the rate of runoff to rate of precipitation. The table below shall be used to determine C values.

Runoff Coefficient, C and Percent Impervious				
Land Use	Average Runoff Coefficient	Range for Runoff Coefficient	Average Percent Impervious	SCS Curve Number
Business				
Downtown	0.87	0.70-0.95	95	92-94
Neighbor-hood	0.81	0.5-0.7	85	92-94

Residential Single-family Multi-family Apartments Churches and schools	 0.51 0.66 0.6 0.75	 0.3-0.6 0.4-0.8 0.5-0.7 0.7-0.9	 35 60 60 75	 75-83 85-90 85-90 88-92
Industrial Light Heavy Parks, Cemeteries Railroad yard	 0.66 0.78 0.30 0.40	 0.5-0.8 0.6-0.9 0.1-0.30 0.2-0.4	 60 80 10 25	 88-91 88-91 61-86 70-80
Undeveloped	0.3	0.1-0.3	0	61-86
Impervious	0.9	0.8-0.95	100	98
Turf	0.3	0.1-0.3	0	61-86
Agricultural	0.3	0.1-0.3	0	61-91

II.1.1.3 Rainfall Intensity. Intensity-duration-frequency curves are tabulated in Table 1. The duration of the design storm shall be equal to the time of concentration of the tributary area.

Time of concentration shall be calculated using the following formula:

$$T_c = T_i + T_t$$

Where: T_c = Time of concentration
T_i = Inlet time
T_t = Travel time

Inlet time is the time required for runoff to be conveyed from the most remote location in the watershed to the channelized system. Inlet time shall be calculated using the following formula:

$$T_i = (1.8*(1.1-C)*D^{1/2})/S^{1/3}$$

Where: C = Rational method runoff coefficient
D = Overland flow distance (300 feet maximum)
S = Slope of tributary area in percent

Inlet time shall be greater than or equal to 5 minutes and less than 15 minutes.

Travel time is the time required for runoff to be conveyed through the channelized system within the watershed. Travel time shall be calculated using Manning's equation. Travel time may include flow in street gutters, swales, open channels, and enclosed pipe systems.

II.1.2 Hydrograph Methods. Numerous hydrograph methods and computer programs are available and it is not the intention of these criteria to include an approved list. Developer shall use methods acceptable to the City.

The design storm duration shall be of adequate length to evaluate the entire watershed area. If detention/retention basins are being considered, the design storm duration shall be a minimum of 24 hours. If detention/retention basins are not being evaluated, the design storm shall be of adequate length to calculate a peak flow rate assuming the whole watershed is contributing runoff. Generally, the duration must be greater than two times the time of concentration of the watershed.

The design storm distribution shall be acceptable to the City. A composite storm developed from the intensity-duration-frequency curves in Table 1 was used to estimate peak flows in the Stormwater Master Plan and is shown in Table 2. Another widely used distribution is the SCS Type II distribution shown in Table 3.

II.2. Drainage System Design

II.2.1. Return Frequencies. Drainage system components shall be designed to convey peak flow rates and volumes resulting from the following design storm return frequencies:

Design Storm Return Frequencies	
10 or 25 year	Enclosed drainage systems
50 year	Crossings of collector roads
100 year	Open channels, crossings of arterials, overflow channels, and emergency spillways

II.2.2 Capacities. Drainage system capacities shall be calculated as follows.

II.2.2.1. Gravity Flow Conditions. New enclosed drainage systems shall be designed for gravity flow conditions. Capacity shall be calculated using Manning's equation:

$$Q=(1.49*A*R^{2/3}*S^{1/2})/n$$

Where:

Q = Flow in cubic feet per second

A = Cross-sectional area of flow in square feet
R = Hydraulic radius which is the cross-sectional area divided by the wetted perimeter in feet
S = Slope of the energy grade line in feet per feet
n = Manning's roughness coefficient, see below

Manning's Roughness Coefficient, n	
Type of Channel	n
Closed Conduits	
Reinforced Concrete Pipe	0.013
Reinforce Concrete Elliptical Pipe	0.013
22/3 x 1/2 inch Annular Corrugations Metal Pipe, unpaved	0.024
22/3 x 1/2 inch Annular Corrugations Metal Pipe, paved invert	0.021
3 x 1 inch Annular Corrugations Metal Pipe, unpaved	0.027
3 x 1 inch Annular Corrugations Metal Pipe, paved invert	0.023
6 x 2 inch Annular Corrugations Metal Pipe, unpaved	0.033
6 x 2 inch Annular Corrugations Metal Pipe, paved invert	0.028
Vitrified Clay Pipe	0.013
Asbestos Cement Pipe	0.012
Stone Arch	0.025
Open Channels (Lined)	
Gabions	0.025
Concrete trowel finish	0.013
Concrete float finish	0.015
Concrete, unfinished	0.017
Concrete, bottom float finished with sides of Dressed Stone	0.017

Concrete, bottom float finished sides of Random Stone	0.020
Concrete, bottom float finished sides of Cement Rubble masonry	0.025
Concrete, bottom float finished sides of Dry Rubble or Riprap	0.030
Gravel bottom, sides of Random Stone	0.023
Gravel bottom, sides of Riprap	0.030
Grass (Sod)	0.030
Riprap	0.035
Grouted Riprap	0.030
Open Channels (Unlined) Excavated or Dredged	
Earth, straight and uniform	0.027
Earth, winding and sluggish	0.035
Channels, not maintained, weeds and brush uncut	0.090
Natural Stream	
Clean stream, straight	0.030
Stream with pools, sluggish reaches, heavy underbrush	0.100
Flood Plains	
Grass, no brush	0.030
With some brush	0.090
Street Curbing	0.014

For materials or conditions not included above, refer to Chow's Open Channel Hydraulics.

II.2.2.3. Surcharge Systems. Existing systems may be evaluated for surcharge conditions, if the following conditions are met:

1. The Hydraulic Grade Line (HGL) must be 0.5 feet below any openings to the ground or street at all locations.
2. Pipe joints are capable of withstanding internal surcharge pressure.

Surcharge capacity shall be determined using Bernoulli's equation accounting for friction losses and minor losses.

II.2.3. Enclosed System Size Requirements. Minimum pipe diameter shall be 15 inches.

Enclosed pipe systems shall be used to convey runoff when peak flows can be conveyed in a 72 inch or smaller diameter concrete pipe. If larger pipe sizes are required, flows can be conveyed either in an enclosed system or open channels.

II.2.3.1. Enclosed System Velocities. Velocities shall be a minimum of 3 feet per second and a maximum of 15 feet per second.

II.2.3.2. Outlet Velocities. The following tables shall be used to determine allowable outlet velocities and erosion control requirements.

II.2.3.2.1. Unimproved (Natural) Receiving Channels. Soil types in Leavenworth are predominantly silty or clay loam, with some sandy loam. For unimproved receiving channels, the following table shows allowable velocities.

Maximum Permissible Velocities for Unimproved Channels of Small Slope			
Soil Type	Manning's n	Permissible Clear Water Velocity, ft/s	Permissible Silty Water Velocity, ft/s
Silt loam, noncolloidal	0.020	2.00	3.00
Stiff clay, very colloidal	0.025	3.75	5.00
Sandy loam, noncolloidal	0.020	1.75	2.50
Ordinary firm loam	0.020	2.50	3.50
Alluvial silts, colloidal	0.025	3.75	5.00
Shales and hardpan	0.025	6.00	6.00
Fine sand, colloidal	0.020	1.50	2.50
Fine gravel	0.0205	2.50	5.00

Graded loam to cobbles when noncolloidal	0.030	3.75	5.00
Graded silts to cobbles when colloidal	0.030	4.00	5.50
Coarse gravel, noncolloidal	0.025	4.00	6.00
Cobbles	0.035	5.00	5.50

Where outlet velocities exceed permissible velocities shown above, energy dissipation or channel lining will be required.

II.2.3.2.2. Improved Receiving Channels. If the receiving stream is an improved channel with lining, the following tables shall be used to determine permissible outlet velocities.

II.2.3.2.3. Grass Lined

Permissible Velocities for Channels Lined with Grass		
Cover	Slope Range, %	Permissible Velocity, ft/s
Bermuda grass	0-5 5-10 >10	6 5 4
Buffalo grass, Kentucky bluegrass, blue grama	0-5 5-10 >10	5 4 3
Grass mixture	0-5 5-10 >10	4 3 do not use

II.2.3.2.2.1. Other Types of Channel Lining. This table provides general guidelines for permissible outlet velocities for the various types of channel lining. The lining material shall be designed specifically for the conditions encountered.

Permissible Velocities for Other Types of Channel Lining	
Material	Permissible Velocity, ft/s
Riprap	5-10

Grouted riprap, gabion revetment, or paved concrete	10-15
Paved concrete or sound in situ bedrock	Over 15

II.2.3.2.3 Easements. Permanent easements shall be dedicated to the City for operation and maintenance of the storm drainage facilities. Easement width shall not be less than 15-feet, or the outside width of the pipe or conveyance structure plus 10 feet; whichever is greater. Easements shall be centered on the pipe. The City Engineer may require wider easements when other utilities are located within the same easement and/or when the depth of cover is greater than 4 feet. Temporary construction easements of sufficient width to provide access for construction shall be acquired when the proposed work is located in areas developed prior to construction.

II.2.3.3 Materials

Pipes shall be constructed of reinforced concrete unless otherwise approved by the City.

II.2.3.3.1. Pipe thickness. Thickness shall be determined based on loading conditions.

II.2.3.3.2. Bedding. Pipe bedding shall be as recommended by pipe manufacturer.

II.2.3.3.3. Trenching and Backfill. Trenching and backfill shall be in accordance with KDOT standards.

II.2.3.3.4. Cover. Minimum cover shall be 30 inches.

II.2.4. Open Channels. Open channel capacities shall be determined using Manning's equation. Constrictions such as bridges and culverts tend to create nonuniform flow conditions; and therefore, design of open channels should include evaluation of backwater conditions. Backwater conditions shall be evaluated using the standard-step backwater procedure or computer models such as HEC-2, SWMM, or other models acceptable to the City.

II.2.4.1. Natural Channels. Drainage improvements may include the use of unimproved natural channels provided the improvements do not significantly alter peak flow rates, velocities, or alignment of the channel, and the provisions of Section II.2.3.1 are met. Existing conditions and post development conditions shall be evaluated. If peak flow rates or velocities are increased significantly, an improved channel shall be provided.

II.2.4.2. Improved Channels. Improved channels shall be used when development will cause significant erosion in existing natural channels.

II.2.4.2.1. Channel Lining. The allowable velocities summarized in Section 2.2 shall apply to improved open channel design.

II.2.4.2.2. Side slopes. Side slopes for improved channels shall not be steeper than:
1. 3 horizontal to 1 vertical for turf lining.
2. 2 horizontal to 1 vertical for other lining materials.
3. Flatter if necessary for slope stability.

II.2.4.2.2.1. Vertical walls. Channels shall be designed to avoid the use of vertical walls. If conditions require the use of vertical walls, they shall be constructed of reinforced concrete, to act as retaining walls, and provisions shall be made for access for maintenance equipment and pedestrians.

II.2.4.2.3. Alignment Changes. Alignment changes shall be achieved by a curve having a minimum radius of:

$$R = (V^2 * W)/(8 * D) \text{ where:}$$

R = Minimum radius of curve along the center line in feet.
V = Design velocity of flow in feet per second
W = Width of channel at water surface in feet
D = Depth of flow in feet

II.2.4.2.4. Freeboard. Channels shall be designed to provide one foot of freeboard for the 100 year flow.

II.2.4.3 Easements. Permanent easements shall be dedicated to the City for operation and maintenance of open channels.

A. Improved Open Channels. Easements shall be as wide as the top of bank width; plus 10 feet on each side. Easements shall be continuous between street right-of-ways. When an improved channel begins or ends at a point other than the right-of-way of a dedicated street, a 15-foot or wider easement graded so as to permit access by truck shall be dedicated from the end of the channel to a street right-of-way.

B. Natural Channels. Natural open channels easements shall be the area between the lines of intersection of the natural ground with a plane 12 inches above the design water surface, plus 10 feet measured horizontally on each side thereof; however the width of the easement shall not be less than 30 feet and the width shall be increased if necessary to permit access by truck along the entire length of the channel.

II.2.5. Manholes and Junction Boxes.

II.2.5.1. Location. Manholes or junction boxes shall be installed at the following locations:

a. All changes in alignment and grade.

b. Changes in conduit size.
c. Branch connections.
d. Probable future connections.
e. Maximum spacing shall be 400 feet for 15 inch pipe, 500 feet for 18 to 36 inch pipe, 600 feet for 42 to 48 inch pipe, and 700 feet for 54 inch and larger pipe.

II.2.5.2. Size. Minimum inside dimensions shall be as follows:

a. 4 feet for 24 inch or less diameter pipe.
b. 5 feet for 27 to 36 inch diameter pipe.
c. 6 feet for 42 to 48 inch diameter pipe.
d. For larger diameter pipe, junction boxes shall be cast-in-place and shall be detailed on the engineering plans.

II.2.6. Culverts.

II.2.6.1. Capacities. Culverts shall be evaluated for both inlet and outlet control. Capacities shall be determined using Federal Highway Administration nomographs or by other means acceptable to the City.

II.2.6.2. Headwalls, Endwalls, and End Sections. Headwalls, endwalls, and/or end sections shall be installed to anchor the culvert and to prevent erosion.

II.2.6.3. Materials. Culverts shall be constructed of reinforced concrete unless otherwise approved by the City.

II.2.6.4. Structural. Culverts shall be designed for the appropriate loading conditions.

II.2.6.5. Bedding. Proper bedding and foundation shall be provided.

II.2.6.6. Trenching and Backfill. Trenching and backfill shall be in accordance with KDOT standards.

II.2.7. Inlets, Curbs, and Gutters

II.2.7.1. Allowable Spread. The following table shall be used to determine the allowable spread of runoff in roadways for the appropriate design storm event.

Allowable Spread	
Type of Road	Allowable Inundation
Residential and Lateral	Maximum 6 inches deep at crown
Collector	One lane open
Arterial and Highways	One lane open each direction

II.2.7.2. Curb Capacity. Curb capacity shall be calculated using Izzard's formula:

$$Q=(0.56*z*S^{1/2}*D^{8/3})/n$$ where:

Q = Flow in cubic feet per second
z = Reciprocal of the average cross-slope, including gutter section, in feet per foot
S = Longitudinal slope of roadway in feet per foot
D = Depth of flow at curb face in feet
n = Manning's "n"

II.2.7.3. Inlets. Inlets shall be designed according to Detail 1 unless otherwise approved by the City. Only curb opening type inlets shall be permitted unless otherwise approved by the City.

II.2.7.3.1. Inlet Capacity. Inlet capacity shall be 80 percent of the theoretical capacity provided in Tables 4-6 and/or Nomographs A through D.

II.2.7.3.2. Inlet Spacing. Maximum inlet spacing shall be 400 feet.

II.2.7.3.4. Inlet Location. Inlets shall be located in sumps where possible. Inlets shall be placed at intersections of cul-de-sacs.

II.2.7.3.5. Hydraulic Grade Line. The hydraulic grade line within the storm drainage system shall be a minimum of 0.5 feet below the minimum inlet opening elevation.

II.2.8. Stormwater Detention. Detention storage can be provided in lieu of off-site drainage improvements. Storage shall be provided so that peak discharge rates are equal to or less than those shown in the Master Plan.

II.2.8.1. Size. Detention basin volume shall be determined by routing a 24-hour design storm. An SCS Type 2 24-hour storm shall be the required storm hyetograph.

II.2.8.2. Principal Spillway. The principal spillway shall be designed to function without requiring attendance or operation of any kind or requiring use of equipment or tools, or any mechanical devices. At least 80 percent of the detention storage volume shall be discharged within 24 hours after the peak flow has entered the basin.

II.2.8.3. Emergency Spillway. The emergency spillway may either be combined with the principal spillway or be a separate structure or channel. Emergency spillways shall be designed so that their crest elevation is 0.5 feet or more above the maximum water surface elevation in the detention facility attained by the 100-year storm.

II.2.8.4. Outlet Works. Outlet works consisting of valves, gates, pipes, and other devices as necessary to completely drain the facility in 72 hours or less shall be provided.

II.2.7.2. Curb Capacity. Curb capacity shall be calculated using Izzard's formula:

$$Q=(0.56*z*S^{1/2}*D^{8/3})/n \text{ where:}$$

Q = Flow in cubic feet per second
z = Reciprocal of the average cross-slope, including gutter section, in feet per foot
S = Longitudinal slope of roadway in feet per foot
D = Depth of flow at curb face in feet
n = Manning's "n"

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II.2.7.3.2. Inlet Spacing. Maximum inlet spacing shall be 400 feet.

II.2.7.3.4. Inlet Location. Inlets shall be located in sumps where possible. Inlets shall be placed at intersections of cul-de-sacs.

II.2.7.3.5. Hydraulic Grade Line. The hydraulic grade line within the storm drainage system shall be a minimum of 0.5 feet below the minimum inlet opening elevation.

II.2.8. Stormwater Detention. Detention storage can be provided in lieu of off-site drainage improvements. Storage shall be provided so that peak discharge rates are equal to or less than those shown in the Master Plan.

II.2.8.1. Size. Detention basin volume shall be determined by routing a 24-hour design storm. An SCS Type 2 24-hour storm shall be the required storm hyetograph.

II.2.8.2. Principal Spillway. The principal spillway shall be designed to function without requiring attendance or operation of any kind or requiring use of equipment or tools, or any mechanical devices. At least 80 percent of the detention storage volume shall be discharged within 24 hours after the peak flow has entered the basin.

II.2.8.3. Emergency Spillway. The emergency spillway may either be combined with the principal spillway or be a separate structure or channel. Emergency spillways shall be designed so that their crest elevation is 0.5 feet or more above the maximum water surface elevation in the detention facility attained by the 100-year storm.

II.2.8.4. Outlet Works. Outlet works consisting of valves, gates, pipes, and other devices as necessary to completely drain the facility in 72 hours or less shall be provided.

II.2.8.5. Access. Provision shall be made to permit access and use of auxiliary equipment for maintenance.

II.2.8.6. Underground Storage. Underground detention facilities shall be designed with adequate access for maintenance. Such facilities shall be provided with positive gravity outlets. Venting shall be provided.

References:
1. Urban Hydrology for Small Watersheds, Soil Conservation Service, 1986.
2. Section 5600 Storm Drainage Systems and Facilities Kansas City Metropolitan Chapter of the American Public Works Association, March 1990.
3. City of Topeka Design Criteria and Drafting Standards, January 1993.
4. City of Lee's Summit Design and Construction Manual, September 1992.
5. KDOT idf curves
6. Standard Specifications for State Road and Bridge Construction, Kansas Department of Transportation, 1990.
7. Hydraulic Design of Highway Culverts, Federal Highway Administration, September 1985.

Table 1

RAINFALL INTENSITY TABLES FOR COUNTIES IN KANSAS

KANSAS DEPARTMENT OF TRANSPORTATION

Revised, September 1991

RAINFALL INTENSITY TABLES

FOR

COUNTIES IN KANSAS

Developed for the

Kansas Department of Transportation

by

Bruce M. McEnroe
John Patrick Jones

Department of Civil Engineering
University of Kansas
Lawrence, Kansas

These tables were developed from data published in Technical Memorandum NWS HYDRO-35 for the U.S. National Weather Service (Frederick et al. 1977) for durations of five (5) minutes through 60 minutes, and Technical Paper No. 40 (TP-40) of the U.S. Weather Bureau (Hershfield 1961) for longer durations as part of:

K-TRAN Research Program
Project KU-92-1

September, 1991

RAINFALL INTENSITY TABLE

LEAVENWORTH COUNTY
KANSAS

THIS TABLE CONTAINS AVERAGE RAINFALL INTENSITIES IN INCHES PER HOUR.

DURATION, HR:MIN	RETURN PERIOD						
	1 YR	2 YR	5 YR	10 YR	25 YR	50 YR	100 YR
0:05	4.63	5.40	6.48	7.26	8.41	9.31	10.20
0:06	4.40	5.15	6.20	6.96	8.08	8.95	9.81
0:07	4.22	4.94	5.97	6.71	7.79	8.64	9.48
0:08	4.05	4.76	5.76	6.48	7.53	8.35	9.17
0:09	3.91	4.59	5.56	6.26	7.28	8.08	8.87
0:10	3.78	4.44	5.38	6.05	7.04	7.81	8.58
0:11	3.66	4.30	5.20	5.86	6.81	7.56	8.30
0:12	3.54	4.16	5.04	5.67	6.60	7.32	8.04
0:13	3.44	4.04	4.89	5.50	6.39	7.09	7.79
0:14	3.33	3.92	4.74	5.34	6.21	6.89	7.57
0:15	3.23	3.80	4.61	5.19	6.04	6.70	7.36
0:16	3.13	3.69	4.48	5.05	5.88	6.53	7.17
0:17	3.04	3.59	4.36	4.92	5.74	6.37	7.00
0:18	2.95	3.49	4.25	4.80	5.60	6.22	6.85
0:19	2.86	3.39	4.15	4.69	5.48	6.09	6.70
0:20	2.78	3.30	4.05	4.58	5.36	5.96	6.56
0:21	2.70	3.22	3.96	4.48	5.25	5.84	6.43
0:22	2.63	3.14	3.87	4.39	5.14	5.73	6.31
0:23	2.56	3.06	3.78	4.30	5.04	5.62	6.19
0:24	2.49	2.99	3.70	4.21	4.94	5.51	6.08
0:25	2.43	2.92	3.63	4.13	4.85	5.42	5.97
0:26	2.37	2.85	3.56	4.05	4.76	5.32	5.87
0:27	2.31	2.79	3.49	3.98	4.68	5.23	5.77
0:28	2.26	2.73	3.42	3.90	4.60	5.14	5.68
0:29	2.21	2.67	3.36	3.84	4.52	5.06	5.59
0:30	2.16	2.62	3.29	3.77	4.45	4.98	5.50
0:31	2.11	2.57	3.24	3.70	4.37	4.90	5.41
0:32	2.07	2.52	3.18	3.64	4.30	4.82	5.33
0:33	2.03	2.47	3.13	3.58	4.24	4.74	5.25
0:34	1.99	2.43	3.07	3.53	4.17	4.67	5.17
0:35	1.95	2.38	3.02	3.47	4.11	4.60	5.10
0:36	1.91	2.34	2.97	3.42	4.05	4.53	5.02
0:37	1.88	2.30	2.93	3.36	3.99	4.47	4.95
0:38	1.85	2.26	2.88	3.31	3.93	4.40	4.88
0:39	1.81	2.23	2.84	3.26	3.87	4.34	4.81
0:40	1.78	2.19	2.80	3.22	3.82	4.28	4.74
0:41	1.75	2.16	2.75	3.17	3.76	4.22	4.68
0:42	1.73	2.12	2.71	3.13	3.71	4.16	4.62
0:43	1.70	2.09	2.68	3.08	3.66	4.11	4.55
0:44	1.67	2.06	2.64	3.04	3.61	4.05	4.49
0:45	1.65	2.03	2.60	3.00	3.56	4.00	4.43

RAINFALL INTENSITY TABLE

LEAVENWORTH COUNTY
KANSAS

THIS TABLE CONTAINS AVERAGE RAINFALL INTENSITIES
IN INCHES PER HOUR.

DURATION, HR:MIN	RETURN PERIOD 1 YR	2 YR	5 YR	10 YR	25 YR	50 YR	100 YR
0:46	1.62	2.00	2.57	2.96	3.52	3.95	4.38
0:47	1.60	1.97	2.53	2.92	3.47	3.90	4.32
0:48	1.58	1.95	2.50	2.88	3.42	3.85	4.27
0:49	1.56	1.92	2.47	2.84	3.38	3.80	4.21
0:50	1.53	1.90	2.43	2.81	3.34	3.75	4.16
0:51	1.51	1.87	2.40	2.77	3.30	3.70	4.11
0:52	1.49	1.85	2.37	2.74	3.26	3.66	4.06
0:53	1.48	1.82	2.34	2.70	3.22	3.61	4.01
0:54	1.46	1.80	2.32	2.67	3.18	3.57	3.96
0:55	1.44	1.78	2.29	2.64	3.14	3.53	3.91
0:56	1.42	1.76	2.26	2.61	3.10	3.49	3.87
0:57	1.41	1.74	2.23	2.58	3.07	3.44	3.82
0:58	1.39	1.72	2.21	2.55	3.03	3.40	3.78
0:59	1.37	1.70	2.18	2.52	3.00	3.36	3.73
1:00	1.36	1.68	2.16	2.49	2.96	3.33	3.69
1:05	1.29	1.59	2.04	2.36	2.80	3.14	3.49
1:10	1.23	1.51	1.94	2.23	2.65	2.98	3.30
1:15	1.17	1.44	1.85	2.13	2.52	2.83	3.14
1:20	1.12	1.38	1.76	2.03	2.40	2.70	2.99
1:25	1.08	1.32	1.68	1.94	2.30	2.58	2.85
1:30	1.04	1.27	1.62	1.86	2.20	2.46	2.73
1:35	1.00	1.22	1.55	1.78	2.11	2.36	2.62
1:40	0.96	1.18	1.49	1.71	2.03	2.27	2.51
1:45	0.93	1.14	1.44	1.65	1.95	2.19	2.42
1:50	0.90	1.10	1.39	1.59	1.88	2.11	2.33
1:55	0.87	1.06	1.34	1.54	1.82	2.04	2.25
2:00	0.85	1.03	1.30	1.49	1.76	1.97	2.18
2:05	0.82	1.00	1.26	1.44	1.71	1.91	2.11
2:10	0.80	0.97	1.22	1.40	1.66	1.85	2.05
2:15	0.77	0.94	1.19	1.36	1.61	1.80	1.99
2:20	0.75	0.92	1.16	1.32	1.56	1.75	1.94
2:25	0.73	0.89	1.12	1.29	1.52	1.71	1.89
2:30	0.71	0.87	1.10	1.26	1.48	1.66	1.84
2:35	0.69	0.85	1.07	1.22	1.45	1.62	1.79
2:40	0.68	0.82	1.04	1.20	1.41	1.58	1.75
2:45	0.66	0.80	1.02	1.17	1.38	1.55	1.71
2:50	0.64	0.79	0.99	1.14	1.35	1.51	1.67
2:55	0.63	0.77	0.97	1.12	1.32	1.48	1.64
3:00	0.61	0.75	0.95	1.09	1.29	1.45	1.60

RAINFALL INTENSITY TABLE

LEAVENWORTH COUNTY
KANSAS

THIS TABLE CONTAINS AVERAGE RAINFALL INTENSITIES IN INCHES PER HOUR.

DURATION,	RETURN PERIOD						
HR:MIN	1 YR	2 YR	5 YR	10 YR	25 YR	50 YR	100 YR
3:15	0.57	0.70	0.89	1.03	1.22	1.36	1.51
3:30	0.54	0.66	0.84	0.97	1.15	1.29	1.43
3:45	0.51	0.63	0.80	0.92	1.09	1.22	1.35
4:00	0.48	0.60	0.76	0.87	1.04	1.16	1.29
4:15	0.46	0.57	0.72	0.83	0.99	1.11	1.23
4:30	0.44	0.54	0.69	0.80	0.95	1.06	1.18
4:45	0.42	0.52	0.66	0.77	0.91	1.02	1.13
5:00	0.40	0.50	0.64	0.74	0.87	0.98	1.09
5:15	0.39	0.48	0.61	0.71	0.84	0.95	1.05
5:30	0.37	0.46	0.59	0.68	0.81	0.91	1.01
5:45	0.36	0.45	0.57	0.66	0.79	0.88	0.98
6:00	0.35	0.43	0.56	0.64	0.76	0.86	0.95
6:30	0.33	0.41	0.52	0.60	0.72	0.81	0.90
7:00	0.31	0.38	0.49	0.57	0.68	0.76	0.85
7:30	0.29	0.36	0.47	0.54	0.65	0.73	0.81
8:00	0.28	0.35	0.45	0.52	0.62	0.69	0.77
8:30	0.27	0.33	0.43	0.49	0.59	0.66	0.74
9:00	0.26	0.32	0.41	0.47	0.57	0.64	0.71
9:30	0.25	0.31	0.39	0.46	0.54	0.61	0.68
10:00	0.24	0.29	0.38	0.44	0.52	0.59	0.65
10:30	0.23	0.28	0.37	0.42	0.50	0.57	0.63
11:00	0.22	0.27	0.35	0.41	0.49	0.55	0.61
11:30	0.21	0.26	0.34	0.39	0.47	0.53	0.59
12:00	0.20	0.25	0.33	0.38	0.45	0.51	0.57
13:00	0.19	0.24	0.31	0.36	0.43	0.48	0.53
14:00	0.18	0.23	0.29	0.34	0.40	0.45	0.50
15:00	0.17	0.21	0.28	0.32	0.38	0.43	0.47
16:00	0.16	0.20	0.26	0.30	0.36	0.41	0.45
17:00	0.15	0.19	0.25	0.29	0.34	0.39	0.43
18:00	0.15	0.18	0.24	0.27	0.33	0.37	0.41
19:00	0.14	0.18	0.23	0.26	0.31	0.35	0.39
20:00	0.13	0.17	0.22	0.25	0.30	0.34	0.37
21:00	0.13	0.16	0.21	0.24	0.29	0.32	0.36
22:00	0.12	0.15	0.20	0.23	0.28	0.31	0.34
23:00	0.12	0.15	0.19	0.22	0.27	0.30	0.33
24:00	0.12	0.14	0.19	0.21	0.26	0.29	0.32

BLACK & VEATCH

MEMORANDUM

Leavenworth, Kansas
Stormwater Master Plan
New Development Plan Review Criteria

B&V Project 26529.110
B&V File W
May 24, 1999

To: Mike McDonald

From: Jeff Henson

New Development Plan Review Policies and Procedures

I. OBJECTIVE

This document lists the policies and procedures to be used by the City in reviewing drainage plans associated with new developments. A new development is defined as a tract of land containing four (4) or more lots to be developed.

II. POLICIES

The following policies relating to storm drainage were adopted by the City as part of the development of a Stormwater Master Plan (Master Plan).

II.1. A drainage report must be submitted by a professional engineer registered in the State of Kansas. The report shall be signed and sealed.

II.2. New Development plans shall include plans for the conveyance of stormwater and shall be signed and sealed by a professional engineer registered in the State of Kansas. The stormwater facilities shall be designed in accordance with design criteria set forth in "Drainage Criteria Manual, City of Leavenworth, Kansas," (Design Criteria) developed as part of the Master Plan.

II.3. Easements for drainage shall be granted to the City for access to underground drainage improvements and along open channels where the flow is greater than which could be conveyed by a 72 inch diameter pipe. Minimum easement requirements are listed in the Design Criteria.

II.4. Curbs and gutters shall be provided on all new roadways.

II.5. Off-site drainage improvements or detention storage shall be provided if peak flow rates resulting from the new development are greater than those shown in the Master Plan.

II.6. Underground drainage systems shall be installed in all areas where the flow can be contained in a 72 inch diameter pipe.

II.7. Systems shall be designed to address State and Federal regulations regarding stormwater quality.

III. PLAN REVIEW PROCEDURES

As part of the site plan approval process, Drainage Plans shall be reviewed by the Engineering staff. The drainage plan submittal shall consist of a Drainage Report and Drainage System Plans.

III.1. Drainage Report. The drainage report shall be submitted by the developer and it shall be signed and sealed by a professional engineer in the State of Kansas. The Drainage Report shall consist of the following:

III.1.1. Assumptions. A listing of the assumptions used in calculation of peak runoff rates and capacities of the proposed system and the existing receiving system.

III.1.2. Topographic Map. A topographic map showing the location of the site. The map shall include a plan of the existing surface features; the proposed development; the proposed drainage system location, size, and capacity; the existing receiving system location, size, and capacity; delineation of tributary areas to points of concentration in the drainage system; and delineation of individual lot drainage patterns. The map shall be at a scale of 1"=100' with 2 foot ground elevation contour lines.

III.1.3. Watershed Information. A table showing the land use, soil type, area, and slope of each tributary area.

III.1.4. Runoff Information. Tables summarizing the runoff characteristics shall be provided. The Rational method shall be used for estimating peak runoff for areas less than 300 acres. A hydrograph method for estimating peak runoff shall be used for areas larger than 300 acres. Computer models such as TR-55, TR-20, HEC-1, or SWMM are acceptable.

III.1.4.1. Rational Method Runoff Information. A table shall be provided showing the Rational method calculations including: cumulative area to the point of concentration, cumulative C value, time of concentration, rainfall intensity, and peak flow rate, drainage system size, and drainage system capacity. These calculations should be provided for both the pre-development and post-development conditions.

III.1.4.2. Hydrograph Method Runoff Information. A table shall be provided showing the runoff information including: drainage areas to each point of concentration, cumulative percent impervious, time of concentration for the watershed, design storm, peak flow rates, drainage system size, and drainage system capacity. These calculations should be provided for both the pre-development and post-development conditions.

III.1.5. Receiving System Information. A comparison of the ultimate development peak flow rate shown in the Master Plan versus the peak flow rate calculated in the report should be made. If the new development increases peak flows above those shown in the Master Plan, then off-site drainage improvements or a detention basin will be required.

III.1.5.1. Off-Site Drainage. Off-site drainage improvements required in section III.1.5. shall be identified in the Drainage Report. A topographic map, watershed information, and runoff information shall be provided for off-site drainage improvements in accordance with sections III.1.1. through III.1.4.

III.1.5.2. Detention Storage. Detention storage can be provided in lieu of off-site drainage improvements. Storage shall be provided so that peak discharge rates are equal to or less than those shown in the Master Plan. A topographic map meeting the requirements of III.1.2 shall be included. Additional items shall include stage-storage-discharge curves, inflow and outflow hydrographs, and spillway configuration and capacity.

III.2. Drainage System Plans. Plan and profile of the drainage system shall be submitted. The drainage system drawings shall be in conformance with the following.

Plan:	1-inch =	50-feet
Profile:		
Vertical:	1-inch =	10-feet
Horizontal:	1-inch =	50-feet
Cross-Sections:		
Vertical:	1-inch =	10-feet
Horizontal:	1-inch =	50-feet

III.3. City Review. Drainage Plans shall be reviewed by Engineering staff. Comments shall be provided to the developer within 60 days of receipt. Building permits shall not be granted until final approval of the Drainage Plans is obtained.

III.4. Construction Inspection. City building inspectors shall verify that the drainage system and site grading are constructed according to plans. Any changes in the plan during construction shall be approved by the City.

III.5. Permit to Occupy. The developer must show proof that the drainage system and site grading were constructed in accordance with plans to receive the permit to occupy. Proof shall consist of a final site survey including spot elevation checks. Verification of any changes to the plans during construction shall also be submitted with the final site survey and shall show altered drainage patterns. Comments shall be provided to the developer within 30 days of receipt of the final site survey.

COMPOSITE ME[illegible]N STORMS

RETURN PERIOD = 10 YEARS
RAIN INTERVAL = 15 MINUTES

Storm Duration Hrs	Storm Duration Minutes	Storm Duration Cum. Min.	Average Intensity in/hr	Rainfall Allotted inches	Rainfall Incremental inches	Rainfall Incremental in/hr	Decreasing Intensities in/hr	Reordered Intensities in/hr	Computed Reordered Rainfall inches	Modify Reordered Rainfall inches
0	0	0								
0	15	15	5.19	1.30	1.30	5.20	5.20	0.00	0.00	0.00
0	30	30	3.77	1.89	0.59	2.36	2.36	0.00	0.00	0.00
0	45	45	3.00	2.25	0.37	1.48	1.48	0.00	0.00	0.00
1	0	60	2.49	2.49	0.24	0.96	0.96	0.00	0.00	0.00
1	15	75	2.13	2.66	0.17	0.68	0.68	0.00	0.00	0.00
1	30	90	1.86	2.79	0.13	0.52	0.52	0.00	0.00	0.00
1	45	105	1.65	2.89	0.10	0.40	0.40	0.00	0.00	0.00
2	0	120	1.49	2.98	0.09	0.36	0.36	0.00	0.00	0.00
2	15	135	1.36	3.06	0.08	0.32	0.36	0.00	0.00	0.00
2	30	150	1.26	3.15	0.09	0.36	0.32	0.00	0.00	0.00
2	45	165	1.17	3.22	0.07	0.28	0.32	0.04	0.01	0.00
3	0	180	1.09	3.27	0.05	0.20	0.28	0.04	0.01	0.00
3	15	195	1.03	3.35	0.08	0.32	0.28	0.04	0.01	0.00
3	30	210	0.97	3.40	0.05	0.20	0.28	0.04	0.01	0.00
3	45	225	0.92	3.45	0.05	0.20	0.28	0.04	0.01	0.00
4	0	240	0.87	3.48	0.03	0.12	0.24	0.04	0.01	0.00
4	15	255	0.83	3.53	0.05	0.20	0.24	0.04	0.01	0.00
4	30	270	0.80	3.60	0.07	0.28	0.24	0.04	0.01	0.01
4	45	285	0.77	3.66	0.06	0.24	0.20	0.08	0.02	0.02
5	0	300	0.74	3.70	0.04	0.16	0.20	0.08	0.02	0.02
5	15	315	0.71	3.73	0.03	0.12	0.20	0.08	0.02	0.02
5	30	330	0.68	3.74	0.01	0.04	0.20	0.08	0.02	0.02
5	45	345	0.66	3.80	0.06	0.24	0.20	0.08	0.02	0.02
6	0	360	0.64	3.84	0.04	0.16	0.20	0.08	0.02	0.02
6	15	375	0.62	3.88	0.04	0.16	0.20	0.12	0.03	0.03
6	30	390	0.60	3.90	0.03	0.12	0.20	0.12	0.03	0.03
6	45	405	0.59	3.95	0.05	0.20	0.16	0.12	0.03	0.03
7	0	420	0.57	3.99	0.04	0.16	0.16	0.12	0.03	0.03
7	15	435	0.56	4.02	0.03	0.12	0.16	0.12	0.03	0.03
7	30	450	0.54	4.05	0.03	0.12	0.16	0.12	0.03	0.03
7	45	465	0.53	4.11	0.06	0.24	0.16	0.12	0.03	0.03
8	0	480	0.52	4.16	0.05	0.20	0.16	0.16	0.04	0.04
8	15	495	0.51	4.17	0.01	0.04	0.16	0.16	0.04	0.04
8	30	510	0.49	4.17	0.00	0.00	0.12	0.16	0.04	0.04
8	45	525	0.48	4.20	0.04	0.16	0.12	0.20	0.05	0.05
9	0	540	0.47	4.23	0.03	0.12	0.12	0.20	0.05	0.05
9	15	555	0.47	4.30	0.07	0.28	0.12	0.20	0.05	0.05
9	30	570	0.46	4.37	0.07	0.28	0.12	0.20	0.05	0.05
9	45	585	0.45	4.39	0.02	0.08	0.12	0.24	0.06	0.06
10	0	600	0.44	4.40	0.01	0.04	0.12	0.24	0.06	0.06
10	15	615	0.43	4.41	0.01	0.04	0.12	0.28	0.07	0.07
10	30	630	0.42	4.41	0.00	0.00	0.12	0.28	0.07	0.07
10	45	645	0.42	4.46	0.05	0.20	0.12	0.32	0.08	0.08
11	0	660	0.41	4.51	0.05	0.20	0.12	0.36	0.09	0.09
11	15	675	0.40	4.50	0.01	0.00	0.12	0.52	0.13	0.13
11	30	690	0.39	4.49	0.01	0.00	0.12	0.96	0.24	0.24
11	45	705	0.39	4.52	0.04	0.16	0.12	2.36	0.59	0.59
12	0	720	0.38	4.56	0.04	0.16	0.08	5.20	1.30	1.30
12	15	735	0.38	4.59	0.03	0.12	0.08	1.48	0.37	0.37
12	30	750	0.37	4.63	0.03	0.12	0.08	0.68	0.17	0.17
12	45	765	0.37	4.65	0.03	0.12	0.08	0.40	0.10	0.10
13	0	780	0.36	4.68	0.03	0.12	0.08	0.36	0.09	0.09
13	15	795	0.36	4.70	0.02	0.08	0.08	0.32	0.08	0.08
13	30	810	0.35	4.73	0.02	0.08	0.08	0.28	0.07	0.07
13	45	825	0.35	4.74	0.02	0.08	0.08	0.28	0.07	0.07
14	0	840	0.34	4.76	0.02	0.08	0.08	0.24	0.06	0.06
14	15	855	0.34	4.77	0.01	0.04	0.08	0.20	0.05	0.05
14	30	870	0.33	4.78	0.01	0.04	0.08	0.20	0.05	0.05
14	45	885	0.33	4.79	0.01	0.04	0.04	0.20	0.05	0.05
15	0	900	0.32	4.80	0.01	0.04	0.04	0.20	0.05	0.05
15	15	915	0.32	4.80	0.00	0.00	0.04	0.16	0.04	0.04
15	30	930	0.31	4.81	0.00	0.00	0.04	0.16	0.04	0.04
15	45	945	0.31	4.80	0.00	0.00	0.04	0.16	0.04	0.04
16	0	960	0.30	4.80	0.00	0.00	0.04	0.16	0.04	0.04
16	15	975	0.30	4.83	0.03	0.12	0.04	0.12	0.03	0.03
16	30	990	0.30	4.87	0.03	0.12	0.04	0.12	0.03	0.03
16	45	1005	0.29	4.90	0.03	0.12	0.04	0.12	0.03	0.03
17	0	1020	0.29	4.93	0.03	0.12	0.04	0.12	0.03	0.03
17	15	1035	0.28	4.92	0.01	0.00	0.04	0.12	0.03	0.03
17	30	1050	0.28	4.90	0.02	0.00	0.04	0.12	0.03	0.03
17	45	1065	0.28	4.88	0.02	0.00	0.04	0.12	0.03	0.03
18	0	1080	0.27	4.86	0.02	0.00	0.04	0.08	0.02	0.02
18	15	1095	0.27	4.88	0.02	0.08	0.04	0.08	0.02	0.02
18	30	1110	0.27	4.90	0.02	0.08	0.04	0.08	0.02	0.02
18	45	1125	0.26	4.92	0.02	0.08	0.00	0.08	0.02	0.02
19	0	1140	0.26	4.94	0.02	0.08	0.00	0.08	0.02	0.02
19	15	1155	0.26	4.96	0.02	0.08	0.00	0.04	0.01	0.01
19	30	1170	0.26	4.97	0.02	0.08	0.00	0.04	0.01	0.00
19	45	1185	0.25	4.99	0.01	0.04	0.00	0.04	0.01	0.00
20	0	1200	0.25	5.00	0.01	0.04	0.00	0.04	0.01	0.00
20	15	1215	0.25	5.01	0.01	0.04	0.00	0.04	0.01	0.00
20	30	1230	0.25	5.02	0.01	0.04	0.00	0.04	0.01	0.00
20	45	1245	0.24	5.03	0.01	0.04	0.00	0.04	0.01	0.00
21	0	1260	0.24	5.04	0.01	0.04	0.00	0.04	0.01	0.00
21	15	1275	0.24	5.05	0.01	0.04	0.00	0.00	0.00	0.00
21	30	1290	0.24	5.05	0.01	0.04	0.00	0.00	0.00	0.00
21	45	1305	0.23	5.06	0.00	0.00	0.00	0.00	0.00	0.00
22	0	1320	0.23	5.06	0.00	0.00	0.00	0.00	0.00	0.00
22	15	1335	0.23	5.06	0.00	0.00	0.00	0.00	0.00	0.00
22	30	1350	0.23	5.06	0.00	0.00	0.00	0.00	0.00	0.00
22	45	1365	0.22	5.06	0.00	0.00	0.00	0.00	0.00	0.00
23	0	1380	0.22	5.06	0.00	0.00	0.00	0.00	0.00	0.00
23	15	1395	0.22	5.06	0.00	0.00	0.00	0.00	0.00	0.00
23	30	1410	0.22	5.05	0.00	0.00	0.00	0.00	0.00	0.00
23	45	1425	0.21	5.05	0.01	0.00	0.00	0.00	0.00	0.00
24	0	1440	0.21	5.04	0.01	0.00	0.00	0.00	0.00	0.00
								Total rain inches	5.18	5.04

COMPOSITE METHOD DESIGN STORMS

RETURN PERIOD = 100 YEARS
RAIN INTERVAL = 15 MINUTES

Storm Duration Hrs	Storm Duration Minutes	Storm Duration Cum. Min.	Average Intensity in/hr	Rainfall Allotted inches	Rainfall Incremental inches	Rainfall Incremental in/hr	Decreasing Intensities in/hr	Reordered Intensities in/hr	Computed Reordered Rainfall inches	Modify Reordered Rainfall inches
0	0	0								
0	15	15	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
0	30	30	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
0	45	45	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
1	0	60	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
1	15	75	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
1	30	90	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
1	45	105	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
2	0	120	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
2	15	135	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
2	30	150	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
2	45	165	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
3	0	180	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
3	15	195	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
3	30	210	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
3	45	225	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
4	0	240	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
4	15	255	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
4	30	270	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
4	45	285	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
5	0	300	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
5	15	315	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
5	30	330	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
5	45	345	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
6	0	360	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
6	15	375	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
6	30	390	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
6	45	405	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
7	0	420	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
7	15	435	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
7	30	450	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
7	45	465	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
8	0	480	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
8	15	495	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
8	30	510	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
8	45	525	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
9	0	540	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
9	15	555	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
9	30	570	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
9	45	585	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
10	0	600	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
10	15	615	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
10	30	630	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
10	45	645	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
11	0	660	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
11	15	675	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
11	30	690	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
11	45	705	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
12	0	720	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
12	15	735	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
12	30	750	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
12	45	765	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
13	0	780	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
13	15	795	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
13	30	810	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
13	45	825	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
14	0	840	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
14	15	855	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
14	30	870	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
14	45	885	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
15	0	900	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
15	15	915	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
15	30	930	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
15	45	945	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
16	0	960	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
16	15	975	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
16	30	990	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
16	45	1005	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
17	0	1020	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
17	15	1035	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
17	30	1050	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
17	45	1065	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
18	0	1080	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
18	15	1095	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
18	30	1110	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
18	45	1125	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
19	0	1140	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
19	15	1155	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
19	30	1170	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
19	45	1185	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
20	0	1200	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
20	15	1215	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
20	30	1230	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
20	45	1245	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
21	0	1260	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
21	15	1275	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
21	30	1290	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
21	45	1305	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
22	0	1320	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
22	15	1335	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
22	30	1350	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
22	45	1365	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
23	0	1380	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
23	15	1395	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
23	30	1410	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
23	45	1425	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
24	0	1440	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
								Total rain inches	7.77	7.66

COMPOSITE METHOD DESIGN STORMS

RETURN PERIOD = 500 YEARS
RAIN INTERVAL = 15 MINUTES

Storm Duration Hrs	Storm Duration Minutes	Storm Duration Cum. Min.	Average Intensity in/hr	Rainfall Allotted inches	Rainfall Incremental inches	Rainfall Incremental in/hr	Decreasing Intensities in/hr	Reordered Intensities in/hr	Computed Reordered Rainfall inches	Modify Reordered Rainfall inches
0	0	0								
0	15	15	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
0	30	30	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
0	45	45	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
1	0	60	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
1	15	75	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
1	30	90	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
1	45	105	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
2	0	120	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
2	15	135	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
2	30	150	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
2	45	165	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
3	0	180	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
3	15	195	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
3	30	210	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
3	45	225	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
4	0	240	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
4	15	255	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
4	30	270	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
4	45	285	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
5	0	300	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
5	15	315	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
5	30	330	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
5	45	345	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
6	0	360	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
6	15	375	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
6	30	390	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
6	45	405	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
7	0	420	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
7	15	435	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
7	30	450	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
7	45	465	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
8	0	480	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
8	15	495	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
8	30	510	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
8	45	525	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
9	0	540	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
9	15	555	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
9	30	570	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
9	45	585	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
10	0	600	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
10	15	615	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
10	30	630	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
10	45	645	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
11	0	660	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
11	15	675	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
11	30	690	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
11	45	705	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
12	0	720	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
12	15	735	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
12	30	750	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
12	45	765	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
13	0	780	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
13	15	795	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
13	30	810	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
13	45	825	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
14	0	840	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
14	15	855	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
14	30	870	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
14	45	885	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
15	0	900	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
15	15	915	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
15	30	930	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
15	45	945	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
16	0	960	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
16	15	975	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
16	30	990	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
16	45	1005	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
17	0	1020	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
17	15	1035	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
17	30	1050	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
17	45	1065	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
18	0	1080	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
18	15	1095	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
18	30	1110	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
18	45	1125	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
19	0	1140	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
19	15	1155	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
19	30	1170	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
19	45	1185	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
20	0	1200	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
20	15	1215	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
20	30	1230	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
20	45	1245	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
21	0	1260	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
21	15	1275	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
21	30	1290	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
21	45	1305	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
22	0	1320	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
22	15	1335	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
22	30	1350	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
22	45	1365	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
23	0	1380	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
23	15	1395	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
23	30	1410	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
23	45	1425	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
24	0	1440	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
								Total rain inches	[illegible]	[illegible]

Table 2

Table 3

SCS TYPE II DISTRIBUTION DESIGN STORM METHOD

RETURN PERIOD = 10 YEARS
STORM DURATION = 24 HOURS
PT RAINFALL DEPTH 5.04 INCHES
NWS ADJUSTMENT* = 1

NONDIMENSIONAL TIME fract of 24 hr	NONDIMENSIONAL RAINFALL Px/P24 **	Cumulative Minutes	Accumul Rainfall inches	Increment Rainfall inches	Adjusted Rainfall inches
0	0	0	0.000	0.000	0.000
0.01	0.002	14	0.010	0.010	0.010
0.021	0.005	30	0.025	0.015	0.015
0.031	0.008	45	0.040	0.015	0.015
0.042	0.011	60	0.055	0.015	0.015
0.052	0.014	75	0.071	0.015	0.015
0.063	0.017	91	0.086	0.015	0.015
0.073	0.02	105	0.101	0.015	0.015
0.083	0.023	120	0.116	0.015	0.015
0.094	0.026	135	0.131	0.015	0.015
0.104	0.029	150	0.146	0.015	0.015
0.115	0.032	166	0.161	0.015	0.015
0.125	0.035	180	0.176	0.015	0.015
0.135	0.038	194	0.192	0.015	0.015
0.146	0.041	210	0.207	0.015	0.015
0.156	0.044	225	0.222	0.015	0.015
0.167	0.048	240	0.242	0.020	0.020
0.177	0.052	255	0.262	0.020	0.020
0.188	0.055	271	0.282	0.020	0.020
0.198	0.06	285	0.302	0.020	0.020
0.208	0.064	300	0.323	0.020	0.020
0.219	0.068	315	0.343	0.020	0.020
0.229	0.072	330	0.363	0.020	0.020
0.24	0.076	346	0.383	0.020	0.020
0.25	0.08	360	0.403	0.020	0.020
0.26	0.085	374	0.428	0.025	0.025
0.271	0.09	390	0.454	0.025	0.025
0.281	0.095	405	0.479	0.025	0.025
0.292	0.1	420	0.504	0.025	0.025
0.302	0.105	435	0.529	0.025	0.025
0.313	0.11	451	0.554	0.025	0.025
0.323	0.115	465	0.580	0.025	0.025
0.333	0.12	480	0.605	0.025	0.025
0.344	0.126	495	0.635	0.030	0.030
0.354	0.133	510	0.670	0.035	0.035
0.365	0.14	526	0.706	0.035	0.035
0.375	0.147	540	0.741	0.035	0.035
0.385	0.155	554	0.781	0.040	0.040
0.396	0.163	570	0.822	0.040	0.040
0.406	0.172	585	0.867	0.045	0.045
0.417	0.181	600	0.912	0.045	0.045
0.427	0.191	615	0.963	0.050	0.050
0.438	0.203	631	1.023	0.060	0.060
0.448	0.219	645	1.099	0.076	0.076
0.458	0.236	660	1.189	0.091	0.091
0.469	0.257	675	1.295	0.106	0.106
0.479	0.283	690	1.426	0.131	0.131
0.49	0.387	706	1.950	0.524	0.524
0.5	0.663	720	3.342	1.391	1.391
0.51	0.707	734	3.563	0.222	0.222
0.521	0.735	750	3.704	0.141	0.141
0.531	0.758	765	3.820	0.116	0.116
0.542	0.776	790	3.911	0.091	0.091
0.552	0.791	795	3.987	0.076	0.076
0.563	0.804	811	4.052	0.066	0.066
0.573	0.815	825	4.108	0.055	0.055
0.583	0.825	840	4.158	0.050	0.050
0.594	0.834	855	4.203	0.045	0.045
0.604	0.842	870	4.244	0.040	0.040
0.615	0.849	886	4.279	0.035	0.035
0.625	0.856	900	4.314	0.035	0.035
0.635	0.863	914	4.350	0.035	0.035
0.646	0.869	930	4.380	0.030	0.030
0.656	0.875	945	4.410	0.030	0.030
0.667	0.881	960	4.440	0.030	0.030
0.677	0.887	975	4.470	0.030	0.030
0.688	0.893	991	4.501	0.030	0.030
0.698	0.898	1005	4.526	0.025	0.025
0.708	0.903	1020	4.551	0.025	0.025
0.719	0.908	1035	4.576	0.025	0.025
0.729	0.913	1050	4.602	0.025	0.025
0.74	0.918	1066	4.627	0.025	0.025
0.75	0.922	1080	4.647	0.020	0.020
0.76	0.926	1094	4.667	0.020	0.020
0.771	0.93	1110	4.687	0.020	0.020
0.781	0.934	1125	4.707	0.020	0.020
0.792	0.938	1140	4.728	0.020	0.020
0.802	0.942	1155	4.748	0.020	0.020
0.813	0.946	1171	4.768	0.020	0.020
0.823	0.95	1185	4.788	0.020	0.020
0.833	0.953	1200	4.803	0.015	0.015
0.844	0.956	1215	4.818	0.015	0.015
0.854	0.959	1230	4.833	0.015	0.015
0.865	0.962	1246	4.848	0.015	0.015
0.875	0.965	1260	4.864	0.015	0.015
0.885	0.968	1274	4.879	0.015	0.015
0.896	0.971	1290	4.894	0.015	0.015
0.906	0.974	1305	4.909	0.015	0.015
0.917	0.977	1320	4.924	0.015	0.015
0.927	0.98	1335	4.939	0.015	0.015
0.938	0.983	1351	4.954	0.015	0.015
0.948	0.986	1365	4.969	0.015	0.015
0.958	0.989	1380	4.985	0.015	0.015
0.969	0.992	1395	5.000	0.015	0.015
0.979	0.995	1410	5.015	0.015	0.015
0.99	0.998	1426	5.030	0.015	0.015
1	1	1440	5.040	0.010	0.010

* NWS Adjustment of point rainfall depth to average over an area from 1967 B&V report; contributing drainage area, acres: 10.000
** Px/P24 is the ratio of accumulated rainfall at time 'x' to the accumulated rainfall in 24 hours

Total rain, inches 5.040

SCS TYPE II DISTRIBUTION DESIGN STORM METHOD

RETURN PERIOD = 100 YEARS
STORM DURATION = 24 HOURS
PT RAINFALL DEPTH 7.68 INCHES
NWS ADJUSTMENT* = 1

NONDIMENSIONAL TIME fract of 24 h	NONDIMENSIONAL RAINFALL Px/P24 **	Cum Min	Accumul Rainfall inches	Increment Rainfall inches	Adjusted Rainfall inches
0	0	0	0.000	0.000	0.000
0.01	0.002	14	0.015	0.015	0.015
0.021	0.005	30	0.038	0.023	0.023
0.031	0.008	45	0.061	0.023	0.023
0.042	0.011	60	0.084	0.023	0.023
0.052	0.014	75	0.108	0.023	0.023
0.063	0.017	91	0.131	0.023	0.023
0.073	0.02	105	0.154	0.023	0.023
0.083	0.023	120	0.177	0.023	0.023
0.094	0.026	135	0.200	0.023	0.023
0.104	0.029	150	0.223	0.023	0.023
0.115	0.032	166	0.246	0.023	0.023
0.125	0.035	180	0.269	0.023	0.023
0.135	0.038	194	0.292	0.023	0.023
0.146	0.041	210	0.315	0.023	0.023
0.156	0.044	225	0.338	0.023	0.023
0.167	0.048	240	0.369	0.031	0.031
0.177	0.052	255	0.399	0.031	0.031
0.188	0.056	271	0.430	0.031	0.031
0.198	0.06	285	0.461	0.031	0.031
0.208	0.064	300	0.492	0.031	0.031
0.219	0.068	315	0.522	0.031	0.031
0.229	0.072	330	0.553	0.031	0.031
0.24	0.076	346	0.584	0.031	0.031
0.25	0.08	360	0.614	0.031	0.031
0.26	0.085	374	0.653	0.038	0.038
0.271	0.09	390	0.691	0.038	0.038
0.281	0.095	405	0.730	0.038	0.038
0.292	0.1	420	0.768	0.038	0.038
0.302	0.105	435	0.806	0.038	0.038
0.313	0.11	451	0.845	0.039	0.039
0.323	0.115	465	0.883	0.038	0.038
0.333	0.12	480	0.922	0.038	0.038
0.344	0.126	495	0.968	0.046	0.046
0.354	0.133	510	1.021	0.054	0.054
0.365	0.14	526	1.075	0.054	0.054
0.375	0.147	540	1.129	0.054	0.054
0.385	0.155	554	1.190	0.061	0.061
0.396	0.163	570	1.252	0.061	0.061
0.406	0.172	585	1.321	0.069	0.069
0.417	0.181	600	1.390	0.069	0.069
0.427	0.191	615	1.467	0.077	0.077
0.438	0.203	631	1.559	0.092	0.092
0.448	0.218	645	1.674	0.115	0.115
0.458	0.236	660	1.812	0.138	0.138
0.469	0.257	675	1.974	0.161	0.161
0.479	0.283	690	2.173	0.200	0.200
0.49	0.387	706	2.972	0.799	0.799
0.5	0.663	720	5.092	2.120	2.120
0.51	0.707	734	5.430	0.338	0.338
0.521	0.735	750	5.645	0.215	0.215
0.531	0.758	765	5.821	0.177	0.177
0.542	0.776	780	5.960	0.138	0.138
0.552	0.791	795	6.075	0.115	0.115
0.563	0.804	811	6.175	0.100	0.100
0.573	0.815	825	6.259	0.084	0.084
0.583	0.825	840	6.336	0.077	0.077
0.594	0.834	855	6.405	0.069	0.069
0.604	0.842	870	6.467	0.061	0.061
0.615	0.849	886	6.520	0.054	0.054
0.625	0.856	900	6.574	0.054	0.054
0.635	0.863	914	6.628	0.054	0.054
0.646	0.869	930	6.674	0.046	0.046
0.656	0.875	945	6.720	0.046	0.046
0.667	0.881	960	6.766	0.046	0.046
0.677	0.887	975	6.812	0.046	0.046
0.688	0.893	991	6.858	0.046	0.046
0.698	0.898	1005	6.897	0.038	0.038
0.708	0.903	1020	6.935	0.038	0.038
0.719	0.908	1035	6.973	0.038	0.038
0.729	0.913	1050	7.012	0.038	0.038
0.74	0.918	1066	7.050	0.038	0.038
0.75	0.922	1080	7.081	0.031	0.031
0.76	0.926	1094	7.112	0.031	0.031
0.771	0.93	1110	7.142	0.031	0.031
0.781	0.934	1125	7.173	0.031	0.031
0.792	0.938	1140	7.204	0.031	0.031
0.802	0.942	1155	7.235	0.031	0.031
0.813	0.946	1171	7.265	0.031	0.031
0.823	0.95	1185	7.296	0.031	0.031
0.833	0.953	1200	7.319	0.023	0.023
0.844	0.956	1215	7.342	0.023	0.023
0.854	0.959	1230	7.365	0.023	0.023
0.865	0.962	1246	7.388	0.023	0.023
0.875	0.965	1260	7.411	0.023	0.023
0.885	0.968	1274	7.434	0.023	0.023
0.896	0.971	1290	7.457	0.023	0.023
0.906	0.974	1305	7.480	0.023	0.023
0.917	0.977	1320	7.503	0.023	0.023
0.927	0.98	1335	7.526	0.023	0.023
0.938	0.983	1351	7.549	0.023	0.023
0.948	0.986	1365	7.572	0.023	0.023
0.958	0.989	1380	7.596	0.023	0.023
0.969	0.992	1395	7.619	0.023	0.023
0.979	0.995	1410	7.642	0.023	0.023
0.99	0.998	1426	7.665	0.023	0.023
1	1	1440	7.680	0.015	0.015

* NWS Adjustment of point rainfall depth to average over an area from 1967 B&V report; contributing drainage area, acres: 10.000
** Px/P24 is the ratio of accumulated rainfall at time 'x' to the accumulated rainfall in 24 hours

Total rain, inches 7.680

SCS TYPE II DISTRIBUTION DESIGN STORM METHOD

RETURN PERIOD = 500 YEARS
STORM DURATION = 24 HOURS
PT RAINFALL DEPTH 9.84 INCHES
NWS ADJUSTMENT* = 1

NONDIMENSIONAL TIME fract of 24 h	NONDIMENSIONAL RAINFALL Px/P24 **	Cum Min	Accumul Rainfall inches	Increment Rainfall inches	Adjusted Rainfall inches
0	0	0	0.000	0.000	0.000
0.01	0.002	14	0.020	0.020	0.020
0.021	0.005	30	0.049	0.030	0.030
0.031	0.008	45	0.079	0.030	0.030
0.042	0.011	60	0.108	0.030	0.030
0.052	0.014	75	0.138	0.030	0.030
0.063	0.017	91	0.167	0.030	0.030
0.073	0.02	105	0.197	0.030	0.030
0.083	0.023	120	0.226	0.030	0.030
0.094	0.026	135	0.256	0.030	0.030
0.104	0.029	150	0.285	0.030	0.030
0.115	0.032	166	0.315	0.030	0.030
0.125	0.035	180	0.344	0.030	0.030
0.135	0.038	194	0.374	0.030	0.030
0.146	0.041	210	0.403	0.030	0.030
0.156	0.044	225	0.433	0.030	0.030
0.167	0.048	240	0.472	0.039	0.039
0.177	0.052	255	0.512	0.039	0.039
0.188	0.056	271	0.551	0.039	0.039
0.198	0.06	285	0.590	0.039	0.039
0.208	0.064	300	0.630	0.039	0.039
0.219	0.068	315	0.669	0.039	0.039
0.229	0.072	330	0.708	0.039	0.039
0.24	0.076	346	0.748	0.039	0.039
0.25	0.08	360	0.787	0.039	0.039
0.26	0.085	374	0.836	0.049	0.049
0.271	0.09	390	0.886	0.049	0.049
0.281	0.095	405	0.935	0.049	0.049
0.292	0.1	420	0.984	0.049	0.049
0.302	0.105	435	1.033	0.049	0.049
0.313	0.11	451	1.082	0.049	0.049
0.323	0.115	465	1.132	0.049	0.049
0.333	0.12	480	1.181	0.049	0.049
0.344	0.126	495	1.240	0.059	0.059
0.354	0.133	510	1.309	0.069	0.069
0.365	0.14	526	1.378	0.069	0.069
0.375	0.147	540	1.446	0.069	0.069
0.385	0.155	554	1.525	0.079	0.079
0.396	0.163	570	1.604	0.079	0.079
0.406	0.172	585	1.692	0.089	0.089
0.417	0.181	600	1.781	0.089	0.089
0.427	0.191	615	1.879	0.098	0.098
0.438	0.203	631	1.998	0.118	0.118
0.448	0.218	645	2.145	0.148	0.148
0.458	0.236	660	2.322	0.177	0.177
0.469	0.257	675	2.529	0.207	0.207
0.479	0.283	690	2.785	0.256	0.256
0.49	0.387	706	3.808	1.023	1.023
0.5	0.663	720	6.524	2.716	2.716
0.51	0.707	734	6.957	0.433	0.433
0.521	0.735	750	7.232	0.276	0.276
0.531	0.758	765	7.459	0.226	0.226
0.542	0.776	780	7.636	0.177	0.177
0.552	0.791	795	7.783	0.148	0.148
0.563	0.804	811	7.911	0.128	0.128
0.573	0.815	825	8.020	0.108	0.108
0.583	0.825	840	8.118	0.098	0.098
0.594	0.834	855	8.207	0.089	0.089
0.604	0.842	870	8.285	0.079	0.079
0.615	0.849	886	8.354	0.069	0.069
0.625	0.856	900	8.423	0.069	0.069
0.635	0.863	914	8.492	0.069	0.069
0.646	0.869	930	8.551	0.059	0.059
0.656	0.875	945	8.610	0.059	0.059
0.667	0.881	960	8.669	0.059	0.059
0.677	0.887	975	8.728	0.059	0.059
0.688	0.893	991	8.787	0.059	0.059
0.698	0.898	1005	8.836	0.049	0.049
0.708	0.903	1020	8.886	0.049	0.049
0.719	0.908	1035	8.935	0.049	0.049
0.729	0.913	1050	8.984	0.049	0.049
0.74	0.918	1066	9.033	0.049	0.049
0.75	0.922	1080	9.072	0.039	0.039
0.76	0.926	1094	9.112	0.039	0.039
0.771	0.93	1110	9.151	0.039	0.039
0.781	0.934	1125	9.191	0.039	0.039
0.792	0.938	1140	9.230	0.039	0.039
0.802	0.942	1155	9.269	0.039	0.039
0.813	0.946	1171	9.309	0.039	0.039
0.823	0.95	1185	9.348	0.039	0.039
0.833	0.953	1200	9.378	0.030	0.030
0.844	0.956	1215	9.407	0.030	0.030
0.854	0.959	1230	9.437	0.030	0.030
0.865	0.962	1246	9.466	0.030	0.030
0.875	0.965	1260	9.496	0.030	0.030
0.885	0.968	1274	9.525	0.030	0.030
0.896	0.971	1290	9.555	0.030	0.030
0.906	0.974	1305	9.584	0.030	0.030
0.917	0.977	1320	9.614	0.030	0.030
0.927	0.98	1335	9.643	0.030	0.030
0.938	0.983	1351	9.673	0.030	0.030
0.948	0.986	1365	9.702	0.030	0.030
0.958	0.989	1380	9.732	0.030	0.030
0.969	0.992	1395	9.761	0.030	0.030
0.979	0.995	1410	9.791	0.030	0.030
0.99	0.998	1426	9.820	0.030	0.030
1	1	1440	9.840	0.020	0.020

* NWS Adjustment of point rainfall depth to average over an area from 1967 B&V report; contributing drainage area, acres: 10.000
** Px/P24 is the ratio of accumulated rainfall at time 'x' to the accumulated rainfall in 24 hours

Total rain, inches 9.840

Table 4

CURB INLET CAPACITY FOR 12.0-FOOT GUTTER SPREAD

GUTTER SLOPE IN PERCENT	GUTTER CAPACITY C.F.S.	CURB INLET DESIGN CAPACITY C.F.S. FOR INLET LENGTH						
		4 FOOT	5 FOOT	6 FOOT	8 FOOT	10 FOOT	11 FOOT	12 FOOT
0.5	2.7	G	G	G	G	G	G	G
1	3.7	G	G	G	G	G	G	G
2	5.3	5.3	G	G	G	G	G	G
3	6.5	5.4	5.6	5.7	G	G	G	G
4	7.5	5.4	5.9	6.0	6.8	7.1	7.3	7.4
6	9.1	5.6	6.4	6.5	7.4	8.1	8.5	8.9
8	10.6	5.7	6.8	6.9	8.0	9.0	9.4	9.8
10	11.8	6.4	7.2	7.9	9.1	10.1	10.6	11.1
12	12.9	7.1	7.9	8.6	10.0	11.2	11.7	12.2
14	14.0	7.6	8.6	9.4	10.8	12.1	12.7	13.2

NOTES & REFERENCES:

1. Inlet capacities derived from "The Design of Stormwater Inlets" Johns Hopkins University, 1956
2. Gutter capacity calculated by Izzard's Equation
3. Inlet capacity is for ¼" per foot street crown and inlet throat and transition geometry per Figure 8-0
4. Gutter deflectors are required for inlets on slopes of 4 percent and steeper.
5. Linear interpolation within the range of the table is permitted for slopes and corresponding capacities not shown.
6. Reduce above theoretical capacities by 20% for clogging allowance per Section 5603.1.B.
7. "G" indicates inlet capacity is greater than gutter capacity and the 20% capacity reduction is not required.

From Kansas City Metropolitan Chapter of the
American Public Works Association
Section 5600 Storm Drainage Systems and Facilities

Table 5
CURB INLET CAPACITY FOR 11.5-FOOT GUTTER SPREAD

GUTTER SLOPE IN PERCENT	GUTTER CAPACITY C.F.S.	CURB INLET DESIGN CAPACITY C.F.S. FOR INLET LENGTH 4 FOOT	5 FOOT	6 FOOT	8 FOOT	10 FOOT	11 FOOT	12 FOOT
0.5	2.4	G	G	G	G	G	G	G
1	3.3	G	G	G	G	G	G	G
2	4.7	G	G	G	G	G	G	G
3	5.7	5.5	G	G	G	G	G	G
4	6.6	5.3	5.9	6.0	6.3	6.6	6.6	6.6
6	8.1	5.1	6.1	6.5	7.2	7.9	8.1	8.1
8	9.4	5.7	6.3	6.9	8.0	8.9	9.1	9.2
10	10.5	6.3	7.0	7.7	8.9	9.9	10.1	10.3
12	11.5	6.9	7.7	8.4	9.7	10.8	11.1	11.4
14	12.4	7.6	8.5	9.3	10.8	12.0	12.4	12.4

NOTES & REFERENCES:

1. Inlet capacities derived from "The Design of Stormwater Inlets" Johns Hopkins University, 1956
2. Gutter capacity calculated by Izzard's Equation
3. Inlet capacity is for ¼" per foot street crown and inlet throat and transition geometry per Figure 8-0
4. Gutter deflectors are required for inlets on slopes of 4 percent and steeper.
5. Linear interpolation within the range of the table is permitted for slopes and corresponding capacities not shown.
6. Reduce above theoretical capacities by 20% for clogging allowance per Section 5603.1.B.
7. "G" indicates inlet capacity is greater than gutter capacity and the 20% capacity reduction is not required.

From Kansas City Metropolitan Chapter of the
American Public Works Association
Section 5600 Storm Drainage Systems and Facilities

Table 6
CURB INLET CAPACITY
FOR
10.5-FOOT GUTTER SPREAD

GUTTER SLOPE IN PERCENT	GUTTER CAPACITY C.F.S.	CURB INLET DESIGN CAPACITY C.F.S. FOR INLET LENGTH						
		4 FOOT	5 FOOT	6 FOOT	8 FOOT	10 FOOT	11 FOOT	12 FOOT
0.5	1.8	G	G	G	G	G	G	G
1	2.6	G	G	G	G	G	G	G
2	3.7	G	G	G	G	G	G	G
3	4.5	G	G	G	G	G	G	G
4	5.1	4.6	4.8	5.1	G	G	G	G
6	6.3	4.9	5.3	5.7	6.3	7.2	G	G
8	7.3	5.1	5.7	6.3	7.2	G	G	G
10	8.2	5.9	6.6	7.2	8.1	G	G	G
12	8.9	6.3	7.1	7.8	8.9	G	G	G
14	9.6	6.9	7.7	8.4	9.6	G	G	G

NOTES & REFERENCES:

1. Inlet capacities derived from "The Design of Stormwater Inlets" Johns Hopkins University, 1956

2. Gutter capacity calculated by Izzard's Equation

3. Inlet capacity is for ¼" per foot street crown and inlet throat and transition geometry per Figure 8-0

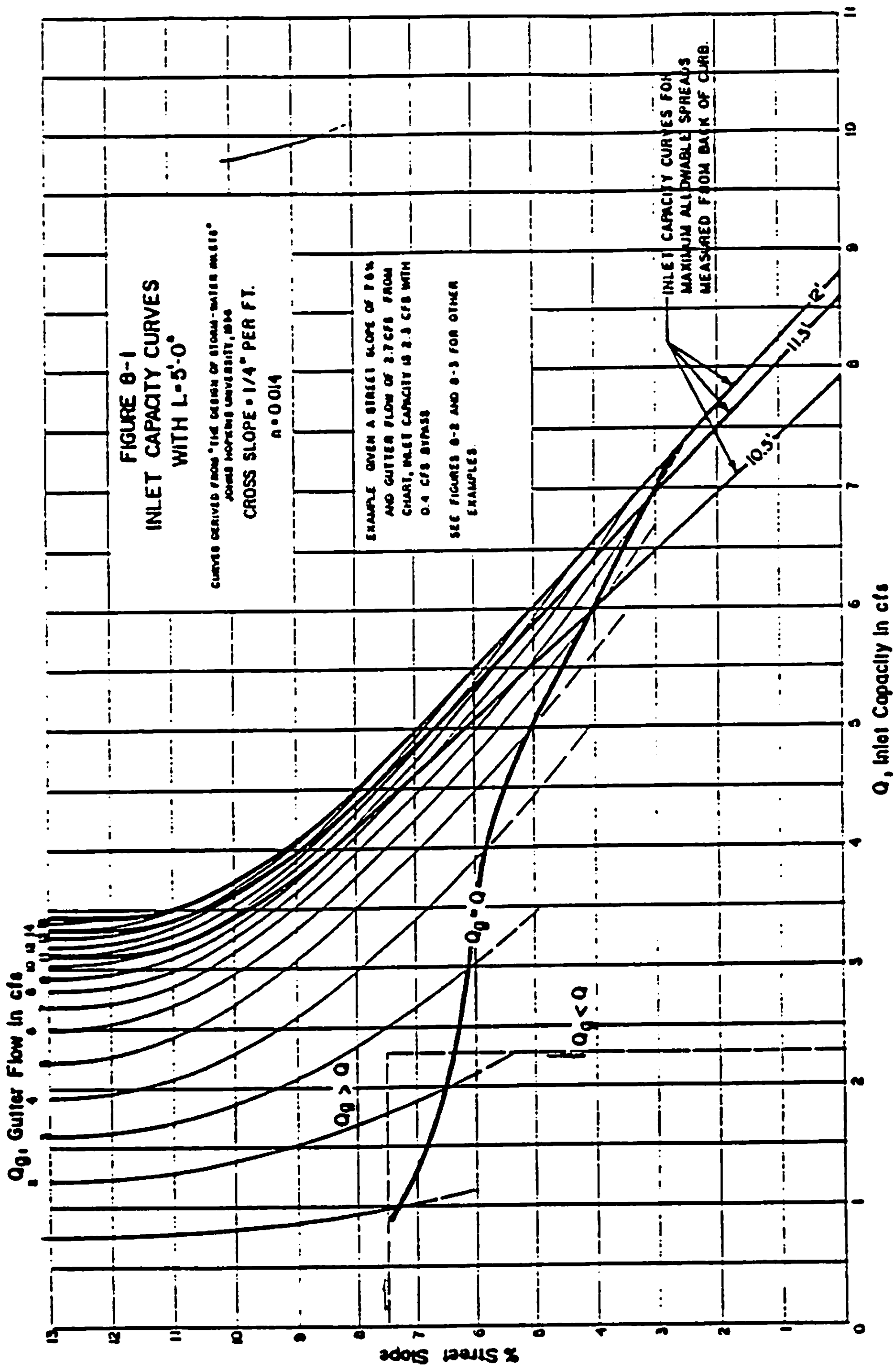
4. Gutter deflectors are required for inlets on slopes of 4 percent and steeper.

5. Linear interpolation within the range of the table is permitted for slopes and corresponding capacities not shown.

6. Reduce above theoretical capacities by 20% for clogging allowance per Section 5603.1.B.

7. "G" indicates inlet capacity is greater than gutter capacity and the 20% capacity reduction is not required.

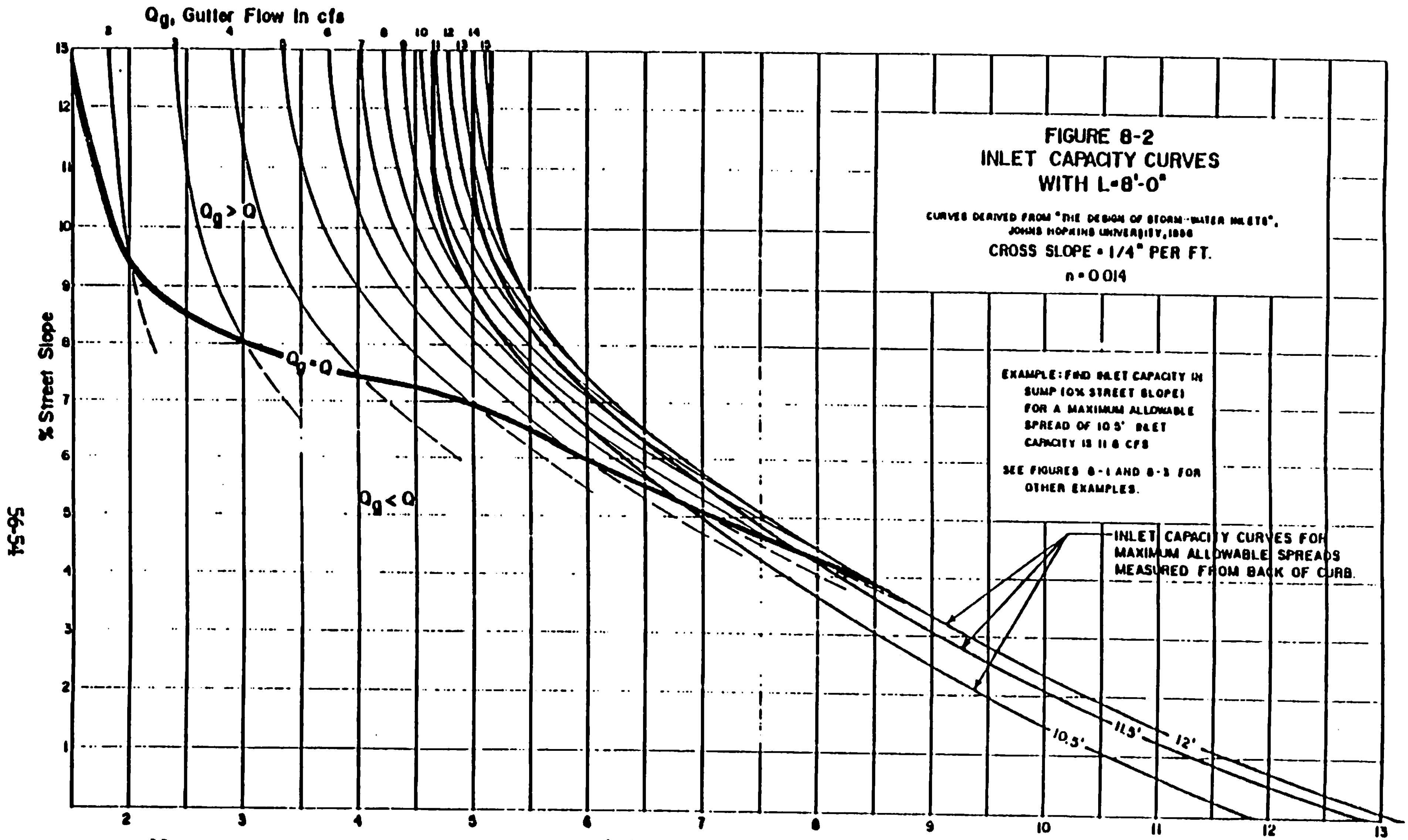
From Kansas City Metropolitan Chapter of the
American Public Works Association
Section 5600 Storm Drainage Systems and Facilities



Reduce above theoretical capacities by 20% for clogging allowance per Section 5603.1.B.

Nomograph A

From Kansas City Metropolitan Chapter of the American Public Works Association
Section 5600 Storm Drainage Systems and Facilities



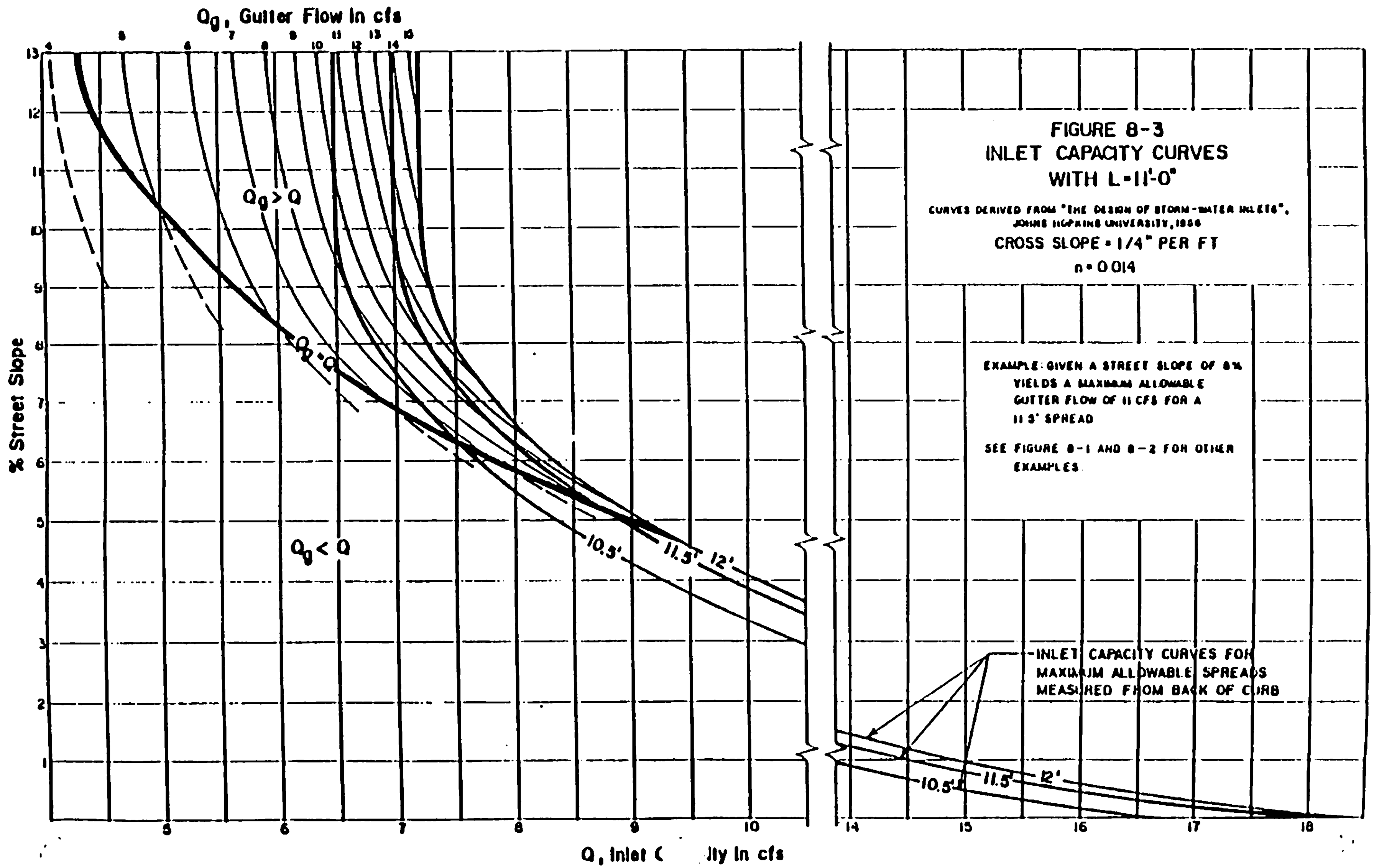
Nomograph B

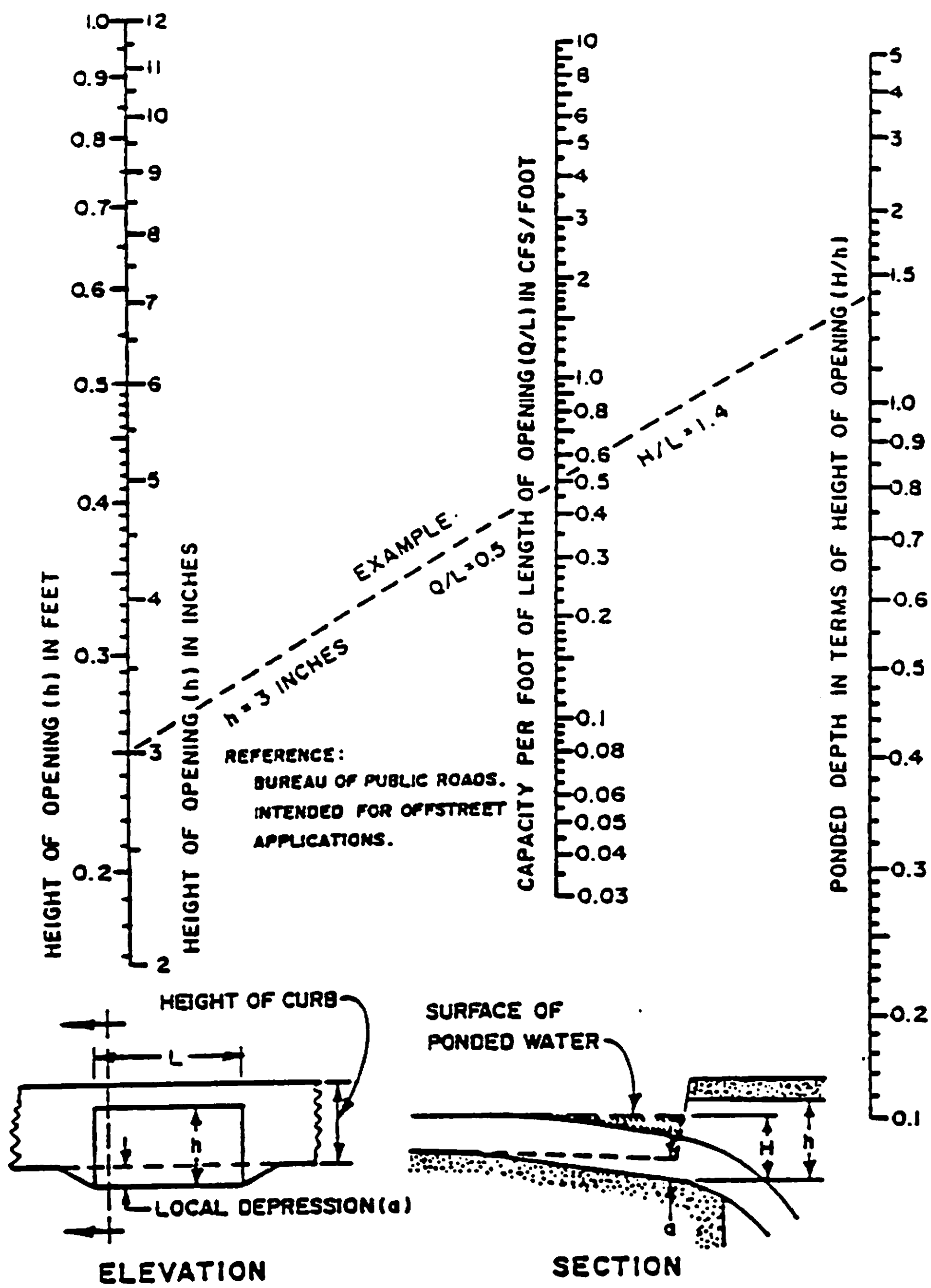
From Kansas City Metropolitan Chapter of the American Public Works Association
Section 5600 Storm Drainage Systems and Facilities

Reduce above theoretical capacities by 20% for clogging allowance per Section 5603.1.B.

Nomograph C

From Kansas City Metropolitan Chapter of the
American Public Works Association
Section 5600 Storm Drainage Systems and Facilities



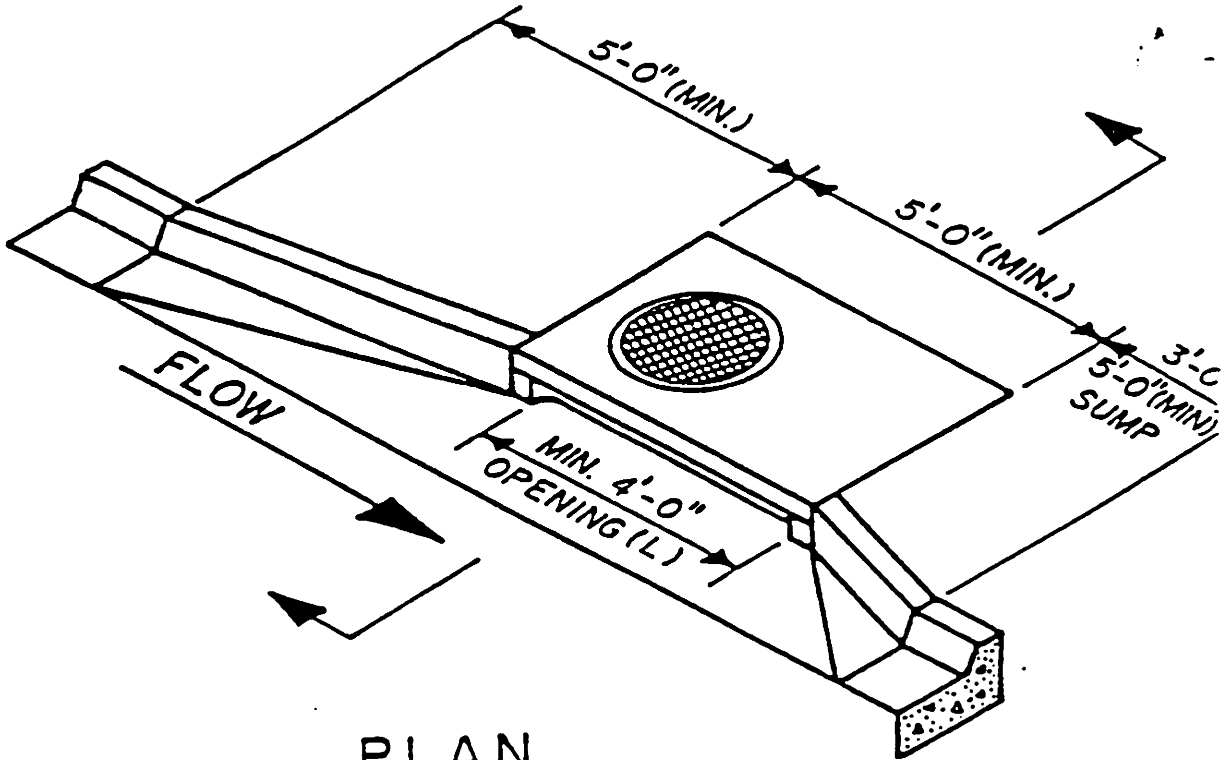


CAPACITY OF CURB OPENING INLET AT LOW POINT IN GRADE.

FIGURE 8-4

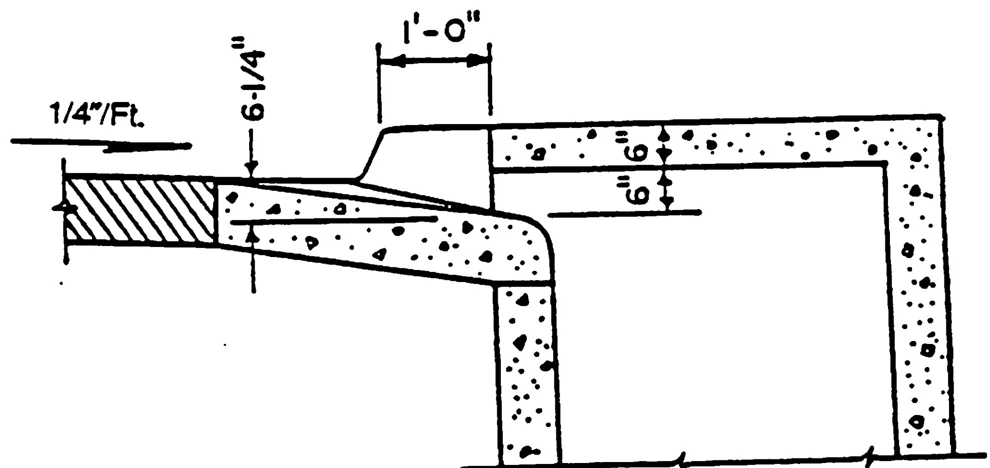
Nomograph D

From Kansas City Metropolitan Chapter of the
American Public Works Association
Section 5600 Storm Drainage Systems and Facilities



PLAN

NO SCALE



Detail 1

SECTION

NO SCALE

From Kansas City Metropolitan Chapter of the
American Public Works Association
Section 5600 Storm Drainage Systems and Facilities

FIGURE
8-0

CURB INLETS
MINIMUM HYDRAULIC DIMENSIONS

BLACK & VEATCH

MEMORANDUM

Leavenworth, Kansas
Stormwater Master Plan
New Development Plan Review Criteria

B&V Project 26529.110
B&V File W
May 28, 1999

To: Mike McDonald

From: Jeff Henson

New Development Plan Review Policies and Procedures

I. OBJECTIVE

This document lists the policies and procedures to be used by the City in reviewing drainage plans associated with new developments. A new development is defined as a tract of land containing four (4) or more lots to be developed.

II. POLICIES

The following policies relating to storm drainage were adopted by the City as part of the development of a Stormwater Master Plan (Master Plan).

II.1. A drainage report must be submitted by a professional engineer registered in the State of Kansas. The report shall be signed and sealed.

II.2. New Development plans shall include plans for the conveyance of stormwater and shall be signed and sealed by a professional engineer registered in the State of Kansas. The stormwater facilities shall be designed in accordance with design criteria set forth in "Drainage Criteria Manual, City of Leavenworth, Kansas," (Design Criteria) developed as part of the Master Plan.

II.3. Easements for drainage shall be granted to the City for access to underground drainage improvements and along open channels where the flow is greater than which could be conveyed by a 72 inch diameter pipe. Minimum easement requirements are listed in the Design Criteria.

II.4. Curbs and gutters shall be provided on all new roadways.

II.5. Off-site drainage improvements or detention storage shall be provided if peak flow rates resulting from the new development are greater than those shown in the Master Plan.

II.6. Underground drainage systems shall be installed in all areas where the flow can be contained in a 72 inch diameter pipe.

II.7. Systems shall be designed to address State and Federal regulations regarding stormwater quality.

III. PLAN REVIEW PROCEDURES

As part of the site plan approval process, Drainage Plans shall be reviewed by the Engineering staff. The drainage plan submittal shall consist of a Drainage Report and Drainage System Plans.

III.1. Drainage Report. The drainage report shall be submitted by the developer and it shall be signed and sealed by a professional engineer in the State of Kansas. The Drainage Report shall consist of the following:

III.1.1. Assumptions. A listing of the assumptions used in calculation of peak runoff rates and capacities of the proposed system and the existing receiving system.

III.1.2. Topographic Map. A topographic map showing the location of the site. The map shall include a plan of the existing surface features; the proposed development; the proposed drainage system location, size, and capacity; the existing receiving system location, size, and capacity; delineation of tributary areas to points of concentration in the drainage system; and delineation of individual lot drainage patterns. The map shall be at a scale of 1"=100' with 2 foot ground elevation contour lines.

III.1.3. Watershed Information. A table showing the land use, soil type, area, and slope of each tributary area.

III.1.4. Runoff Information. Tables summarizing the runoff characteristics shall be provided. The Rational method shall be used for estimating peak runoff for areas less than 300 acres. A hydrograph method for estimating peak runoff shall be used for areas larger than 300 acres. Computer models such as TR-55, TR-20, HEC-1, or SWMM are acceptable.

III.1.4.1. Rational Method Runoff Information. A table shall be provided showing the Rational method calculations including: cumulative area to the point of concentration, cumulative C value, time of concentration, rainfall intensity, and peak flow rate, drainage system size, and drainage system capacity. These calculations should be provided for both the pre-development and post-development conditions.

III.1.4.2. Hydrograph Method Runoff Information. A table shall be provided showing the runoff information including: drainage areas to each point of concentration, cumulative percent impervious, time of concentration for the watershed, design storm, peak flow rates, drainage system size, and drainage system capacity. These calculations should be provided for both the pre-development and post-development conditions.

III.1.5. Receiving System Information. A comparison of the ultimate development peak flow rate shown in the Master Plan versus the peak flow rate calculated in the report should be made. If the new development increases peak flows above those shown in the Master Plan, then off-site drainage improvements or a detention basin will be required.

III.1.5.1. Off-Site Drainage. Off-site drainage improvements required in section III.1.5. shall be identified in the Drainage Report. A topographic map, watershed information, and runoff information shall be provided for off-site drainage improvements in accordance with sections III.1.1. through III.1.4.

III.1.5.2. Detention Storage. Detention storage can be provided in lieu of off-site drainage improvements. Storage shall be provided so that peak discharge rates are equal to or less than those shown in the Master Plan. A topographic map meeting the requirements of III.1.2 shall be included. Additional items shall include stage-storage-discharge curves, inflow and outflow hydrographs, and spillway configuration and capacity.

III.2. Drainage System Plans. Plan and profile of the drainage system shall be submitted. The drainage system drawings shall be in conformance with the following.

Plan:	1-inch =	50-feet
Profile:		
Vertical:	1-inch =	10-feet
Horizontal:	1-inch =	50-feet
Cross-Sections:		
Vertical:	1-inch =	10-feet
Horizontal:	1-inch =	50-feet

III.3. City Review. Drainage Plans shall be reviewed by Engineering staff. Comments shall be provided to the developer within 60 days of receipt. Building permits shall not be granted until final approval of the Drainage Plans is obtained.

III.4. Construction Inspection. City building inspectors shall verify that the drainage system and site grading are constructed according to plans. Any changes in the plan during construction shall be approved by the City.

III.5. Permit to Occupy. The developer must show proof that the drainage system and site grading were constructed in accordance with plans to receive the permit to occupy. Proof shall consist of a final site survey including spot elevation checks. Verification of any changes to the plans during construction shall also be submitted with the final site survey and shall show altered drainage patterns. Comments shall be provided to the developer within 30 days of receipt of the final site survey.

Summary of Data Collected					
Number	Agency Contacted for Document	Title of Document	Date	Preparer of Document	Type of Information Received
Utility Maps					
1	City of Leavenworth Public Works Dept.	Stormwater Sewer Maps Sections 1, 2, 3, 4 (SE), 6 (SW), 7 (NW,SW), 9(NE), 10, 11, 12, 13 (NE,NW), 14 (NE,NW), 15 (NE), 18 (NW), 25 (SE,SW,NW), 26, 27, 34, 35, 36	June 1994	M. J. Harden Associates, Inc.	Maps include streets, buildings with addresses, waterbodies, waterways, 2-foot contours, ground elevations, manholes, inlets, area drains, culverts, and storm sewers with size and type. Digital files include DTM-generated top-of-structure elevations and x-y coordinates. (3 full-size sets, 1 w/Flow Line depths, scale 1" = 100 feet).
2	City of Leavenworth Public Works Dept.	Leavenworth, Kansas Scale: 1 inch = 500 feet	September 1983	City of Leavenworth	City plan map with streets, major buildings, waterways with main channel, 100-year and 500-year flood boundaries, and storm sewers with sizes.

Summary of Data Collected (Continued)					
Number	Agency Contacted for Document	Title of Document	Date	Preparer of Document	Type of Information Received
Data on Recent Improvement Projects					
3	City of Leavenworth Public Works Dept.	Storm Drainage Improvements 17th St. & Vilas St. Leavenworth, Kansas Storm Drainage Improvements 5th Ave. & South St. Leavenworth, Kansas	April 27, 1995 April 27, 1995	Shafer, Kline, & Warren, P.A.	Culvert plan, profile, and details.
4	City of Leavenworth Public Works Dept.	4th Street at the Veteran's Hospital Access Road Leavenworth, Kansas	April 1986	Johnson, Brickell, Mulcahy, and Associates, Inc. Consulting Engineers	Plan sheet.
5	City of Leavenworth Public Works Dept.	Hometown Village P.V.D. Phase I	February 1992 July 1994	D. G. White & Associates Engineering and Surveying	Plan, profile, and storm sewer details.
6	City of Leavenworth Public Works Dept.	Storm Sewer Line 1 As-Built Plans Leavenworth Plaza Shop Center	March 10, 1995	Shafer, Kline, & Warren, P.A.	Storm sewer plan and profile to Hughes Road.
7	City of Leavenworth Public Works Dept.	Grading Plan - WalMart Storm Sewer Profiles	None Indicated	Kaw Valley Engineering & Development	Storm sewer plan and profile.

Summary of Data Collected (Continued)					
Number	Agency Contacted for Document	Title of Document	Date	Preparer of Document	Type of Information Received
Development Plans					
8	City of Leavenworth Public Works Dept.	State of Kansas Department of Transportation Kansas Project West Leavenworth Trafficway Leavenworth County City of Leavenworth	Preliminary May 16, 1995	Bucher, Willis & Ratliff Engineers, Planners, Architects	Plan and profile sheets of centerline and side roads, and drainage area plan sheets for proposed new major arterial. (1 half-size set, sheets 1-31A, 114-119).
9	City of Leavenworth Public Works Dept.	West Leavenworth Annexation Plan Future Land Use Existing Land Use	August 1992	Bucher, Willis & Ratliff	City plan maps w/color-coded land use areas.
10	Larkin Associates Consulting Engineers, Inc.	City of Leavenworth, Kansas 760 Cherokee Drainage Improvements	Preliminary March 7, 1996	Larkin Associates Consulting Engineers, Inc.	Site and Grading Plan, Sheet 3 of 8; Plan and Profile, Sheet 4 of 8. Show re-routing of Three Mile Creek tributary from Cherokee to Broadway.

Summary of Data Collected (Continued)					
Number	Agency Contacted for Document	Title of Document	Date	Preparer of Document	Type of Information Received
Aerial Photos					
11	City of Leavenworth Public Works Dept.	Aerial photos of the Leavenworth area: T.8.S., R.22.E; Sections: 20, 21, 22, 23, 24, 25, 26, 27, 28, 29, 32, 33, 34, 35, 36 T.9.S., R.22.E; Sections: 1, 2, 3, 4, 5, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 20, 21, 22, 23, 24, 25, 26, 27, 28, 29 T.9.S., R.23.E; Sections: 6, 7, 18, 19, 30 T.8.S., R.23.E; Section 31	March 25, 1992	M. J. Harden & Associates, Inc.	Aerial photos of the Leavenworth area showing streets, waterbodies, etc. Scale 1" = 200 feet.
FEMA Flood Plain Studies and Maps					
12	Federal Emergency Management Agency	Flood Insurance Study, County of Leavenworth, Kansas Unincorporated Areas	February 1980	Federal Emergency Management Agency	Study of stormwater flooding caused by: Missouri River, Kansas River, Stranger Creek, Seven Mile Creek, Nine Mile Creek, Dawson Creek, and Tonganoxie Creek.

Summary of Data Collected (Continued)					
Number	**Agency Contacted for Document**	**Title of Document**	**Date**	**Preparer of Document**	**Type of Information Received**
13	Federal Emergency Management Agency	Flood Insurance Study City of Leavenworth, Kansas	January 1978	Federal Emergency Management Agency	Study of stormwater flooding caused by: Three Mile Creek, Three Mile Creek South Branch, and Five Mile Creek.
Complaint Files and Reports					
14	City of Leavenworth Public Works Dept.	Stormwater Management Questionnaire	1995	Black & Veatch	Mailed questionnaires and newspaper version received from residents, including details about flooding problem areas.
15	Black & Veatch	Telephone Memorandum	1995	Black & Veatch	Calls received on stormwater hotline from residents.
City Design Standards for Storm Sewers					
16	City of Leavenworth Public Works Dept.	Shawnee Steel & Welding, Inc. 6" Steel Inlet Frame-Welded	February 1987	Shawnee Steel & Welding, Inc.	Construction detail for City standard inlet.
17	City of Leavenworth Public Works Dept.	City of Leavenworth, Kansas Office of the City Engineer Type "A" Curb Inlet Detail	None Indicated	City of Leavenworth	Construction detail for City standard inlet.
18	City of Leavenworth Public Works Dept.	City of Leavenworth, Kansas Asphaltic Concrete Paving C. & G. Details	None Indicated	Office of the City Engineer	Construction details for City standard streets.

Summary of Data Collected (Continued)					
Number	Agency Contacted for Document	Title of Document	Date	Preparer of Document	Type of Information Received
City Ordinances/Codes					
19	City of Leavenworth Public Works Dept.	Zoning Ordinance 1985 as Amended through July 1992, City of Leavenworth	1985	City of Leavenworth	Regulations applied to all land and structures within the incorporated area of the City of Leavenworth. Building permits and development guidelines.
Soils Reports					
20	U.S. Department of Agriculture, Soil Conservation Service, National Cooperative Soil Survey	State Soil Geographic Data Base (STATSGO)	October 1994	U.S. Department of Agriculture	Georeferenced digital map data, attribute data, and metadata. It is a broad-based inventory of soils and nonsoil areas that occur in a repeatable pattern on the landscape.
Corps of Engineers Studies					
21	City of Leavenworth Public Works Dept.	Flood Plain Information Five Mile Creek Leavenworth, Kansas	June 1972	Corps of Engineers, U.S. Army, Kansas City District	Flood hazard information report for the Leavenworth area along Five Mile Creek, including past floods, historic flood peaks, and factors affecting flooding and its impact.
22	City of Leavenworth Public Works Dept.	Flood Plain Information Three Mile Creek Leavenworth, Kansas	December 1970	Corps of Engineers, U.S. Army, Kansas City District	Flood hazard information report for the Leavenworth area along Three Mile Creek, including past floods, historic flood peaks, and factors affecting flooding and its impact.

Summary of Data Collected (Continued)					
Number	Agency Contacted for Document	Title of Document	Date	Preparer of Document	Type of Information Received
USGS Maps and Studies					
23	U.S. Geological Survey	Leavenworth Quadrangle Map	1984	U.S. Geological Survey	Quadrangle map of the greater Leavenworth area showing streets, waterbodies, topographical information, etc.
Other Past Studies					
24	Black & Veatch	Report on Stormwater Drainage Leavenworth, Kansas	October 1967	Black & Veatch	Report of the results of an engineering study covering the existing storm sewers, additional sewers required in developed areas and potential areas of future development, and the estimated cost of such facilities.
25	City of Leavenworth Public Works Dept.	City of Leavenworth FEMA Damage Report, Site 1 through 33	August 1993	City Staff	Photographs and written descriptions of damages sustained due to Great Flood of 1993.
Street and Bridge Data					
26	City of Leavenworth Public Works Dept.	City of Leavenworth, Kansas Bridges (20 or more feet in length)	February 1979	D. J. Pennington City Engineer?	Blue-line map, 1" = 600 feet, with streets, waterways, bridges, and bridge data.
27	City of Leavenworth Public Works Dept.	Map of Leavenworth, Kansas Wards & Precincts	November 1994	City?	Blue-line map, 1" = 2,000 feet, with wards, precincts, and city limits boundaries and streets.
28	City of Leavenworth Public Works Dept.	Shopping Guide and Membership Directory	1994-1995	Leavenworth-Lansing Area, Chamber of Commerce	Current city street map in centerfold.

Summary of Data Collected (Continued)					
Number	Agency Contacted for Document	Title of Document	Date	Preparer of Document	Type of Information Received
29	City of Leavenworth Public Works Dept.	Figure 16 Arterial and Collector Streets	?	?	Skeleton street map of Leavenworth with arterial and collector streets indicated.
30	City of Leavenworth Public Works Dept.	Report on 1993, Biennial Bridge Inspection	July 1993	Bucher, Willis, & Ratliff Engineers Planners Architects	Recommended repair or replacement of existing bridges and cost estimates.
31	Kansas Department of Transportation (KDOT)	Bridge Reports and Inventory System for Kansas (BRISK) diskette, Version 2, Release 3	1993	KDOT	Location, description, and dimensions of most bridges in Leavenworth.
32	City of Leavenworth Public Works Dept.	Construction Layout, Bridge over Three Mile Creek	1988	Cook, Flatt, & Strobel Engineers, P.A.	Construction drawing, plan and elevation of bridge at Broadway.
33	City of Leavenworth Public Works Dept.	7th Street Bridge over Three Mile Creek, Construction Layout	1991	Wilson & Company Engineers & Architects	Construction drawing, plan and elevation of bridge at 7th Street.
34	City of Leavenworth Public Works Dept.	Construction Layout, Bridge over Three Mile Creek	1979	Cook, Flatt, & Strobel Engineers, P.A.	Construction drawing, plan and elevation of bridge at Cherokee Street.
35	City of Leavenworth Public Works Dept.	Construction Layout & Geology, Bridge over Three Mile Creek	1985	Michael Engineering	Construction drawing, plan and elevation of bridge at Third Street.
36	City of Leavenworth Public Works Dept.	Construction Project 1961-54	1961	Truman Schlup Consulting Engineers	Plan, profile, and sections of bridge improvements at Shawnee Street and Three Mile Creek.

Summary of Data Collected (Continued)					
Number	Agency Contacted for Document	Title of Document	Date	Preparer of Document	Type of Information Received
37	City of Leavenworth Public Works Dept.	Construction Project 1964-75	1964?	Truman Schlup Consulting Engineers	Plan and sections for bridge at 13th Street and Three Mile Creek.
38	City of Leavenworth Public Works Dept.	Construction Project 1964-75	1964?	Truman Schlup Consulting Engineers	Plan and sections for bridge at Osage Street.
39	City of Leavenworth Public Works Dept.	Ottawa Street Bridge and Approach at Three Mile Creek, Sheets 1 & 2 of 10	1956	Truman Schlup Consulting Engineers	Plans and general layout for bridge and channel change at Ottawa Street and Three Mile Creek.
40	City of Leavenworth Public Works Dept.	Project No. 52U-0807-01, 083-164, Sheet 3 of 14	1983	FHWA?	Plan and profile for bridge at Shawnee Street and east of 11th Street.
41	City of Leavenworth Public Works Dept.	Project 1967-10	1967	Leo M. Martell Associates	Plan and elevation for bridge at 20th Street and Three Mile Creek.
42	City of Leavenworth Public Works Dept.	5th Street Bridge over Three Mile Creek	1969	Kenneth M. Blom, P.E.	Plan, elevation, and profile for bridge at 5th Street and Three Mile Creek.
43	City of Leavenworth Public Works Dept.	6th Street Bridge and Approach at Three Mile Creek	1956	Truman Schlup Consulting Engineers	Plan, elevation, section, and details for bridge at 6th Street and Three Mile Creek.
44	City of Leavenworth Public Works Dept.	Construction Layout, 10th Street Bridge	1982	M.D. Cooper & Associates Consulting Engineers	Plan and elevation for bridge at 10th Street and Three Mile Creek.
45	City of Leavenworth Public Works Dept.	Construction Layout, Bridge over Five Mile Creek	1981	Cook, Flatt, & Strobel Engineers, P.A.	Plan and elevation for bridge at 2nd Street and Five Mile Creek.

Summary of Data Collected (Continued)					
Number	Agency Contacted for Document	Title of Document	Date	Preparer of Document	Type of Information Received
46	City of Leavenworth Public Works Dept.	Construction Layout, U.S.-73 over Five Mile Creek	1981	Kansas Department of Transportation	Plan and elevation for bridge at 4th Street and Five Mile Creek.
47	City of Leavenworth Public Works Dept.	Limit Street Bridge over Five Mile Creek	1957	Truman Schlup Consulting Engineers	Plan, elevation, and section for bridge at Limit Street and Five Mile Creek.
48	City of Leavenworth Public Works Dept.	Shrine Park Road Bridge over Five Mile Creek Construction Layout	1992	Wilson & Company Engineers and Architects	Plan and section for bridge at Shrine Park Road and Five Mile Creek.
Hydrologic Data					
49	Kansas Department of Transportation	Rainfall Intensity Tables for Counties in Kansas	September 1991	Dr. Bruce McEnroe, et al., of University of Kansas for KDOT	Rainfall intensity table, containing average rainfall intensities in inches per hour, for durations of 5 minutes through 24 hours and return periods 1-, 2-, 5-, 10-, 25-, 50-, and 100-year for Leavenworth County.
50	University of Kansas	Final Report K-TRAN Research Project KU-93-5 Rainfall Inputs for Simulation of Design Floods in Kansas	July 1994	Dr. Bruce McEnroe, et al., of University of Kansas for KDOT	Comparison of fixed-shape and composite design storms, and development of modified-uniform design storm.
Historical Flooding Data					
51	City of Leavenworth Public Works Dept.	Historic Flooding Locations, B&V Memorandum	June 26, 1995	Black & Veatch	Compilation of historic flooding locations from City records and other documents.

Summary of Data Collected (Continued)					
Number	Agency Contacted for Document	Title of Document	Date	Preparer of Document	Type of Information Received
References					
52	U.S. EPA	Stormwater Management Model, Version 4, User's Manual	August 1988	Wayne Huber & Robert Dickinson, University of Florida, for EPA	Description, theory, and use of computer model.
53	XP Software	XP-SWMM User's Manual, Version 2	November 1995	XP Software, Inc. WP Software, Inc.	Description, theory, and use of computer model.
Other					
54	City of Leavenworth Public Works Dept.	Missouri River Gauge Data	August 1990 through January 1996	Leavenworth City Staff	Morning and evening temperature and water surface elevation measurements at Dakota Street.