PART III - TECHNICAL METHODS & CRITERIA

PART III

TECHNICAL METHODS AND CRITERIA

A. FIELD INVESTIGATION

A field reconnaissance survey was conducted by BG Consultants, Inc. to observe and confirm physical features of the existing drainage system throughout the City. Specific data regarding reach size, configuration, and hydraulic conditions were measured and recorded for approximately 155 of the individual reach elements modeled. In addition to measured data, notes were taken concerning the apparent physical condition and state of maintenance of a number of the storm drainage structures, both City-owned and private. Additional information was obtained from the City's drainage system base maps, files and records.

Field information was recorded concerning pertinent hydraulic and hydrologic data for each reach of the system surveyed. In addition to verifying sizes and materials of existing enclosed system and culvert elements, the following information was obtained where applicable:

- Channel/culvert depth to overflow or structural damage: Measurements were made of the available headwater (freeboard) at a number of principal culverts before overflow of the roadway or downstream property begins. These data were later used in office studies to evaluate allowable flow depths in the system reaches.

- Open channel conveyance capacity: Cross sections were measured for important open-channel reaches on the major system.

- Hydraulic roughness coefficients: Roughness coefficients (Manning's "n") values were estimated and recorded for system reaches in their existing condition. Table III-1 indicates the standards applied for estimating existing roughness coefficients.

TABLE III-1

FIELD EVALUATION STANDARDS FOR ROUGHNESS COEFFICIENTS

Conveyance Structure	Manning's "n"
Closed Conduits	
Reinforced Concrete Pipe	.013
Corrugated Metal Pipe	.023
Reinforced Concrete Box Culverts:	
a. Single Barrel	.013
b. Multiple Barrel, Effective	.016
Stone or Brick Masonry	.022
Improved Open Channels	
Full Concrete Lining - Good Condition	.015
Full Concrete Lining - Minor Joint Problems	.017
Full Concrete Lining - Advanced Deterioration	.020
Full Asphalt Lining - Good Condition	.017
Full Asphalt Lining - Poor Condition	.020
Grouted Masonry - Good Condition	.023
Grouted Masonry - Poor Condition	.030
Riprap	.035
Concrete Invert - Maintained Turf Sides	.020
Concrete Invert - Moderate Brush/Shrub Sides	.030
Concrete Invert - Tree and/or Improvement Obstruction	.035
Concrete Invert - Appreciable Fences	.045
Turfed - Clean, Few Obstructions	.030
Turfed - Moderate Obstructions	.035
Turfed - Severe Obstructions	.045
RR Tie - One Bank	.023
RR Tie - Both Banks	.020
Concrete Block Sides - Concrete Bottom	.019
Concrete Block Sides - Earth or Turf Bottom	.023
Natural Ditches or Channels	
Straight to Moderately Sinuous	
Clean Earth Banks, Earth Bottom or Smooth Rock	.030
Clean Earth Banks, Rough Rock Bottom	.035
Brushy Banks - Few Obstructions	.040
Brushy Banks - Significant Obstructions	.050
Debris and/or Weed Choked	.070
Overbank Floodways	
Street R/W Perpendicular to Flow	.035
Yards - Open Grass	.030
Yards - Grass - Some Bushes and Trees	.040
Yards - Significant Trees and Bushes	.050
Unimproved - Weedy - Moderate Brush	.050
Unimproved - Heavy Brush and Trees	.060
Unimproved - Dense	.100
Unimproved - Open	.040

B. SYSTEM MAPPING

The primary source of information for mapping was the existing drainage system maps maintained by the City. Information concerning the location of existing drainage structures was obtained by reference to these maps supplemented by information from files and records maintained by the Community Development Department and obtained during the field investigation phase of the work. Updated computer-drafted drainage system maps for this study were then created by transferring the major system components onto a computerized city base map indicating streets, lots, zoning and other similar data.

During the office study phase, the system maps were expanded to include definition of subwatershed boundaries and drainage areas tributary to each modeled reach of the drainage system. U.S.G.S. topographic maps were the primary source of information for defining the major watershed boundaries and many of the subareas. The existing system maps also provided considerable information on drainage areas for individual reaches in older, developed parts of the city. More detailed topographic maps, prepared for other projects, provided information primarily in the Eureka Valley Tributary area.

After defining the system and individual drainage areas, the maps were keyed and coded to correspond to the computer models used for performance evaluation and confirmation of system hydraulic capacity. The completed full-size maps which indicate 362 individual reaches of the system, have been separately furnished to city staff. Reduced copies are included for reference at the end of Part IV of this report.

C. COMPUTER MODELING

1. GENERAL

Office studies were conducted to accomplish the following objectives.

- Define the performance level of the present drainage system under conditions of current land use and development.

- Define the hydraulic demand on the drainage system under conditions of future land use as defined by the City's comprehensive land use plan.

- Confirm the performance capacity of the system as improved by recommendations contained in other sections of this report.

- Evaluate alternative system improvement possibilities and evaluate the effect of various sequences and priorities of recommended improvements.

2. <u>COMPUTER MODELS</u>

Two computer models, HEC-1 and HEC-2, developed by the Corps of Engineers Hydrologic Engineering Center for storm drainage analysis, were the primary tools used to model the existing and proposed drainage systems. In addition, three programs developed by Burns & McDonnell were used to evaluate capacities of some system components, to estimate costs and to prioritize recommended improvements. Each program has a number of options to tailor the model to the specific system components and conditions.

a. <u>HEC-1 and HEC-2</u>

The HEC-1 "Flood Hydrograph Package" generates streamflow or runoff hydrographs at desired locations for specific storm events over a watershed. The model simulates surface runoff within an area and the subsequent routing through various drainage system components, including pipes, channels and reservoirs, by representing the watershed as an interconnected system, or network, of hydrologic and hydraulic components. The runoff and routing simulation is based on the specific input parameters for each component of the process including the subwatershed.

For this study, the HEC-1 model was used to generate hydrographs to determine the peak flows at each of the drainage system components for return periods of 2, 5, 10, 25, 50 and 100 years. Options used in modeling the runoff to the system include the hypothetical storm, the SCS curve number for the loss rate, and the SCS dimensionless unit hydrograph. The Muskingum-Cunge method was used for channel and pipe routing. Typical input included is curve number and lag time for the drainage area; diameter or width, slope, roughness coefficient and length for pipes and box culverts; and a typical cross section, length, slope and roughness coefficients for open channels.

The HEC-2 "Water Surface Profiles" program is used to calculate water surface profiles for steady, gradually varied flow in natural or improved open channels and to evaluate the effects of various obstructions such as bridges, culverts, weirs and structures within the floodplain of the particular stream. The procedure used for computations in the program is generally known as the standard step method and is based on solution of the one-dimensional energy equation with energy loss due to friction determined by Manning's equation.

The HEC-2 program was used in this study primarily to evaluate the capacities of a number of the larger open channels in the drainage system. In addition, water surface profiles based on peak flows in several channels were calculated where determination of the impact of storm flows on adjacent existing or proposed development was required.

b. <u>URBMOD Program</u>

The URBMOD program was developed by Burns & McDonnell specifically for modeling the performance of a complex urban drainage system and is based on SCS methodology. It was used to determine capacities of some reaches of the enclosed drainage system components since the HEC-2 program does not generate rating curves for enclosed facilities.

c. <u>SYCOST Program</u>

The SYCOST program is a program primarily for estimating the budget grade costs of storm drainage systems for study and planning purposes. The program performs conceptual grade design of component system facilities then estimates their capital and annual cost using current unit prices for key items. It accommodates pipe systems with pipe sizes up to 96 inches diameter, single and multi-span box culverts, lined or natural open channels, and site specific detention facilities. Output data for each reach includes structure type and size, and cost estimates for construction, land acquisition, design fees and contingencies, total capital cost, and annual maintenance cost.

This program was used in this study to determine the value of and annual maintenance costs for the existing drainage system; to evaluate alternative facility designs; and to develop cost estimates for the most feasible proposed improvements.

c. <u>PRIOR Program</u>

The PRIOR program is a model for developing rational and logical priorities among discrete "projects" included in a large scale program or proposal for storm water system improvements. The model design is biased to assign the highest priorities to those projects that relieve deficiencies benefitting the greatest number of people at the lowest capital cost per benefitted system "user." Operation of the model sequentially determines a "score" for each project on an internally weighted scale then differentiates between equal "score" projects by secondary level comparison of component factors to establish an absolute priority ranking of all projects within the model. The evaluation scale used to determine project scores is presented in Part VI of this report.

Parameters analyzed for each project are frequency of damage from overflow of the existing system; number of damaged properties; type of damage such as structure and/or contents damage, erosion only, or nuisance only with no direct economic damage; frequency of existing system overflow; effect of inadequate system on future land development; structural condition of an existing facility, if present; magnitude of the absolute hydraulic deficiency; and capital cost of the project.

Output data from this program for each project includes priority number, priority points (or raw score), capital cost, and priority control which was the model's justification for assigning that project's priority.

For this study, the PRIOR program was utilized with the recommended improvement plan to rank the series of projects made up of the reaches proposed for improvement.

D. RAINFALL

The design storm used in the analyses of the drainage system is defined as the pattern of rainfall over a specific period of time, or duration, for a given return period. The duration that tends to put the greatest demand on the system is termed the "critical storm duration" and is roughly equal to the time of concentration of the watershed. The time of concentration, T_c, is defined as the time at which all parts of the drainage area begin to contribute runoff or the time of flow from the farthest point in the watershed to the outlet.

The regional conditions that are expected to produce these demands on the system are those associated with short-duration, high-intensity thunderstorms occurring as part of longer duration rainfall. Within the HEC-1 program the "hypothetical storm" option most closely simulates those conditions. Storm duration was selected based on the critical storm concept mentioned previously. Although the times of concentration for the various watersheds included in this study vary from approximately one to three hours, a storm duration of three hours was used for all watersheds, except Eureka Valley, to insure that the modeling reflected the peak flow when all areas of the watershed were contributing runoff. Because of the very flat slopes in the Eureka Valley watershed, the time of concentration is slightly longer so a six-hour duration was used in that case.

Rainfall data for Riley County were obtained from the Kansas Department of Transportation (KDOT) "Rainfall Intensity Tables for Counties in Kansas," 1991 edition. From this information, total rainfall depths for return periods of 2, 5, 10, 25, 50 and 100 years, and durations of three and six hours, were determined as indicated in Table III-2.

TABLE III-2

DESIGN RAINFALL EVENTS

Return Period (Years)	3-hour Rainfall (Inches)	6-hour Rainfall (Inches)
2	2.19	2.52
5	2.79	3.24
10	3.21	3.72
25	3.81	4.44
50	4.26	4.98
100	4.74	5.52

E. LAND USE

Land use parameters influencing runoff were evaluated on the basis of aerial photographic assessment maps supplemented by data from the City's Comprehensive Land Use Plan and field observation to develop existing system performance models. The Comprehensive Land Use Plan was also used to develop model data for future fully-developed conditions.

In general, the land currently within the Manhattan corporate limits is substantially developed, or currently under development, with the exception of relatively small areas along the eastern and western "fringe." Residential development is the largest single land use accounting for approximately 40 percent of the developed area within the city. The Kansas State University campus represents the second largest single land use. Commercial, industrial and institutional uses each occupy less than ten percent of the developed land. Parks and recreation areas cover approximately ten percent of the area. Future development will, for the most part, require the city to expand its corporate boundaries since relatively little undeveloped land is available within the existing city limits. Several areas currently under development are outside the city at this time but will be annexed soon.

Runoff parameters with respect to land use are as set forth in Table III-3 on the following page. The land use categories indicated generally match the categories contained in the Comprehensive Land Use Plan.

TABLE III-3

LAND USE RUNOFF PARAMETERS

Land Use	Surface Use % Imp.	Surface Use % Perv.	SCS CN	Rational "C"
Residential, Low-Med Density	35	65	80	0.43
Residential, Med-High Density	60	40	87	0.59
Residential, High Density	80	20	92	0.72
Office & Office Parks	70	30	90	0.66
Neighborhood Commercial	85	15	94	0.75
General Commercial	95	5	97	0.82
Industrial	80	20	92	0.72
Institutional	70	30	90	0.66
Agricultural	5	95	71	0.23
Open Space	10	90	73	0.27

NOTES:
Impervious Surfaces: "C" = 0.85 and CN = 98
Pervious Surfaces: "C" = 0.20 and CN = 70

F. COMPARISON TO PREVIOUS STUDIES

Both the FEMA Flood Insurance Study (FIS) and the previous stormwater master plan were completed approximately 20 years ago. In that period of time, the extent and type of development within Manhattan has obviously changed. Less obvious are the many changes in the technical methods and the increased information available for analyzing the storm drainage system and simulating its performance. Therefore, it is somewhat difficult to directly compare the results of this report with the previous studies. It should not be concluded, however, that any of the reports are incorrect simply because different results have been obtained.

As an example, the FIS peak flows and those determined in this study may or may not compare favorably in several of the watersheds. This is due primarily to the different technical methods used to determine those flows in each case. At the time the FIS study was performed, a method based on the use of regression equations to calculate peak flows was considered acceptable for this application and, in some cases, is still applicable. However, the accuracy of this method when applied to small, developed urban watersheds is much less than in larger watersheds of primarily open land, for which the equations were developed. Therefore, variations in the peak flows between the two studies can be considerable since all of the watersheds identified for this study are considered small, urbanized areas in this context..

At the time of this report, restudies for both Manhattan and Riley County flood insurance reports were underway. Updated information and technical methods may eliminate at least some of the apparent differences.

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