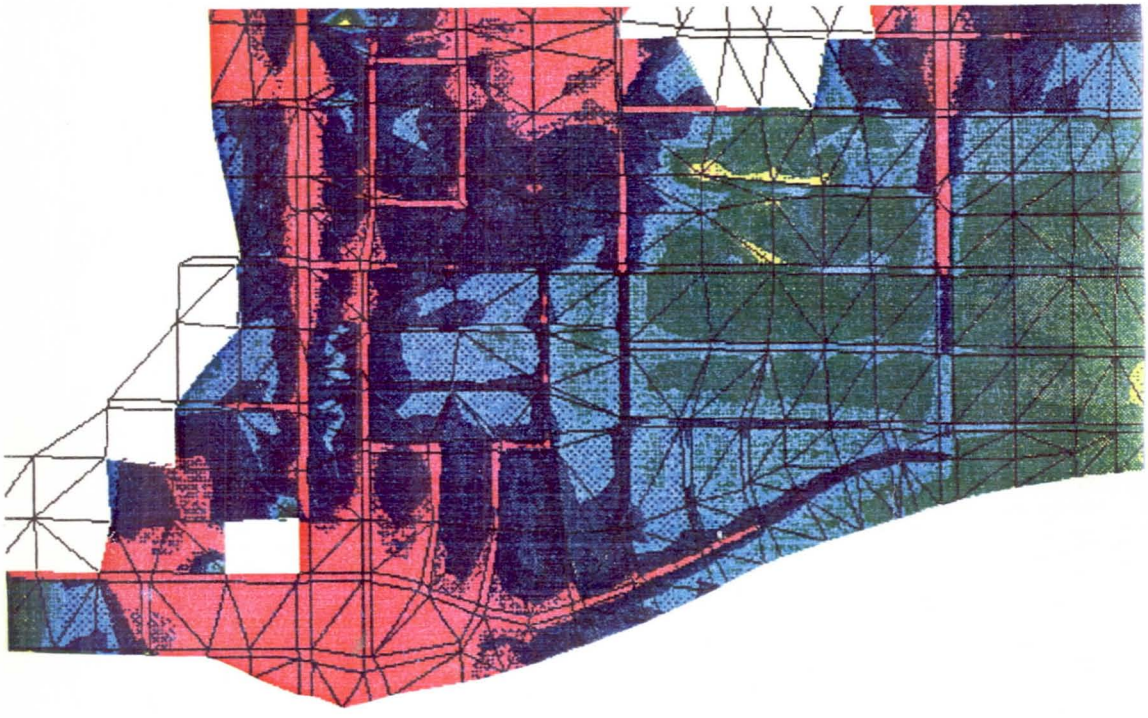
Summary Report

CHRISTOWN MALL AREA FLOODPLAIN STUDY

2-DIMENSIONAL FLOW ANALYSIS RESULTS



FLOOD CONTROL DISTRICT

OF MARICOPA COUNTY

Submitted by:

Simons, Li & Associates, Inc.
Water Resources & Civil Engineering Consultants

November 18, 1994

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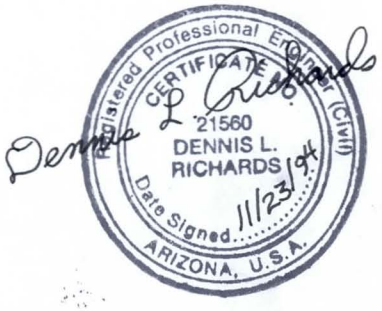

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Summary Report

Christown Mall Area Floodplain Study
2-Dimensional Flow Analysis Results

Introduction

This report summarizes the results of the 2-dimensional flow analysis portion of the Christown Mall Area Floodplain Study currently underway. This report has been prepared to update the County on current project progress, and to identify and discuss the characteristics of the floodplain within the study area as indicated by the results of the latest modeling efforts.

Study Area

The area modeled for this study is located within the city of Phoenix, and is bounded by Glendale Avenue on the north, the Grand Canal on the south, 17th Avenue on the west and 3rd Avenue on the east. **Figure 1** is an aerial photo of the study area, with the major streets identified.

Major Features in Study Area

The study area lies within the historical flood path of the Cave Creek Wash. The study area has been cut off from a large portion of the upstream watershed by the Arizona Canal Diversion Channel (the ACDC), which is located about 2 miles north of the northern boundary of the study area. The predominant slope of the study area is from north to south, with a general trend toward the southeast corner of the study area. **Figures 2 through 6** illustrate the profiles of the major east-west streets within the study area. The southeasterly trend of the historical Cave Creek Wash may be seen through comparison of these figures.

A major feature located within the study area is the Christown Mall. Located at the intersection of 17th Avenue and Bethany Home Road, this large structure stands in the way of flows proceeding southward down 17th Avenue. The 17th Avenue flow path is cut off, and the runoff is forced eastward, to mix with those flows carried southward by 15th Avenue.

The Grand Canal is an additional major feature located within the study area. This canal is banked on its north side by a slight berm, which forces flow reaching it from the upstream watershed to parallel its path. Two street crossings of the Grand Canal are located within the study area -- at 7th Avenue and 15th Avenue.

Computational Mesh

An elemental mesh of interconnected nodes was developed to model the flow characteristics of the study area using the U.S. Army Corps of Engineers' TABS model. **Figure 7** illustrates the final mesh configuration, which was created after many trial meshes were attempted and determined to be unstable.

The characteristics of the study application (relatively steep grade in an urbanized area with gradual east-west relief and very shallow flooding depths), stretched to the limit the capabilities of TABS routines, and required the development of a fairly intricate arrangement of computational elements. The final mesh consists of a total of 6,614 nodes and 2554 elements. Each node was defined in three dimensions (x,y,z), with the z value representing the local ground elevation at the given point, and with east/west and north/south coordinates of x and y, respectively. Each element, composed of three or four nodes, was assigned a Manning roughness value and an eddy viscosity value. In initial mesh development, high values of both Manning n and eddy viscosity were used to develop the initial steady state condition. As the mesh was further developed and a stable steady state solution was achieved, these values were incrementally adjusted to represent more realistic conditions. Final computations were preformed using Manning n values of 0.020 for the streets within the mesh (identical to the value used in the previous floodplain analysis for the study area), and 0.200 for the areas surrounding the street network. The order of magnitude higher Manning roughness assigned to the non-street areas was applied to model the extra resistance of the buildings, vegetation, etc., located in these areas, and to encourage the flow to concentrate in the streets as much as deemed appropriate. The size of the area being modeled did not allow elemental definition down to the level of the curb and gutter, and the large contrast in flow resistance between street and non-street areas was used to compensate for this lack of topographic refinement. **Figure 8** identifies the street and non-street areas within the computational mesh. Final eddy viscosity values were reduced to 25.0 (all directions), which is of appropriate magnitude for the given flow conditions (as indicated by the FastTABS manual) and provided Peclet numbers of 50 or less, which ensured numerical stability.

Boundary Conditions

Boundary and interior inflows to the study area were determined from the previous HEC-1 modeling of the Cave Creek Wash performed by Cella Barr Associates. Flows of concern to the study area include inflows from concentration points upstream, split flows into the study area from concentration points adjacent to the study area, split flows and storm drain flows out of the study area, and watershed runoff from sub-basins enclosed within the study area. In the previous hydrologic analysis, rating curves were used to determine the characteristics of the flow splits that are expected to occur at all major street intersections. For the current analysis, the previously computed sub-basin runoff quantities, storm drain losses and split flow quantities were used to define flows which enter and split out of the study area, but interior flow splits, flow distributions within the study area, and the outflow hydrograph at the major downstream outlet location (Grand Canal and 15th Avenue) were computed using the 2-dimensional TABS flow model.

The following table summarizes the flow items considered at each of the major concentration points within the study area (see also **Figure 9**):

Intersection	Flows Considered
Glendale and 17th Ave.	Inflow from Glendale and 19th Ave flow split Sub-basin runoff
Glendale and 15th Ave.	Inflow from upstream watershed Outflow to storm drain
Glendale and 12th Ave.	Sub-basin runoff
Glendale and 7th Ave.	Inflow from Glendale and Central flow split Inflow from Northern and 7th Ave flow split Sub-basin runoff
Bethany and 17th Ave.	Inflow from Bethany and 19th Ave. flow split
Bethany and 15th Ave.	Sub-basin runoff Outflow to storm drain
Bethany and 11th Ave.	Sub-basin runoff
Bethany and 7th Ave.	Inflow from Bethany and Central flow split Sub-basin runoff Outflow to storm drain
Camelback and 15th Ave	Inflow from Camelback and 19th Ave. flow split Sub-basin runoff Outflow to storm drain
Camelback and 11th Ave	Sub-basin runoff
Camelback and 7th Ave.	Sub-basin runoff
Camelback and 3rd Ave.	Inflow from Camelback and Central flow split Sub-basin runoff
Grand Canal and 15th Ave.	Sub-basin runoff Outflow to storm drain Outflow to downstream system
Grand Canal and 7th Ave.	Flow split over canal
Grand Canal and 3rd Ave.	Inflow from Grand Canal and Central flow split

The boundary inflows, sub-basin runoff values, and losses from the study area are actually hydrographs rather than steady-state discharges. **Figures 10 though 13** illustrate the boundary inflow hydrographs computed using the HEC-1 model for the study area. (Note that the acronyms used in the previous HEC-1 modeling for the concentration point locations have been used for the legend in the figure -- i.e. GLEN12 is the intersection of Glendale and 12th Ave., etc.). These boundary inflow hydrographs, as well as those previously computed for sub-basin runoff, storm drain loss, and split flows out of the system, were used to compute the time-varying floodplain for the study area.

Flood Simulation

Application of the TABS model requires an initial flowing or "wet" condition through the mesh. Boundary flows at each of the inflow points to the mesh were reduced to the extent possible to minimize distortion of the final results, while maintaining a stable model. The 100-year hydrograph for each of the boundary inflow points (reduced to account for the loss to the storm drain system, where appropriate), was added to the base flow required for the initial steady state condition. Forty time steps, each 10 minutes apart, were computed in the simulation of the 100-year flood event. The flow depths and unit discharges at each node under each time step were adjusted to account for the initial condition, and the results were plotted.

Three conditions were analyzed to investigate the sensitivity of the solution to the condition applied to generate the "wet" initial conditions. The first condition was that described above: initial flows at each boundary inflow point that were the minimum required for a stable steady state condition. The second condition used flows at each inflow point that were double those used in the first condition. For the third condition, the z values of each of the nodal points were reduced by an amount equal to the flow depth computed in condition 2, and condition 2 was recomputed, resulting in "wet" topography which approximated (but still slightly distorted) that of the original, non-wet topography. Each of these procedures produced comparable results, but the effect of the distortion is identifiable -- the larger the flows used at the initial condition, the larger the spreading that will occur as the flood hydrographs pass over this initial condition, and the smaller the local flood depths tend to be. Thus, the areas with flow depths of 0.4 feet or greater is larger under condition 1 than under condition 2, and condition 3 results appear to be between those of 1 and 2. The absolute magnitude of the depth differences under each condition are actually very small, however.

Figures 14 through 19 illustrate these points. Figures 14 through 16 illustrate the maximum flow depths computed for each node throughout passage of the simulated 100-year flood event, for conditions 1, 2, and 3, respectively. Figure 17 highlights the areas with flooding depths exceeding 0.5 feet under condition 1, and Figures 18 and 19 highlight the areas with flooding depths exceeding 0.4 feet under conditions 2 and 3, respectively. Comparison of Figures 17 through 18 indicates that, although different results are obtained under the differing "wet" conditions applied at startup, the magnitude of the difference is on the order of 0.1 foot. The condition 1 startup is judged to provide the most accurate results, as this condition minimizes the wetting depth used as a baseline.

Figure 20 complements Figure 14, with areas of varying flow concentration (maximum unit discharge throughout passage of the simulated 100-year flood event) shown rather than flow depth. These two figures indicate that areas of maximum flow depth and unit discharge are concentrated in seven major

areas: (1) 17th Avenue between Glendale Avenue and Bethany Home Road; (2) 15th Avenue between Maryland Avenue and Missouri Avenue; (3) the extension of 11th Avenue between Glendale Avenue and Maryland Avenue; (4) 7th Avenue between Glendale Avenue and Camelback Road; (5) the area north of Camelback Road between 7th Avenue and 15th Avenue; (6) 3rd Avenue between Camelback Road and the Grand Canal; and, (7) the area paralleling the Grand Canal between 3rd Avenue and 15th Avenue.

The above-described maximum depth and maximum flow concentration figures were developed through screening the results of the 40 computational times steps (with a delta time of 10 minutes) used for simulation of the 100-year flood event. **Figures 21 through 40** and **Figures 41 through 60**, illustrate the time varying depth and unit discharge conditions, respectively, for the odd-numbered time steps used in simulation.

Flood hydrographs within the computational mesh were tracked at numerous locations, identified by string number in **Figure 61**. The inter-mesh hydrographs associated with these strings are plotted by street and location in **Figures 62 through 73**. The variations in peak discharge for the 100-year flood as it passes through each of the major streets are summarized below, and are compared to the values determined in the previous HEC-1 analysis.

Street	**Location**	**HEC-1 Peak cfs**	**TABS-2 Peak Discharge Variation (north to south), cfs**
17th Ave.	Glendale-Bethany	419	464 312 171 62 68 61 101
15th Ave.	Glendale-Bethany	15	34 151 426 461 485 520 489
	Bethany-Camelback	470	511 536 452 436 300 292 294 214
	Camelback-Grand Canal	358	285 294 460
11th Ave.	Glendale-Bethany	519	433 324 373 399 335 356 390
	Bethany-Camelback	490	348 397 415 403 386 359 373 330
	Camelback-Grand Canal	352	438 328
7th Ave.	Glendale-Bethany	254	395 233 179 170 191 138 133
	Bethany-Camelback	495	462 501 389 388 470 401 472 440
	Camelback-Grand Canal	386	376 456 330
3rd Ave.	Camelback-Grand Canal	602	452 388 241
Grand Canal	3rd Ave.-7th Ave.	203	475
	7th Ave.-11th Ave.	515	319
	11th Ave.-15th Ave.	771	552
	15th Ave. (outflow)	765	785

Discussion of Results

The results of the 2-dimensional flow analysis are quite different from those previously determined using the HEC-1 model at several locations. The major differences are along 17th Avenue and 15th Avenue north of the Christown Mall. The TABS model results indicate that, due to the large west-to-east slope that exists between these two streets, a good portion of the flow that enters 17th Avenue at the Glendale Avenue concentration point passes over to 15th Avenue via the cross streets that exist between Glendale Avenue and Maryland Avenue. Another area of major difference is evident along 7th Avenue between Glendale Avenue and Bethany Home Road. The 2-dimensional modeling indicates that a large fraction of the flow that enters 7th Avenue at the Glendale Avenue intersection flows to the west to mix with the flows passing south along the 11th Avenue extension.

Both the previous HEC-1/HEC-2 and current TABS analyses indicate that the major flooding potential within the study area occurs along the Grand Canal. Due to the shape of the underlying topography, flows tend toward the southeast corner of the study area (the intersection of 3rd Avenue and the Grand Canal), and then are forced back to the west-south-west by the raised berm which parallels the canal. This redirection of the flow along a path which does not follow that of the historic Cave Creek Wash thalweg causes the flow to increase in depth, until an outlet (storm drain, 7th Avenue bridge, or 15th Avenue bridge) is reached or weir flowing occurs.

An area of probable flow accumulation which was apparently overlooked in the previous floodplain study is the golf course which exists near the intersection of 15th and Maryland Avenues. This golf course is located within a well-defined depression (the low point of the historical flow path of the Cave Creek Wash), and is indicated as a major flow accumulation point by the TABS analysis.

Next Phase of Analysis

The next phase of analysis will involve application of the HEC-2 water surface profile model to the study area. The HEC-2 analysis will use the results of the TABS analysis for discharge variation along each of the major streets. Difference in results between the HEC-2 analysis results and the TABS results are to be expected, since the HEC-2 analysis will assume simultaneous peaking of discharge at all locations, whereas the TABS model results are indicative of the time-varying nature of the flood event.

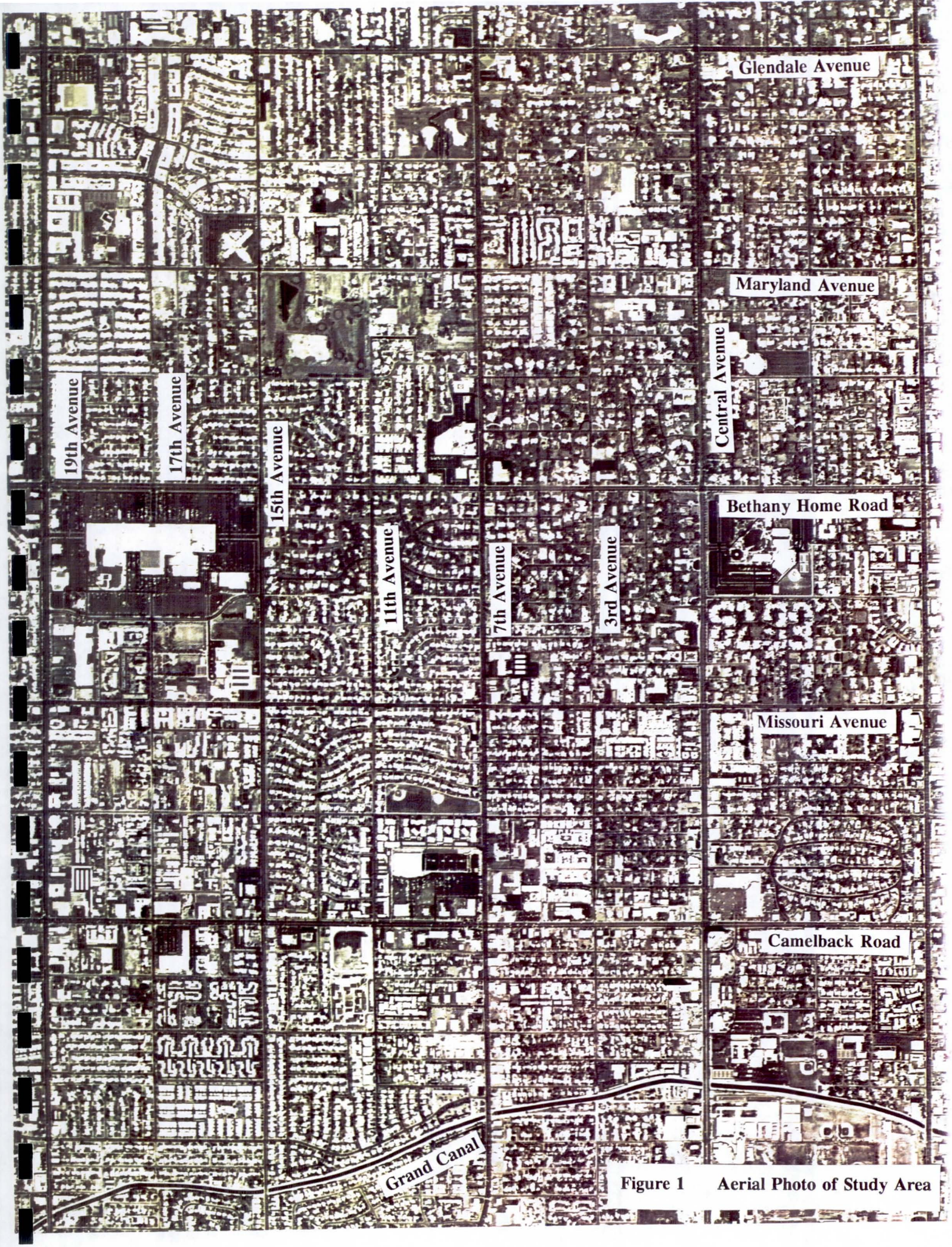

Figure 1 Aerial Photo of Study Area

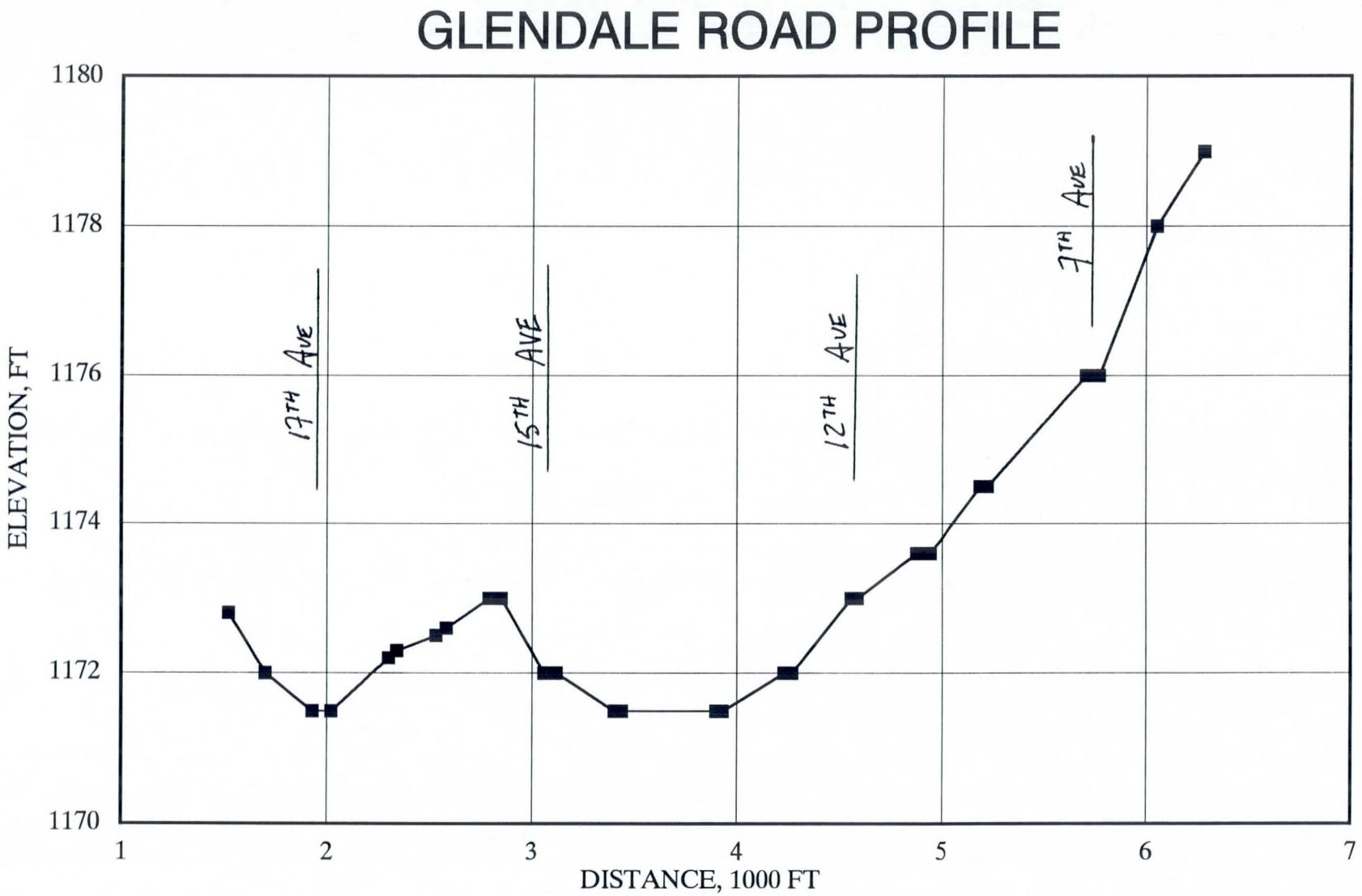

Figure 2 **Glendale Avenue Profile between 17th Avenue and 7th Avenue**

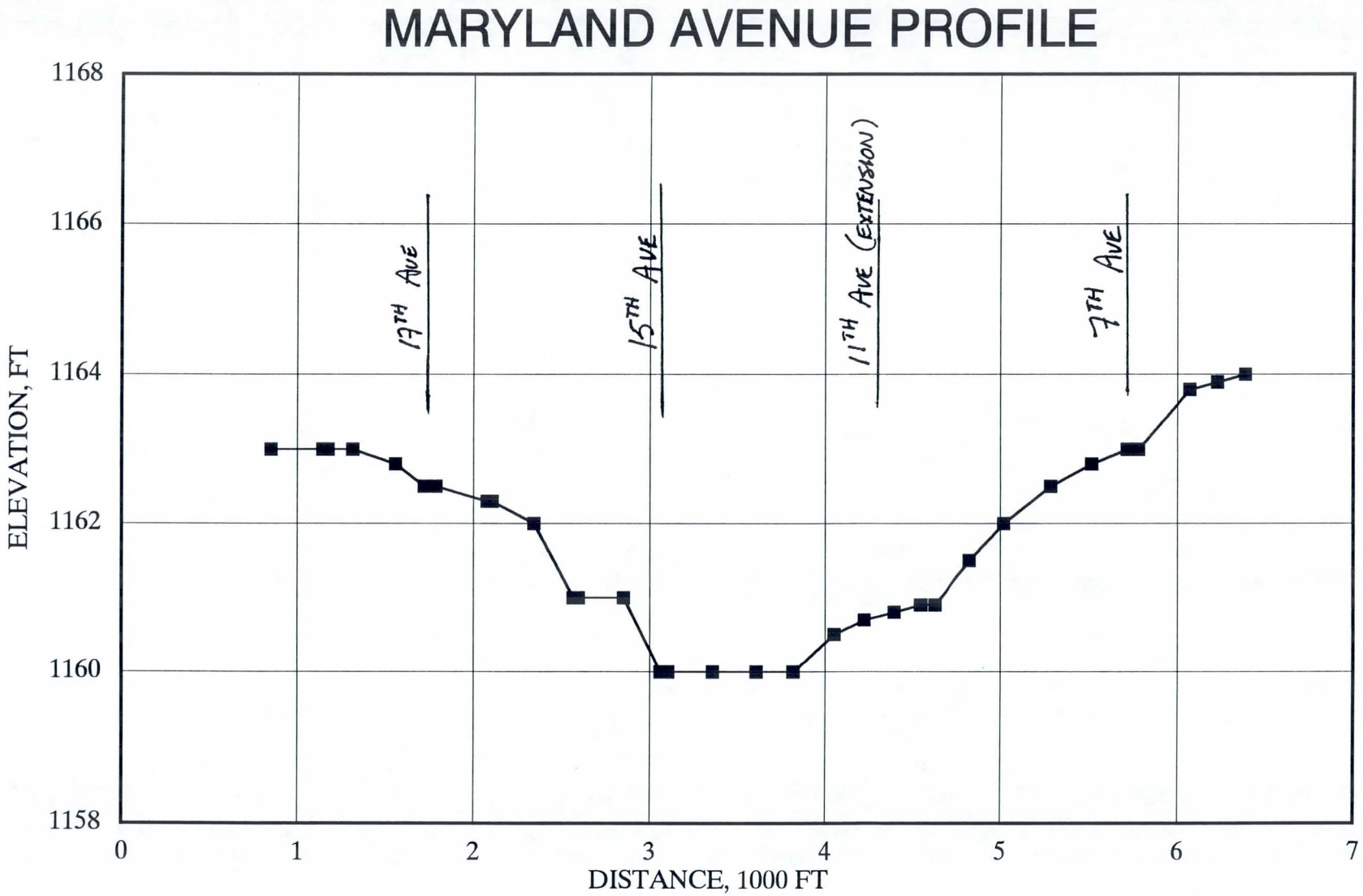

Figure 3 **Maryland Avenue Profile between 17th Avenue and 7th Avenue**

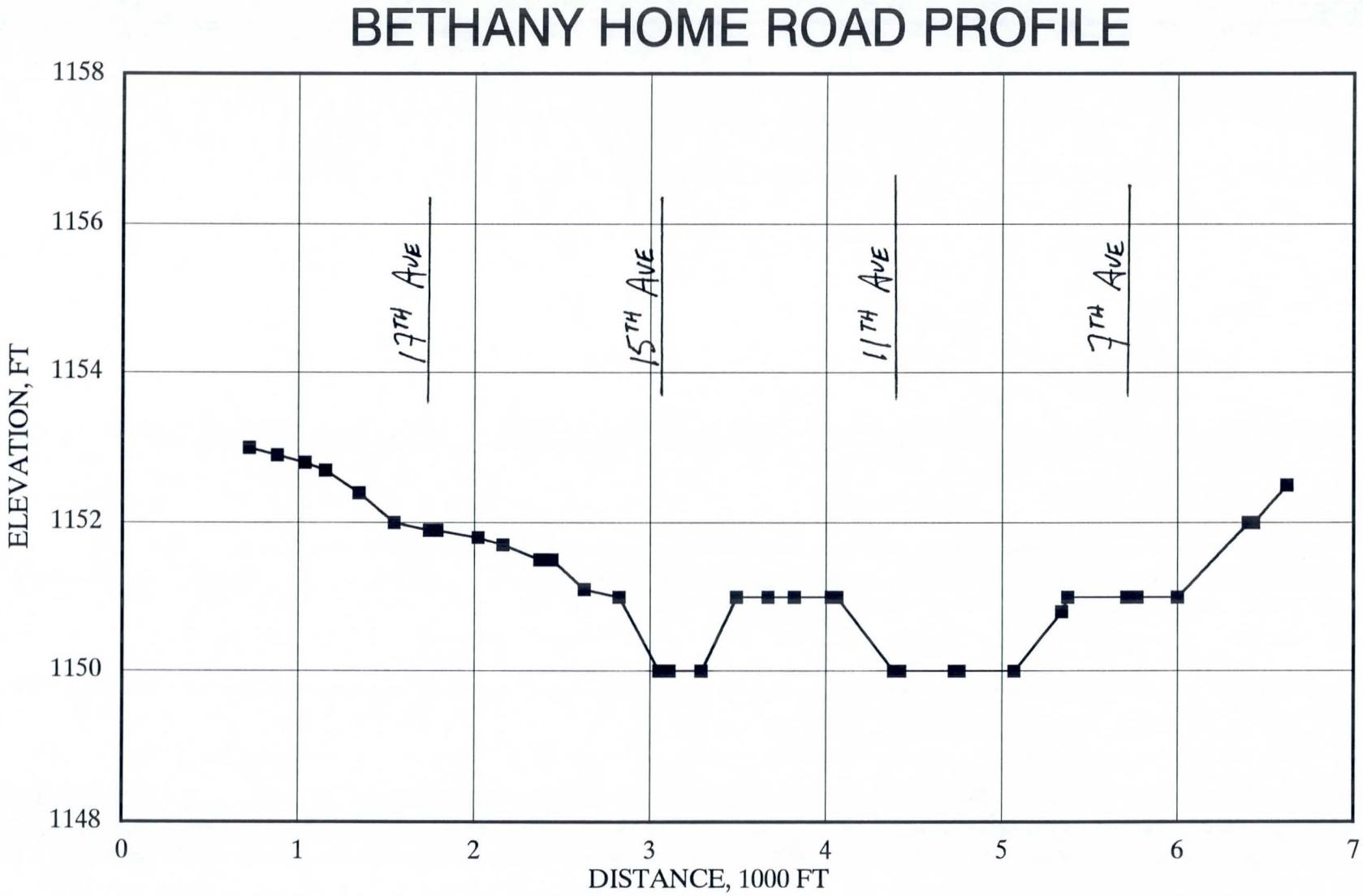

Figure 4 **Bethany Home Road Profile between 17th Avenue and 7th Avenue**

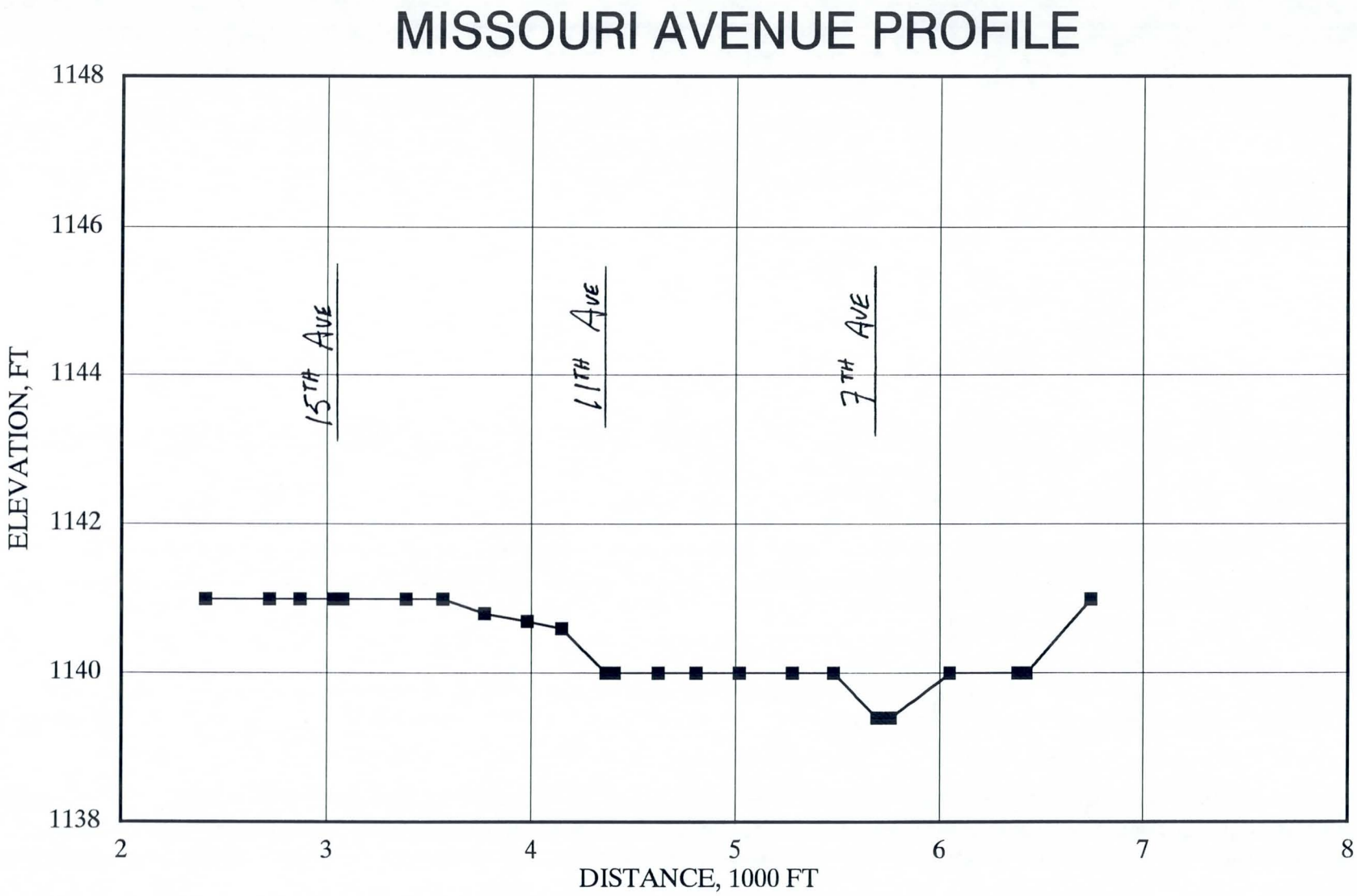

Figure 5 **Missouri Avenue Profile between 17th Avenue and 7th Avenue**

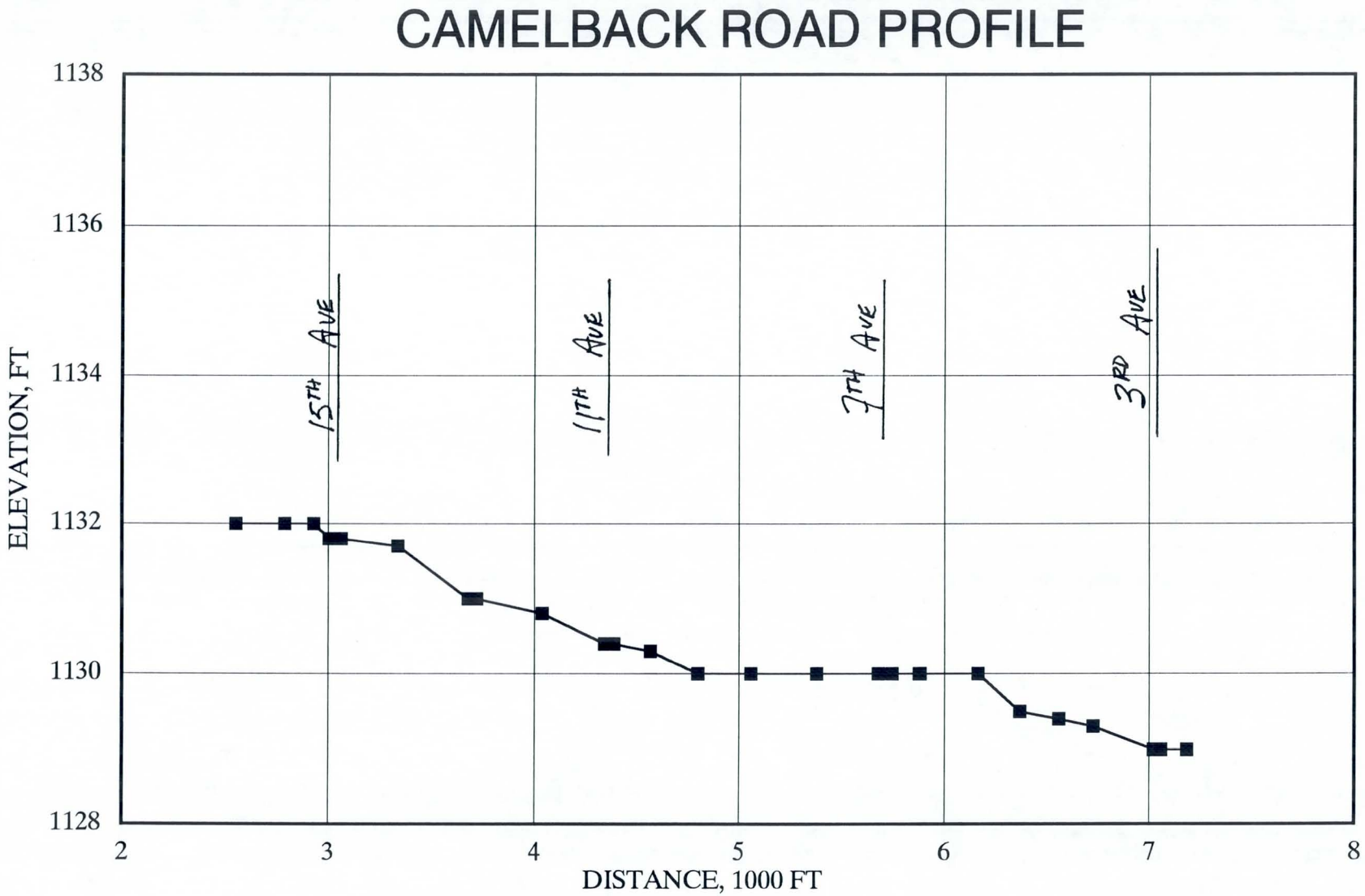

Figure 6 Camelback Road Profile between 17th Avenue and 7th Avenue

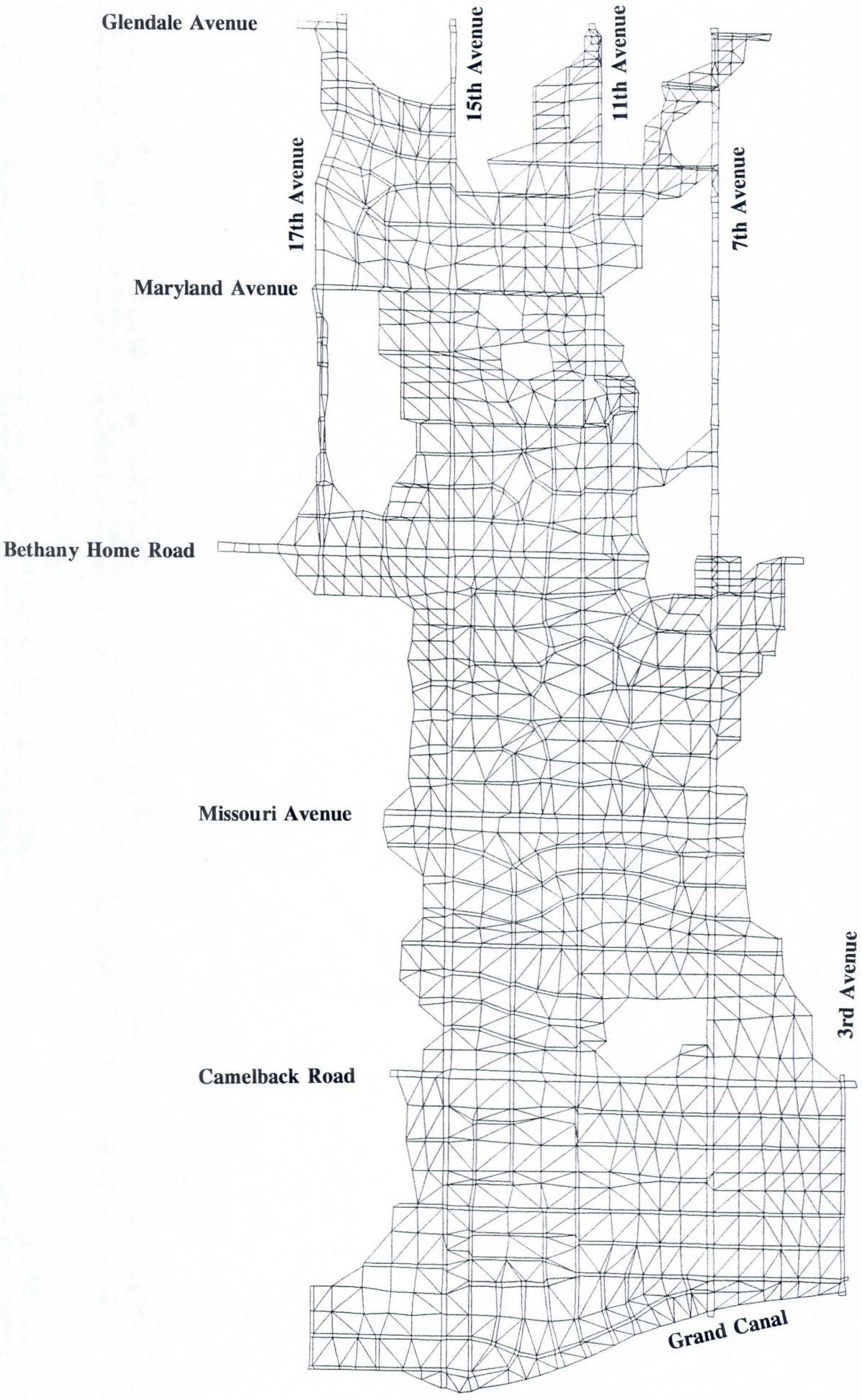

Figure 7 Final Computational Mesh Configuratio

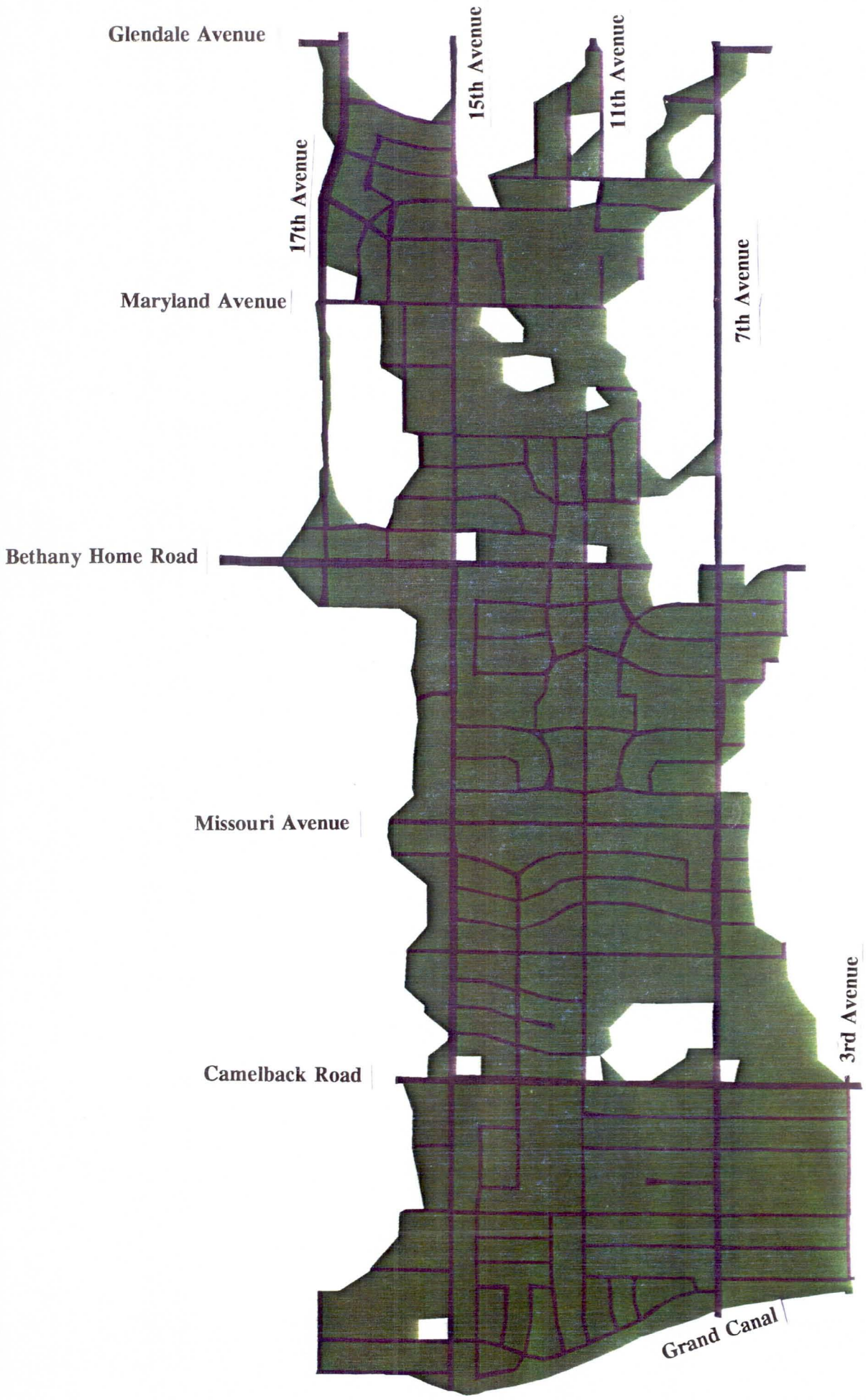

Figure 8 Street and Non-Street Areas within the Computational M

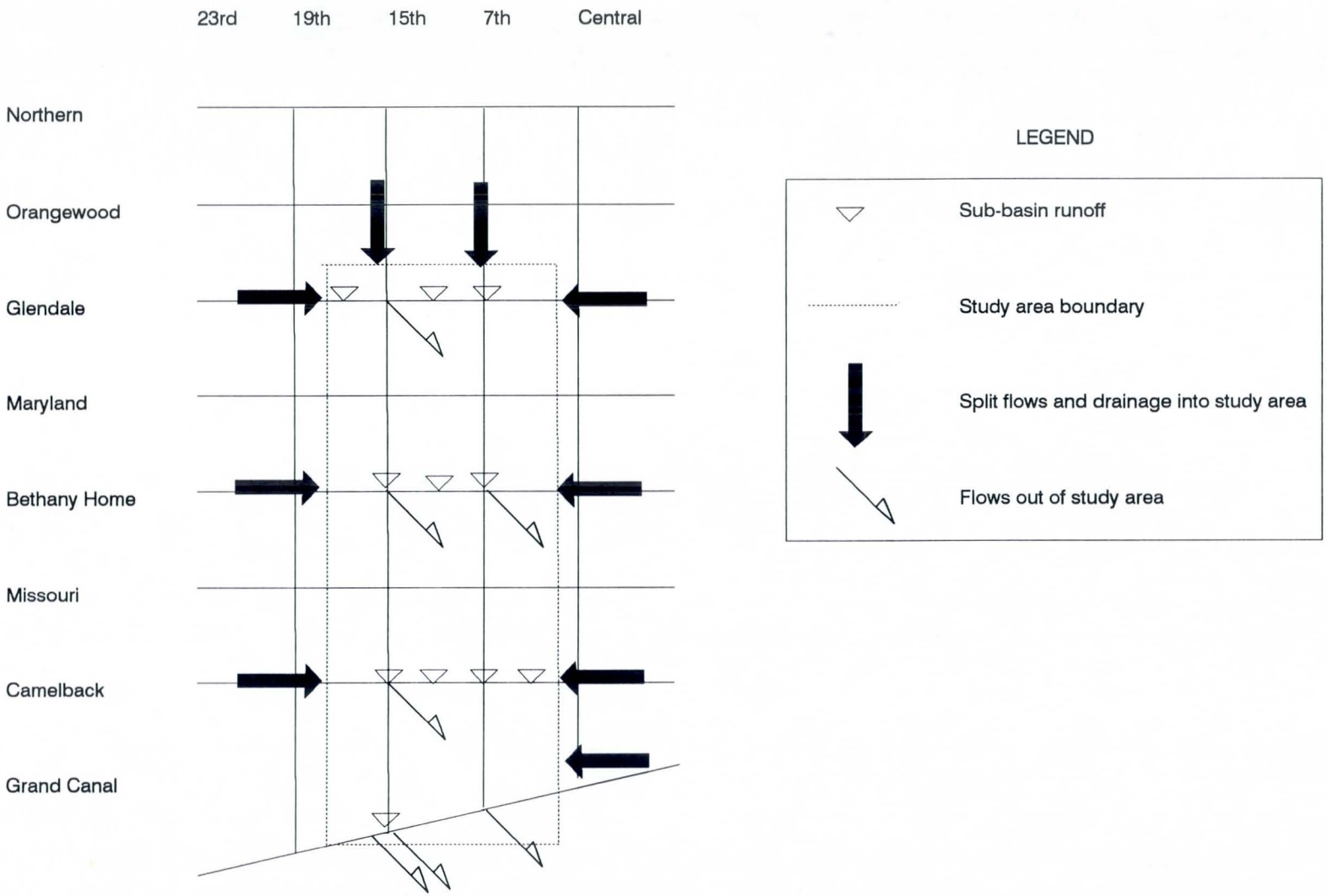

Figure 9 Flow Schematic for the Study Area

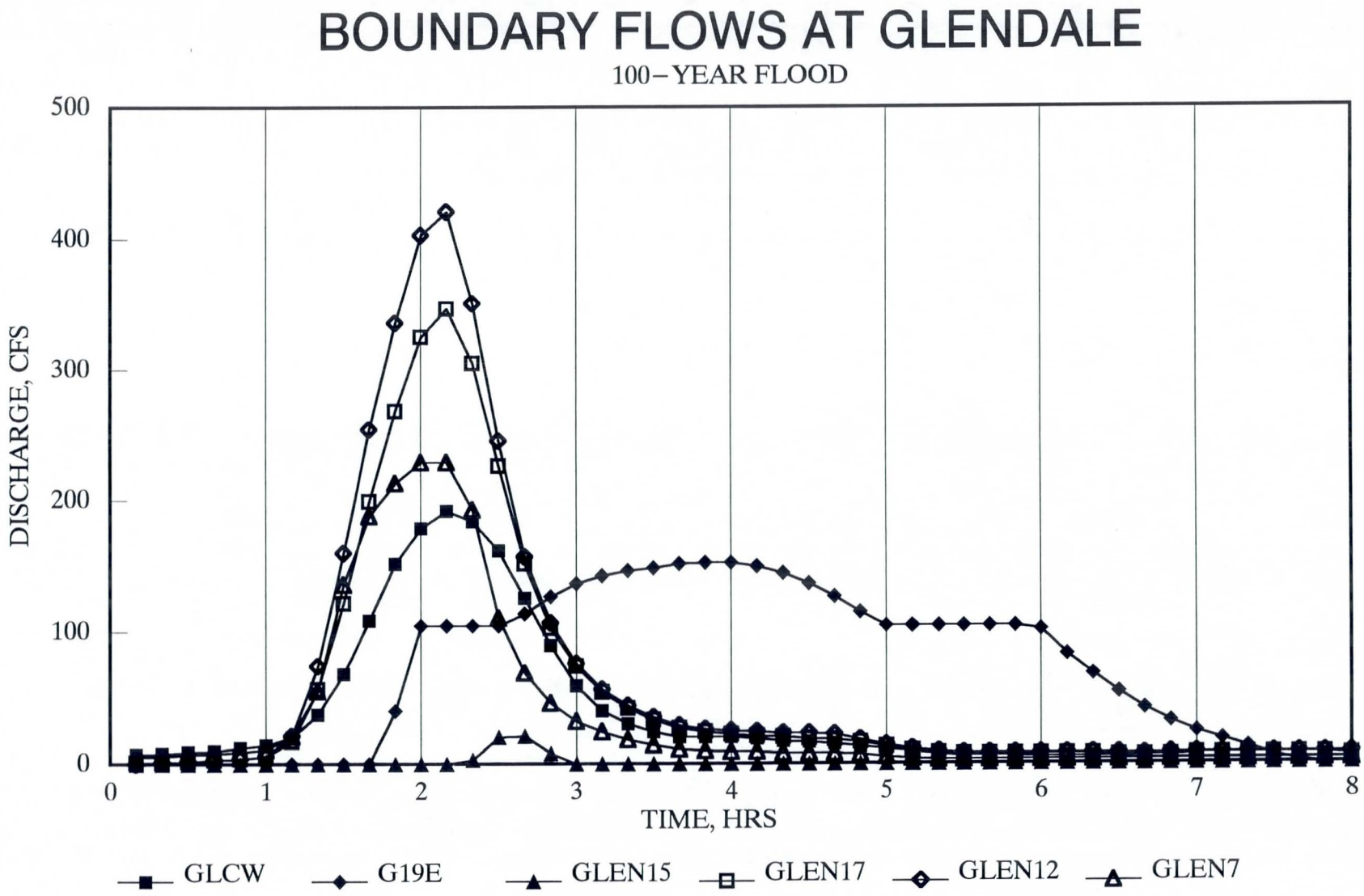

Figure 10 Boundary Flow Hydrographs along Glendale Avenue

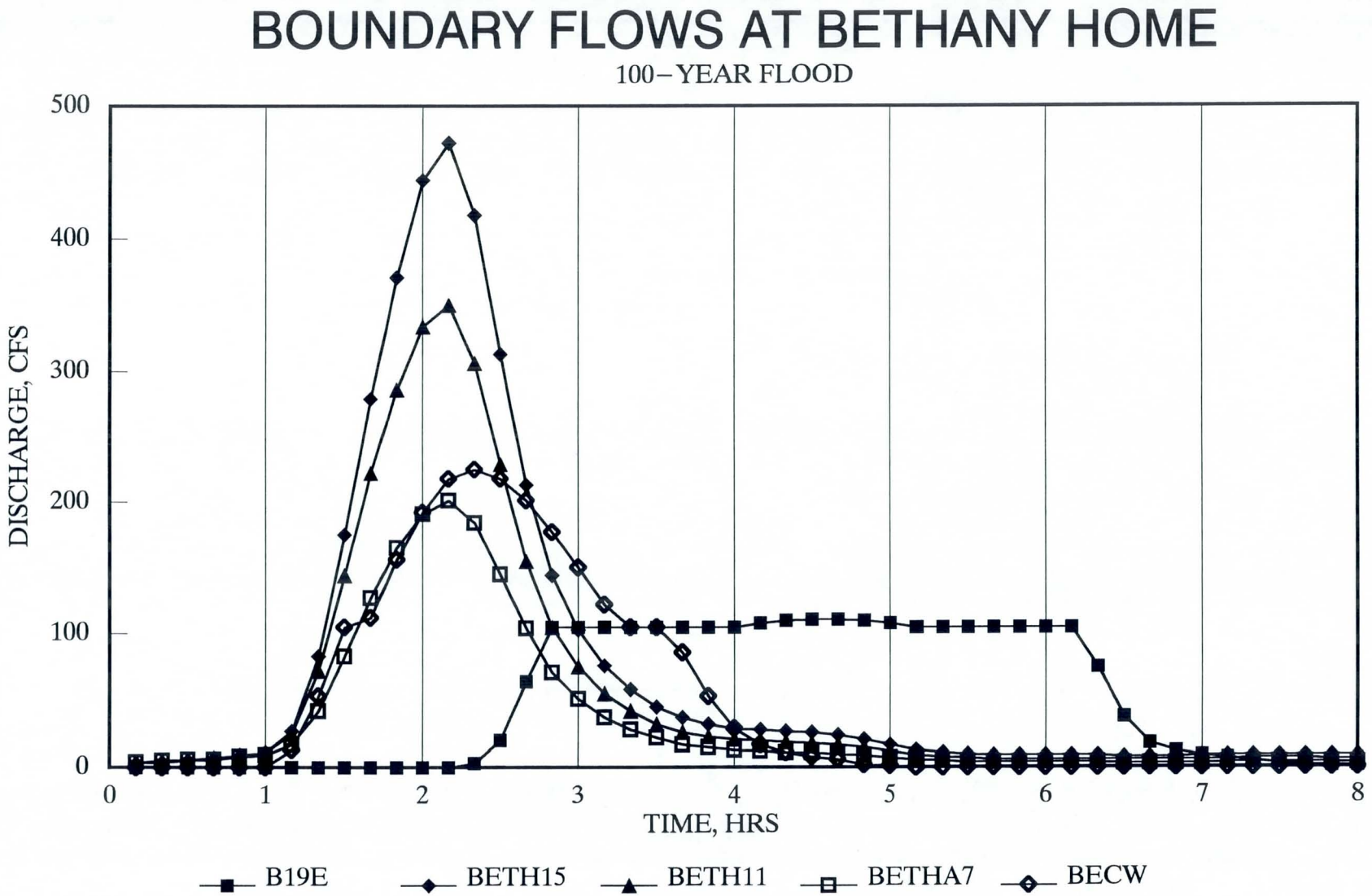

Figure 11 Boundary Flow Hydrographs along Bethany Home Road

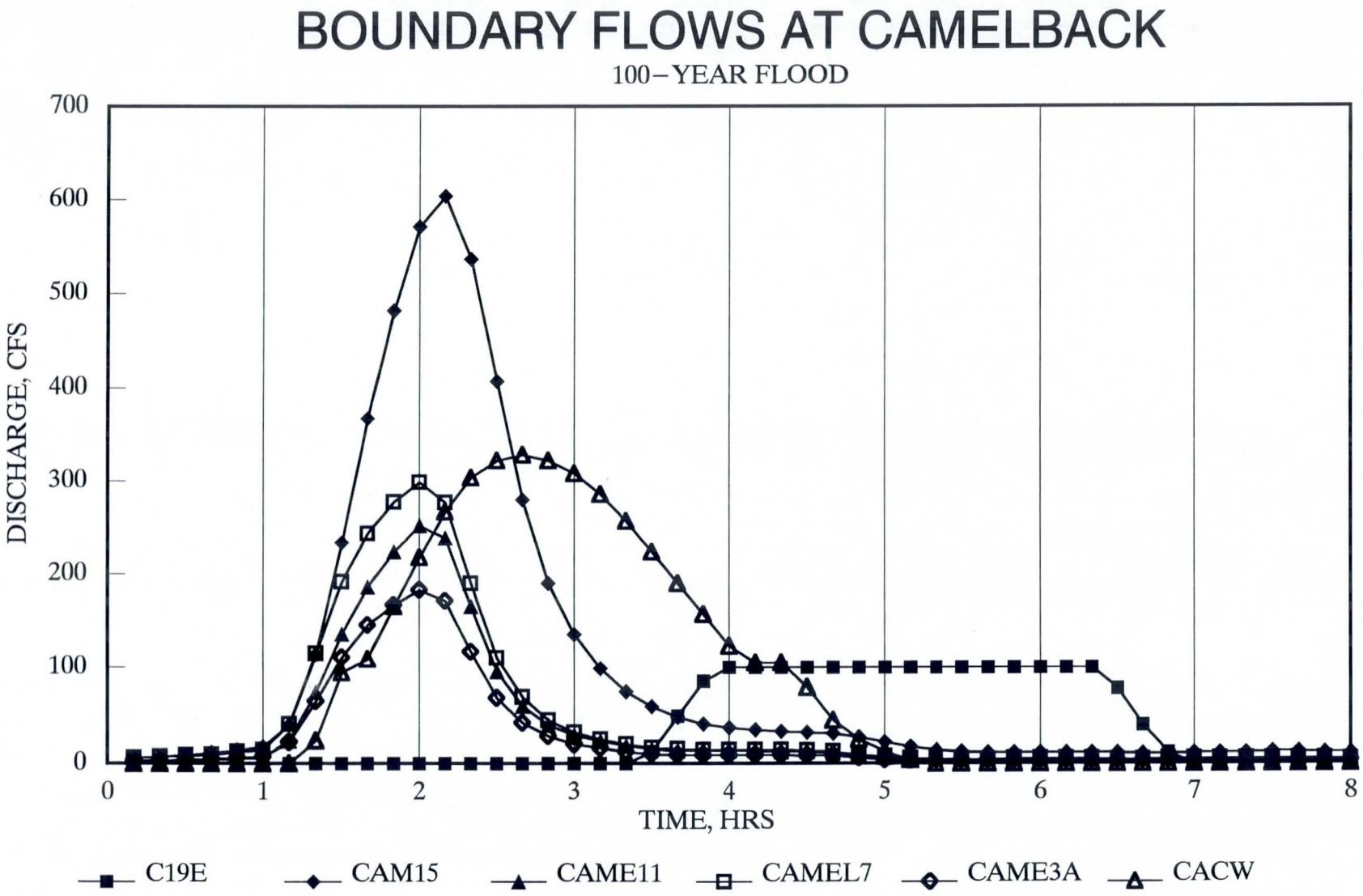

Figure 12 Boundary Flow Hydrographs along Camelback Road

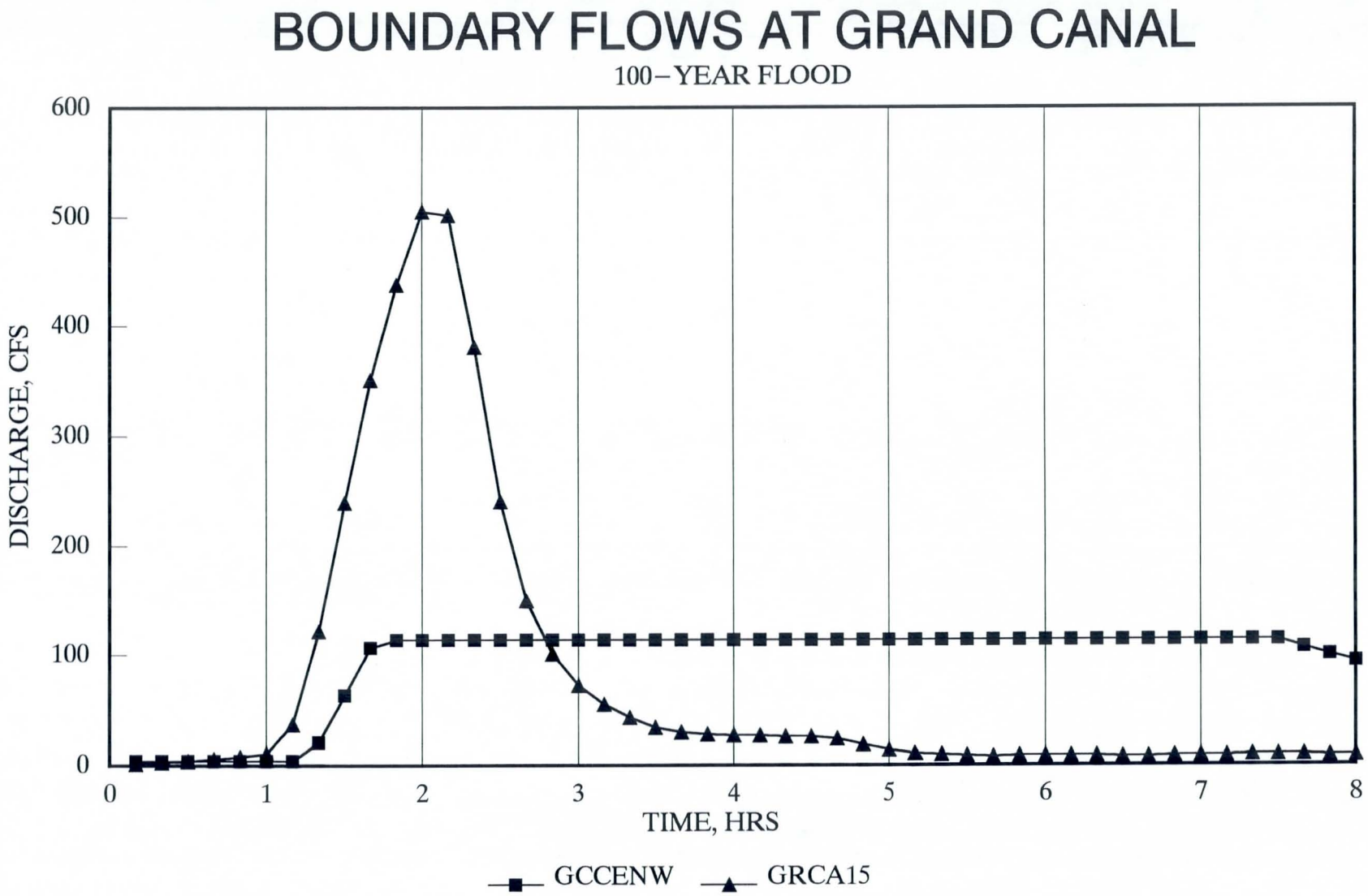

Figure 13 Boundary Flow Hydrographs along the Grand Canal

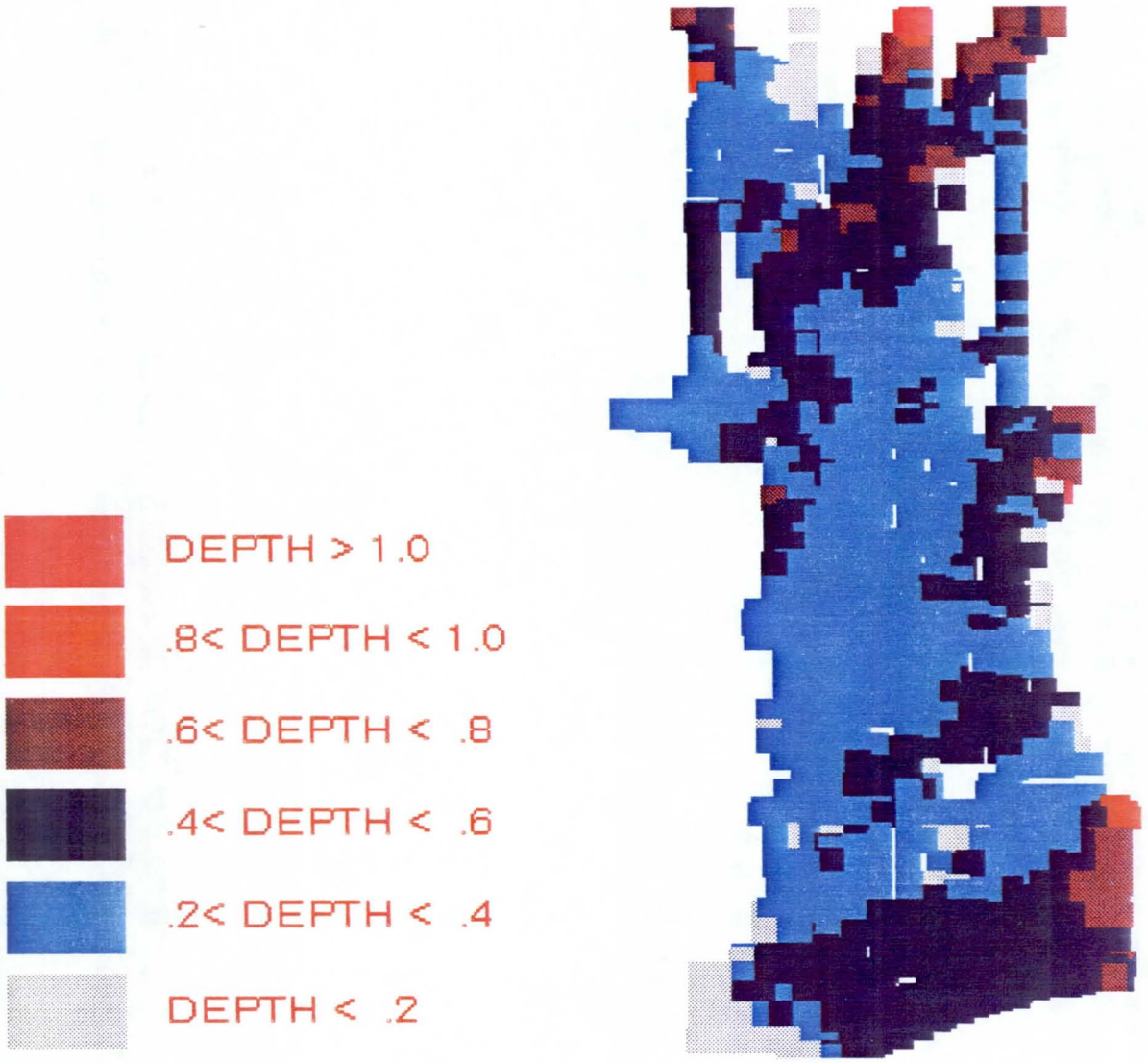

Figure 14 **Maximum Computed Flow Depths -- 100-Year Flood Condition 1 Analysis (minimum initial wet condition)**

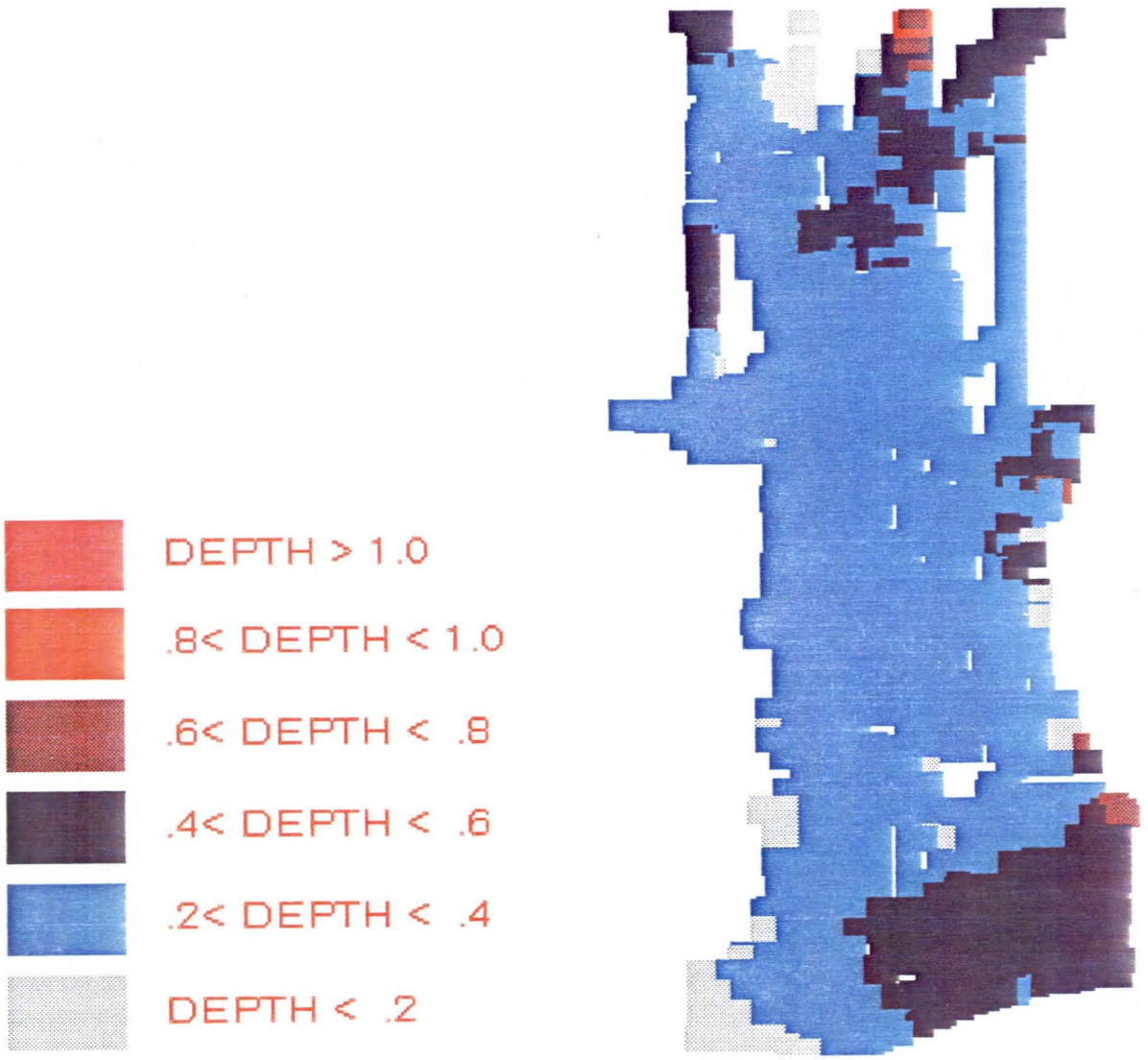

Figure 15 **Maximum Computed Flow Depths -- 100-Year Flood Condition 2 Analysis (increased initial wet condition)**

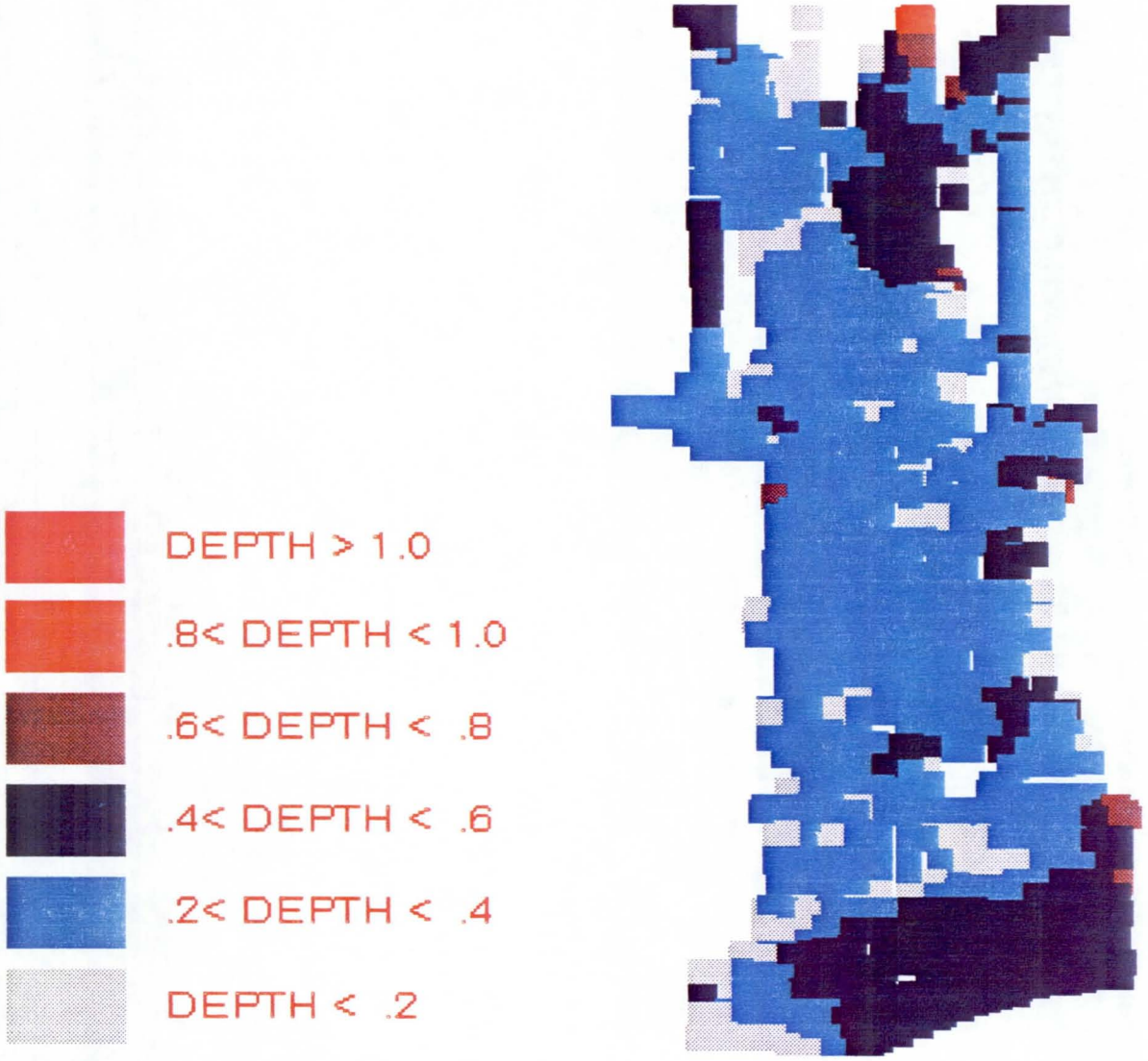

Figure 16 **Maximum Computed Flow Depths -- 100-year Flood Condition 3 Analysis (altered initial geometry condition)**

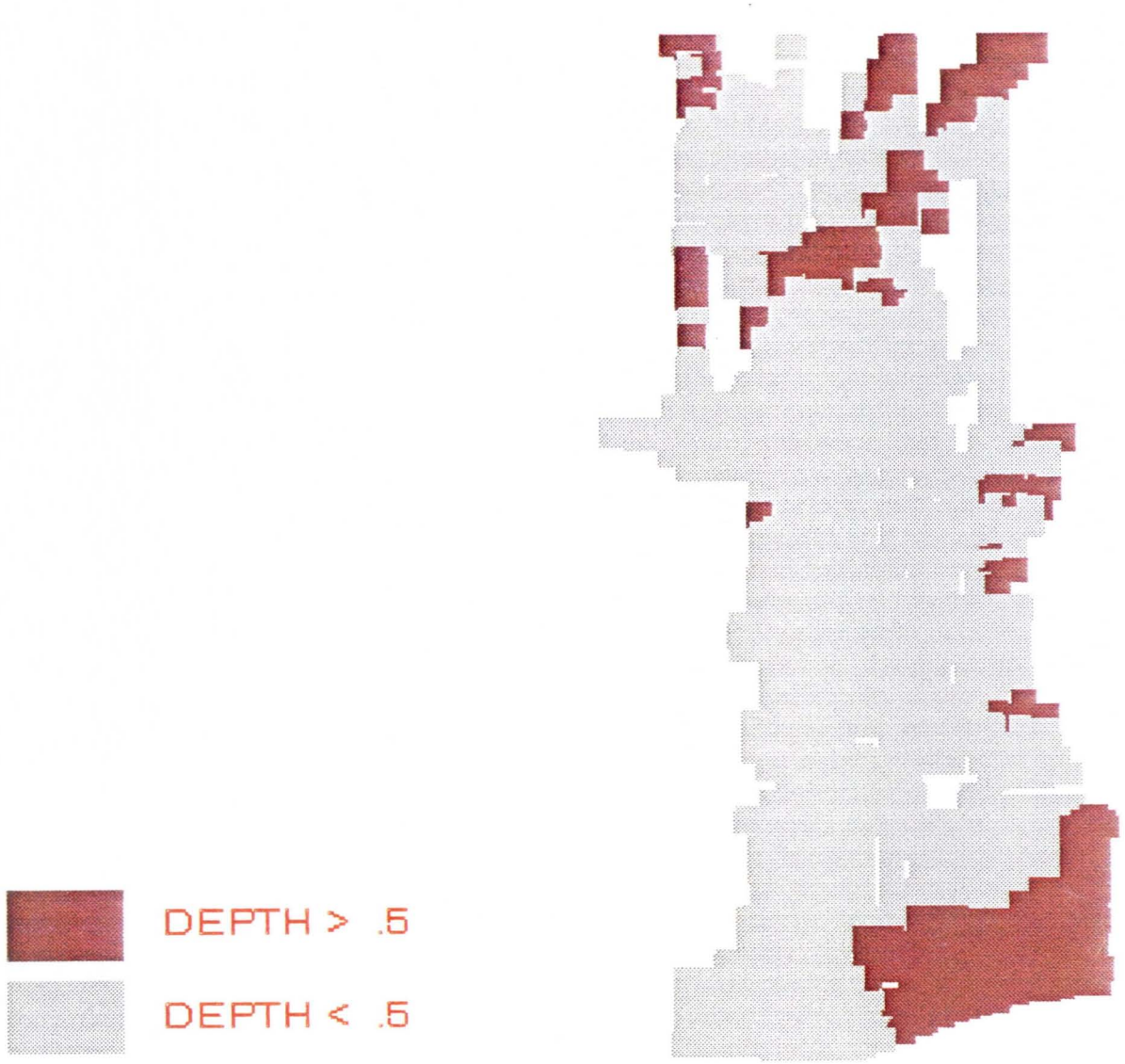

Figure 17 **Areas with 100-Year Flow Depth Exceeding 0.5 feet Condition 1 Analysis (minimum initial wet condition)**

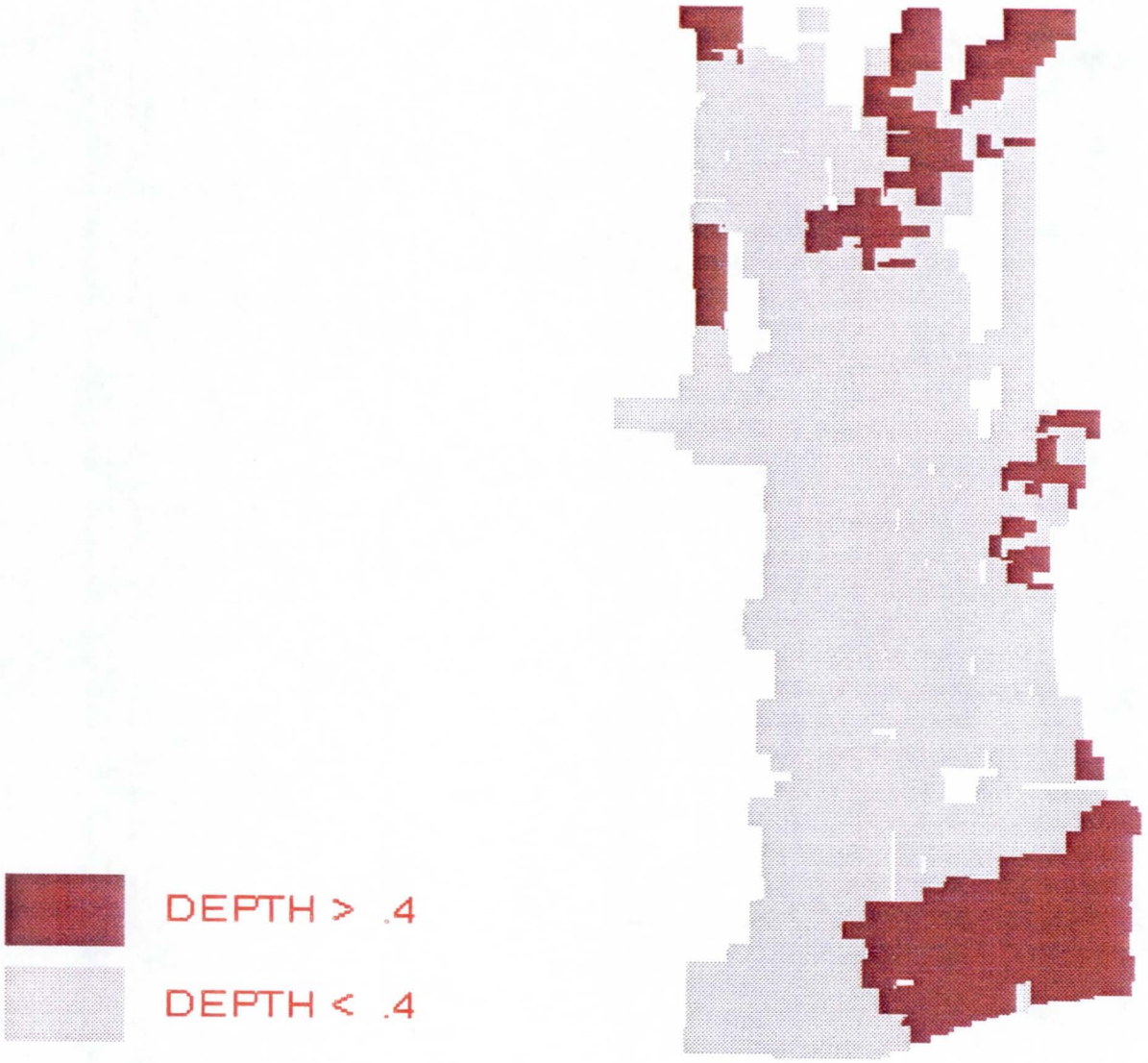

Figure 18 **Areas with 100-Year Flow Depth Exceeding 0.4 feet Condition 2 Analysis (increased initial wet condition)**

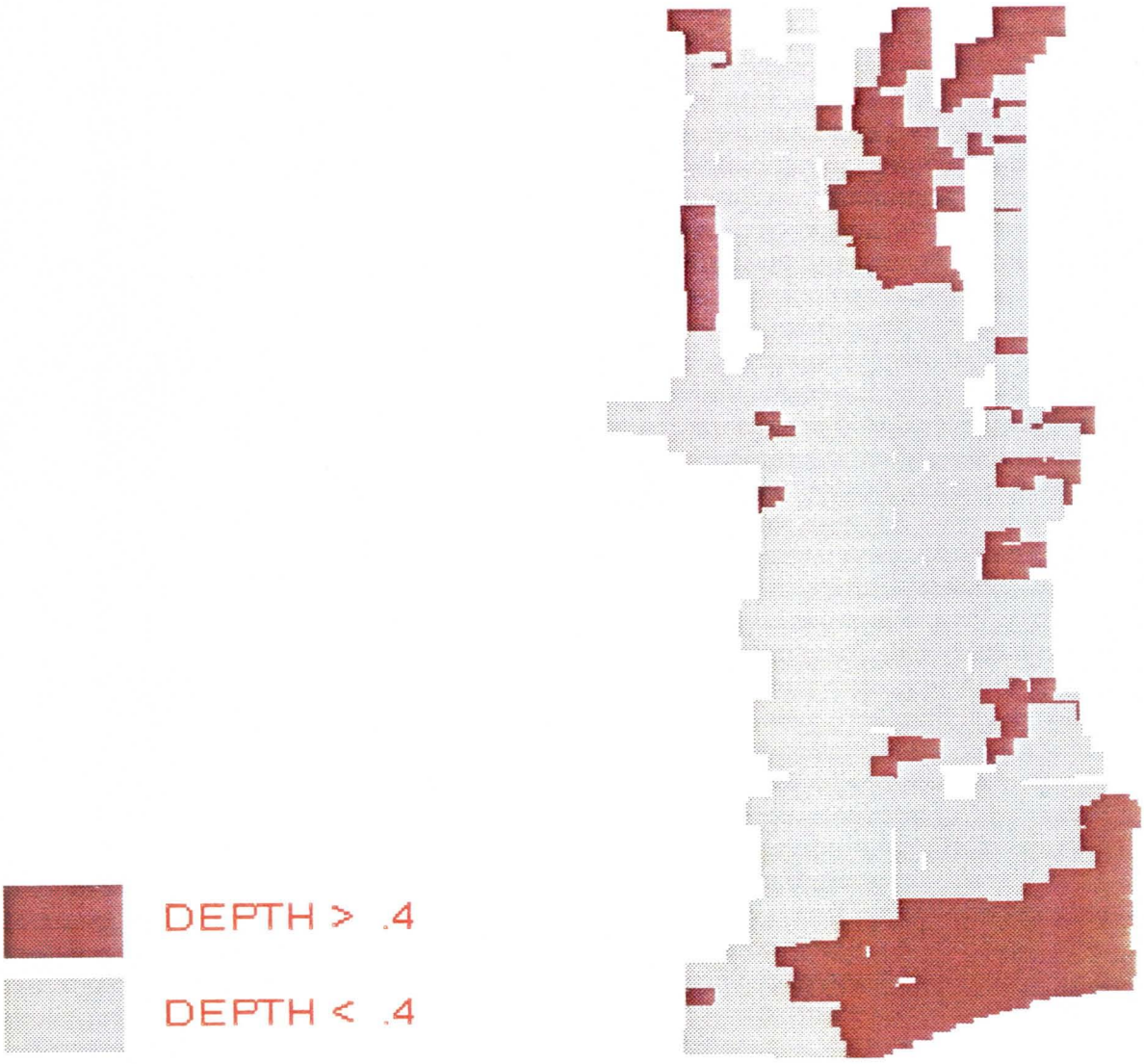

Figure 19 Areas with 100-Year Flow Depth Exceeding 0.4 feet
Condition 3 Analysis (altered initial geometry condition)

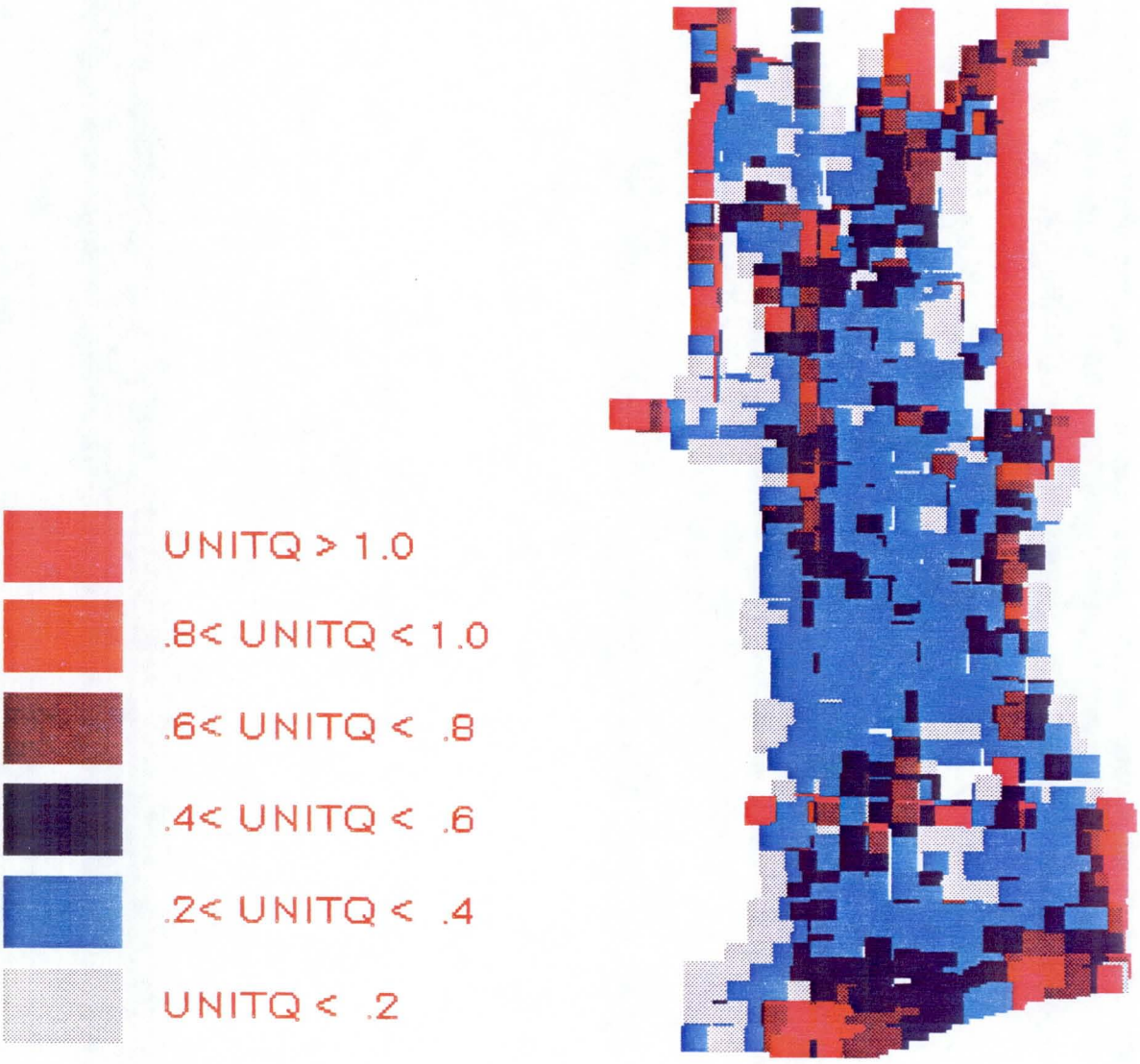

Figure 20 **Maximum Unit Discharge Variation – 100-Year Flood Condition 1 Analysis (minimum initial wet condition)**

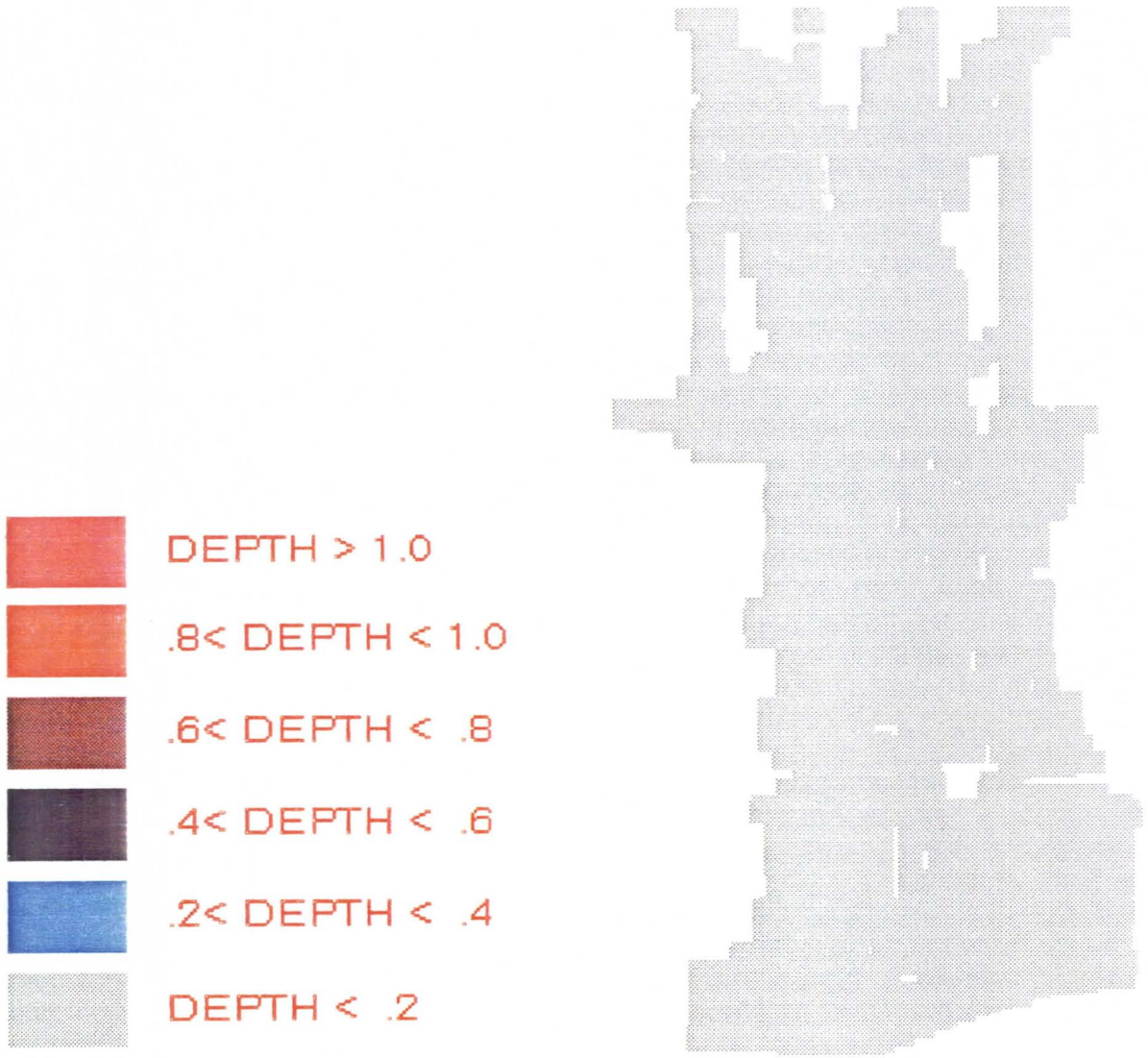

Figure 21 **Dynamic Simulation of the 100-Year Flood through the Study Area Computed Flow Depth at Time Step 1**

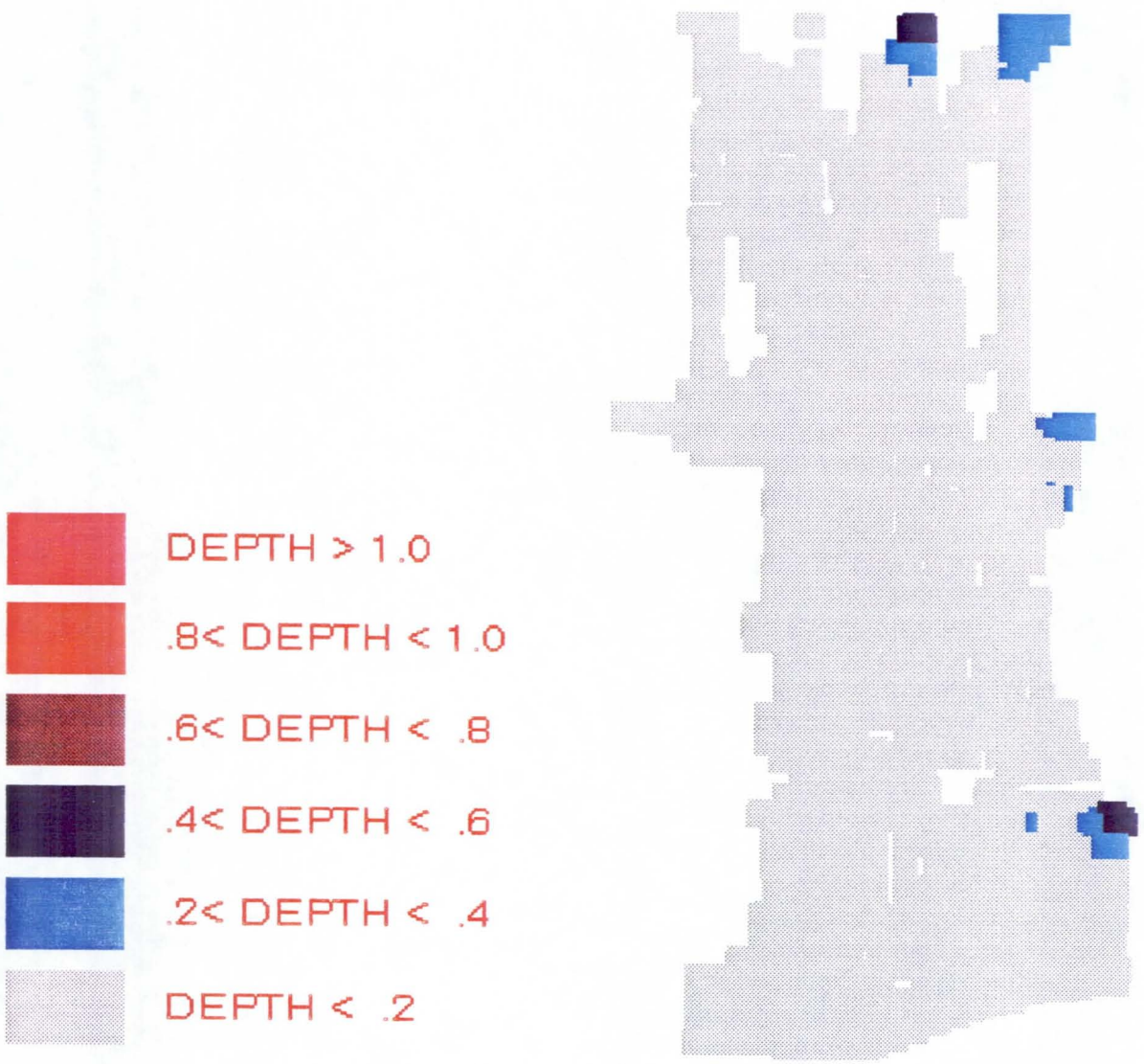

Figure 22 **Dynamic Simulation of the 100-Year Flood through the Study Area Computed Flow Depth at Time Step 3**

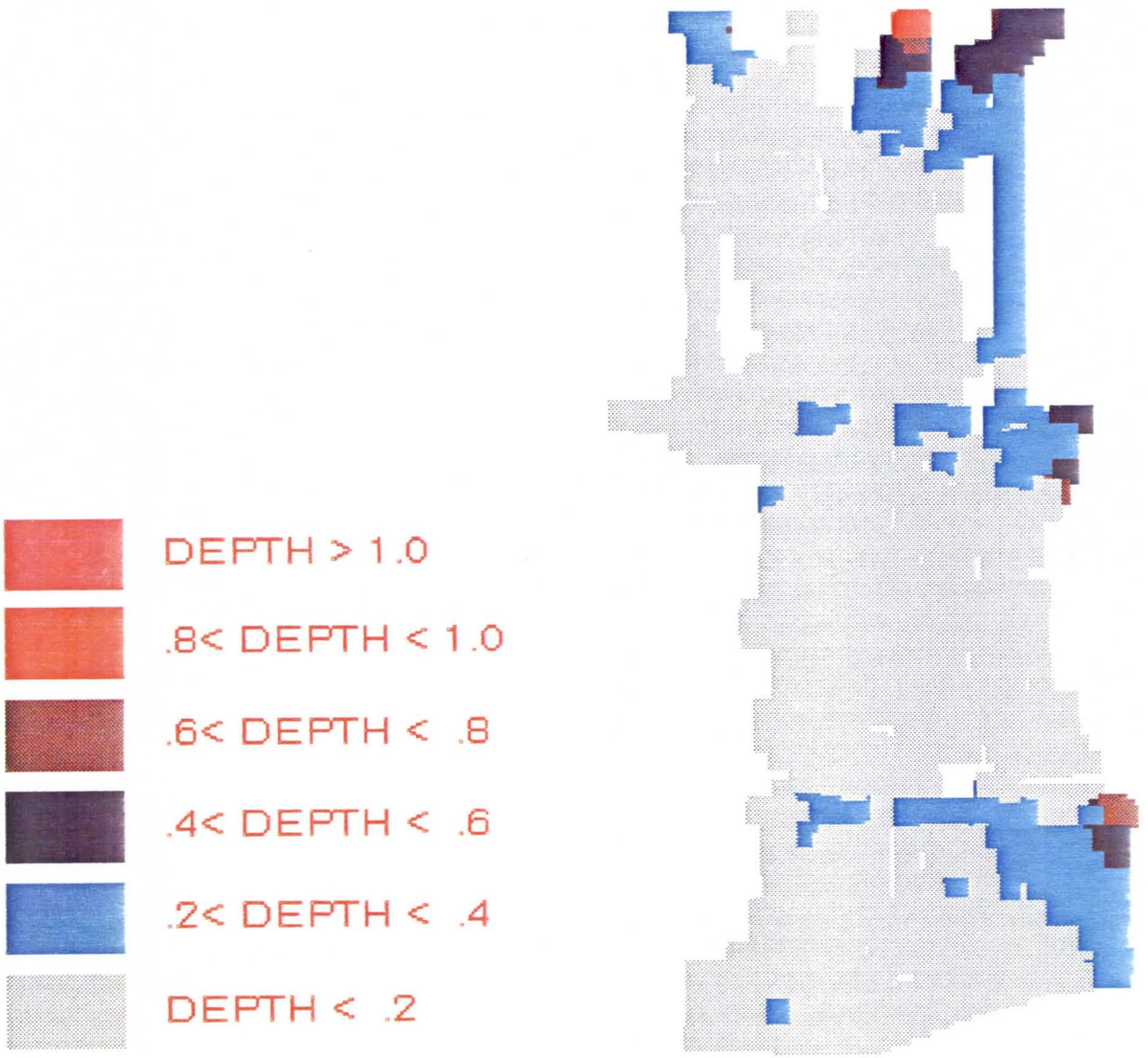

Figure 23 **Dynamic Simulation of the 100-Year Flood through the Study Area Computed Flow Depth at Time Step 5**

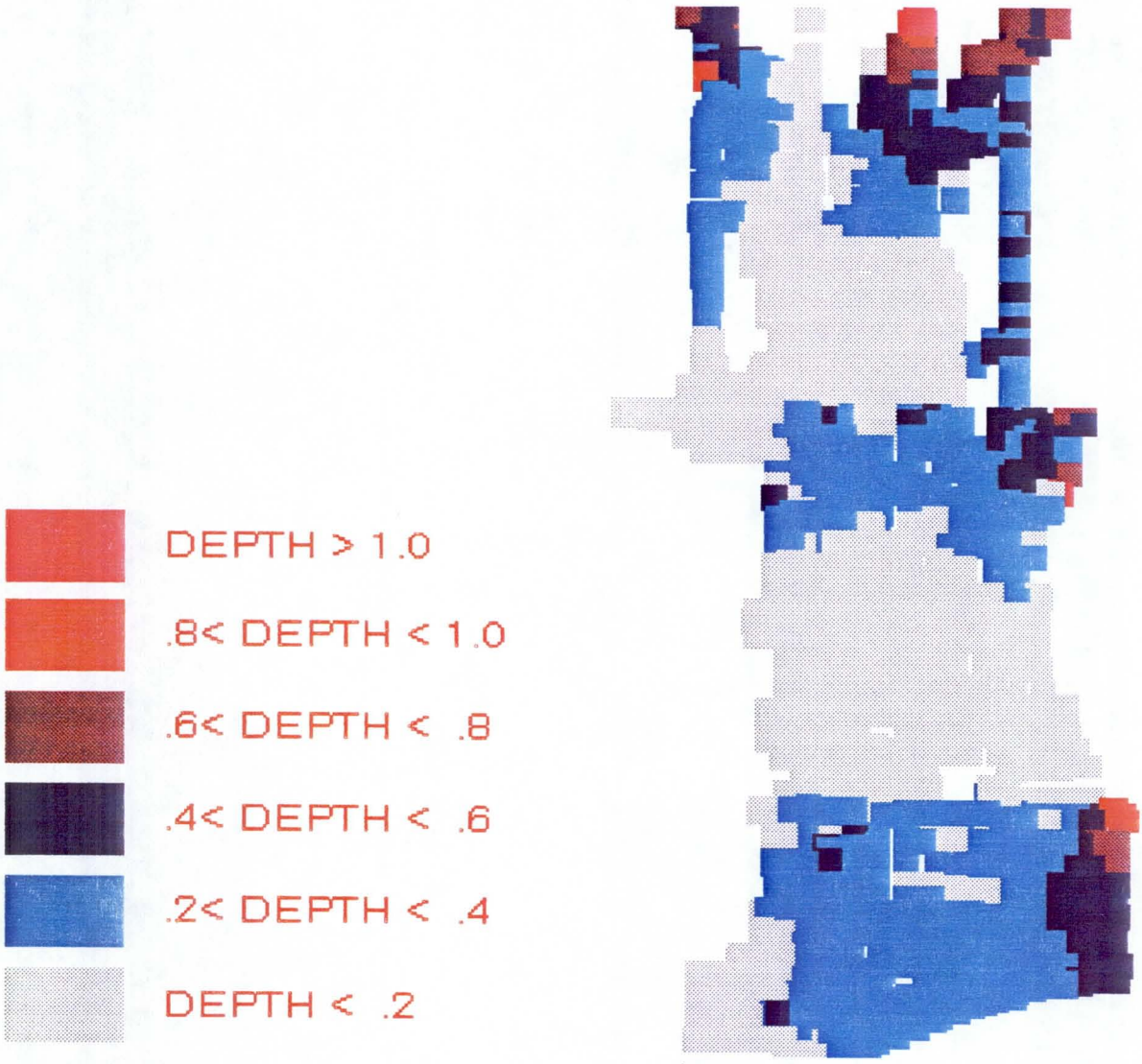

Figure 24 **Dynamic Simulation of the 100-Year Flood through the Study Area Computed Flow Depth at Time Step 7**

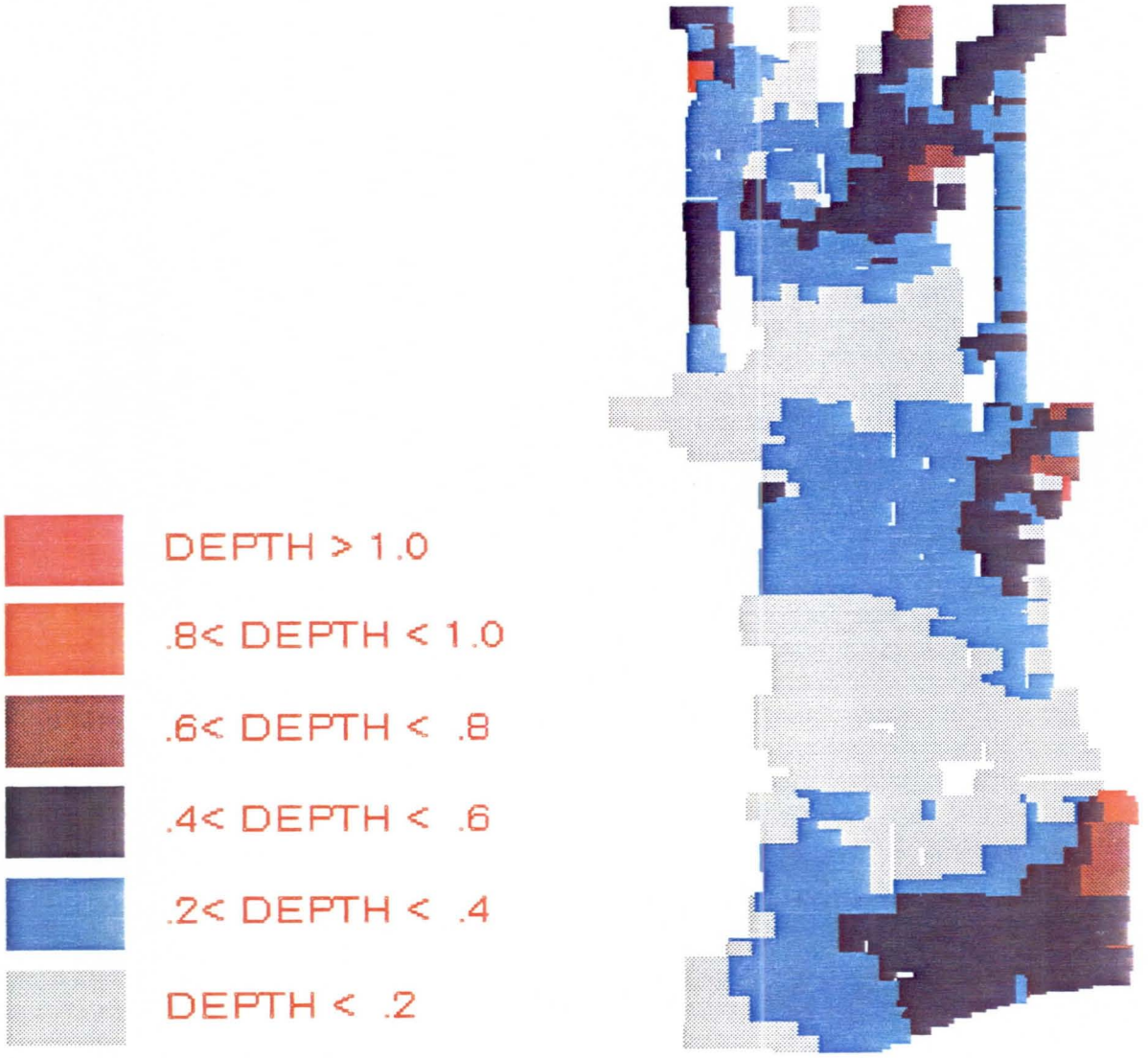

Figure 25 Dynamic Simulation of the 100-Year Flood through the Study Area
Computed Flow Depth at Time Step 9

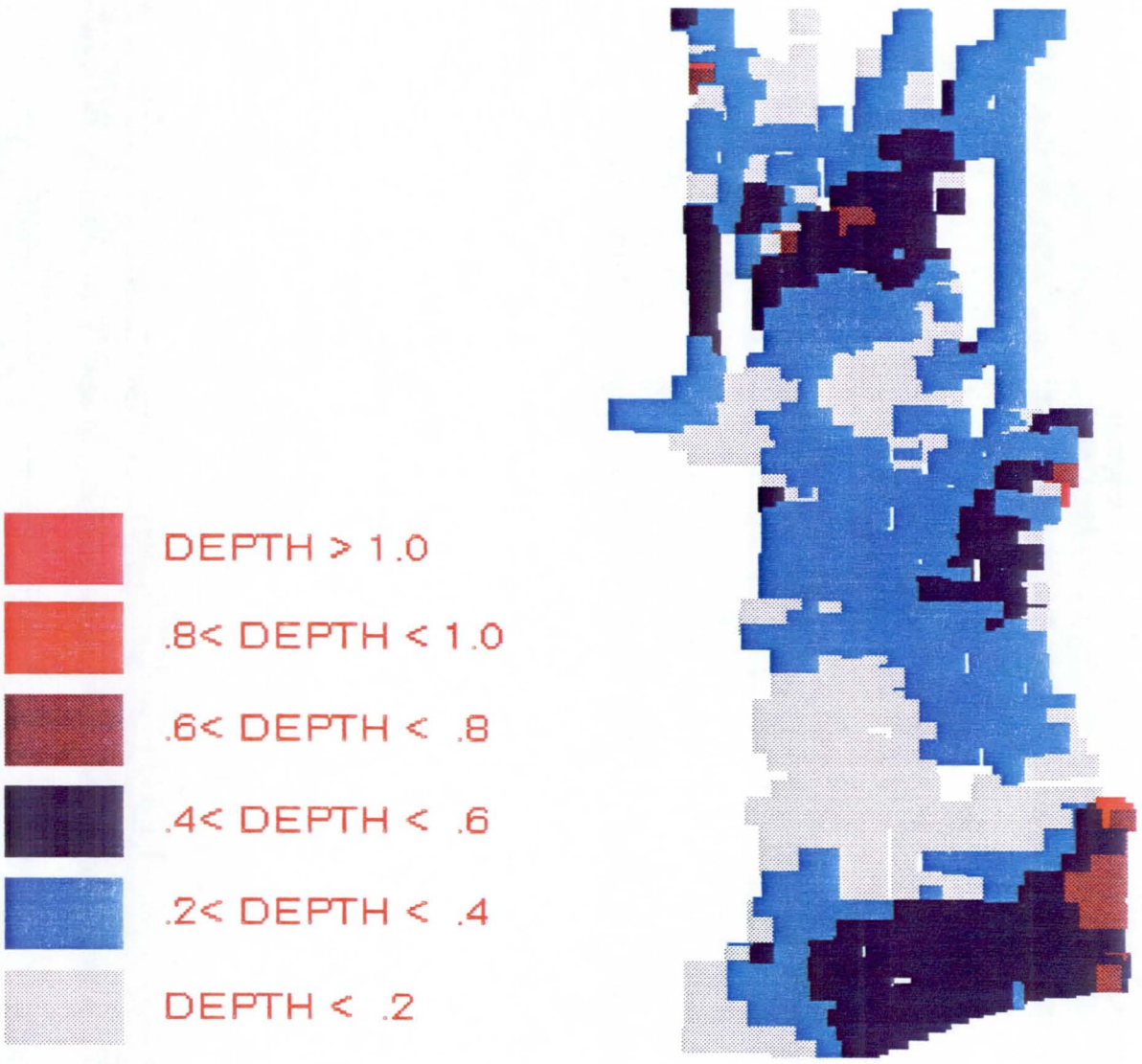

Figure 26 **Dynamic Simulation of the 100-Year Flood through the Study Area Computed Flow Depth at Time Step 11**

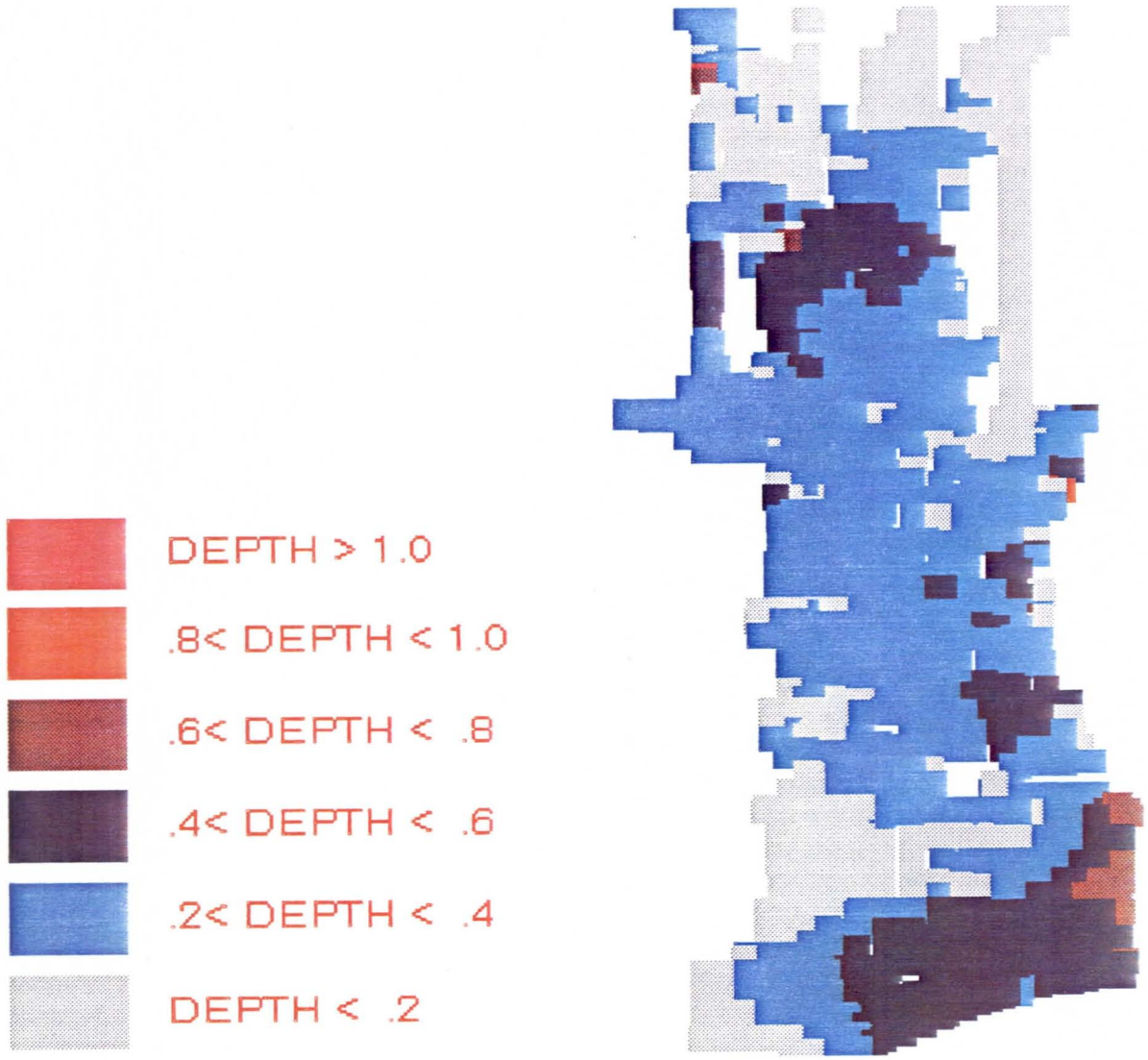

Figure 27 **Dynamic Simulation of the 100-Year Flood through the Study Area Computed Flow Depth at Time Step 13**

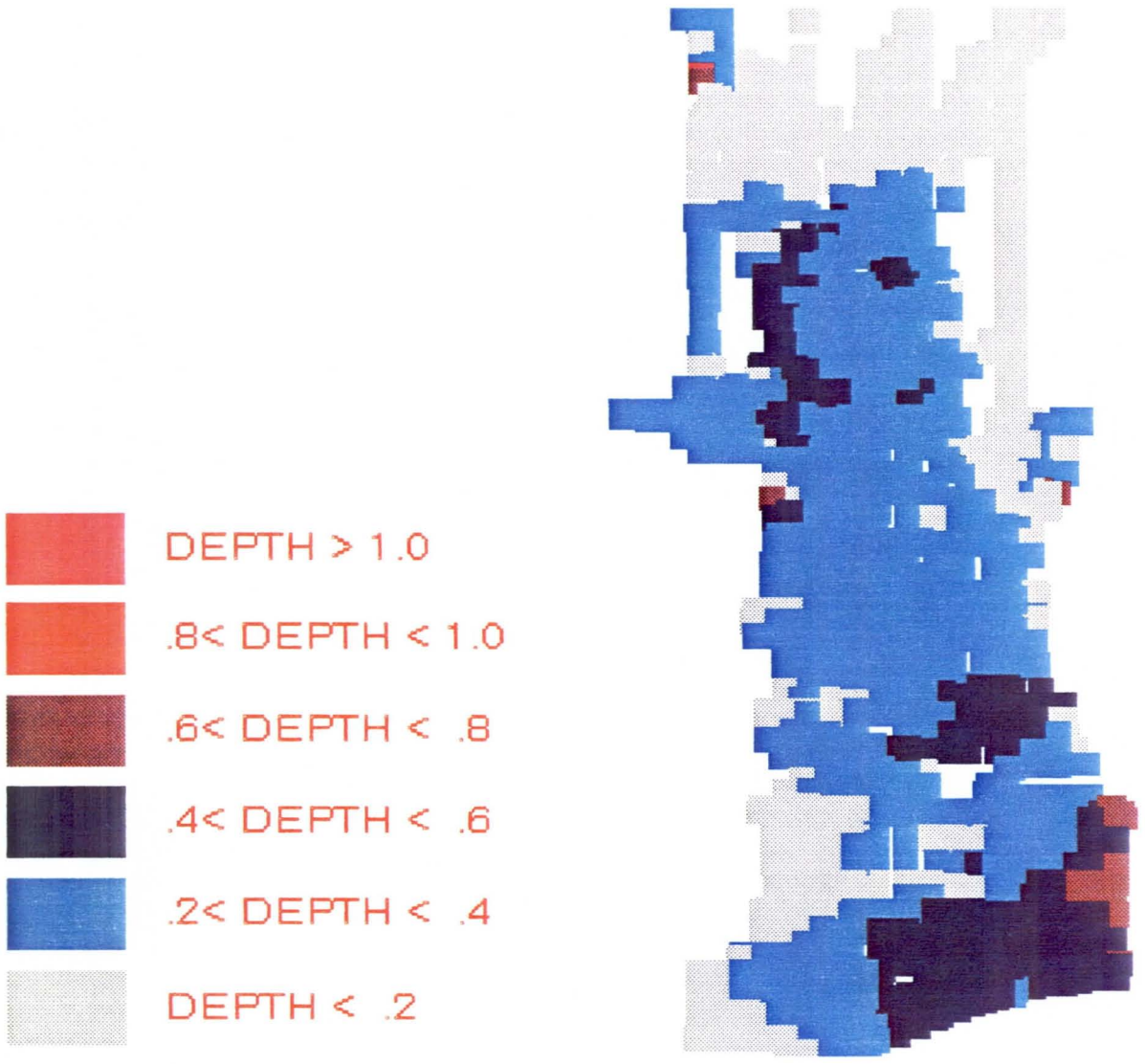

Figure 28 **Dynamic Simulation of the 100-Year Flood through the Study Area Computed Flow Depth at Time Step 15**

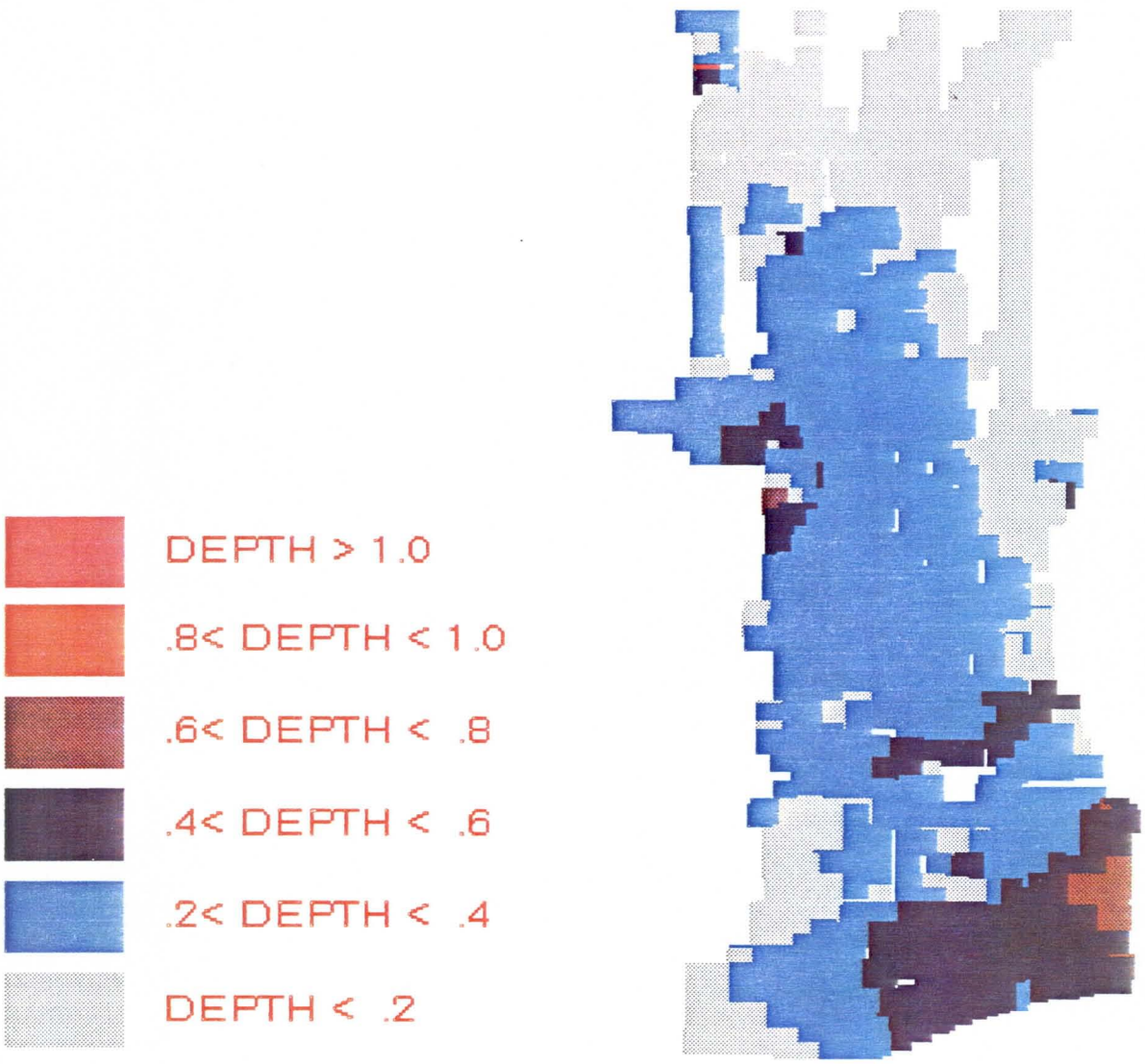

Figure 29 **Dynamic Simulation of the 100-Year Flood through the Study Area Computed Flow Depth at Time Step 17**

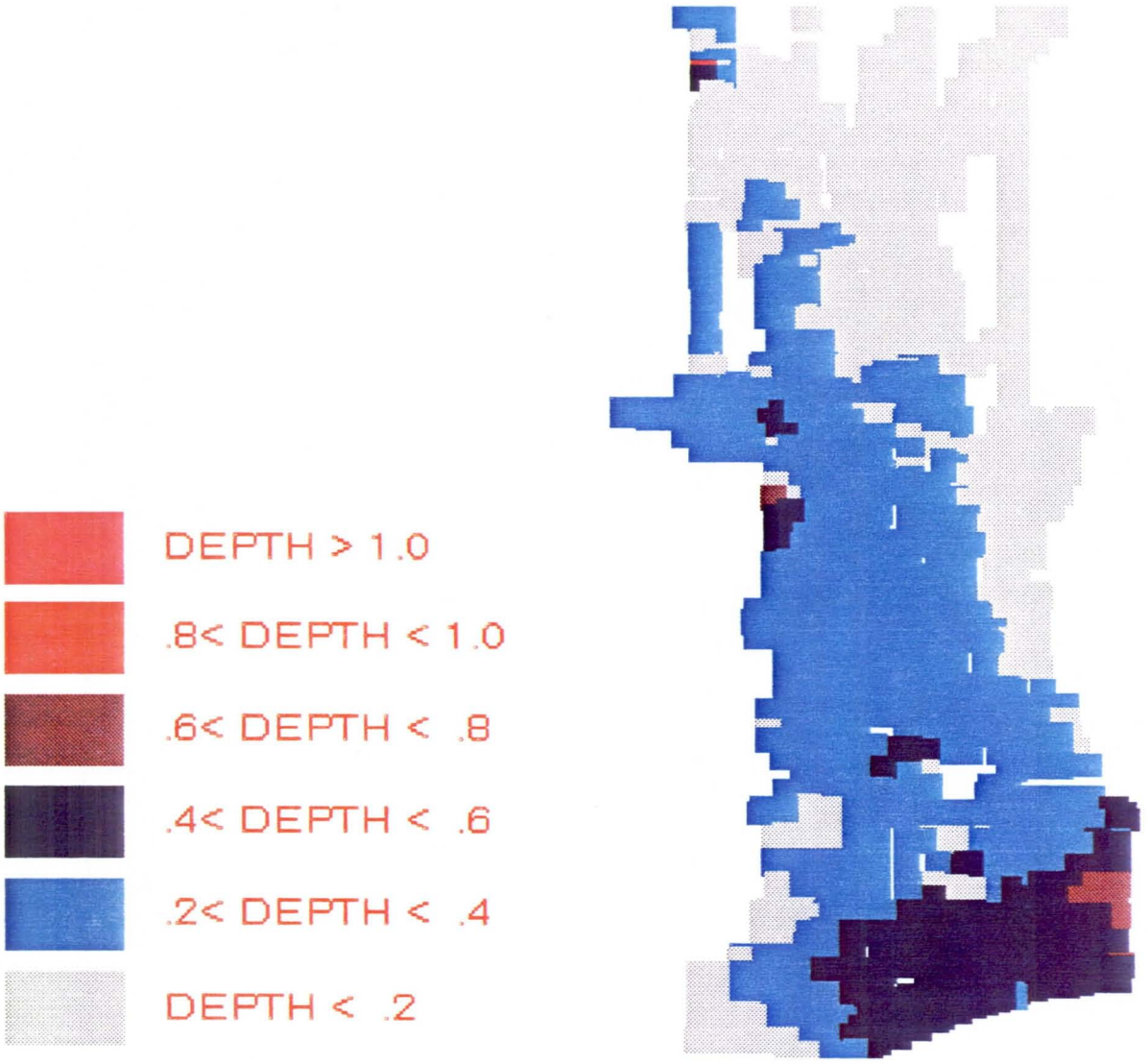

Figure 30 **Dynamic Simulation of the 100-Year Flood through the Study Area Computed Flow Depth at Time Step 19**

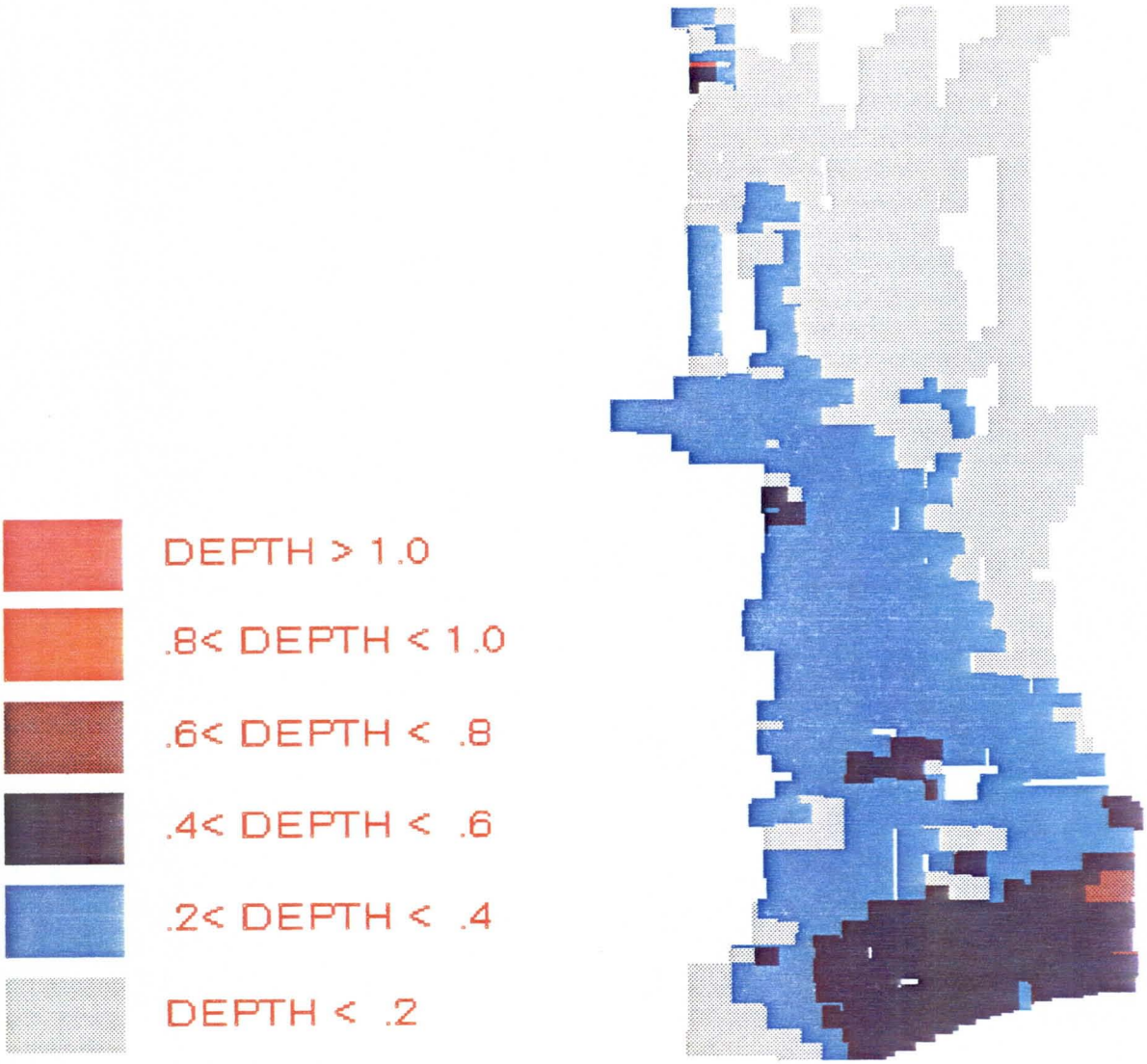

Figure 31 **Dynamic Simulation of the 100-Year Flood through the Study Area Computed Flow Depth at Time Step 21**

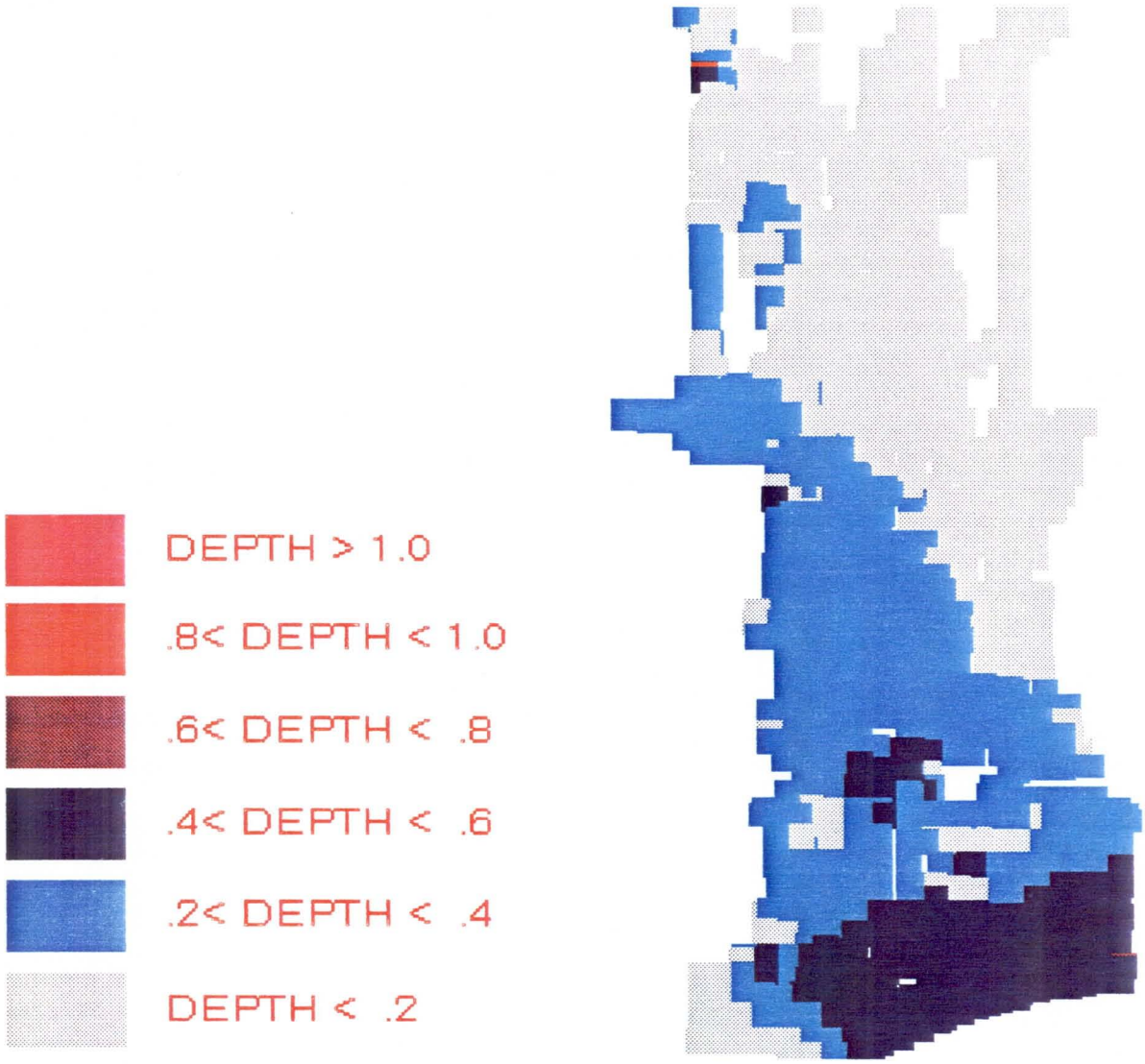

Figure 32 **Dynamic Simulation of the 100-Year Flood through the Study Area Computed Flow Depth at Time Step 23**

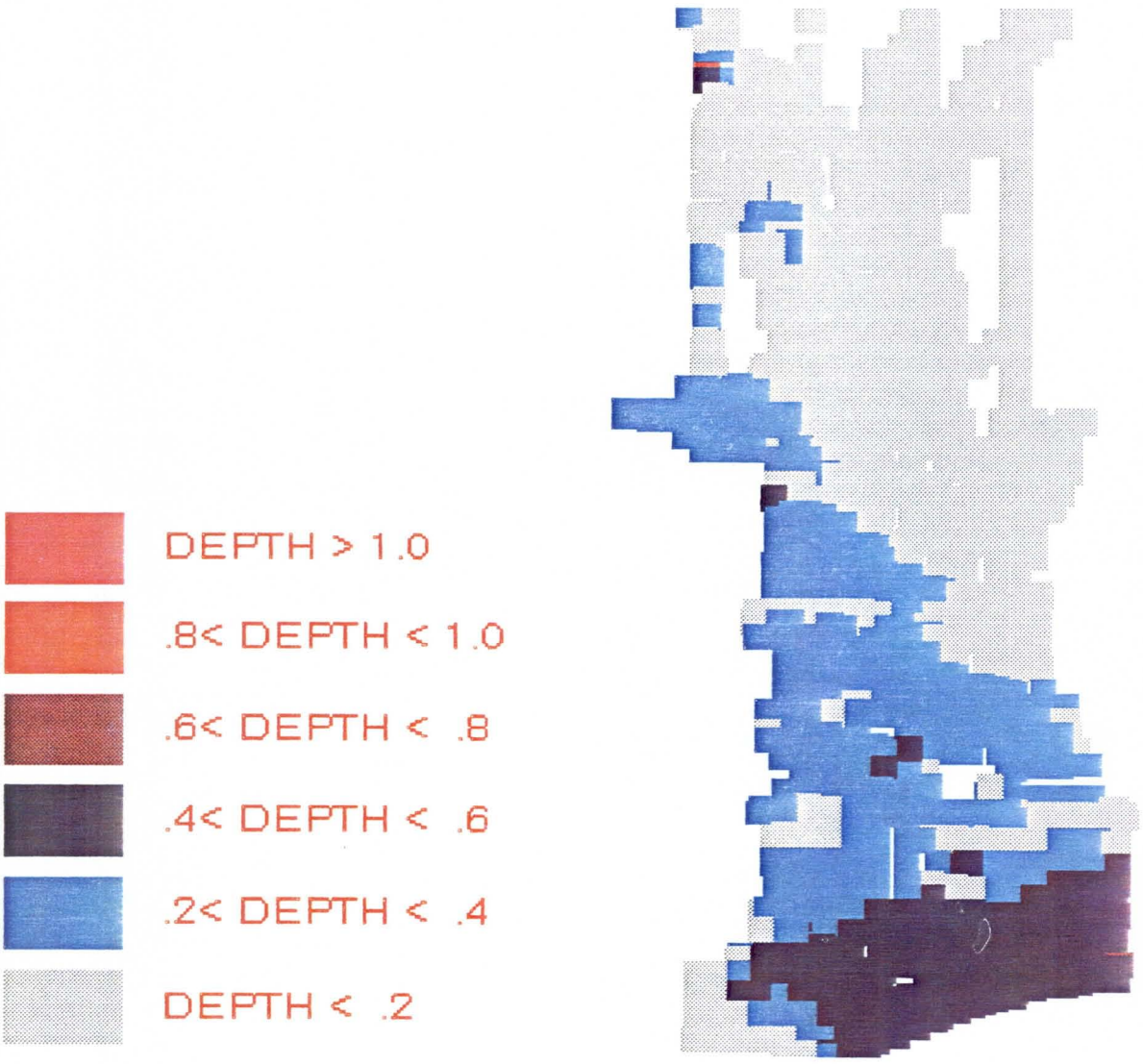

Figure 33 Dynamic Simulation of the 100-Year Flood through the Study Area Computed Flow Depth at Time Step 25

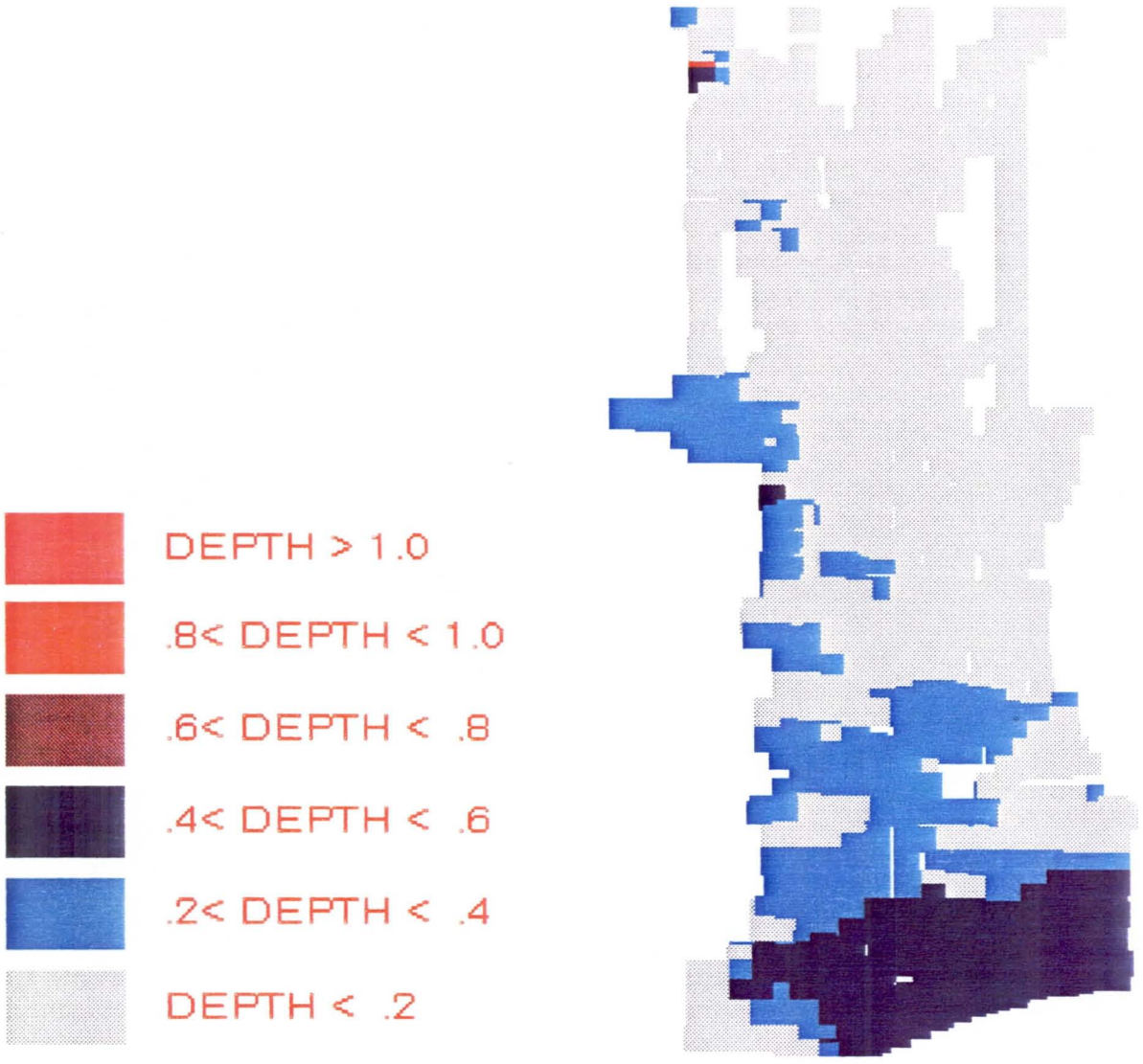

Figure 34 **Dynamic Simulation of the 100-Year Flood through the Study Area Computed Flow Depth at Time Step 27**

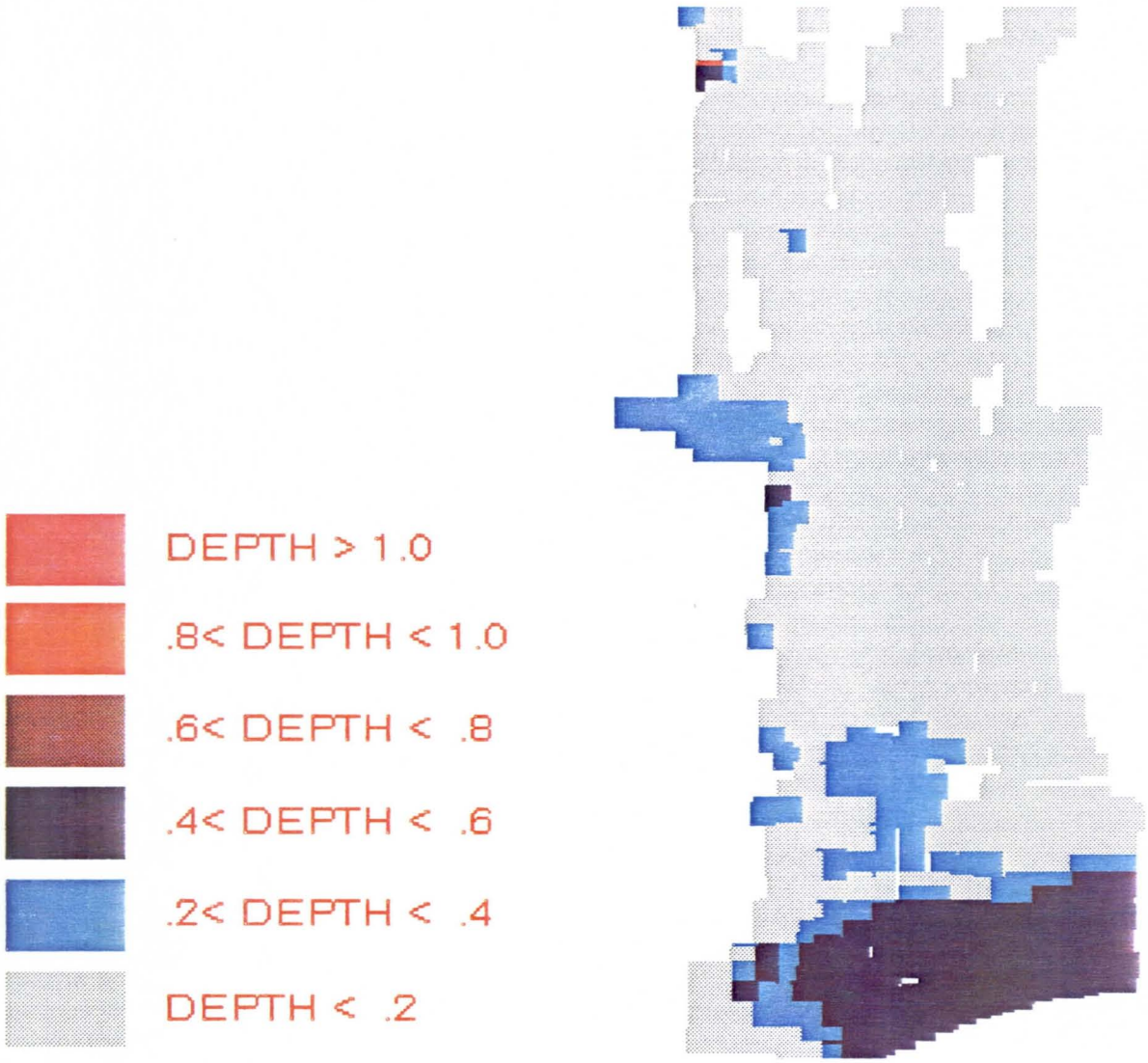

Figure 35 Dynamic Simulation of the 100-Year Flood through the Study Ar
Computed Flow Depth at Time Step 29

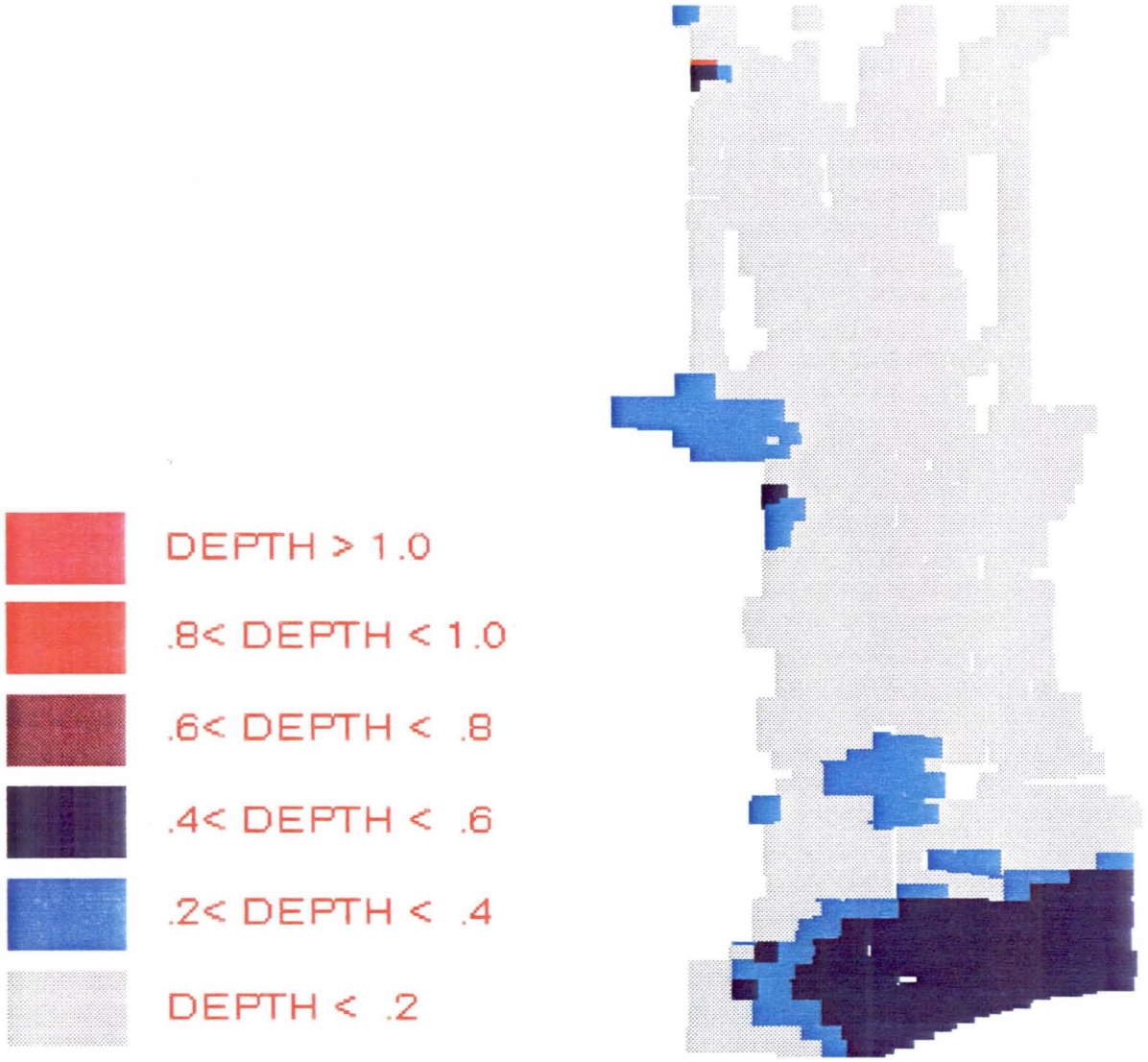

Figure 36 **Dynamic Simulation of the 100-Year Flood through the Study Ar Computed Flow Depth at Time Step 31**

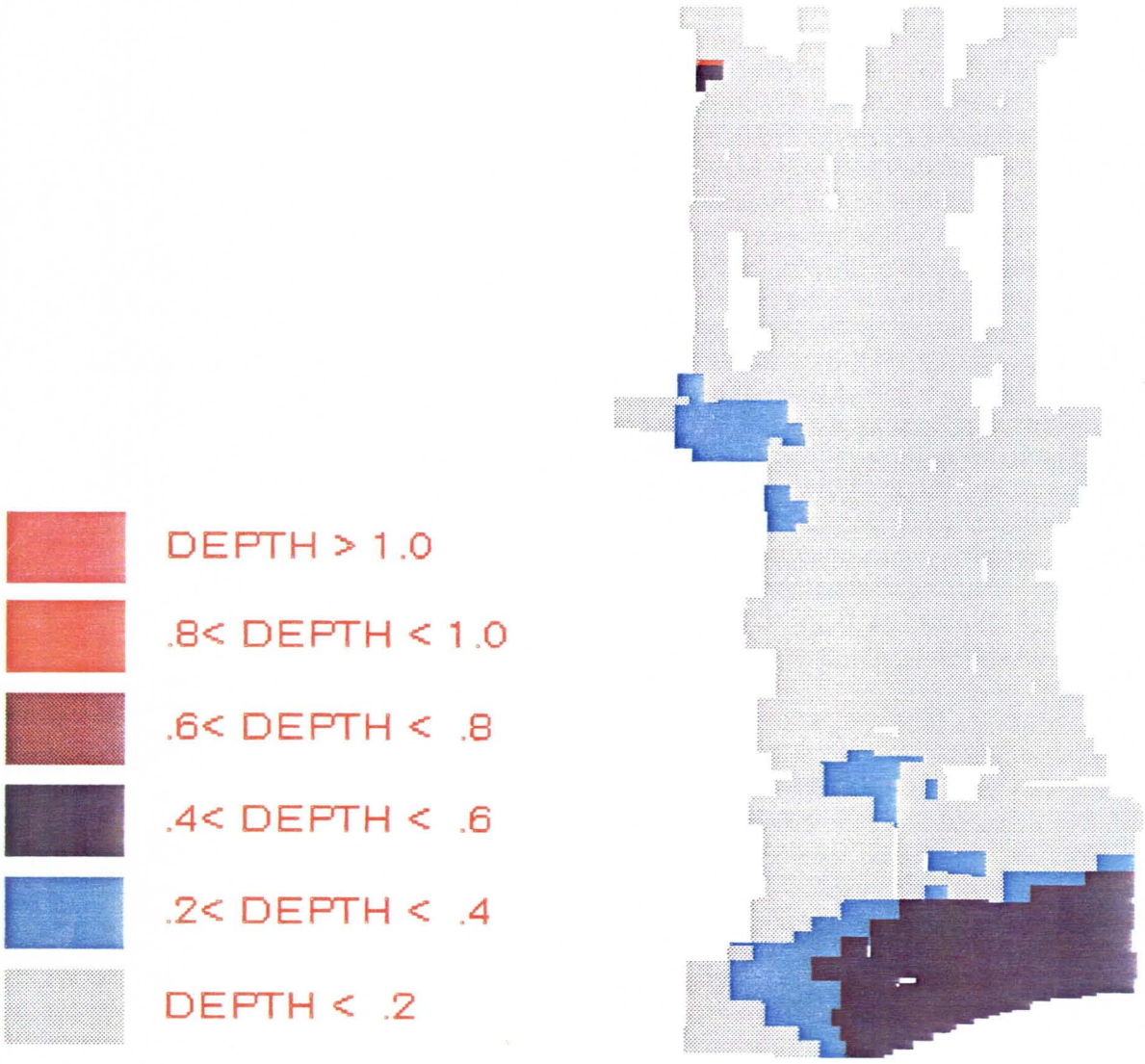

Figure 37 **Dynamic Simulation of the 100-Year Flood through the Study Area Computed Flow Depth at Time Step 33**

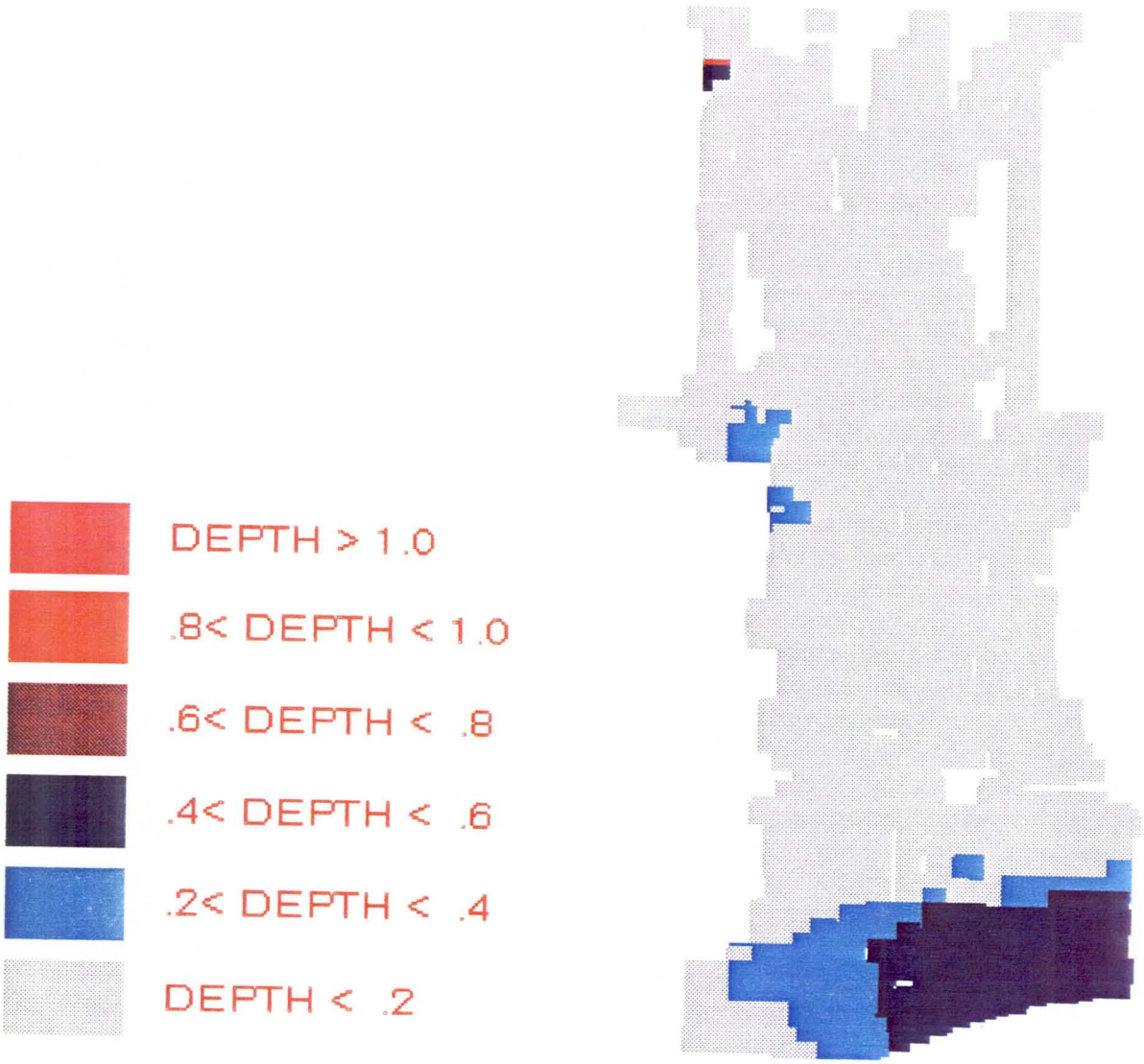

Figure 38 **Dynamic Simulation of the 100-Year Flood through the Study Area Computed Flow Depth at Time Step 35**

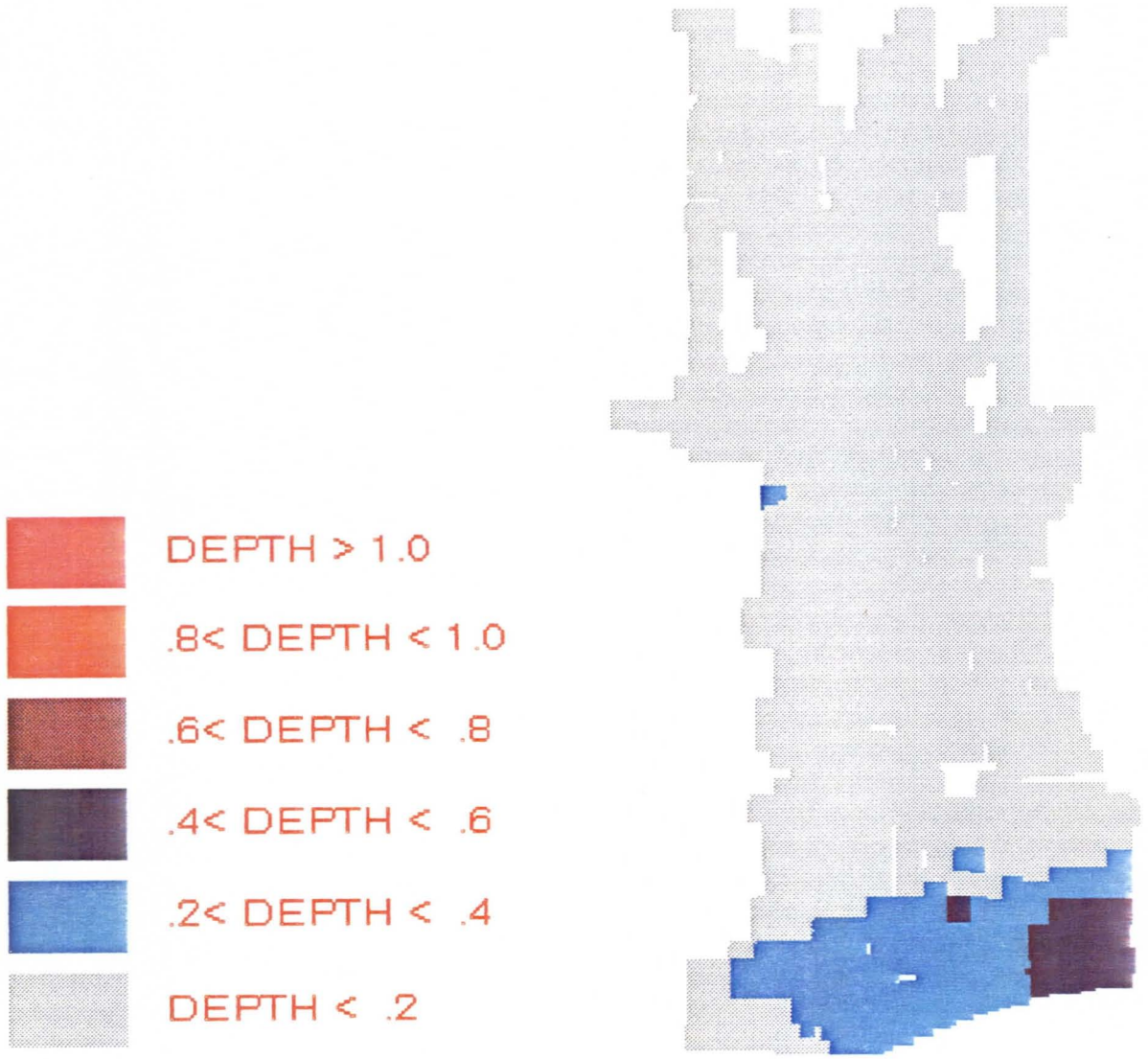

Figure 39 Dynamic Simulation of the 100-Year Flood through the Study Area Computed Flow Depth at Time Step 37

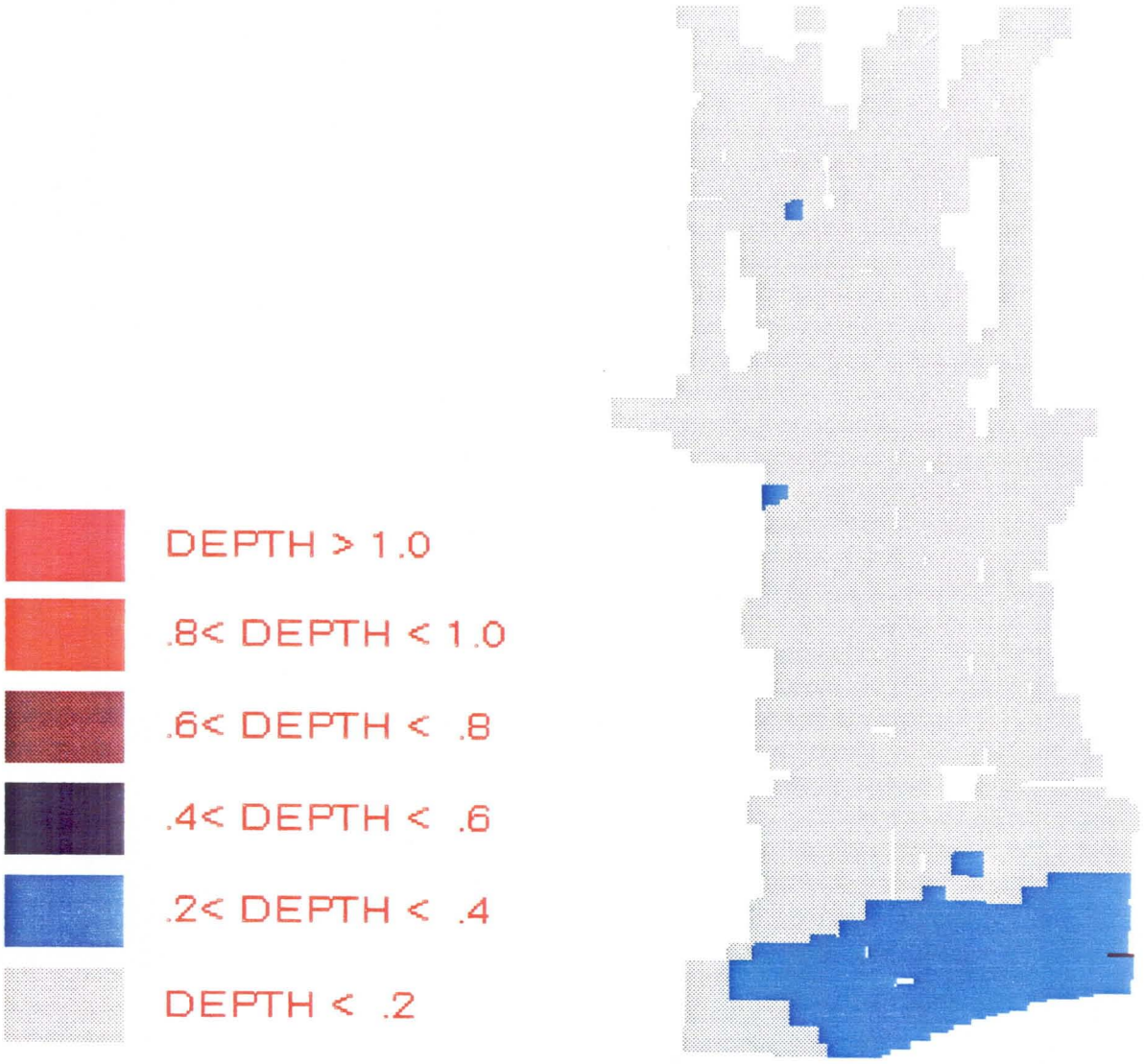

Figure 40 **Dynamic Simulation of the 100-Year Flood through the Study Area Computed Flow Depth at Time Step 39**

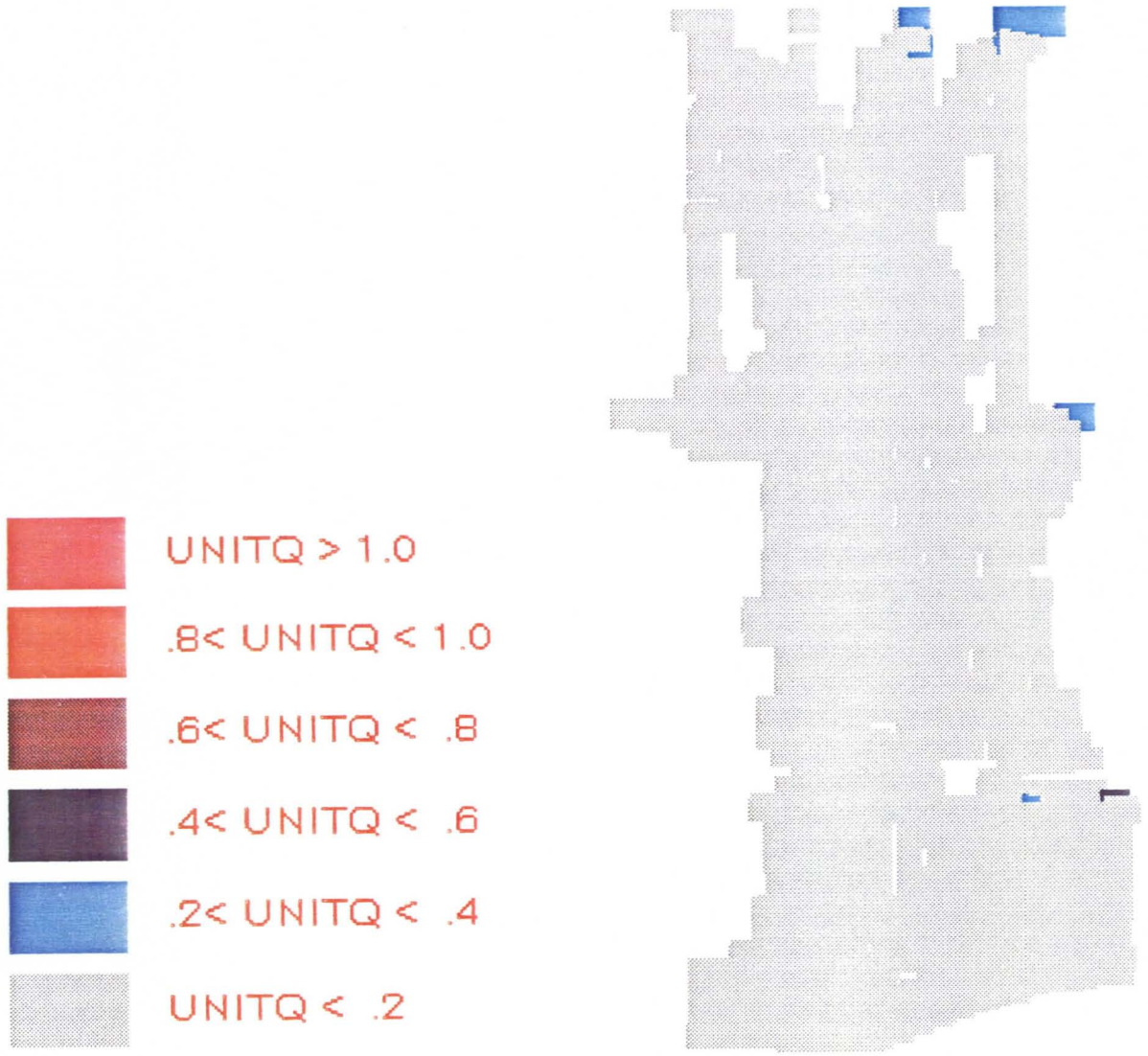

Figure 41 **Dynamic Simulation of the 100-Year Flood through the Study Area Computed Unit Discharge at Time Step 1**

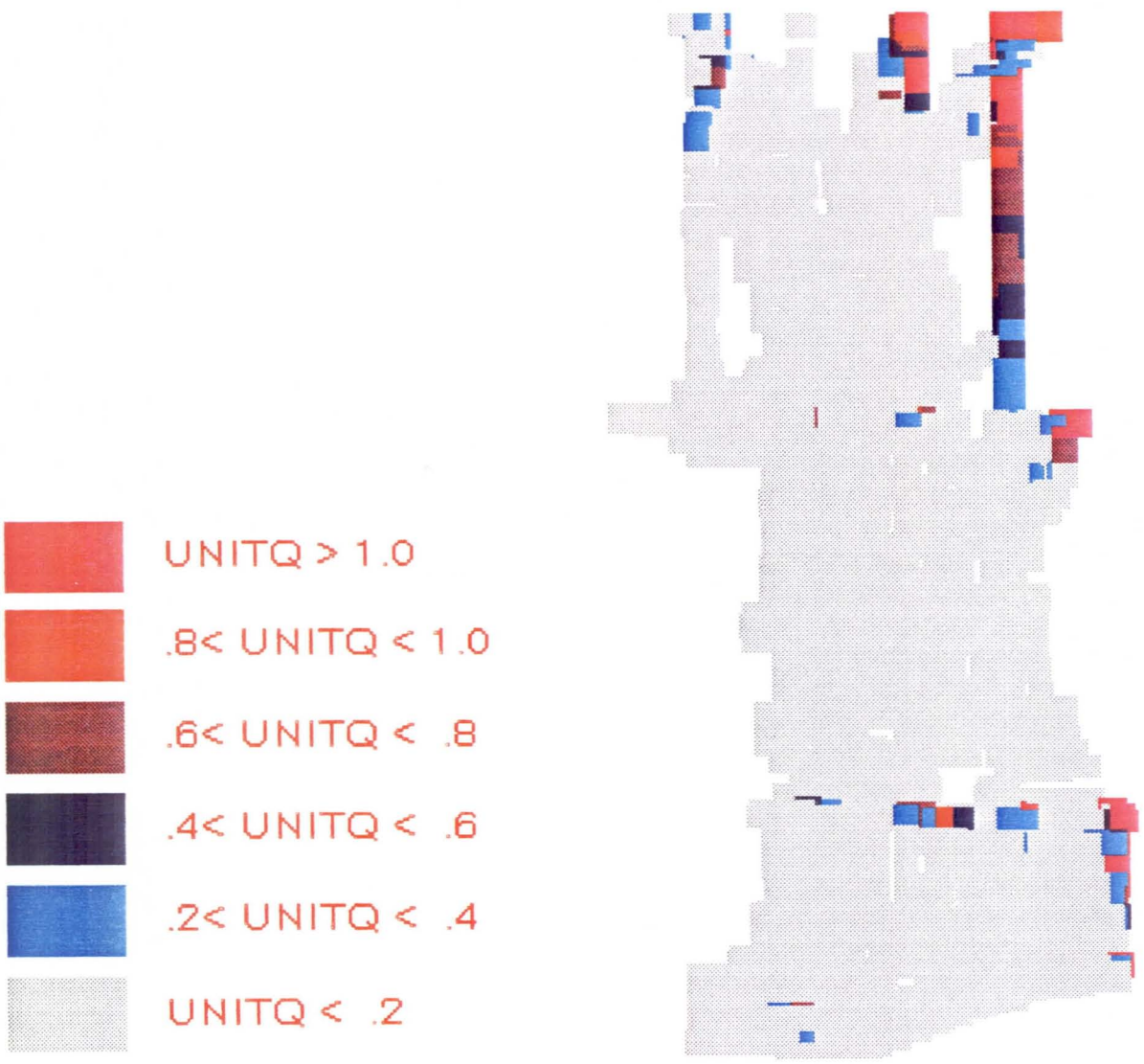

Figure 42 **Dynamic Simulation of the 100-Year Flood through the Study Ar Computed Unit Discharge at Time Step 3**

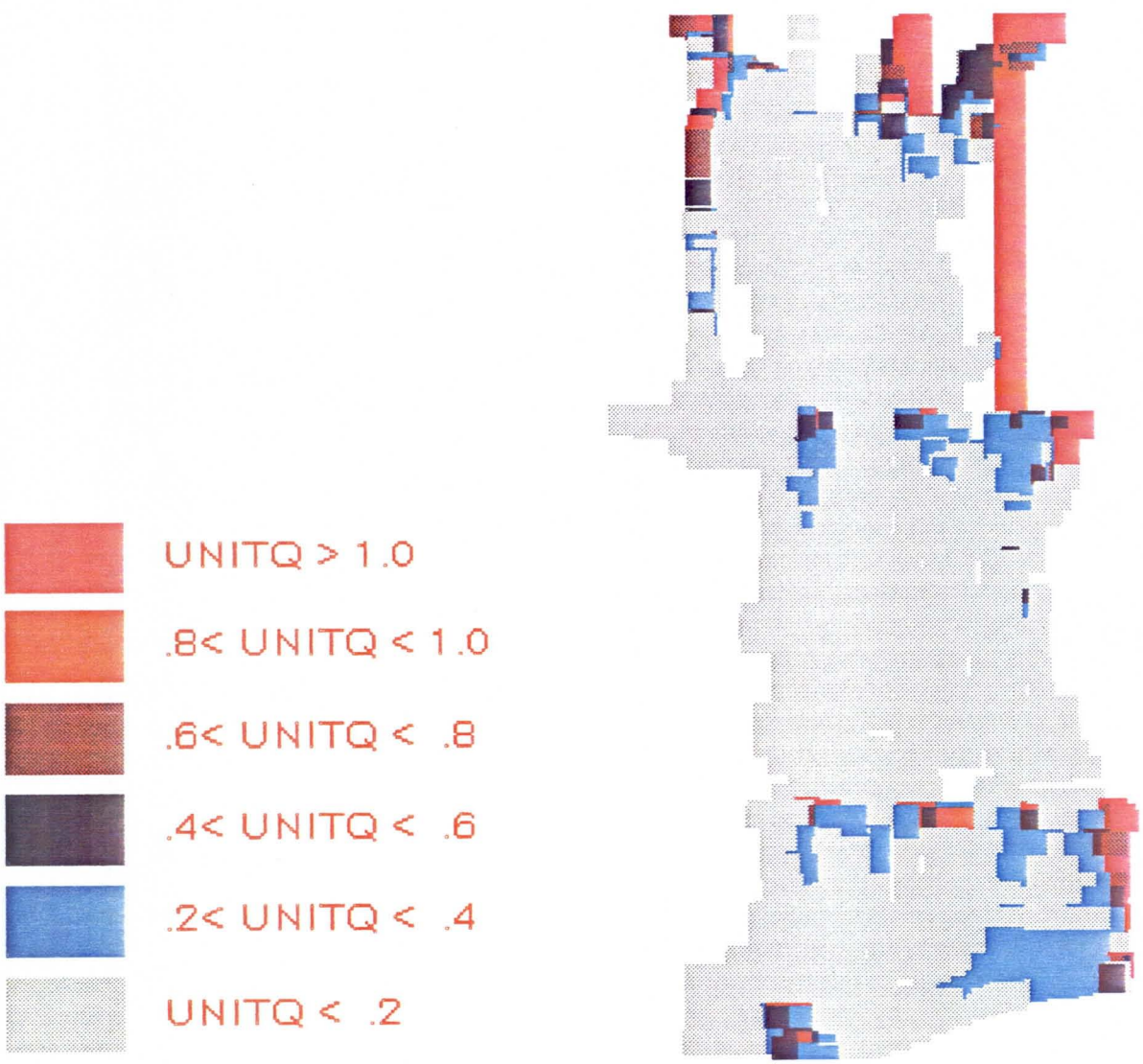

Figure 43 Dynamic Simulation of the 100-Year Flood through the Study Area -Computed Unit Discharge at Time Step 5

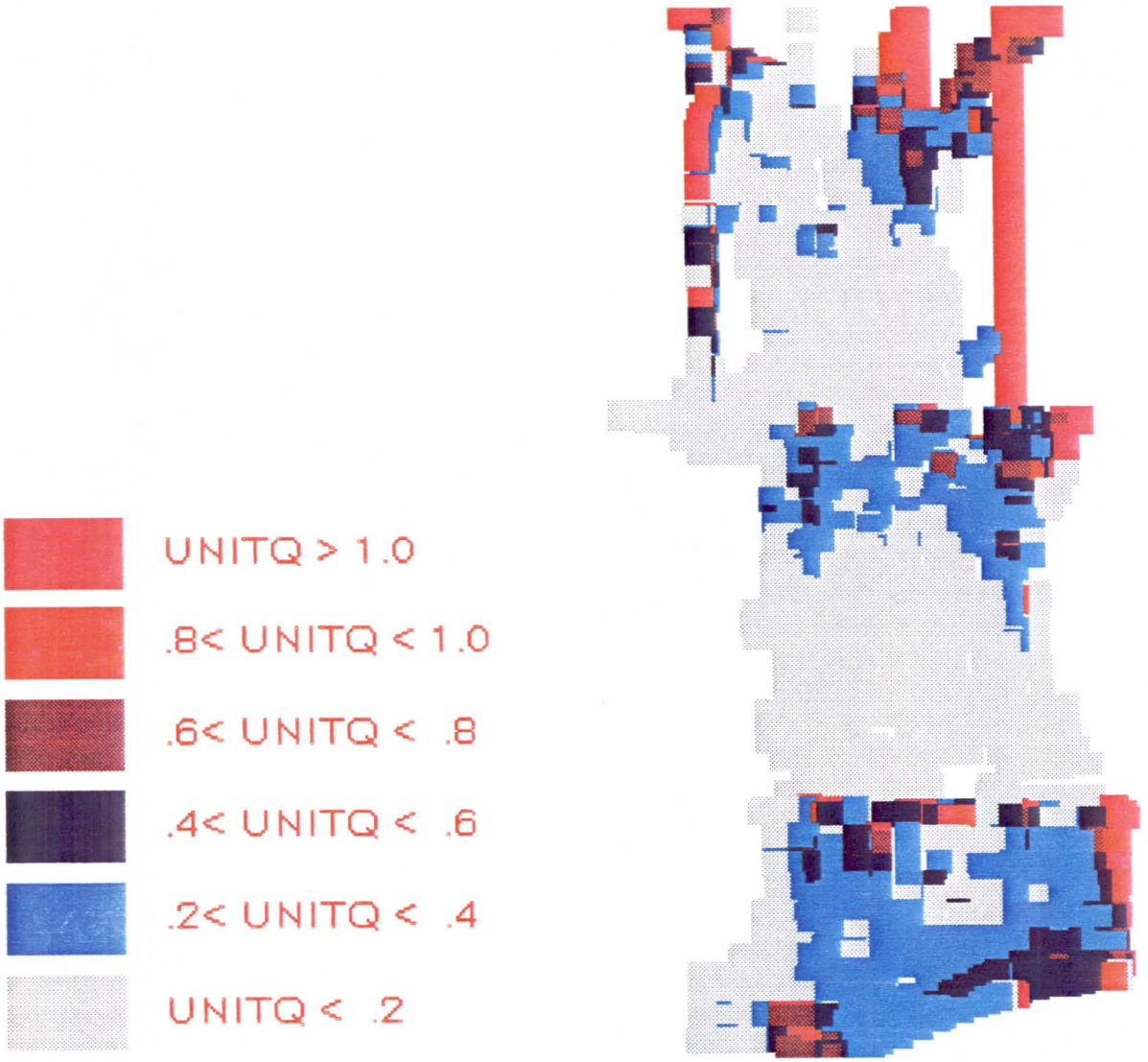

Figure 44 **Dynamic Simulation of the 100-Year Flood through the Study Area Computed Unit Discharge at Time Step 7**

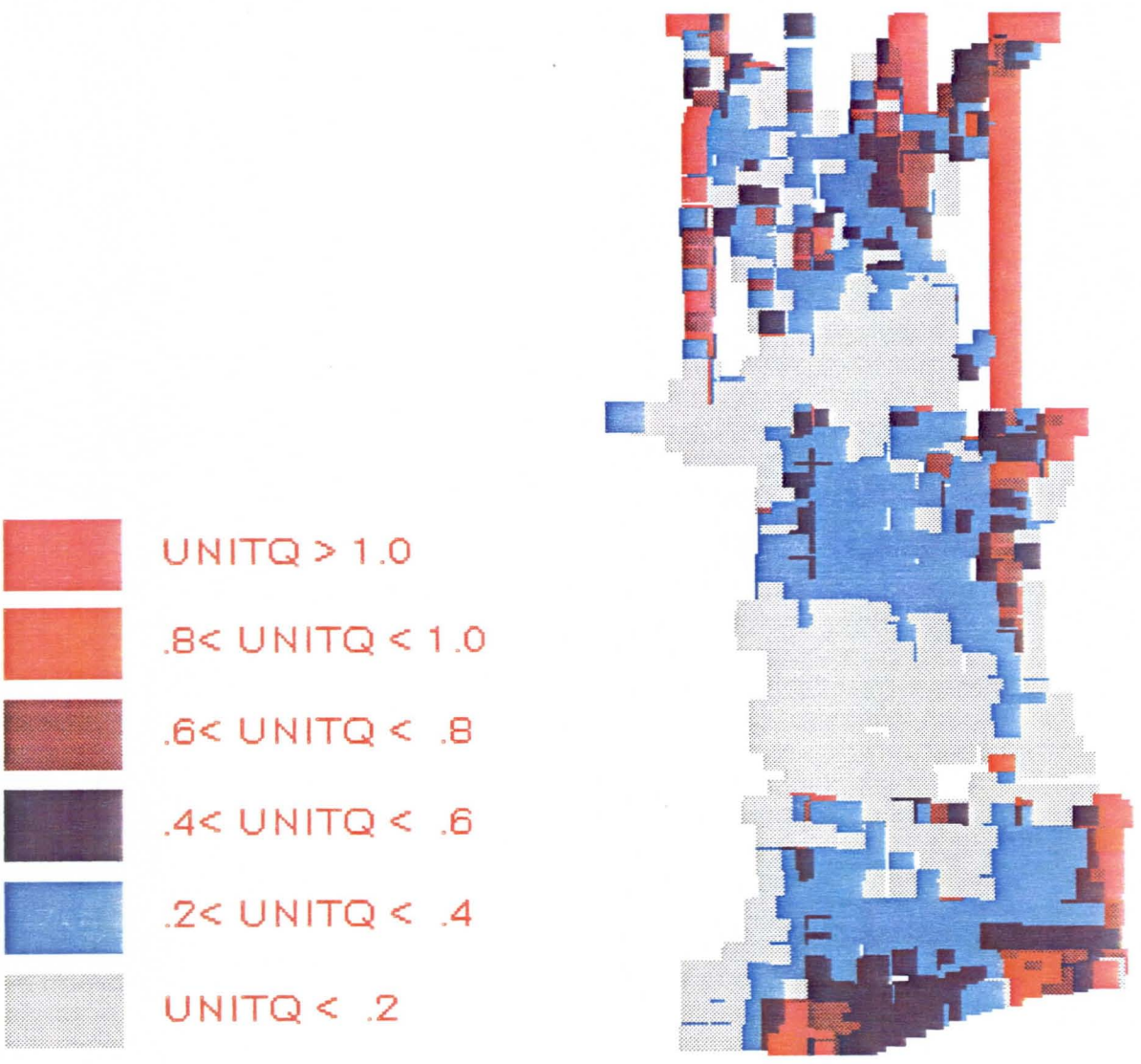

Figure 45 **Dynamic Simulation of the 100-Year Flood through the Study Area Computed Unit Discharge at Time Step 9**

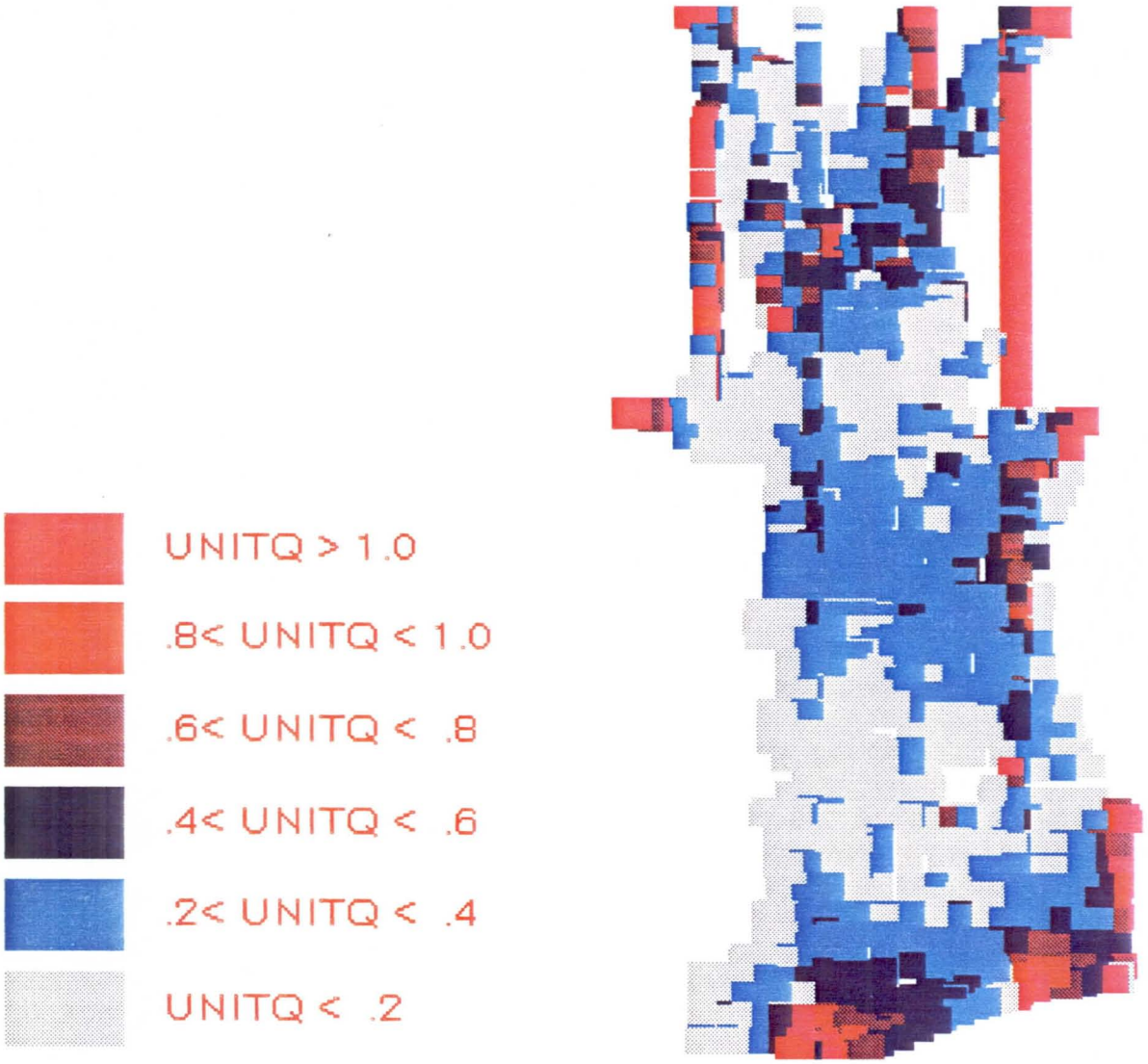

Figure 46 **Dynamic Simulation of the 100-Year Flood through the Study Area Computed Unit Discharge at Time Step 11**

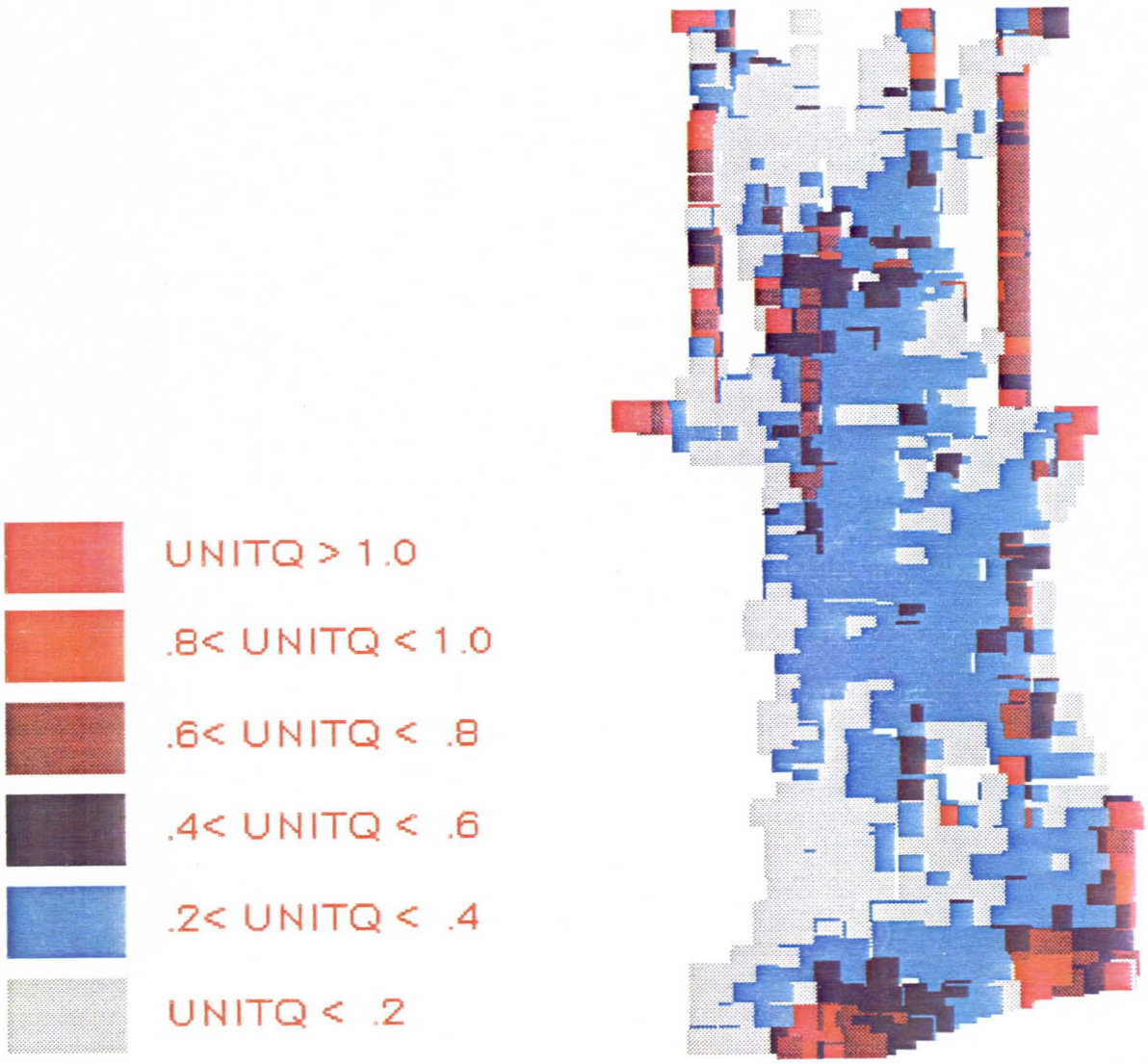

Figure 47 Dynamic Simulation of the 100-Year Flood through the Study Area Computed Unit Discharge at Time Step 13

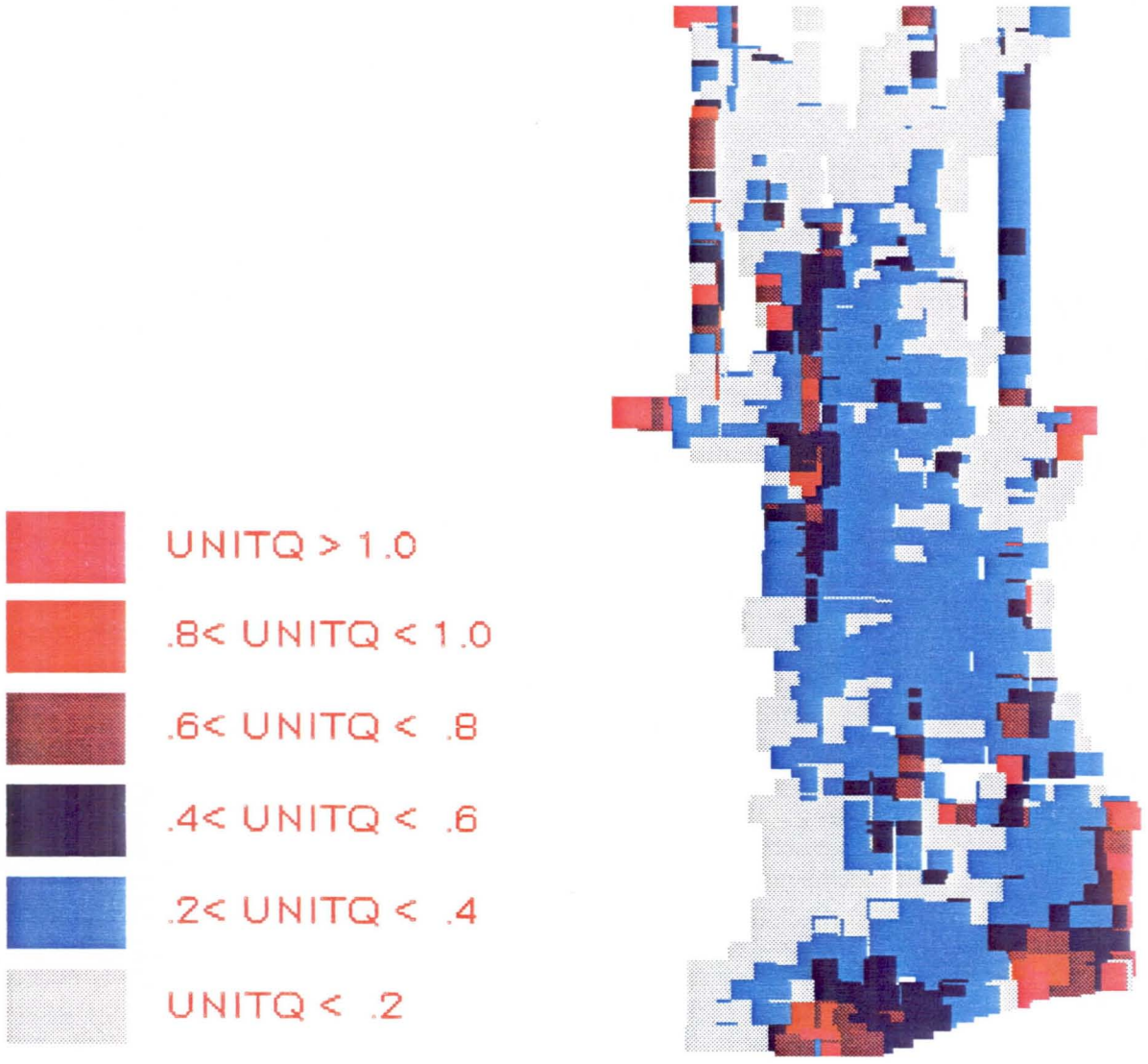

Figure 48 **Dynamic Simulation of the 100-Year Flood through the Study Area Computed Unit Discharge at Time Step 15**

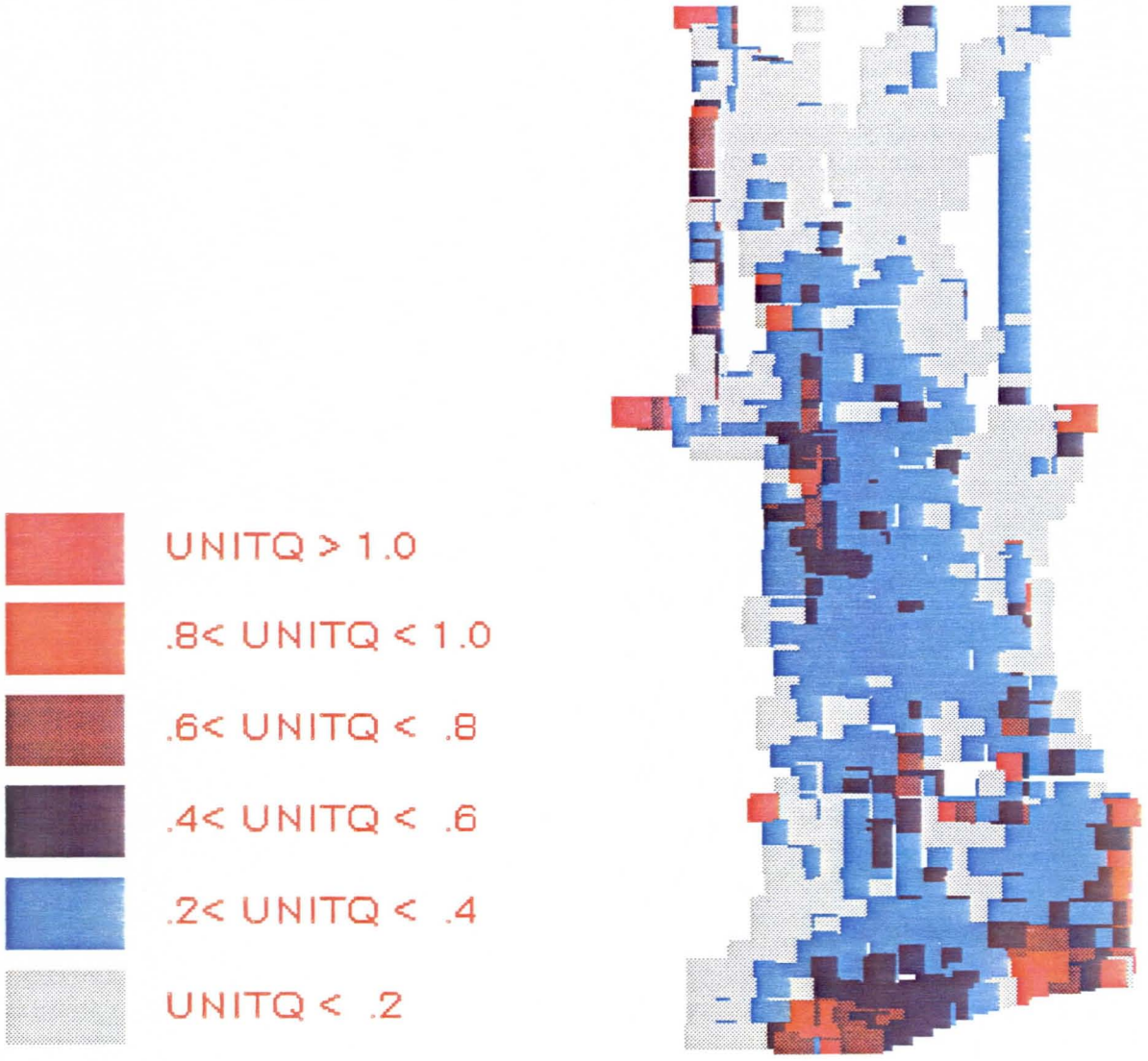

Figure 49 Dynamic Simulation of the 100-Year Flood through the Study Are
Computed Unit Discharge at Time Step 17

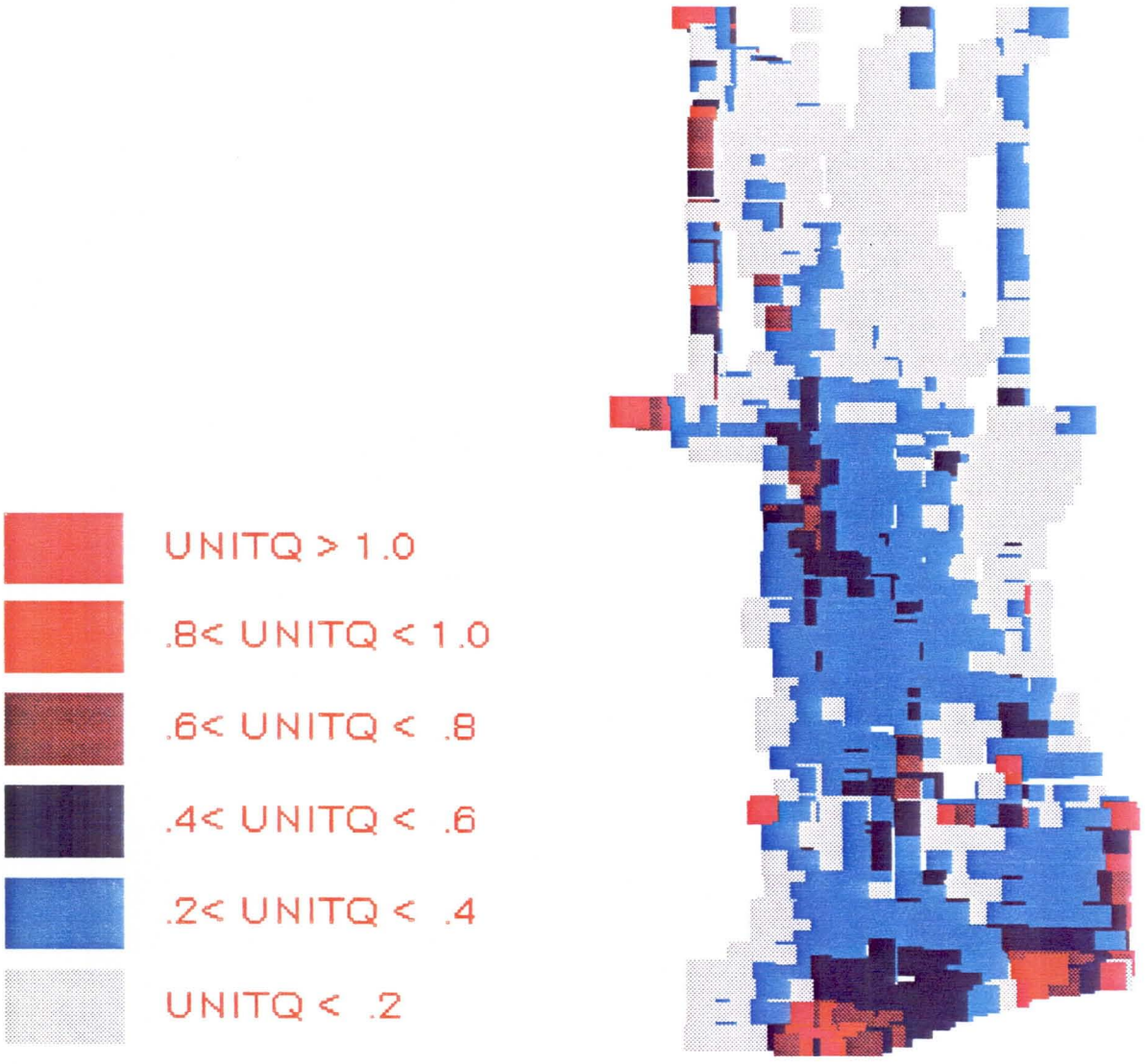

Figure 50 **Dynamic Simulation of the 100-Year Flood through the Study Area Computed Unit Discharge at Time Step 19**

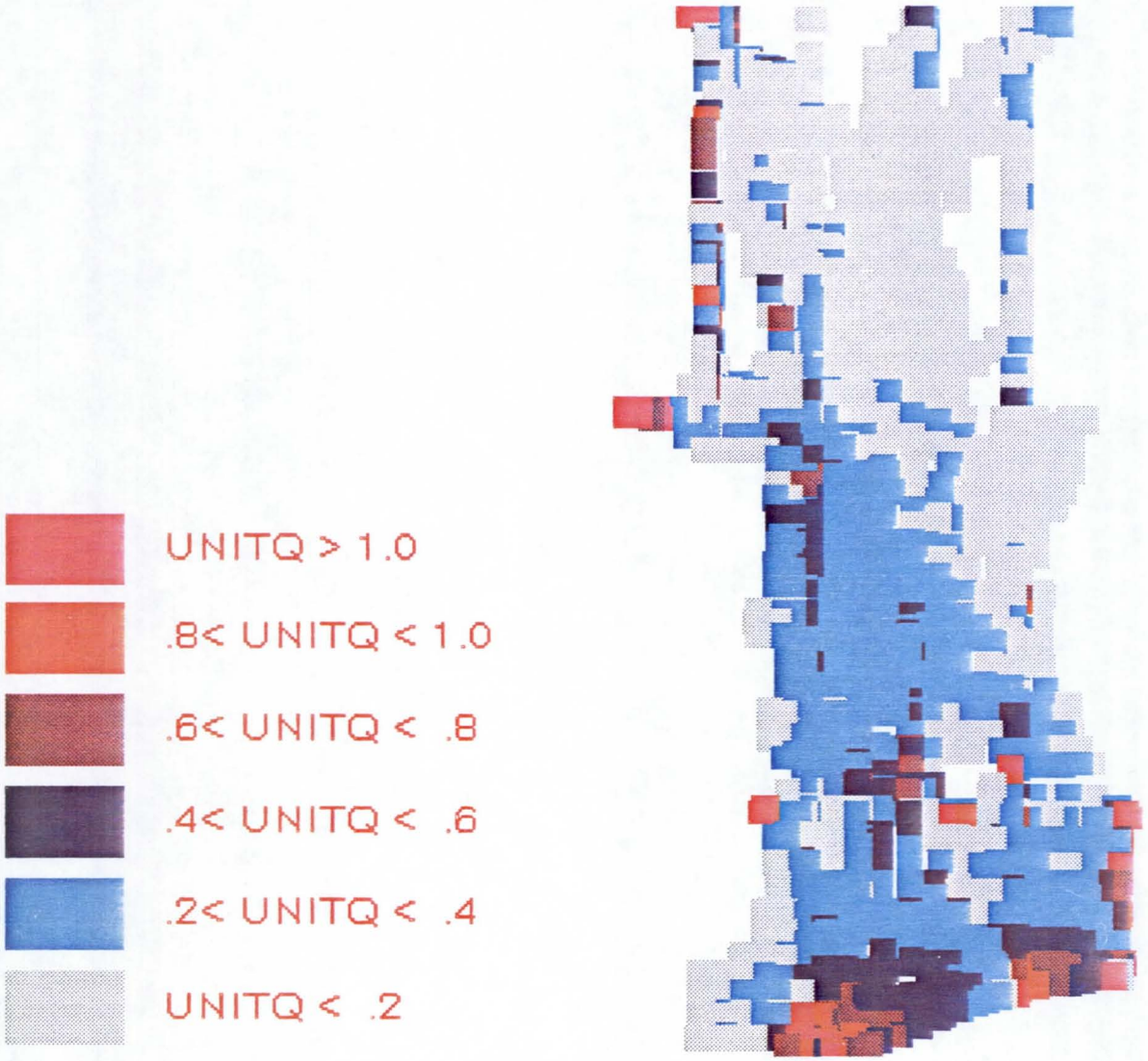

Figure 51 **Dynamic Simulation of the 100-Year Flood through the Study Area Computed Unit Discharge at Time Step 21**

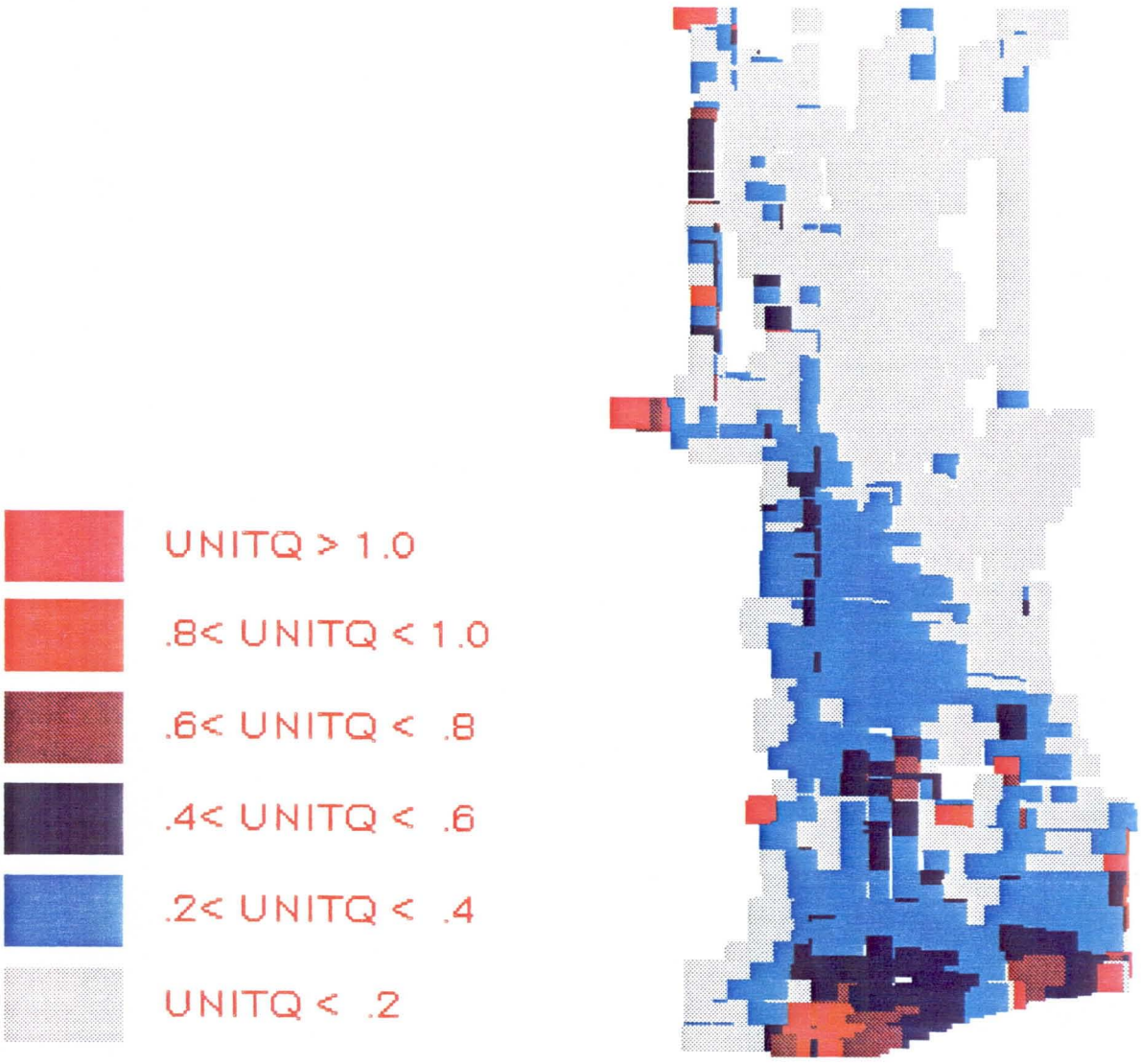

Figure 52 **Dynamic Simulation of the 100-Year Flood through the Study Area Computed Unit Discharge at Time Step 23**

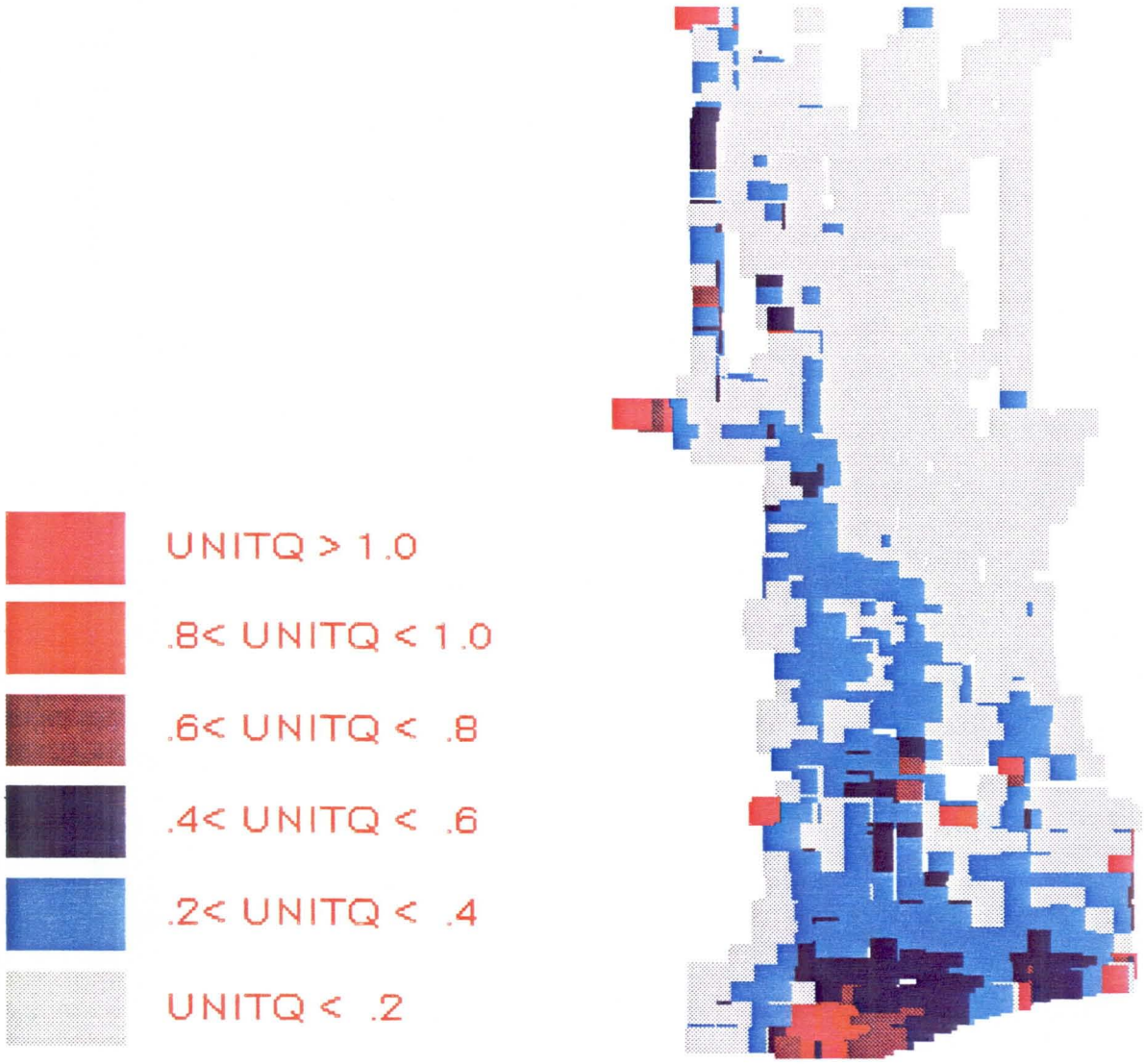

Figure 53 **Dynamic Simulation of the 100-Year Flood through the Study Area Computed Unit Discharge at Time Step 25**

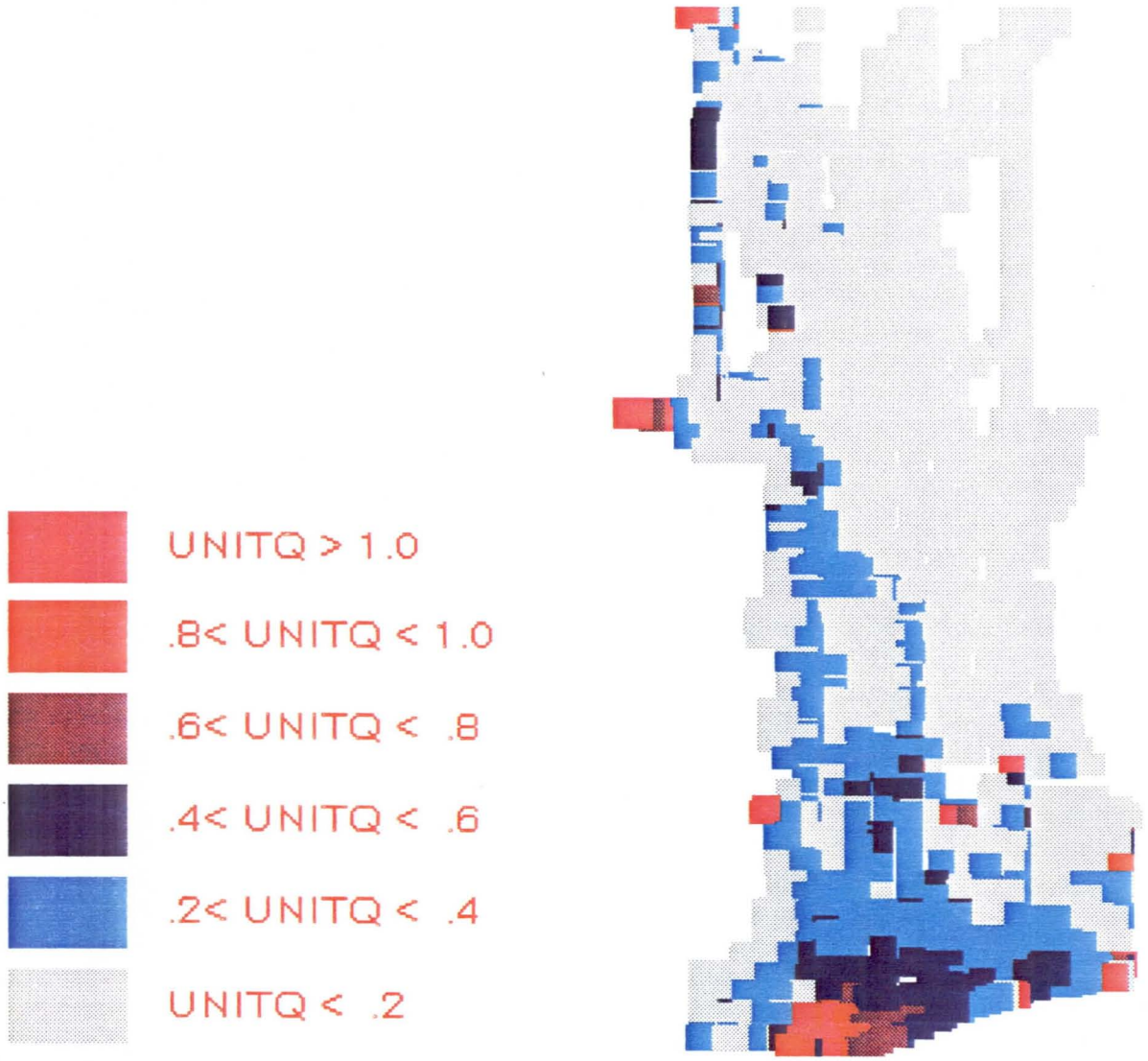

Figure 54 **Dynamic Simulation of the 100-Year Flood through the Study Area Computed Unit Discharge at Time Step 27**

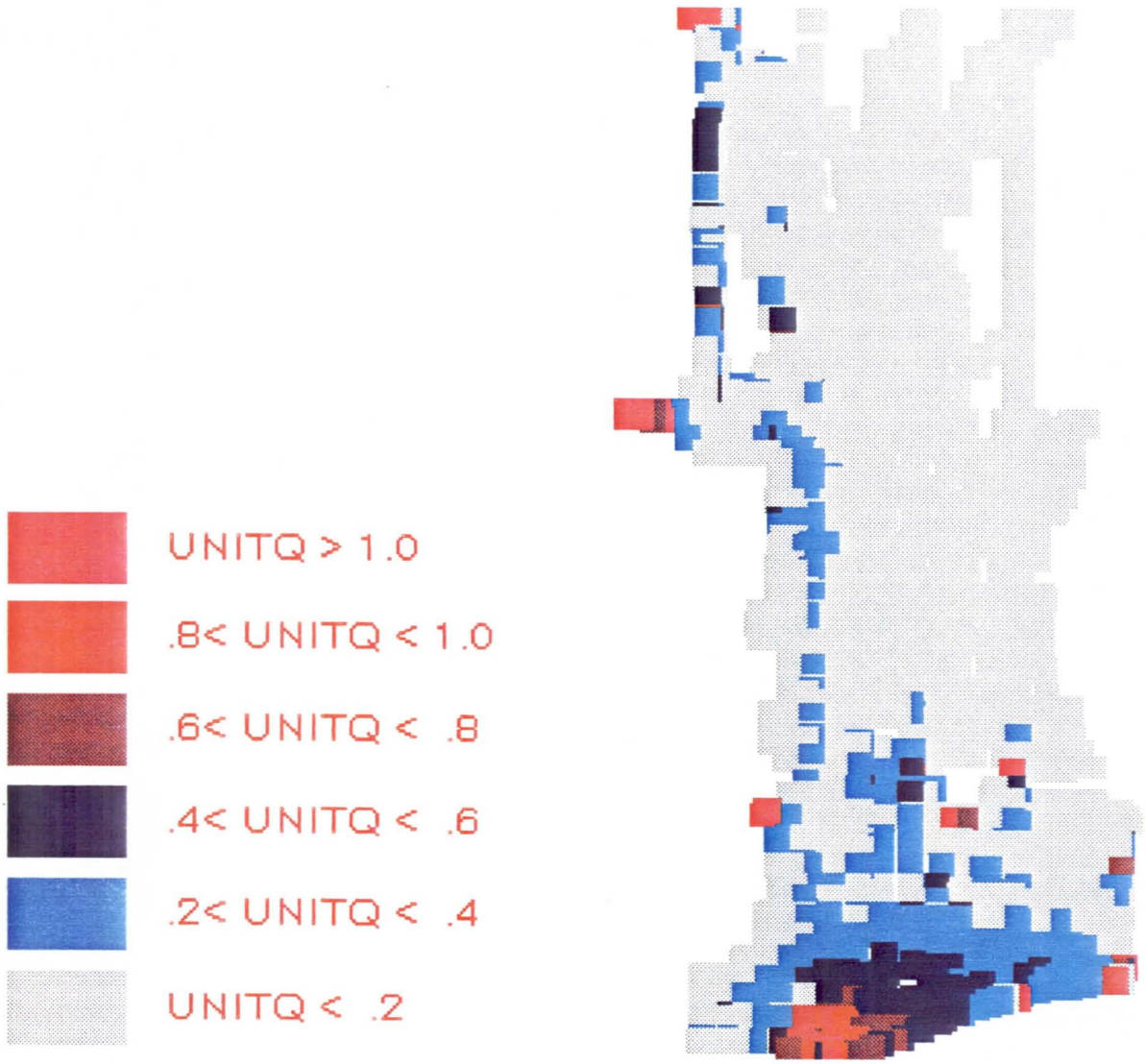

Figure 55 **Dynamic Simulation of the 100-Year Flood through the Study Area Computed Unit Discharge at Time Step 29**

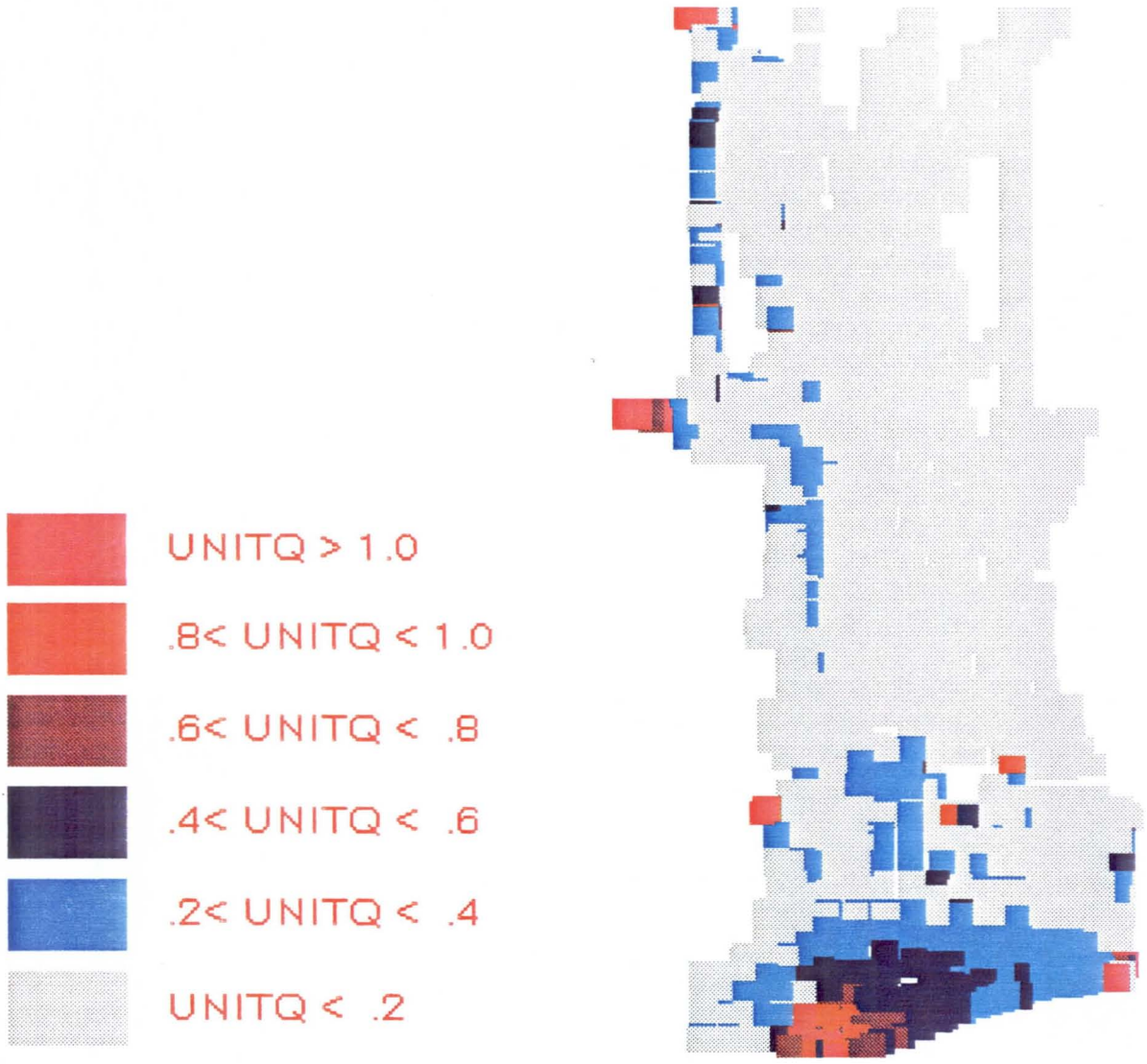

Figure 56 **Dynamic Simulation of the 100-Year Flood through the Study Area Computed Unit Discharge at Time Step 31**

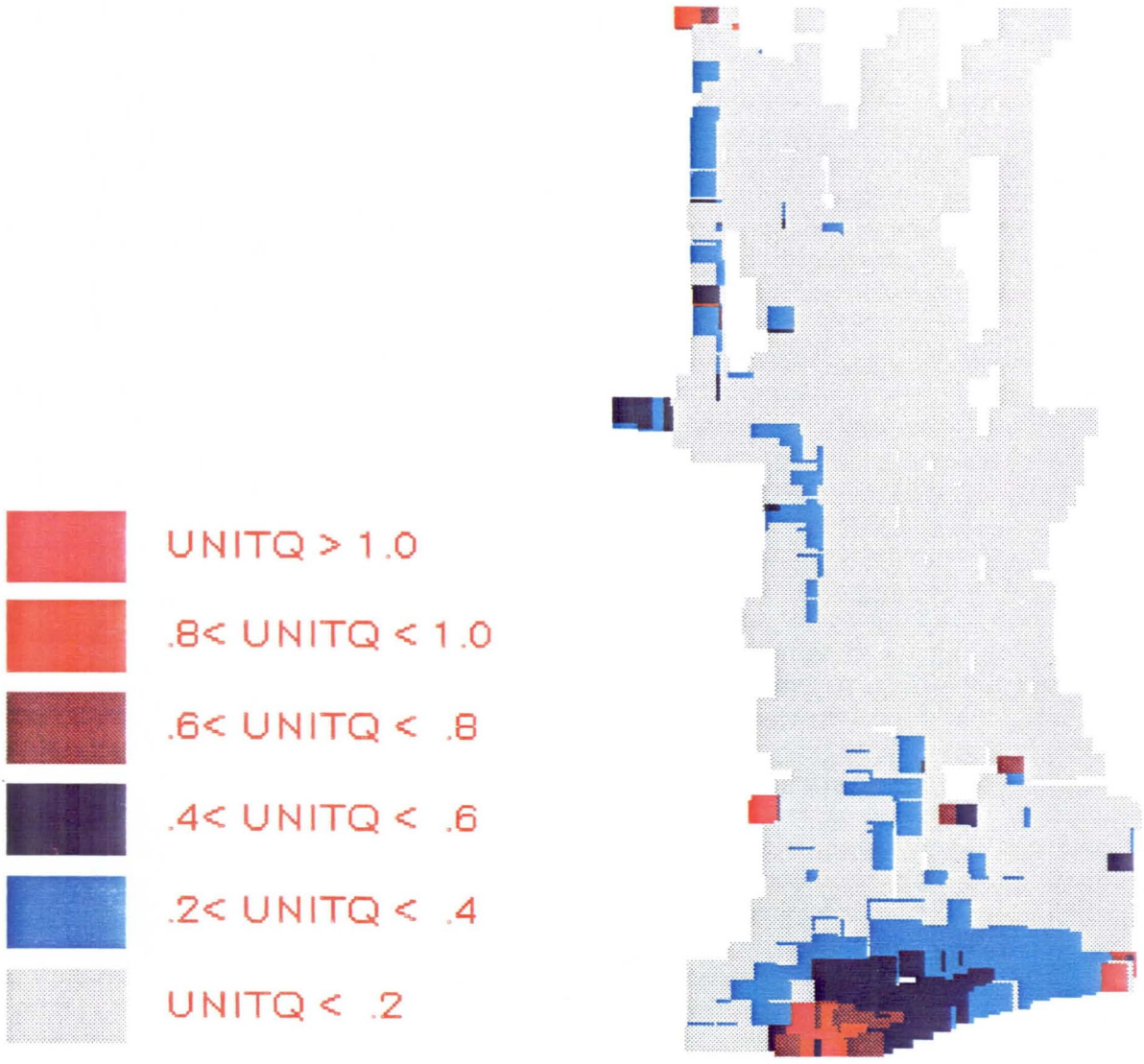

Figure 57 **Dynamic Simulation of the 100-Year Flood through the Study Area Computed Unit Discharge at Time Step 33**

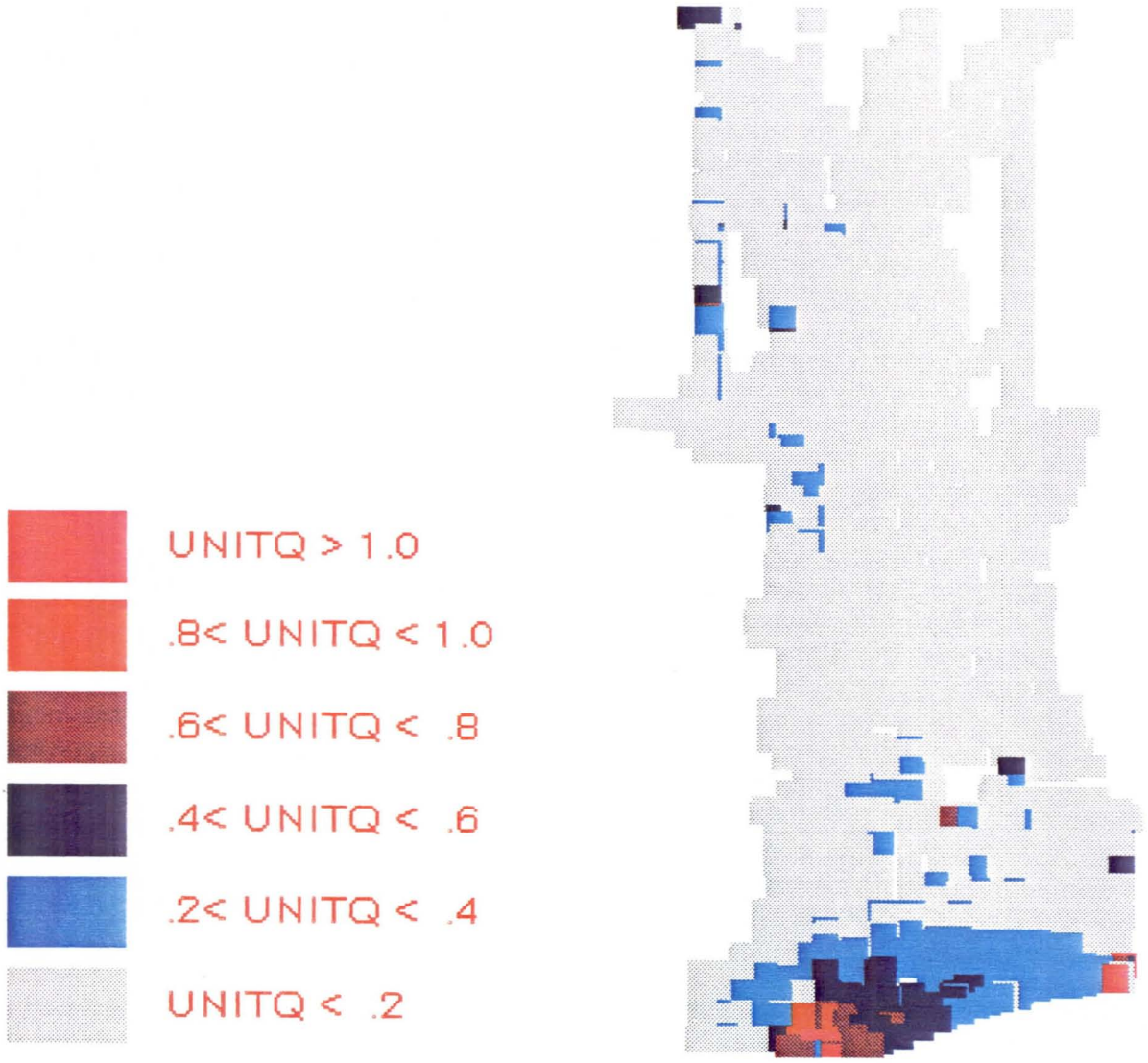

Figure 58 **Dynamic Simulation of the 100-Year Flood through the Study Area Computed Unit Discharge at Time Step 35**

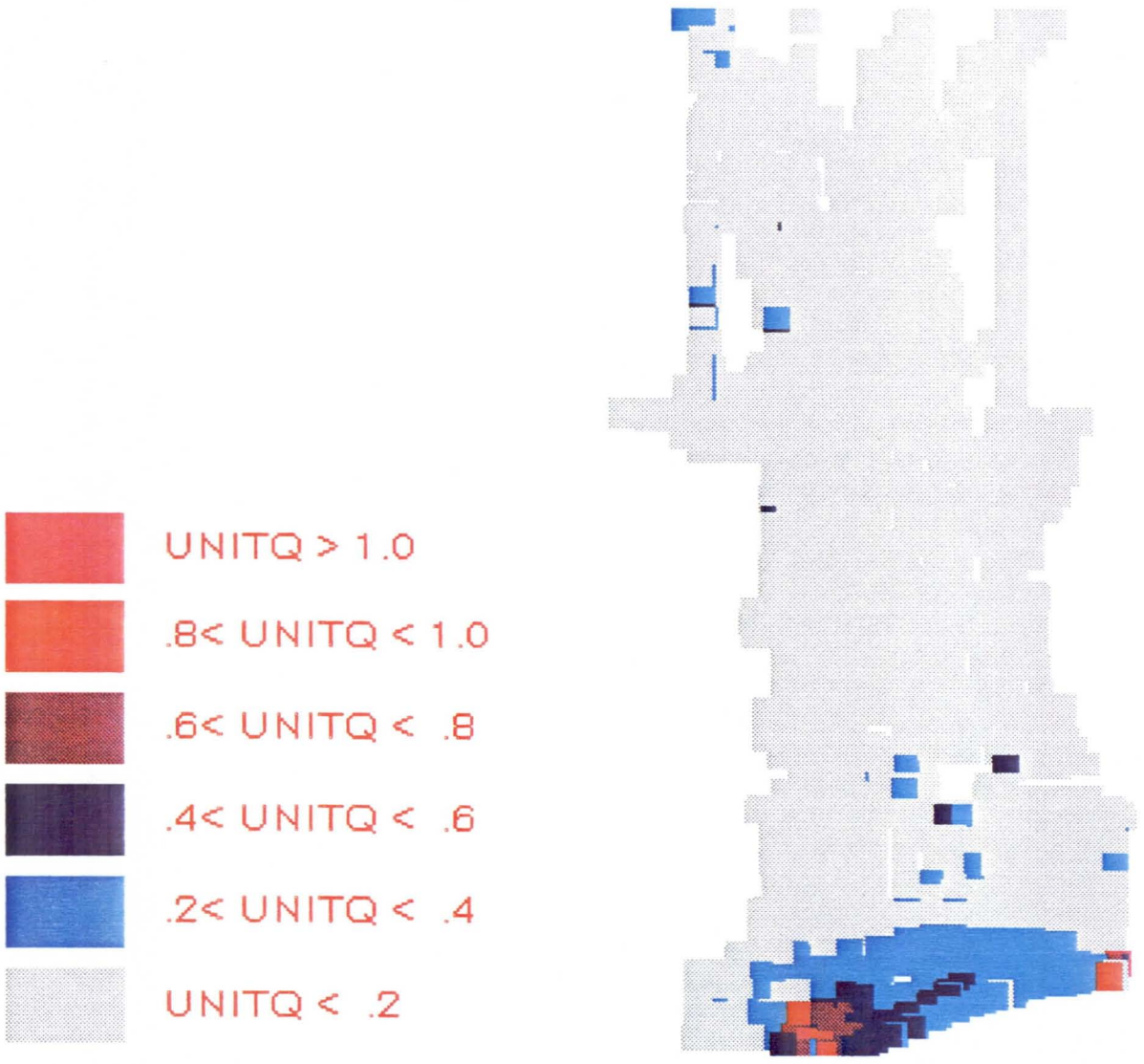

Figure 59 **Dynamic Simulation of the 100-Year Flood through the Study Area Computed Unit Discharge at Time Step 37**

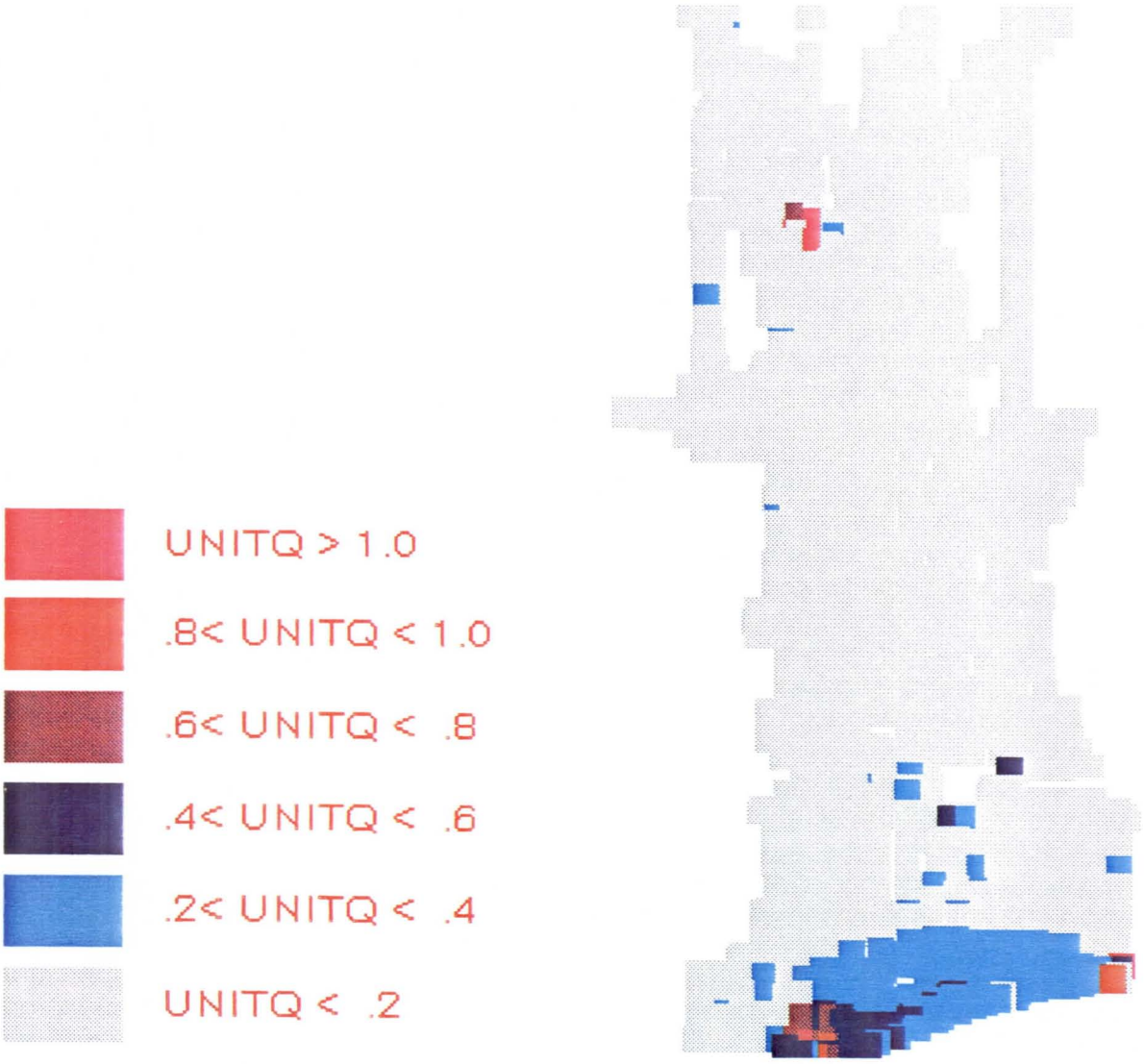

Figure 60 **Dynamic Simulation of the 100-Year Flood through the Study Area Computed Unit Discharge at Time Step 39**

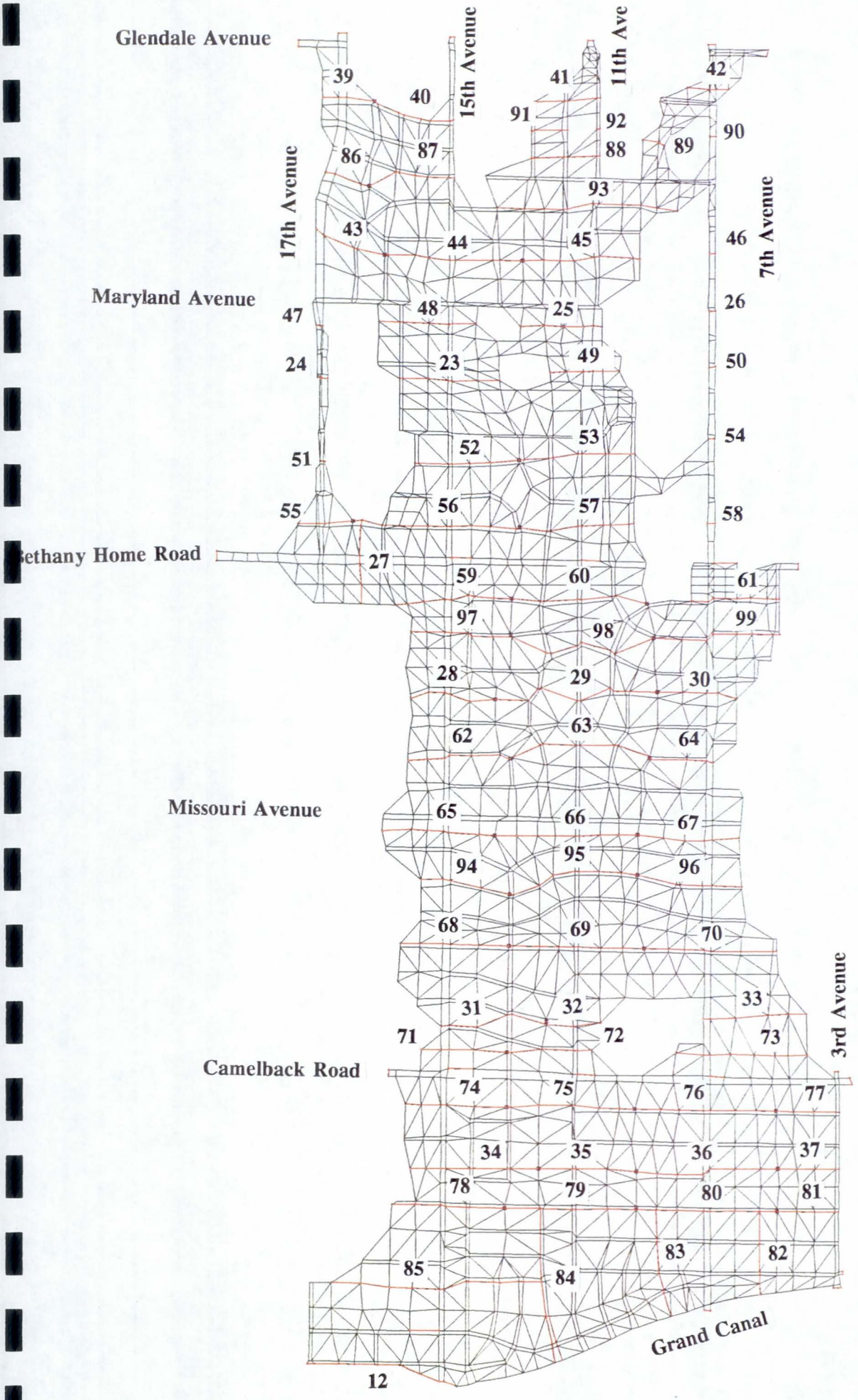

Figure 61 Inner-Mesh Flood Hydrograph Computation Section (TABS-2 GC Strings)

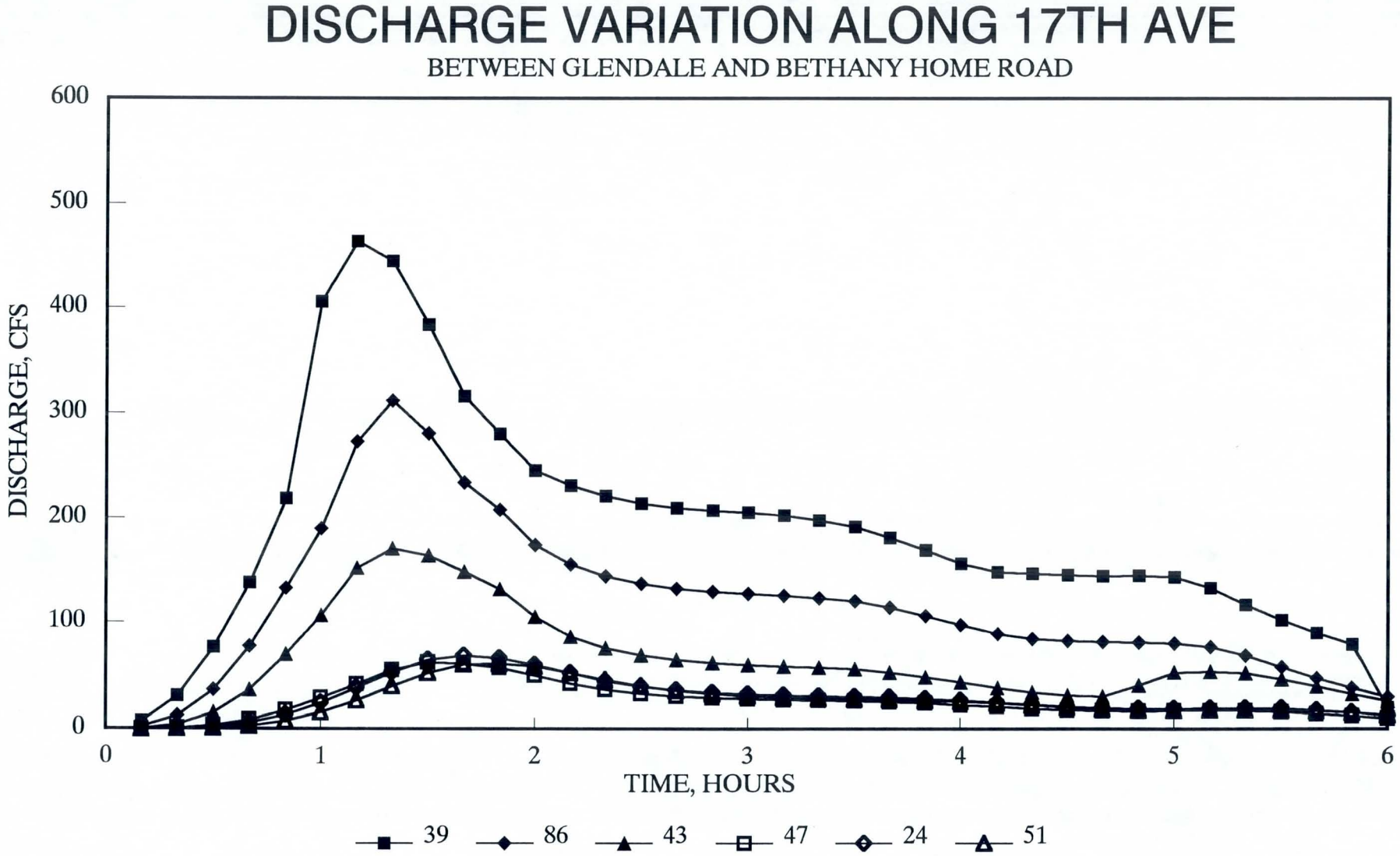

Figure 62 **Computed Inner-Mesh Flood Hydrographs**
17th Avenue within the Northern Portion of the Study Area

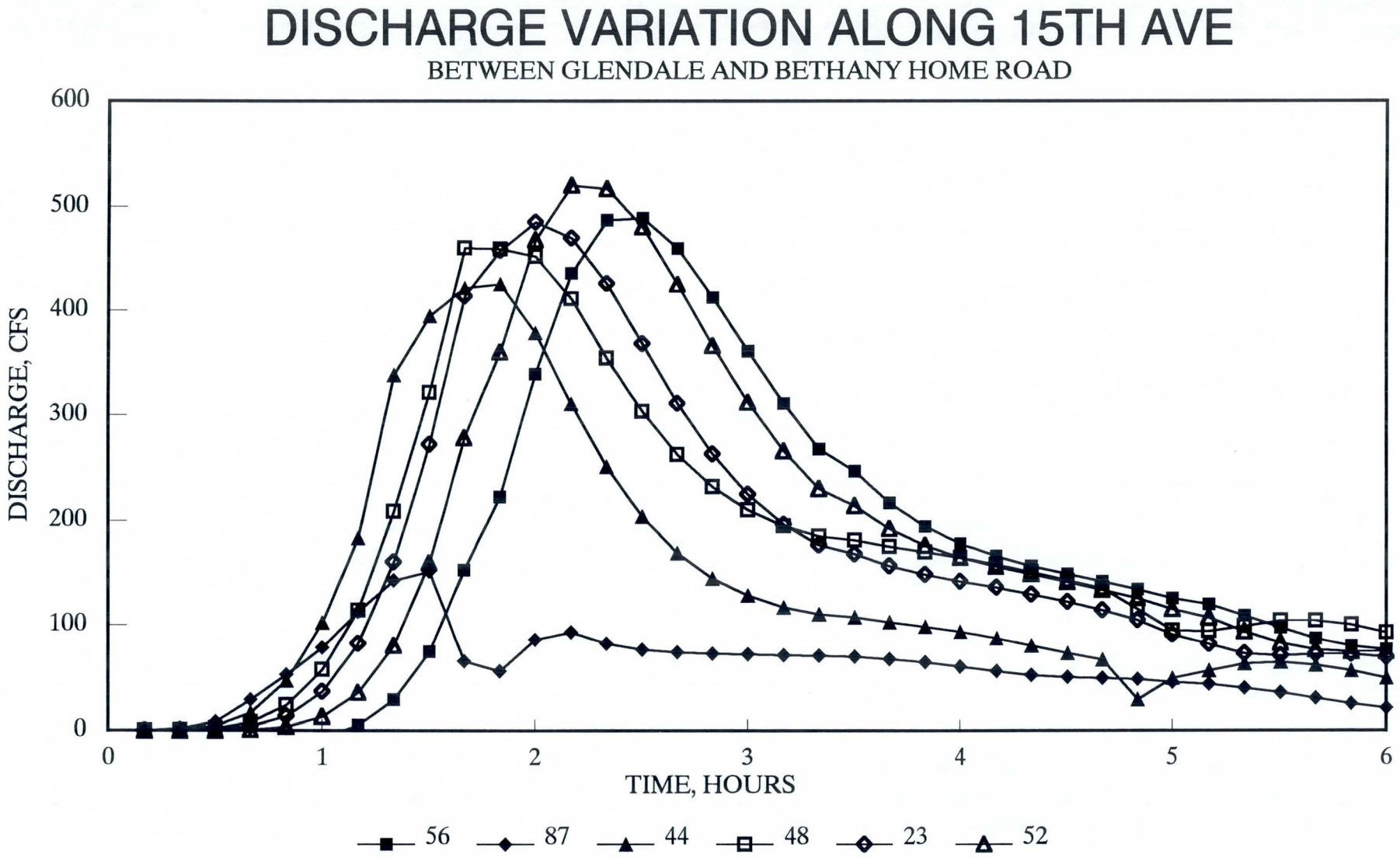

Figure 63 Computed Inner-Mesh Flood Hydrographs
15th Avenue within the Northern Portion of the Study Area

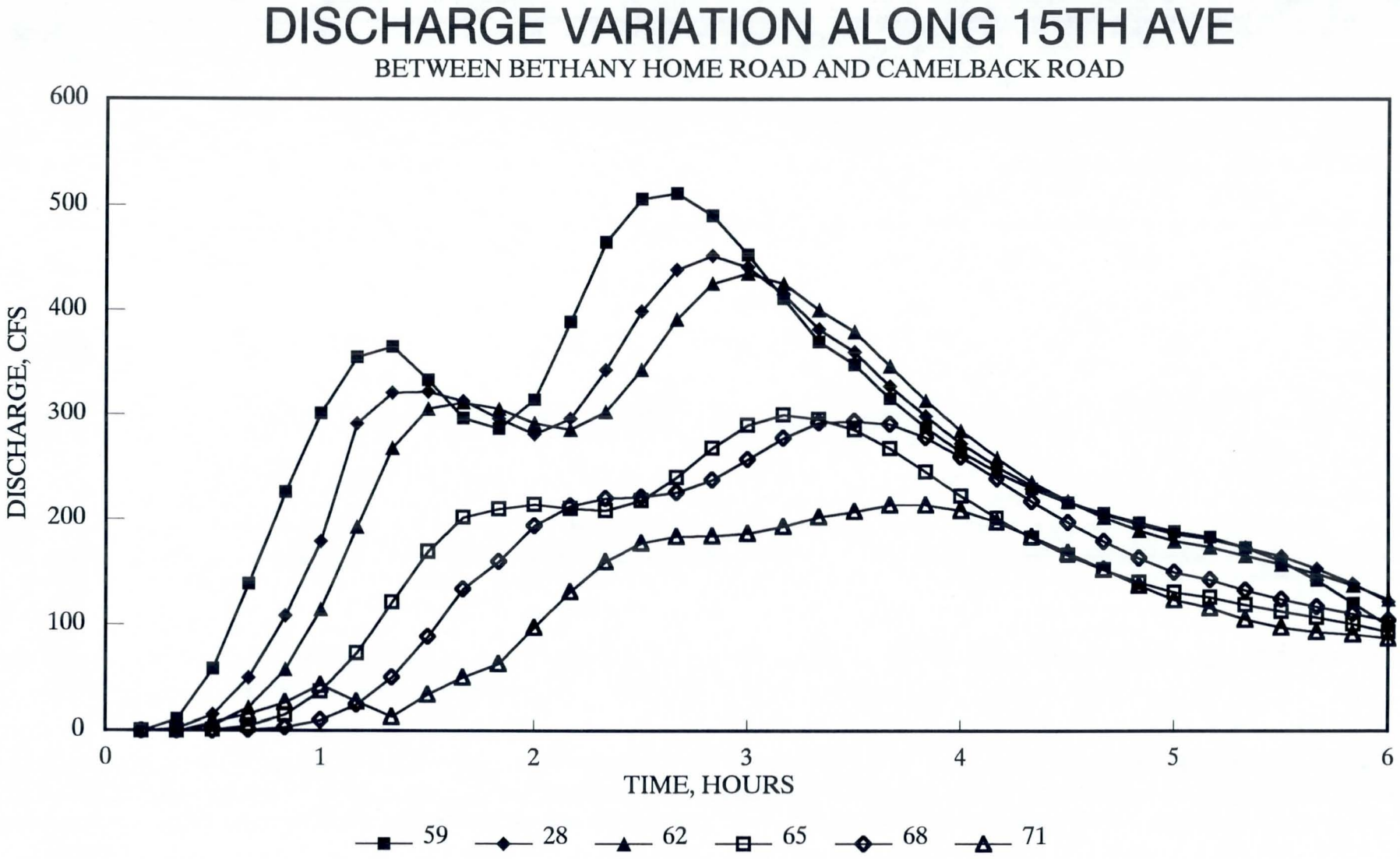

Figure 64 **Computed Inner-Mesh Flood Hydrographs**
15th Avenue within the Middle Portion of the Study Area

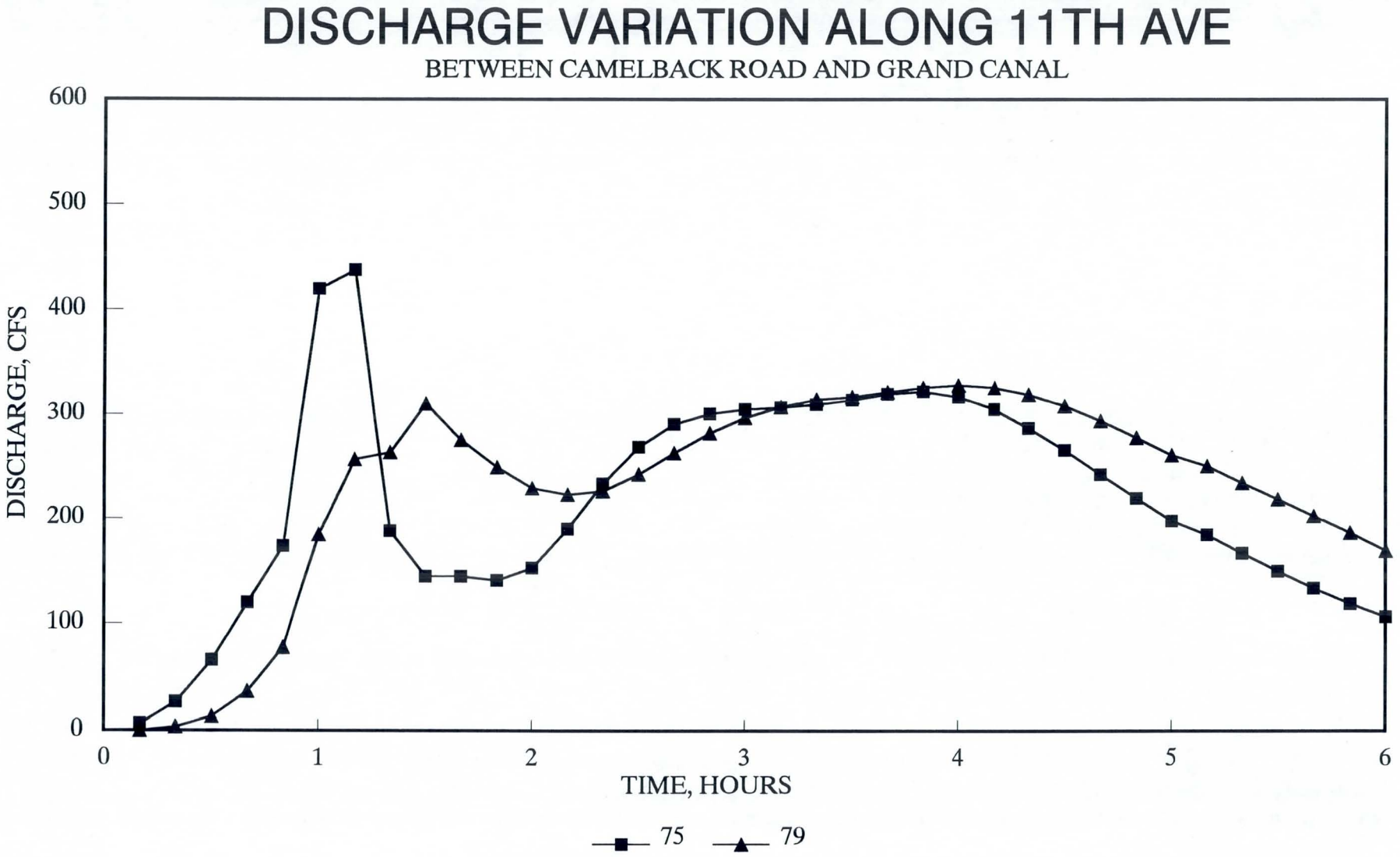

Figure 65 **Computed Inner-Mesh Flood Hydrographs**
11th Avenue within the Southern Portion of the Study Area

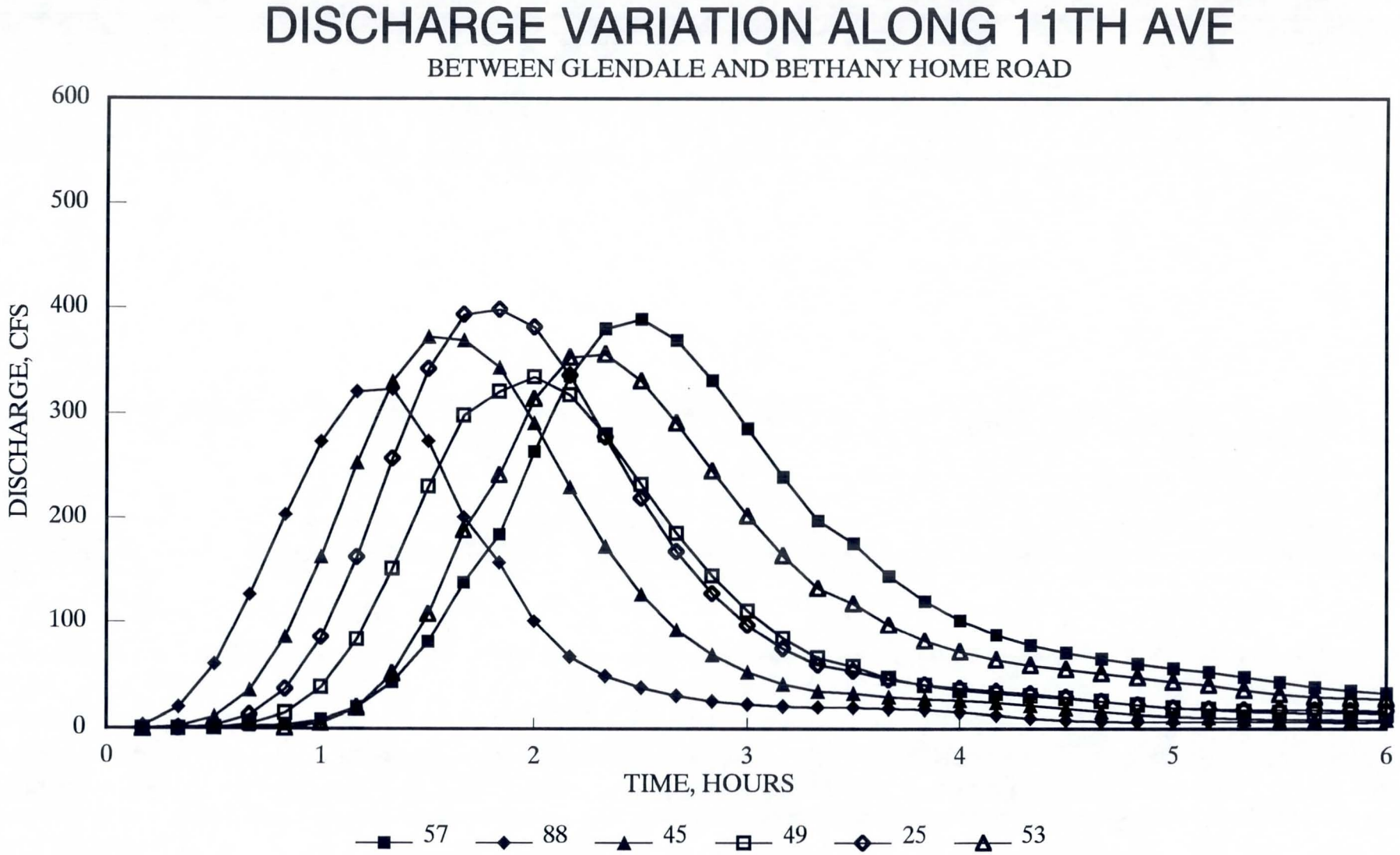

Figure 66 **Computed Inner-Mesh Flood Hydrographs**
11th Avenue within the Northern Portion of the Study Area

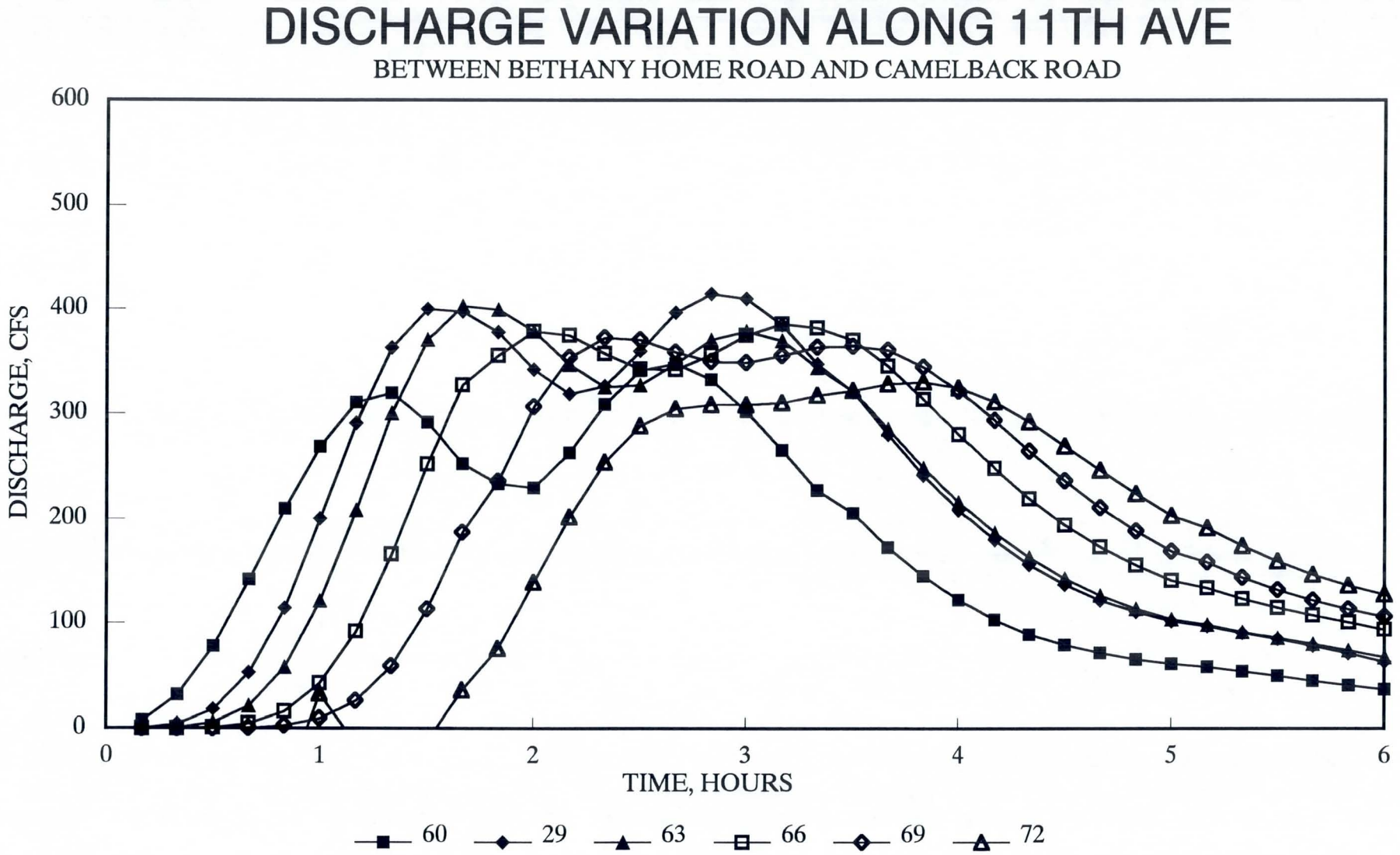

Figure 67 **Computed Inner-Mesh Flood Hydrographs**
11th Avenue within the Middle Portion of the Study Area

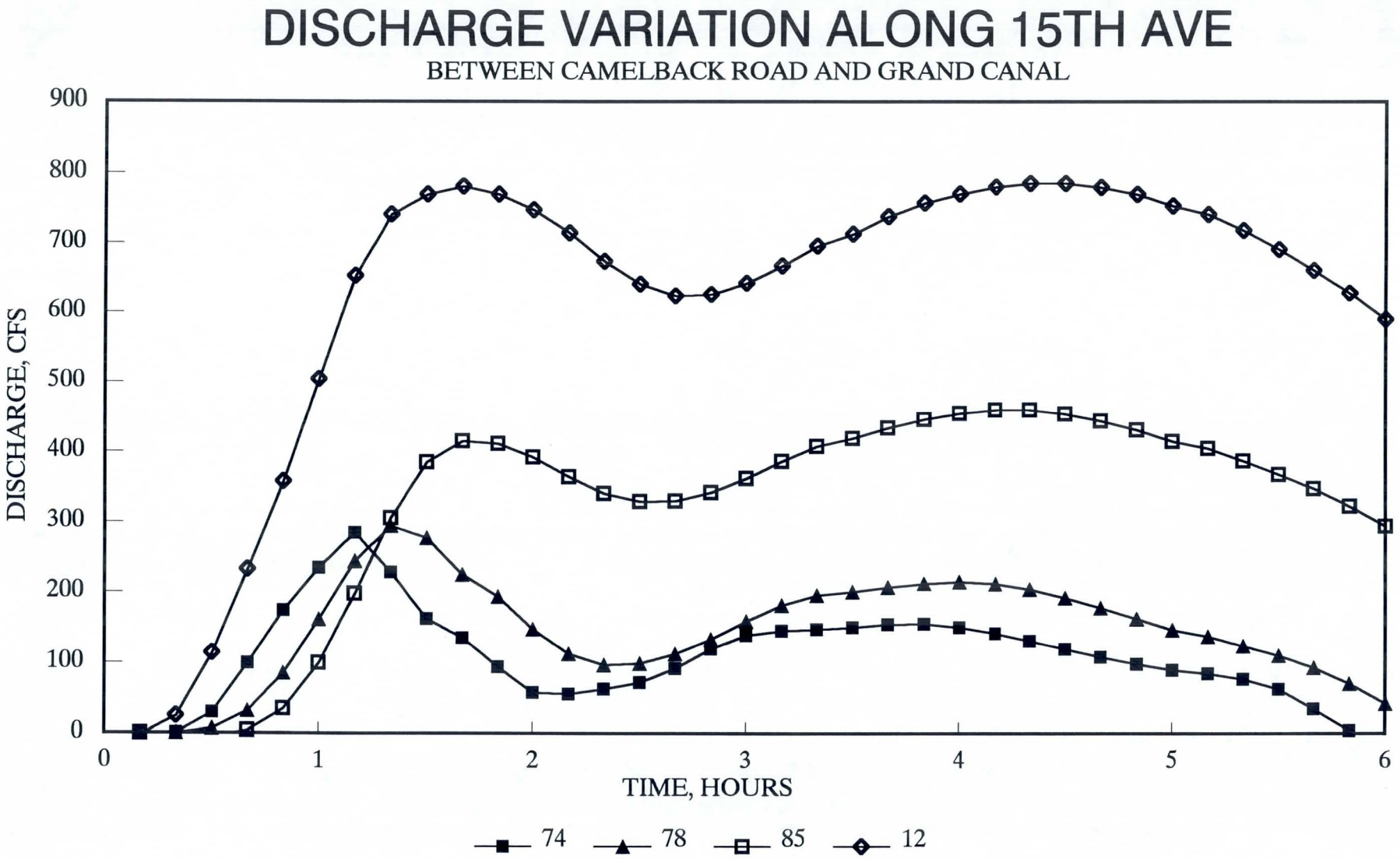

Figure 68 Computed Inner-Mesh Flood Hydrographs
15th Avenue within the Southern Portion of the Study Area

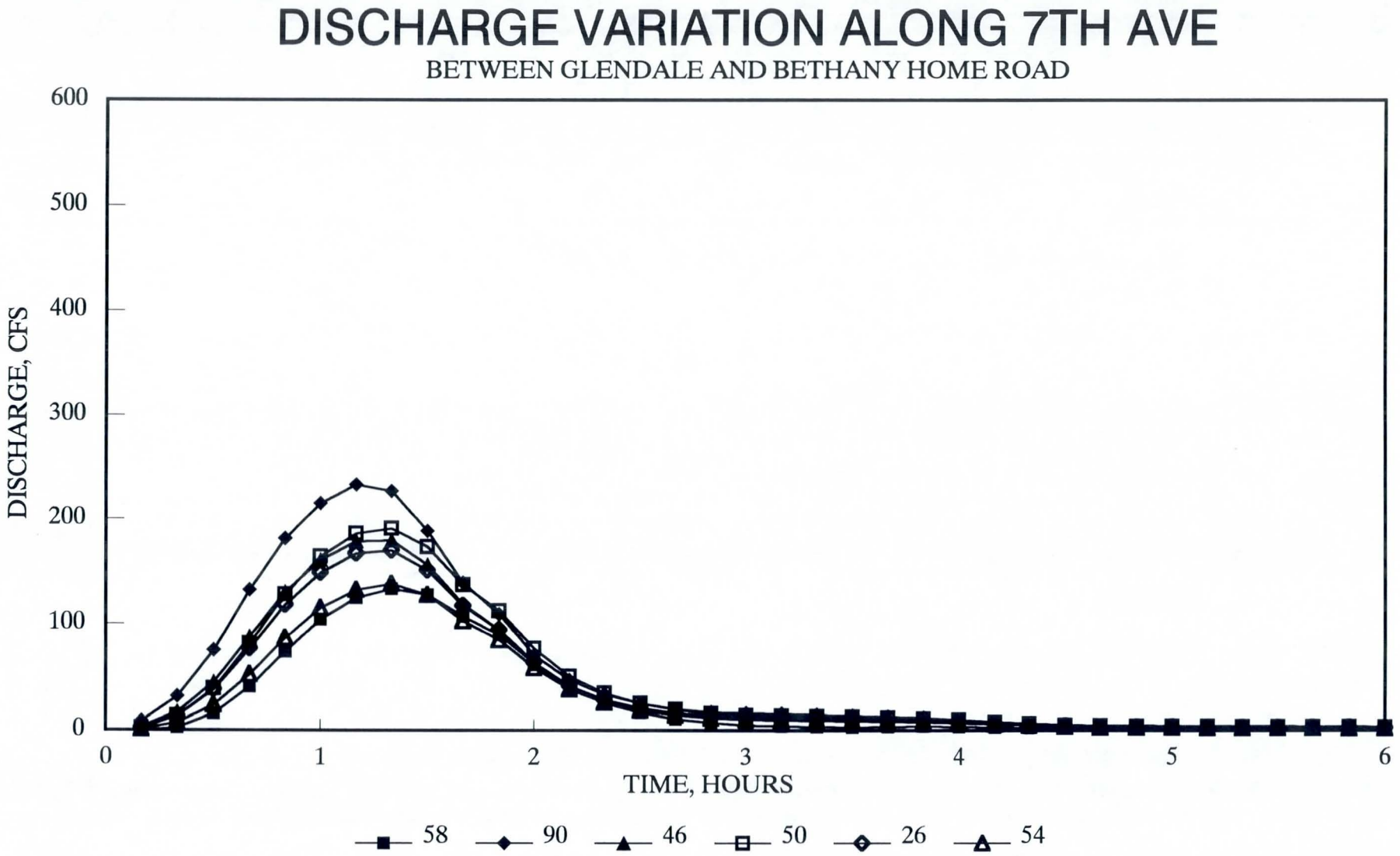

Figure 69 **Computed Inner-Mesh Flood Hydrographs**
7th Avenue within the Northern Portion of the Study Area

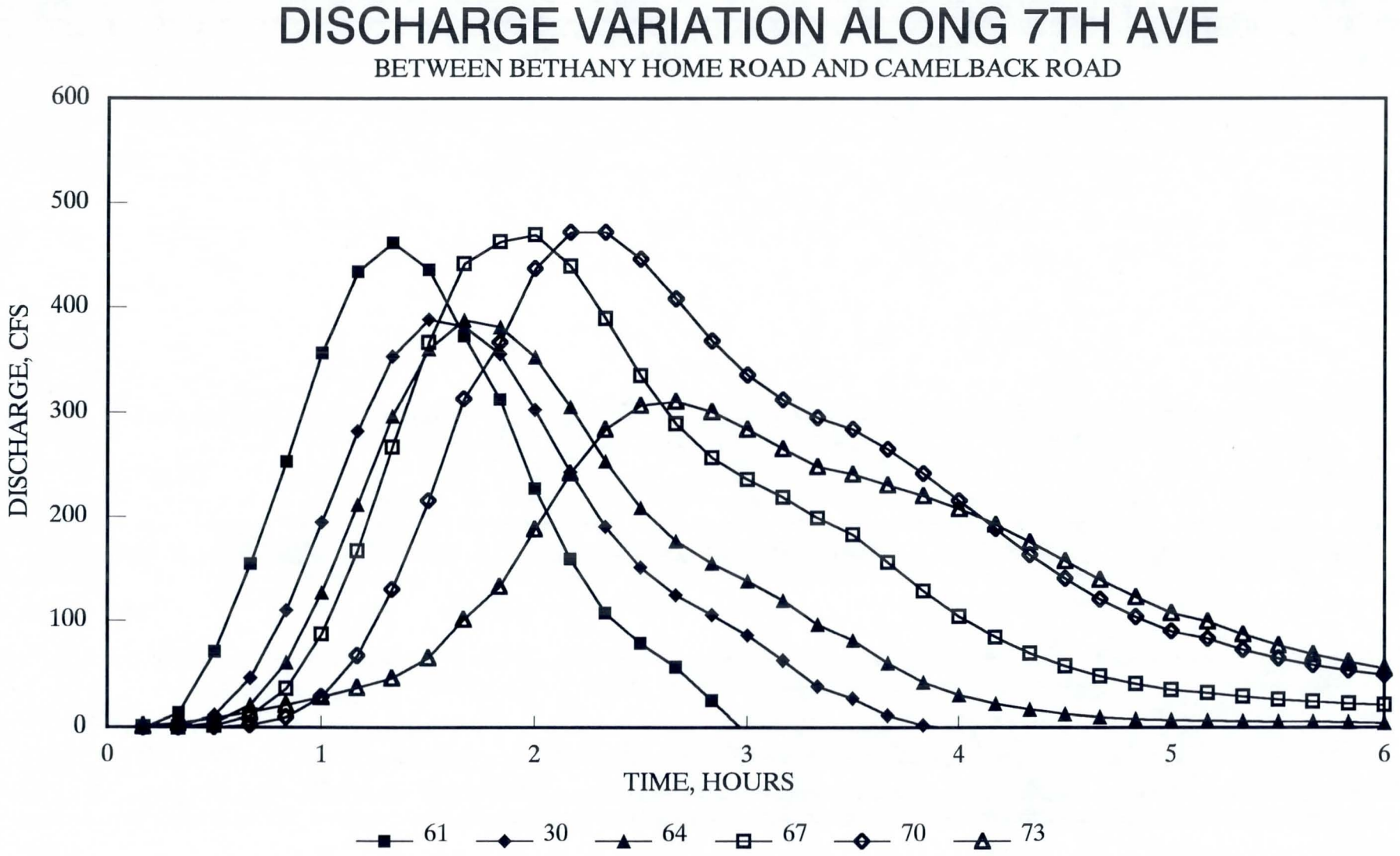

Figure 70 **Computed Inner-Mesh Flood Hydrographs**
7th Avenue within the Middle Portion of the Study Area

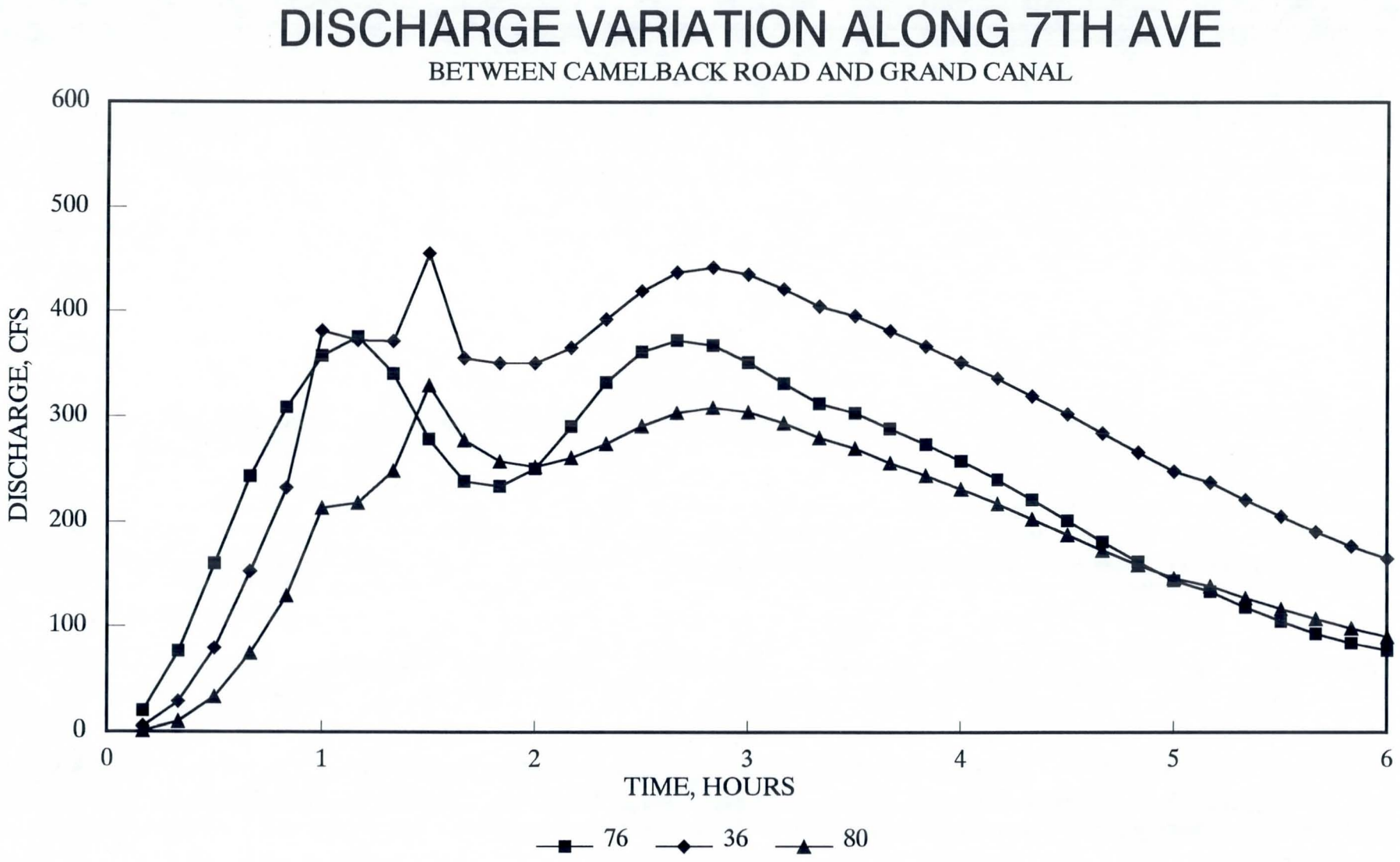

Figure 71 Computed Inner-Mesh Flood Hydrographs 7th Avenue within the Southern Portion of the Study Area

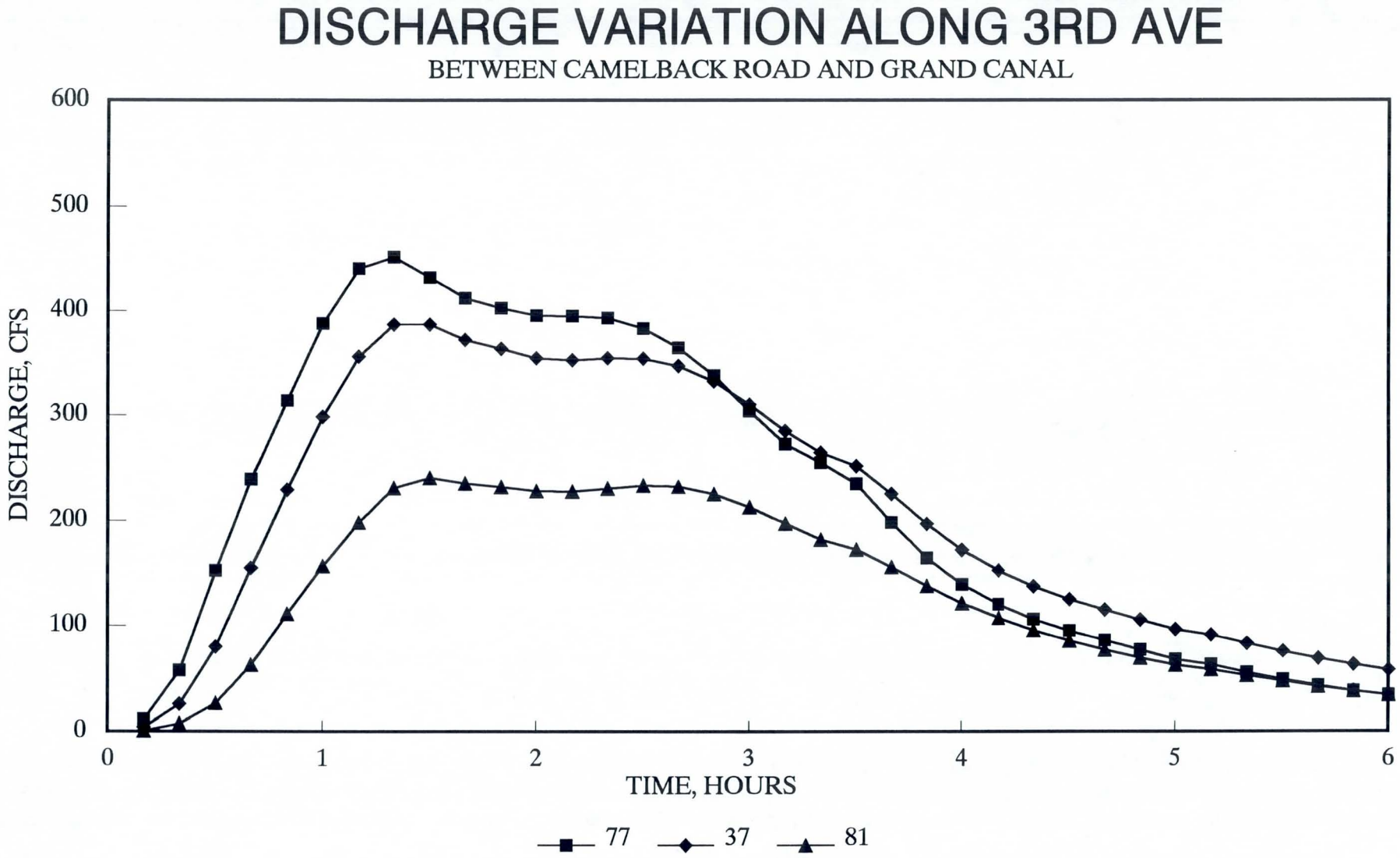

Figure 72 **Computed Inner-Mesh Flood Hydrographs**
3rd Avenue within the Southern Portion of the Study Area

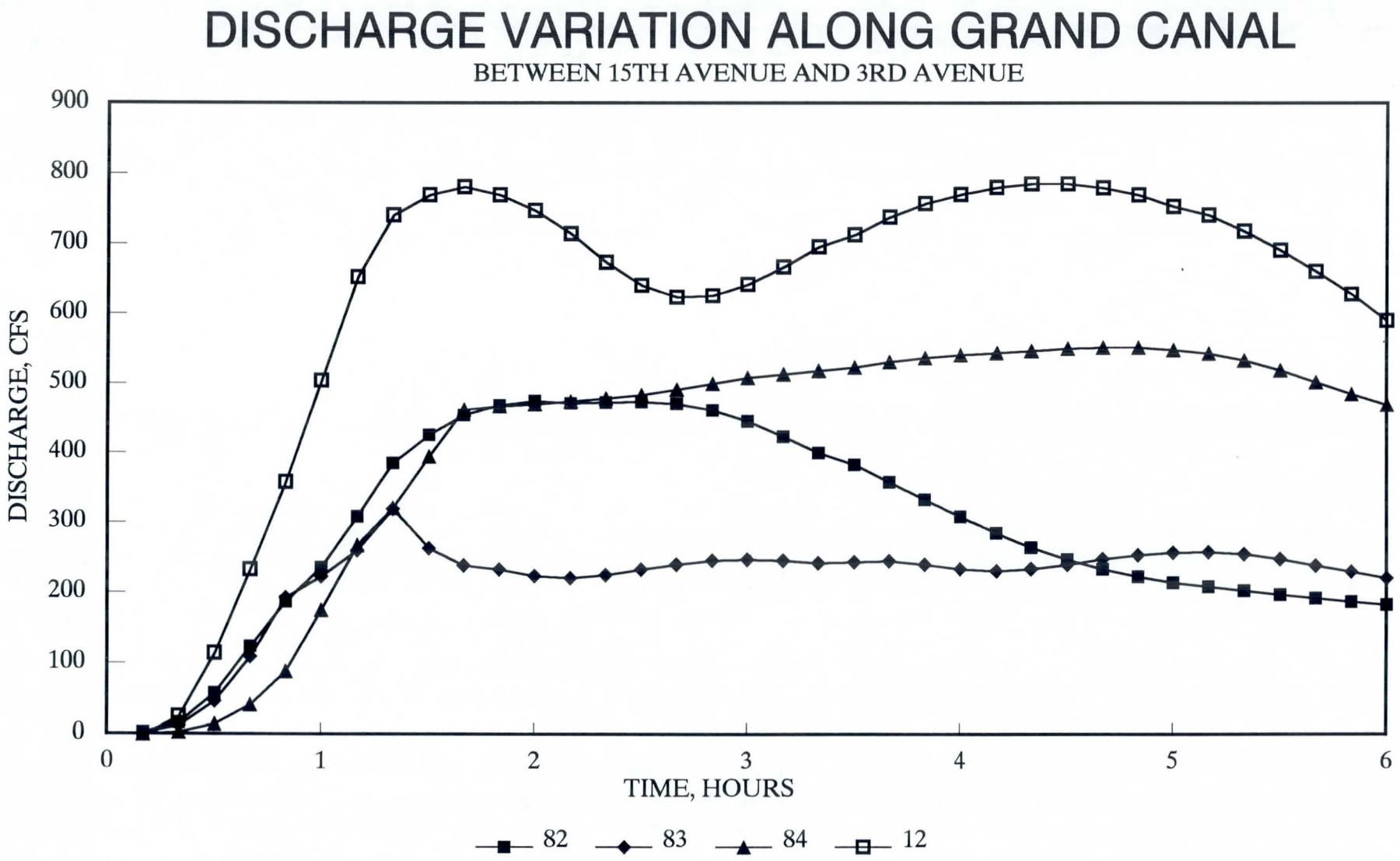

Figure 73 **Computed Inner-Mesh Flood Hydrographs Along the Grand Canal**