THE HAZARDS OF PLACE: A STUDY OF VULNERABILITY TO FLOOD HAZARDS IN WALNUT CREEK BASIN

THESIS

Presented to the Graduate Council of
Southwest Texas State University
in Partial Fulfillment of
the Requirements

For the Degree

Master of Applied Geography

By

Kathy Ann Alexander, B.A.

San Marcos, Texas
December 2001

ACKNOWLEDGEMENTS

I would like to express my deep appreciation to my parents, Baird and Betty Martin, and my children, Rosemary and Rachel Bickerstaff, for their unconditional support throughout this project. I would also like to thank my special friends, David Harkins and Danna Barnes, for their understanding during the drafting of this thesis.

I would also like to thank Dr. Ben Zhan for his assistance in reviewing this paper. I am very grateful to Dr. Fred Shelley and Dr. Susan Hardwick for their support throughout my graduate studies.

Dr. Richard Earl provided invaluable assistance and technical guidance throughout this project. His concern and support for students is unparalled.

Finally, I am forever indebted to Dr. Pamela Showalter, my supervising professor and advisor on this project, for her encouragement, understanding and assistance throughout the revisions to this document.

TABLE OF CONTENTS

TABLES

FIGURES

ABSTRACT

THE HAZARDS OF PLACE : A STUDY OF VULNERABILITY TO FLOOD HAZARDS IN WALNUT CREEK BASIN

By

KATHY ANN ALEXANDER, B.A.

Southwest Texas State University

December 2001

SUPERVISING PROFESSOR: PAMELA SHOWALTER

In 1981, flooding in the Walnut Creek Basin resulted in two deaths, widespread property damage and disruption of city services. In subsequent years, flood damage continued to occur despite structural improvements and the participation of the City of Austin in the National Flood Insurance Program. Because of its uneven distribution over space and time, land use change appears to be the major factor affecting vulnerability in this basin. This study uses HEC-HMS (U.S. Army Corps of Engineer's Hydrologic Modeling System) to evaluate the impact of land use change on the magnitude of flood peaks in the Walnut Creek Basin between 1960 and 1990. Census tract data and

historiographic analysis are then used to examine the interplay of physical and social factors that create vulnerability, as well as the relationship between risk and mitigation that contributes to the process by which certain groups become vulnerable to a hazard. This study will identify the processes that result in the current "riskscape" and their cumulative effect over time.

CHAPTER 1

INTRODUCTION

> *...the heavy annual toll from flood losses in the Unites States is a payment which nature capriciously exacts from man in return for his occupation of her flood plains. This rental charge is collected erratically and mercilessly (White 1942, 50)*

James Wright (1994) points out that although the United States made progress in reducing losses from flood events over the last twenty-five years, the potential for serious loss still exists. Wright notes a trend toward a decrease in flood related deaths and an increase in flood related losses. Texas, in particular Central Texas, follows the nationwide trend. This is because of geographic location and climate characteristics. Baker (1977) examined stream channel response to floods in central Texas and found that "small basins in regions of highly variable flood magnitudes appear to have a high potential for catastrophic response" (1057).

This is certainly true of Walnut Creek Basin in Austin, Texas, where flooding in 1981 resulted in two deaths, damage to many homes and disruption of city services (Moore et al. 1982). The two fatalities, Mike Villareal, an 18 year old pre-law student at St. Edward's University and Kao Chin Lu, a 47 year old recent immigrant and mother of a 16 year old apparently felt safe on Austin roadways. Both perished on major transit routes when flood waters estimated in excess of 8 feet in height overcame their vehicles.

A catastrophic event? Yes, for them. However, this was not the 1% (100 year) event. In fact, the United States Geological Survey (USGS) and the National Weather Service identified the 1981 flood event in Walnut Creek Basin as the 4% (25 year) event.

Although the 1981 flood event prompted structural improvements in the Walnut Creek Basin and motivated the Austin City Council to take action with regard to flood plain regulation, flood damage continues to occur. More recent flood events did not result in loss of life in this watershed, however, property losses continue to occur in neighborhoods in the lower reaches of creek (Austin American Statesman 1998). Walnut Creek Basin in the 1960s was predominantly rural. City policies discouraged growth in the eastern portion of the watershed in the 1970s and directed high density growth to this area in the 1980s. In the 1990s, the City of Austin began to direct development to rural areas within the Walnut Creek Basin by including this area in the Desired Development Zone. Uneven growth distribution in the basin may contribute to spatial and temporal variability in the location of vulnerability to flood hazards.

Assessments of vulnerability to flood hazards traditionally rely on the National Flood Insurance Program (NFIP) standard, or the 100 year floodplain, as the boundary within which direct risk exists. Use of this standard may not be reliable in urban areas because storm drainage systems in older neighborhoods may be unable to handle increased flood peaks associated with more concentrated development. Therefore, this study is not confined to areas within the 100 year floodplain boundary. Previous research evaluating risk outside the 100 year floodplain boundary used a grid system based on an assumption of even distribution of development over space and time. Uneven growth distribution over time calls into question the reliability of earlier models for this type of study.

This study used the Hazards of Place Model (Cutter 1996) to examine risks associated with flood hazards. A site specific study using HEC-HMS (U.S. Army Corps of Engineers Hydrologic Simulation Model) evaluated the impact of land use change on the magnitude of flood peaks in the Walnut Creek Basin between 1960 and 1990. ArcView GIS was used to create historic land use coverages and runoff curve numbers for simulation purposes. This study assumed a uniform simultaneous distribution of rainfall throughout the basin to examine the effect of increasing urbanization on stream response. A comparison of simulation results with the social characteristics of basin populations provides the context for an assessment of the vulnerability of place in Walnut Creek Basin.

Chapter II examines other research relevant to this study. Chapter III places flood mitigation strategies within their historical and political context. Chapter IV includes a description of the study area. Chapter V details the methodolgy used in the study including the HEC-HMS simulation and the assessment of the social characteristics of basin populations. Chapter VI provides the results of the simulation. Finally, Chapter VII concludes with a discussion of study results and suggests avenues for further research.

CHAPTER II

LITERATURE REVIEW

Vulnerability, broadly defined as the potential for loss, is an essential concept in hazards research and is central to the development of hazard mitigation strategies at the local, national, and international level (Cutter 1996, 529) Within the context of vulnerability research there are as many definitions of vulnerability as there are researchers; Cutter (1996) lists eighteen definitions. For example, Timmerman (1981) defined vulnerability in terms of system response or, "the degree to which a system acts adversely to the occurrence of a hazardous event." This definition addresses the physical response of a natural system but does not address the human impacts of a hazardous event. Susman et al. (1984) define vulnerability as " the degree to which different segments of society are differentially at risk." This definition addresses exposure and social factors but fails to account for the physical response of natural systems. Dow (1992) defines vulnerability as the "differential capacity of groups and individuals to deal with hazards, based on their positions within the physical and social worlds." This definition does address the interaction of physical and social factors that create vulnerability but does not account for how individuals initially become vulnerable. The fifteen other definitions listed by Cutter are distributed between the categories of exposure and response.

These conceptualizations of vulnerability are lacking because they do not account for the variety and interplay of all the factors, both physical and social, which contribute to vulnerability or the process by which populations become vulnerable. A more complete definition is "vulnerability is the likelihood that an individual or group will be exposed to and adversely affected by a hazard. It is the interaction of the hazards of place (risk and mitigation) with the social profile of the community" (Cutter 1996, 532). This definition includes not only the interaction of physical and social factors that create vulnerability, but also examines the interplay of risk and mitigation that contribute to the process by which certain groups become vulnerable to a particular hazard.

Cutter (1996) proposes a hazards of place model that synthesizes the various approaches to investigating hazards and assessing vulnerability to them:

> Risk is the likelihood of occurrence (or probability) of the hazard. Risk has two domains: it includes the potential sources of risk (industrial, flooding, transportation) and the contextual nature of the risk itself (high consequence, low consequence). The second domain is a simple probabilities estimate based on the frequency of occurrence (100 year flood, 5% risk). Risks combine with mitigation (efforts to reduce risks such as planning, prior experience) to create an overall hazard potential. Risks can be attenuated with good mitigation or they can be amplified by poor or nonexistent mitigation practices. The hazard potential is filtered through the social fabric of society (socioeconomic indicators, cognition of risk, individual/societal ability to respond) to determine the overall social vulnerability of place. The hazard potential is also filtered through its geographic context (site and situation, proximity) to determine biophysical/ technological vulnerability. It is the intersection and interaction of both the social vulnerability and biophysical/ technological vulnerability that create the vulnerability of places. The place vulnerability provides a feedback loop to both the risk and mitigation, which in turn further reduces or enhances both the risk and mitigation.
> (536-537)

This model has not been utilized in investigating vulnerability to flood hazards. There are several possible reasons why this is so. Perhaps most important is the fact that there is wide disagreement over what vulnerability "really" means, which leads to a somewhat fragmented approach to vulnerability research (Cutter 1996). Second, in the context of flood hazard research, research into the flooding hazard is primarily divided into either the physical or the social aspects of vulnerability. This divergence precludes consideration of the interplay of physical and social factors which lead to vulnerability. Third, choice of the somewhat arbitrary one percent standard, or one hundred year floodplain, as the boundary in which risk from flooding exists limits research into the flooding hazard. Finally, there seems to be a lack of research into the process by which communities become vulnerable to hazards. By ignoring the process by which communities become vulnerable, insights that may lead to a broader research agenda are overlooked.

Cannon (1993) points out that "... hazards are natural, but in general disasters are not, and they should not be seen as the inevitable outcome of a hazard's impact" (92). Furthermore, Cannon argues that the operation of dominant social, political, and economic processes leads to differential risk among social groups. Differential risk is a function of livelihood vulnerability, determined by age, gender, ethnicity, class, and state action. The extent to which vulnerable groups participate in the decision making process determines their level of protection and methods of technical intervention. Emphasis on the process by which communities become vulnerable to hazards may facilitate the ability of vulnerability researchers to answer the question that, according to Cutter (1996), is often ignored in vulnerability studies: what are the underlying causes of increased social vulnerability?

Within the literature of flood hazard investigations in urban areas, the dominant theme of social science researchers centers on the human occupance of floodplains. One of the early pioneers in this area of research was Gilbert White. In a classic study, White et al. (1958) examined seventeen cities and found that risks from flooding were increasing despite structural mitigation. According to White, increasing reliance on structural controls led to increasing occupance of floodplains; a phenomenon dubbed the escalator effect. This early research set the direction taken by most studies since 1958. Montz and Gruntfest (1986) updated the 1958 study for nine of the cities. They found that although the cities implemented many of the non-structural measures suggested by the 1958 study, flood damage figures continued to rise and floodplain encroachment increased rather than decreased.

Other studies evaluate the use of nonstructural mitigation efforts such as the National Flood Insurance Program (NFIP) and land use controls in floodplain areas (Burby and French 1981; Cheatham 1977; Costa 1978; Galloway 1980; Kunreuther and White 1994;Wright 1994). Burby and French (1981) suggest that the outcomes of floodplain land use management programs vary depending on community characteristics. They found that cities with little existing floodplain development and available sites that were not prone to flooding were more successful in reducing floodplain encroachment. The cities that were least successful in limiting floodplain encroachment were those with significant numbers of existing structures in the floodplain and a lack of alternative sites for future development.

The problem with these studies is that the 100 year floodplain in urban areas is not a static boundary, it changes over time because of annexations, flood control structures and increased urbanization (Montz and Gruntfest 1986). Parker (1995) notes that "because flood volumes are greater; the geographical extent of riverine flood plains may also expand especially where valley slopes are gentle. In this way formerly flood free urban land uses can become flood prone" (115). Lord (1994) points out other shortcomings with the use of the one percent standard, or the one hundred year floodplain. He finds that what began as a minimum national standard, created for political reasons and to introduce uniformity into the process of flood insurance purchase became the only standard. Adherence to this standard as the sole determinant of vulnerability leads to a belief that areas outside the boundaries of the one percent zone are not at risk. The five hundred year floodplain, used as a locational guideline for critical facilities, is an additional regulatory boundary. Use of the five hundred year delineation is even more problematic because the period of record for streamflow is too short to allow for accurate determination of this boundary.

The changing nature of the 100 year floodplain boundaries suggests that a count of the numbers of structures in the floodplain may not be a reliable indicator of vulnerability or is only a reliable indicator of vulnerability at a particular moment in time. However, even the assertion of reliability at a given time is debatable given that different modeling techniques are used to delineate the 100 year floodplain at different times (Brown 1997). These boundaries, particularly in the Austin area, are subject to continual revision because of explosive urban growth. The identification of the floodplain is then dependant upon the methods used for its delineation which vary according to the agency or researcher conducting a given study and depends on professional judgement during the process (U. S. Army Corps of Engineers 1980). This leads to difficulty in replicating the results arrived at by various researchers. As Boyer (1992) points out, the question is not what is the 100 year floodplain but what is the better estimate of the 100 year floodplain.

Few studies address vulnerability of the populations that live near but not in the 100 year floodplain. Coxe (1992) examined flood damage and the flooding hazard in the Bayou Fountain Basin in Louisiana, taking into account areas outside the one hundred year floodplain. However, this study was a slice of time approach and did not address how vulnerability changes over time. Additionally, although she compared Flood Insurance Rate Maps (FIRM) maps with a geomorphic assessment of the area and found geomorphic maps a better predictor of flood hazards in some cases, the final hazard maps she produced gave greater weight to the FIRM one hundred year floodplain delineation in determining areas prone to the flooding hazard. The U. S. Army Corps of Engineers (1980) also attempted to address vulnerability to the flooding hazard experienced by those outside the 100 year flood plain. However, the Corps of Engineers used a grid system based on the assumption that development was evenly distributed in space and time throughout the basin. This approach ignores the fact that development is not evenly distributed in time and space. Additionally, because of changes in development policy at the local level, the studies undertaken by the Corps underestimated the magnitude and extent of future development.

Parker (1995) suggests that although the number of structures in the floodplain may provide an indicator of the direct risks associated with the flooding hazard, there are also indirect risks involved. In particular, he notes the adverse impacts associated with the presence of major roadways in flood prone areas. When these roadways are flooded, not only are the people on the roadway at risk, but the traffic disruption also disperses beyond the immediate area impacted by the flooding. Parker suggests a model to assess vulnerability associated with flooding of transportation routes; with vulnerability as a function of "dependence, transferability, and susceptibility" (119). Parker does not, however, indicate an empirical method for measurement of transportation vulnerability.

The other avenue of research into the flooding hazard examines the physical reaction of natural systems to flooding events. Many of these studies examine the changes in hydrologic and geomorphic reactions in rural settings, where the human impacts are agricultural or human impacts are negligible (Baker 1977; Knox 1977; Magilligan 1985, 1992; Magilligan and Stamp 1997; Potter 1991; Woltemade 1994; Woltemade and Potter 1994). Using HEC-1 modeling (U.S. Army Corps of Engineers rainfall/runoff simulation), Magilligan and Stamp (1997) documented the extent of historical increases in flood peaks caused by human alteration of the landscape by agriculture as well as the decrease in flood peaks associated with the decline in agriculture in the study area.

There are a few studies that address the physical factors associated with flooding in urban areas. Hollis (1975) found that "urbanization can change the flood characteristics of a basin" (431). He concluded that urbanization increases the peak discharge in small floods and that the effect declines as recurrence intervals increase. Several other studies found that urbanization increases flood potential because of reduced concentration times and because concentration of storm runoff in channels is higher (Graf 1976; Waananen 1977). What these studies do not address is the human impacts of these changes.

Another aspect of vulnerability research that receives little attention from scholars is temporal change in the vulnerability of a population or the areas they inhabit. A few studies address this topic using historical narrative (Colten 1991; Pulido et al. 1996; Sidawi 1997). No studies were located that use empirical techniques to evaluate the temporal aspect of vulnerability. Possible reasons for this omission include: the relative youth of the field of vulnerability research, the fragmented nature of vulnerability research (Cutter 1996), and the difficulty of devising empirical measures of vulnerability change.

The literature discussed in this review illustrates that researchers tend to examine either the social or the physical impacts of the flood hazard in an attempt to assess the vulnerability of populations. Green et al. (1991) point out that "different groups (planners, engineers, researchers and the public) vary significantly in their selection and definition of risks from flooding as a focus of concern and that their definition of risk influences their expectations about future events and the appropriate response to those events" (227). The divergent agendas for flood hazard research provide evidence in support of this statement.

There are indications that the research agenda may be expanding in some areas. In the aftermath of the 1993 Mississippi River floods, Leopold (1994) called for more detailed study of "both the separate actions and the interactions of forces and parameters in geomorphology, hydraulics, hydrology, physical geography, economics, engineering, and planning" (11). Such an expanded agenda would certainly provide some unification among the diverse research agendas in the physical realm. However, Leopold did not mention the addition of social factors that combine with physical ones to affect the vulnerability of a particular place.

The purpose of this research is to examine the vulnerability to flood hazards using the hazards of place model proposed by Cutter (1996). This model (Figure 1) incorporates both physical and social factors that influence vulnerability. Furthermore, the structure of

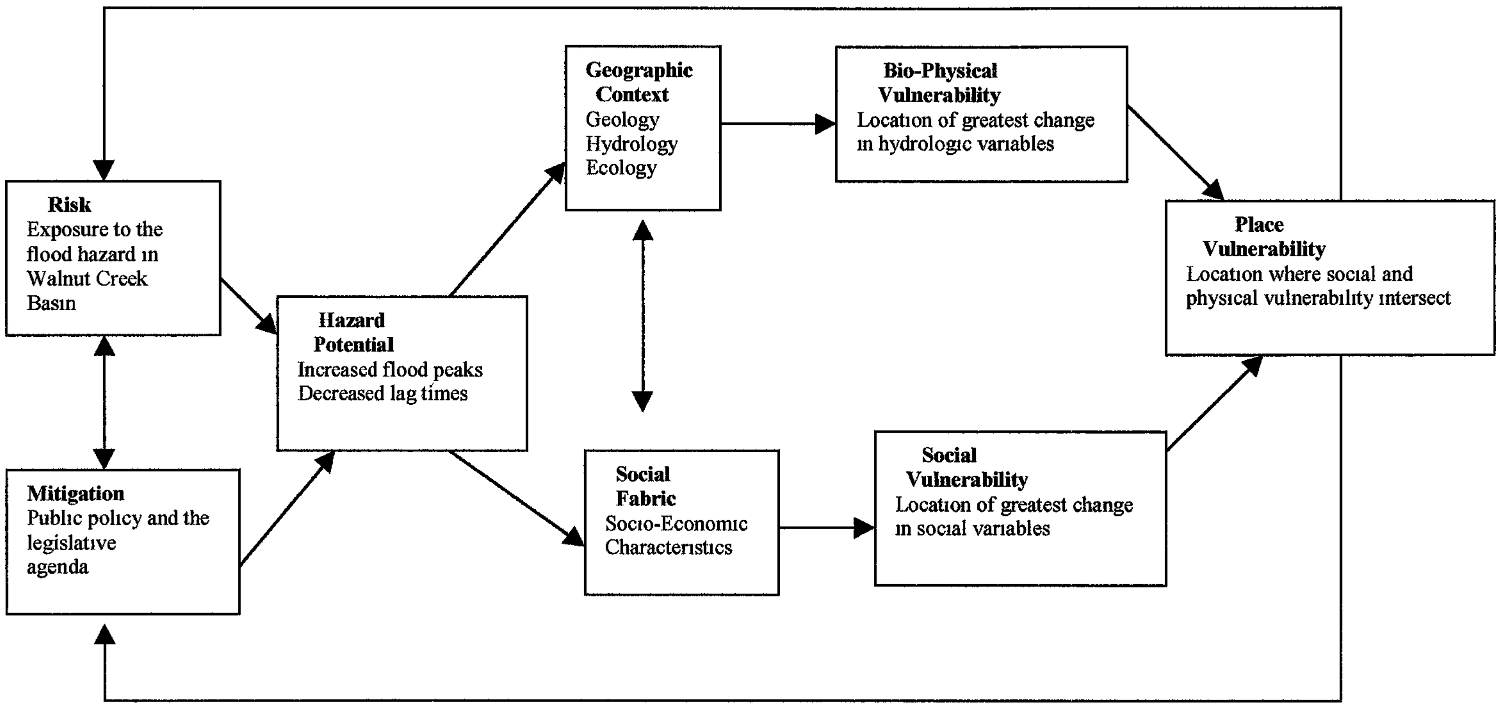


Figure 1: Hazards of Place Model

(Note: The format of this model and the bold face headings are taken from Cutter (1993, 536). The sub-headings are the author's.)

this model permits an examination of how vulnerability changes over time. Shifts in legislative response to flood mitigation during the study period will allow the use of historiographic analysis (cumulative textual histories) to evaluate whether or not public policies and their translation into legislative initiatives led to changes in vulnerability to flood hazards in the Walnut Creek Basin.

CHAPTER III

AUSTIN'S RESPONSE TO FLOOD HAZARDS

Kates (1962) points out that flood hazard perception is an episodic phenomenon. Immediately after a flood, people appreciate and often exaggerate the danger. Time eradicates evidence of the power and extent of the flood and the danger fades in people's minds. However, despite public perception, the danger remains. The occurrence of a major flood event in any given year does not eliminate the chance that a similar event may occur the next year. The response to flood hazards at both the national and local level follows a pattern of disaster occurrence, public outcry, and legislative action followed by a belief that the problem was addressed. In general, states do not play a major role in flood control and floodplain management. There are 1240 communities in Texas that are subject to flood hazards but there is no statewide program to address this hazard and the state of Texas does not directly regulate floodplains. The primary role of the state is that of an intermediary between the federal government and local entities.

Several factors influence legislative response to flood hazards at the federal level. The primary factor influencing legislation is the areal extent of floods and flood damage. The Flood Control Act of 1936 (*Flood Control Act* 1936) followed extensive flooding in the Ohio River Valley. A series of hurricanes and coastal storms in the early 1960s led to another re-evaluation of federal flood control policy. Studies of these events and recognition of the increasing cost of disaster relief expenditures to the federal budget led to enactment of the National Flood Insurance Act in 1968 (*National Flood Insurance Act* 1968). Economic considerations also influenced federal legislation to a certain extent. The Depression in 1936, and fear of a post war depression in 1944, motivated Congress to appropriate funds for major public works projects.

In Austin, Texas, additional factors influenced legislative response. First, local land use regulations are a response to federally mandated minimum standards. After 1973, federal requirements of the Flood Disaster Protection Act (*Flood Disaster Protection Act* 1973) mandated that local governments adopt minimum land-use standards. Austin responded with ordinances amending existing city codes. Second, the geographical extent of the Memorial Day Floods of 1981 resulted in tightened requirements for floodplain development. A third geographic factor also influenced local legislation. The extent of allowable human alteration of natural landscapes and the power of the environmental lobby played a major role in determining both the form and the outcomes of the City of Austin's response to flood hazards.

FEDERAL LEGISLATION

During the 1930s political interest in a national water resources program existed among several branches of the federal government including the Corps of Engineers, Congress and the Executive branch. President Franklin Roosevelt recognized that major public works projects, such as dam construction, were potential sources of employment and often encouraged economic revitalization. Consistent with the philosophical focus of the New Deal, Roosevelt favored a water resources policy based in centralized planning.

He appointed a Committee on Water Flow in 1934 to provide input into water resources policy. Based on committee recommendations, Roosevelt submitted a report to Congress favoring a comprehensive water policy involving acquisition of information and provisions for division of federal and non-federal responsibilities in administration of the program (U.S. Congress, Senate 1956). Congress did not act, in part, because many in Congress viewed centralized planning as a threat to constitutionally mandated separation of powers. Additionally, Congress and the Corps of Engineers preferred a continuation of Congressional authorization of individual projects that preserved the close relationship between individual members of Congress and the Corps of Engineers (Moore and Moore 1989).

Floods in the Ohio River Valley in the winter of 1935-1936 motivated Congress and the Executive branch to resolve their disputes and on June 22, 1936 Roosevelt signed the Flood Control Act of 1936 (*Flood Control Act* 1936). This act declared that floods were a menace to the national welfare, that flood control was a federal responsibility, and established a federal flood control policy. Although the 1936 legislation established a national program for flood control, the focus remained on congressional authorization for single purpose structural control projects. Congressional recognition of the potential drain on national financial resources resulted in Section 3 of the Flood Control Act of 1936 requiring local entities to provide land easements, and to operate and maintain completed flood control works. The legislation also required a cost-benefit analysis; qualification as a federal project was contingent on benefits exceeding costs, regardless of whom benefited.

The Flood Control Act of 1936 set the standard for federal floodplain management efforts for the next forty years. Although Congress enacted numerous amendments to the Flood Control Act in subsequent years, they made no substantive changes. The amendments primarily provided federal authorization for specific projects and addressed allocation of costs among federal, state and local governmental entities. The Flood Control Act of 1938 (*Flood Control Act* 1938) amended Section 3 of the 1936 act and provided federal funding for reservoir construction and channel improvements. The Flood Control Act of 1944 (*Flood Control Act* 1944) was a response to fears of a post war depression. In addition to authorization for new projects, this amendment provided for funding for drainage improvements under the purview of flood control. Section 205 of the Flood Control Act of 1948 (*Flood Control Act* 1948) permitted construction of small projects without specific congressional authorization. Section 205 gave the Corps of Engineers (COE) authorization responsibility for these projects and limited the cost of individual projects to $100,000. Section 205 also prohibited construction of projects within areas protected by other authorized projects.

During the late 1950s, a trend toward more localized floodplain management efforts emerged. Francis Murphy, a COE hydrologist working with researchers at the University of Chicago, published a study of floodplain development regulations (Murphy 1958). Murphy found that local communities needed to regulate floodplain development to reduce the rising national costs of flood control projects. He pointed out that lack of information about flood risk areas prevented local governments from enacting legislation to control floodplain development. Murphy suggested that the federal government develop a method to gather and disseminate information about flood risk areas. At the same time, White and others (1958) examined the issue of floodplain occupancy. As previously mentioned, those authors examined seventeen cities and found that risks from flooding increased despite structural mitigation. According to the researchers, risks increased because reliance on structural controls led to increasing occupancy of floodplains.

These two studies and recommendations from the State Council of Governments that one federal agency be given responsibility for providing local flood plain information led Congress to enact of the Flood Control Act of 1960 (*Flood Control Act* 1960). Title II, Section 206 of this act authorized the Corps of Engineers to conduct studies and to gather and distribute information on floods and flood damage. The floodplain studies included identification of areas at risk from floods of various frequencies and general guidance to local entities for the purposes of land use in flood prone areas. This original enabling legislation set the basis for current floodplain mapping efforts by deeming such efforts a federal responsibility.

The 1960s marked the end of an era of reliance on structural methods for flood damage reduction. A series of hurricanes and coastal storms in the early 1960s led to a re-evaluation of federal flood control policy. In 1965, Congress directed the Department of Housing and Urban Development (HUD) to study the feasibility of disaster insurance for property losses in natural disasters and the Bureau of the Budget formed a Task Force on Federal Flood Control Policy, chaired by Gilbert White. Both the Task Force and HUD recommended a federal flood insurance program to meet insurance needs in flood prone areas, a shift of floodplain occupancy risk from the federal government to private citizens, and encouragement for local governments to reduce floodplain encroachment.

Based on these studies and in recognition of the increasing burden that disaster relief expenditures placed on the federal budget, Congress enacted The National Flood Insurance Act (NFIA) of 1968 (*National Flood Insurance Act* 1968). This act authorized a national flood insurance program based on the cooperation of the federal government and private insurance carriers. Additionally, the NFIA forced local governments to enact land use controls by conditioning subsidized flood insurance availability on conformance of local land use measures to federally mandated standards.

Congress placed responsibility for the NFIA with HUD. Chapter 1 of Title XIII outlined types of property eligible for subsidized premiums, proposed conditions under which eligibility might be extended and mandated that localities adopt land use controls by June 30, 1970 to participate in the program. Chapter III of Title XIII addressed coordination of land management and flood insurance programs. Section 1360 required HUD, in cooperation with federal, state, local, and private entities, to identify and publish information on all flood plain areas in the United States within five years and to identify flood-risk zones and estimate loss rates for these zones within fifteen years. Section 1361 authorized HUD to investigate the adequacy of state and local land use management efforts and to develop comprehensive criteria to reduce the development of flood prone land. This chapter also contained provisions authorizing HUD to purchase substantially damaged property in flood-risk areas.

The 1968 NFIA marked a major shift in federal flood control policy. Rather than moving floods away from people (the goal of structural improvements), the 1968 NFIA attempted to move people and property away from floods. Unfortunately, lack of funding impeded implementation of the Act. While the COE had the technical capability to conduct both land use studies and floodplain mapping projects, they did not receive the necessary personnel allotments to perform these duties. Additionally, the establishment of actuarial rates for insurance coverage proceeded slowly, which prevented many communities from entering the program. Only four out of 20,000 eligible communities joined the program in its first year of operation (Moore and Moore 1989).

In 1969, Hurricane Camille caused extensive damage in many communities where flood insurance was not available. This storm motivated Congress to amend the 1968 NFIA in December of 1969 (*National Flood Insurance Act* 1969). Section 1336 of the Act created an emergency phase of the National Flood Insurance Program, allowing community participation pending completion of flood hazard boundary and insurance rate maps. Communities entered the emergency phase by adopting minimum land use regulations in flood hazard areas.

Hurricane Agnes, which caused two billion dollars worth of damage in 1972 (Burby et al. 1981) led to a re-evaluation of the voluntary nature of the National Flood Insurance Program (NFIP). Few communities voluntarily participated in the program or adopted land use regulations to mitigate flood hazards. In response, Congress passed the Flood Disaster Protection Act of 1973 (*Flood Disaster Protection Act* 1973) which made community participation compulsory. Title I of this Act increased the aggregate liability for single family dwellings. More importantly, Title I prohibited federal agencies from providing financial assistance for acquisition or construction of any structure in a flood hazard area where sale of flood insurance is authorized under the NFIA unless the applicant purchased flood insurance. Title II prevented federal agencies from approving financial assistance after July 1 1975 for any area identified as a flood hazard area unless the community participated in the NFIP. Additionally, Title II prohibited new loans, extensions, increases or renewal of loans by banks, savings and loans and other federally regulated financial institutions to any flood hazard area unless the community participated in the NFIP.

Environmental concerns entered the flood control and floodplain management policy agenda after passage of the National Environmental Policy Act (NEPA) in 1969. Partially in response to NEPA, Section 209 of the Flood Control Act of 1970 (*Flood Control Act* 1970) required that federally financed projects include the objectives of enhancing regional economic development, the quality of the total environment, the well-being of people, and national economic development. In 1973, the Water Resources Council released *Principles and Standards for Water and Related Land Resources* (U. S. Water Resources Council 1973). This study suggested that all federally financed land and water projects embrace the dual goals of national economic development and environmental quality. Executive Order 11988 (U. S. President 1977) provided further support for the inclusion of environmental objectives in floodplain management programs. President Carter directed federal officials to consider floodplain management in all decisions. The president stated that:

> The floodplains that adjoin the Nation's inland and coastal waters have long been recognized as having special value to our citizens. They have provided us with wildlife habitats, agricultural and forest products, stable ecosystems, and park and recreation areas. However, unwise use and development of our riverine, coastal, and other floodplains not only destroy many of the special qualities of these areas but pose a severe threat to human life, health, and property. (U. S. President 1977, 1001-1002)

Despite the acceptance of environmental concerns at the policy level, Congress did not act to implement these concerns through legislation. Because of the lack of legislation on floodplain environmental issues, the NFIP remained as the primary method for achievement of floodplain management goals.

THE LOCAL RESPONSE

Flood control was not a major item on the political agenda in Austin before the Memorial Day flood of 1981. The lack of attention to flood mitigation issues is attributable, in part, to the fact that the last major flood event in Austin occurred in 1936. This event was a flood of the Colorado River, not flooding of urban tributary streams. Subsequent construction of flood control dams on the Colorado River engendered a sense of security among city residents. Therefore, there was little public pressure in the interim to act in the area of flood control. In response to federal legislation, and, because of severe flooding in 1981, the City of Austin enacted ordinances and regulations to address flood hazards.

The Austin City Code of 1967, Section 41-44 (City of Austin 1967) provided that "lots in any proposed urban subdivision subject to flooding by rainfall, . . . will not be approved until drainage facilities adequate to carry off such rainfall have been installed". Section 41-45 provided methods for computation of flooding and sizing of drainage facilities. These regulations did not address placement of structures in flood prone areas.

In the 1970s, Austin responded to federal legislation by participating in floodplain studies and enacting ordinances to address flood hazards. The City of Austin, through the Texas Water Development Board, requested Floodplain Information Studies from the Corps of Engineers (COE). These studies provided information on flood hazards in area creeks for assisting the City of Austin in determining the best use of flood prone lands

(U.S. Army Corps of Engineers 1972). In compiling the report, the COE considered a "reasonable amount" of future growth. If development plans were proposed but not approved, the Corps excluded these developments from the analysis. The lack of a Comprehensive Master Plan in the City of Austin and the inability to accurately predict growth introduced a high margin of error into flood hazard analysis. For example, the Floodplain Information Study on the Walnut Creek watershed assumed future watershed growth to be residential and incorporated city goals favoring preservation of farmland. Subsequent councils and Austin's high growth rate invalidated these predictions and the floodplain estimations based upon them.

Consistent with the federal enabling legislation and guidelines contained in Engineer Circulars 1120-2-40 and 1120-2-117, the Corps of Engineers provided no specific plans or recommendations. Creation of a program to reduce present and future flood losses was the responsibility of local governments. The Corps outlined methods for managing flood prone areas including zoning and building code provisions, structural measures, and a city policy to discourage extension of basic services to flood prone areas. Austin did not act to implement sections of this report despite state enabling legislation allowing them to do so (Moore et al. 1982).

Although Austin did not respond to the Floodplain Information Studies with new legislation, the studies marked the beginning of an effort at the municipal level to gather information on urban drainage, stormwater runoff, and flood control. Flooding of "certain primary drainage systems" demonstrated the need for master planning and the city authorized development of a Master Drainage Plan in 1972 (City of Austin 1974a, 1). Consultants and city staff analyzed existing drainage systems and established uniform criteria and policies for the analysis and design of all existing and future public and private drainage facilities. The Drainage Criteria Manual (City of Austin 1974a) Section 2.02A required developers to design drainage facilities based on fully developed watershed conditions rather than on existing conditions.

After passage of the NFIA, concerned citizens and some city employees argued for Austin's participation in the federal program. Considerable opposition to the federal program from the development community resulted in the defeat of the proposition urging Austin's participation in 1970. After a concerted educational effort, and because of tightened federal restrictions resulting from the Flood Disaster Protection Act of 1973, Austin joined the NFIP on an emergency basis in 1975 (Moore et al. 1982). Because participation in the federal program required local adoption of floodplain land-use management restrictions, Austin amended the 1967 code to incorporate the minimum federal guidelines.

On March 4, 1974 the city of Austin passed Ordinance No. 740307-1, the "Creek Ordinance" (City of Austin 1974b). The City Council passed this ordinance because of the danger of flooding to public health and property, soil erosion, and alteration of the natural surface flow of water posed by development in the Austin area. Section 29-2 states that the intent of the ordinance was to protect citizens, prevent dangers resulting from improper drainage and "unwise" diversion, and to plan for present and future use of waterways. Additionally, the council recognized that waterways were corridors of natural beauty, which contribute to the economic value of land and to the health and welfare of the citizens. The rapid growth that created flood problems also resulted in the destruction of the natural characteristics of waterways.

Section 29-311 of the Creek Ordinance created a permit system for waterway development. Class A permits allowed development when there was no impact on drainage systems or the environment. Class B permits allowed development where there was a major impact. Section 29-3.2 required the developer to provide information to the city, including the location of the 25 year floodplain and the impact of the proposed development on existing and future drainage. Section 29-3.6 requires that the proposed developments not produce identifiable adverse flooding to other property and preserve the natural and traditional character of the waterway.

In 1975, the council adopted amendments to the building code to allow Austin's entry into the emergency program of the NFIP. The "Floodplain Ordinance" (City of Austin 1975a, 1975b), enacted on March 13, 1975, mandated floodplain management guidelines consistent with minimum federal standards, and in several instances exceeding them. Ordinance No. 750313-D Part 1 (City of Austin 1975a) defined "floodway" and "lines of maximum encroachment". Part 2 deleted Sections 41-44 and 41-45 of the Austin City Code of 1967 and substituted more stringent development requirements. The new provisions mandated drainage facilities adequate to prevent flooding, construction of closed storm sewers to accommodate design runoff in excess of street capacity, and dedication of easements around natural waterways for maintenance purposes. Section 41-44.1 b required that developers base computation of runoff on fully developed watershed conditions as mandated by the Drainage Criteria Manual. Federal regulations did not require this provision and standard practice in floodplain mapping considered only current basin conditions. Austin's rapid growth rate and the lack of a Comprehensive Master Plan contributed to the inclusion of this provision (City of Austin 1974b).

Ordinance 750313-C (City of Austin 1975b) controlled and regulated construction in flood prone areas. Section 36-501 accepted the existing floodplain maps and the Regulatory Flood Datum (RFD) as the regulatory boundaries. Section 36-502 provided definitions of terms including the floodway, floodway fringe, the Regulatory Flood (RF), the RFD, and Secondary Flood Hazard Areas. Section 36-503 addresses non-conforming uses. This section restricted improvements to structures built before adoption of the ordinance, and prohibited reconstruction of flood damaged buildings if the damage exceeded fifty percent or more of its appraised value. Section 36-504 outlined the permit procedure for construction in primary flood hazard areas. Section 36-506 classified buildings in flood hazard areas based on the relationship of building components to the RFD. In combination with Ordinance 750313-D, Austin met the land-use requirements of the 1973 Flood Disaster Protection Act.

Although city legal restrictions met the guidelines of the *Regulations of Flood Hazard Areas to Reduce Flood Losses* Volume 1 and 2 (U.S. Water Resources Council 1970, 1971), environmental concerns embodied in the Creek Ordinance conflicted with the implementation of the Floodplain Ordinance to a certain extent. Both the Creek Ordinance and the Floodplain Ordinance recognized the necessity of adequate provisions for stormwater runoff. However, the provisions of the two ordinances were mutually restrictive. In most cases, maintenance of the stream channel in its natural state, the goal of the Creek Ordinance, prevents construction of adequate storm drainage facilities. The emphasis on avoiding changes in stream channels effectively blocked the use of structural methods to increase the hydraulic capacity of channels, particularly in lower reaches of creeks downstream of newly developing areas (Brown 1997).

The 1981 Memorial Day Floods prompted the city of Austin to tighten previous floodplain restrictions. The City Code of 1981 (City of Austin 1981) replaced the City Code of 1967. Sections 13-3-161 through 13-3-185 of the 1981 Code formally incorporated the Creek Ordinance and the Floodplain Ordinance into the new code. Ordinance No. 830915-L (City of Austin 1983a) provided for the dedication of the entire hundred-year floodplain as a drainage easement as a prerequisite for plat approval. Part 2 of the ordinance enlarged the flood hazard areas specified on preliminary plats to include delineation of the hundred-year floodplain as calculated under fully developed watershed conditions. Ordinance 830915-M (City of Austin 1983b) required additional information on all applications for waterway development. Part 3g1 strengthened provisions for location of structures in the floodplain by prohibiting construction of new buildings within the hundred-year floodplain as calculated under fully developed conditions. This section exceeded federal guidelines that prohibit development in the regulatory floodway or twenty-five year floodplain. Part 3g3 exempted the Central Business District from development prohibitions provided proposed buildings met flood-proofing guidelines. Part 4 placed restrictions on the location of commercial parking lots in the hundred-year floodplain.

Despite tightened restrictions for floodplain development, Austin remains at risk from flood hazards. The City of Austin still administers drainage policy separately from flood control and policies in the two areas conflict. Reasons for lack of a comprehensive policy addressing both drainage and flood control include:

1. Flood events happen at erratic intervals.
2. Austinites have a sense of ownership about waterways on their property.
3. Austinites in general tend to disapprove of government control
4. Council goals often favor minimizing public expenditures.

Another reason for the separation of policy objectives is the strength of the environmental lobby in Austin. During a 1973 public hearing on proposed improvements to Shoal Creek (channelization), a resident recited a poem urging the Council to refrain from turning Shoal Creek into "Shoal Ditch" (Moore et al. 1982). Dunne and Leopold (1978) stated that, in most cases, channelization resulted in a costly cycle of construction because channelization speeds runoff causing downstream bank erosion that in turn requires further channel extension. Appendix C of the *City of Austin Floodplain Task Force's Report to Council* (Brown 1997) documents numerous failures in the effort to control flooding using channel improvements. In accordance with the wishes of the environmental community as embodied in the 1974 Creek Ordinance, responsibility for creek maintenance rested with individual homeowners.

In addition to the lack of a comprehensive policy for drainage and flood control, technical requirements for flood plain construction do not address modifications to smaller drainage areas. Dunne and Leopold (1978) point out that:

> In urban development the smallest rills, swales, or incipient channels tend to be looked upon by the construction crew as being insignificant, unimportant, or a nuisance . . . The net result is the virtual expurgation of many first and even second-order channels that under natural conditions played a role in keeping both sediment and run-off distributed or divided among many small channels, each of which played its part in delaying movements of flood peaks, providing channel storage and slowing the average speed at which water was delivered to larger stream channels (694).

Neither the Drainage Criteria Manual nor the Floodplain ordinance and its amendments address this issue.

There is little evidence to suggest that the solution to flood control problems is more legislation or tighter regulations. Even the most stringent ordinances allow variances. From all indications, the tendency towards more stringent regulations yields few results.

New development is certainly constrained as a result of these regulations. However little attention is given to older structures other than to effectively mandate their removal or the removal of the populations that inhabit them via regulations constraining allowable rebuilding after a flood event. While buyouts of affected properties may lessen the impacts of future flood events, none of the regulations address the impacts of constantly widening floodplain boundaries caused by increased urban development. Nor do city regulations provide for notification to occupants when updated studies suddenly place their properties within regulatory flood plain boundaries.

The Austin City Council called for an examination of flood control and mitigation policies and formed a Floodplain Task Force to examine city policy in this area. The Council's mandate to the Floodplain Task Force stated:

> That Flood Plain Task Force will study the long-term implications of existing and future development along Austin's creeks and various mitigation alternatives such as land acquisition, levees, reservoirs, redirection, and channelization. The Flood Plain Task Force will give particular attention to problems and solutions in the Onion Creek area, will stay in close contact with the consultant hired by the City to examine flood plain issues in the Onion Creek area, and will review and comment on the consultant's report (Brown 1997)

The City Council initiated this study in response to public outcry about changing floodplain boundaries in the Onion Creek watershed. Furthermore, many citizens objected to the lack of notice given to householders regarding proposed boundary changes. Given the politics behind the formation of the task force, the final report addressed flood problems in the Onion Creek watershed specifically. Due to the high profile of the environmental community, there were several references to flood problems in the Shoal Creek and Bull Creek watersheds. There was one mention of drainage problems in the Little Walnut Creek watershed. There were no specific references to flood hazards in the largest urban watershed in Austin, the Walnut Creek watershed.

This lack of a high public profile for flood risk in this watershed is not new. The report on the May 1981 flood event by the Committee on Natural Disasters (Moore 1982) mentioned the impact of this flood event on Shoal Creek almost exclusively and paid little attention to similar hazards in the Walnut Creek watershed. An investigation by the USGS into the flood event of May 1981 did detail the impact of that event on the Walnut Creek watershed as well as the impact on the Shoal Creek watershed. Both the Floodplain Task Force's Report and the Committee on Natural Disaster's report referenced this study, but only with respect to the impacts on Shoal Creek. There is no evidence that the Task Force membership included citizens residing within the boundaries of the Walnut Creek watershed.

The *City of Austin Flood Plain Task Force's Report to Council* (Brown 1997) identified several problems with city floodplain management efforts. First, the Task Force found current floodplain ordinances ineffective, unclear, and uncoordinated and recommended complete revision of these ordinances. Second, the boundaries of urban floodplains change because of increasing urban development. Third, improved methods of floodplain determination render previous floodplain determinations obsolete. Fourth, homeowners are frequently unaware of changes in regulatory floodplain boundaries. The Task Force recommended that Austin notify homeowners **and** renters of any proposed changes in floodplain delineations to increase the ability of citizens to make informed decisions and plan for potentially hazardous events.

Despite the shortcomings with respect to inclusion of Walnut Creek Basin, the Flood Plain Task Force did recommend several solutions to flood problems within the Austin area (Brown 1997):

1. The City of Austin should convene a task force of city staff to draft an ordinance consolidating floodplain regulations in a single location.
2. Provide variances to existing ordinances allowing replacement of mobile homes in existing parks that are within floodplain boundaries, allow improvements to property located within the floodplain with certain restrictions and allow additional construction within regulatory boundaries subject to certain size and cost limitations.
3. Continue to define the 25 year floodplain as the regulatory boundary but remove existing punitive restrictions against existing property within that boundary.
4. The City Council should only adopt current FEMA maps, requiring council action to amend the ordinance whenever new maps are created.
5. Notification of both property owners and renters if changes in regulatory boundaries occur as a result of updated studies.

Strategies to include planning for future flood events, reliable modeling and forecasting, accurate determination and dissemination of information, public education and promotion of flood insurance.

These recommendations are somewhat contradictory, they call for increased public awareness and revamping of floodplain ordinances yet they also call for loosening of existing restrictions. None of these solutions addresses the underlying causes of increased exposure to the flood hazard, increased urbanization. From a political standpoint, it is extremely unlikely that a moratorium on growth in the Austin area will occur any time soon. In fact, inclusion of the Walnut Creek Basin within Austin's "Desired Development Zone" ensures that increased development will occur in the basin thereby increasing the exposure of basin populations to risks associated with flood hazards.

Proposals by Austin city staff to construct a large dam and reservoir in the middle portion of the Walnut Creek watershed or to construct a levee around a minority neighborhood in the lower reaches removing access to a neighborhood park are countered by alternative suggestions from a coalition of various interest groups. In 1995, public and private entities cooperated to form the Walnut Creek Greenway Partnership (Austin Metropolitan Trails Council 1997). Goals include recreation, transportation, flood control, habitat preservation, cultural landscape preservation, air and water quality, view protection, and education. Proposed methods for flood control include creation of "wetland" detention ponds, preservation of connected riparian habitats, and restoration of natural floodplains. There are some obstacles inherent in these solutions, the Supreme Court decision in Dolan v Tigard (Florence Dolan, Petitioner vs. City of Tigard 1994) prevents city ordinances from requiring dedication of floodplain land. The City of Austin requires dedication of easements in the 100 year floodplain; however, alteration of private property on the easement most likely constitutes a taking. Options available to the Greenway Partnership include bond funding and funding from the Trust for Public Lands to buy riparian land in the Walnut Creek Basin for flood control purposes. On November 3, 1998, Austinites approved initial allocation of bond money to assist in the purchase of land adjacent to Walnut Creek for constructing an uninterrupted riparian corridor through the east side of the city (Austin American Statesman 1998). Despite creative financing, the expense of acquiring floodplain land may curtail visions of an environmental solution to flood control problems in Walnut Creek Basin.

CHAPTER IV

STUDY AREA CHARACTERISTICS

There are several reasons for the selection of Walnut Creek Basin in Austin as the study area. First, the potential for serious flooding and flood damage exists in this watershed. The May 25, 1981 flood event, with a peak discharge of 14,300 cubic feet per second (cfs) measured at the U. S. Geological Survey (USGS) gage at Walnut Creek and Webberville Road (USGS 1981), is an excellent example of the magnitude of storm events experienced in the Walnut Creek Basin. It should be noted that after the 1981 flood event, the USGS determined that this gage was improperly rated for large flood events (US Army Corps of Engineers 1987), and the 1981 event probably generated discharges in excess of the reported values. Two deaths within the basin boundaries, during the 1981 event, resulting from the presence of the victims on flooded transportation routes (Austin American Statesman 1981a-h), provide further evidence of the serious nature of the flood hazard in this area.

Second, the spatial distribution of development within the watershed from 1960 to the present was also a factor in the selection of this basin. Development primarily occurred in the western portion of the watershed because of the location of the Austin City limit line in the middle of the watershed. During the early years of the study, 1960-1980, the city of Austin actively discouraged growth in the eastern portion of the watershed as part of the Austin Tomorrow Plan (City of Austin 1979). After 1980, the city abandoned the goal of farmland preservation in northeastern Travis County. By the mid 1990s city policy actively encouraged dense development in the northeastern section of the watershed as part of a plan to halt growth in "environmentally sensitive" areas in the western part of Travis County.

Although flooding may affect all areas within the watershed, for modeling purposes, the watershed above the confluence of Little Walnut Creek and the main stem of Walnut Creek (a subbasin of 38 square miles) was selected as the study area. Little Walnut Creek, a major basin tributary in the lower reaches of the watershed is highly urbanized (US Army Corps of Engineers 1987) and because of limited land use change during the study period, any effect on the model would be negligible. Land use downstream of the confluence of Little Walnut Creek and Walnut Creek is primarily industrial and remained relatively constant throughout the study period.

GEOLOGY AND CLIMATE

The headwaters of Walnut Creek begin in northern Travis County and flow in a southeasterly direction to the basin outlet at the Colorado River at river mile 286.7 (Figure 2). The basin has a drainage area of approximately 51 square miles with an average width of 4 miles and a length of approximately 20 miles. Approximately 50% of the watershed is located within the corporate boundaries of the City of Austin, with the remainder of the basin located within Austin's extraterritorial jurisdiction. Basin elevations vary from 950 feet mean sea level (msl) in the upper reaches of the watershed to approximately 400 feet msl at the confluence with the Colorado River, with an average slope on the main stem of 24.5 feet per mile (U.S. Army Corps of Engineers 1987).

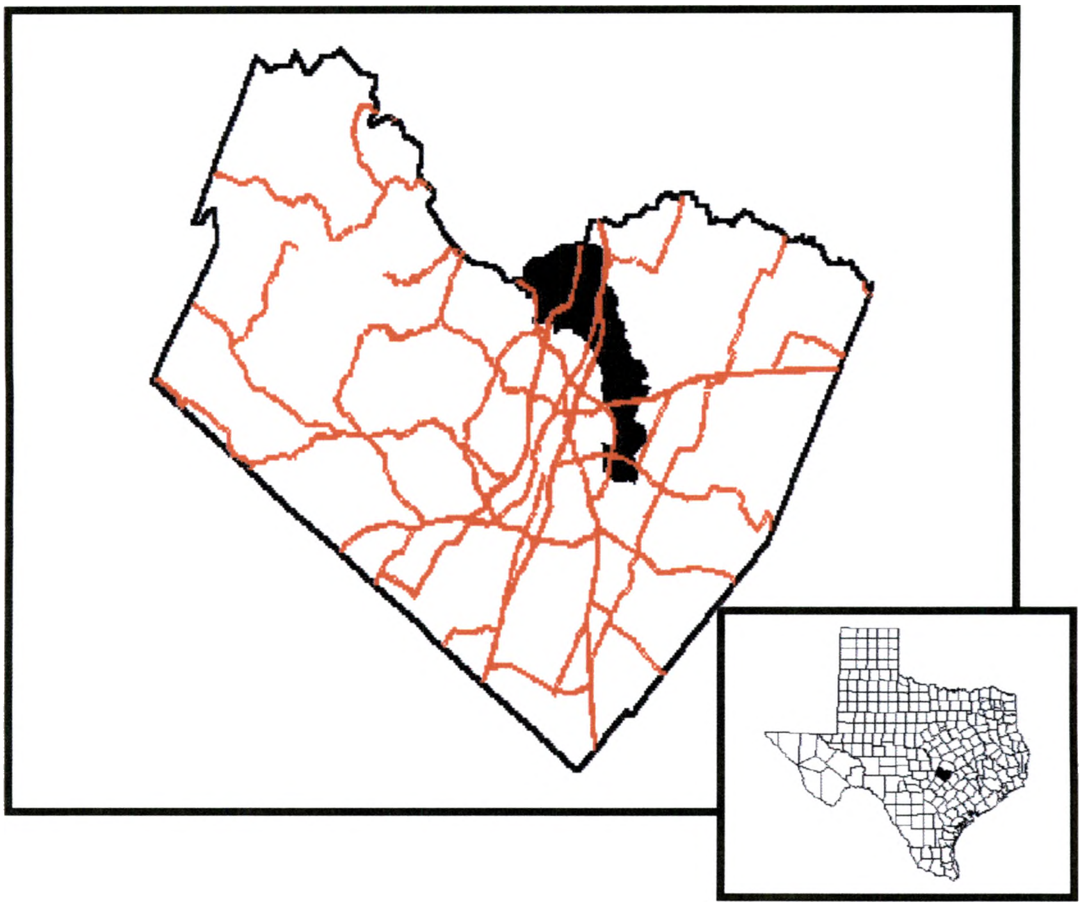


Figure 2: Walnut Creek Basin: Travis County, Texas

The climate in the study area is generally the subtropical margin of the humid subtropical region of the southeastern United States. During the winter months, there are occasional periods of cold caused by the rapid movement of cold continental polar air masses from the northwest (Earl and Kimmel 1995). The annual mean rainfall is 33 inches with a maximum of 64.68 inches and a minimum of 11.42 inches. The maximum 24 hour rainfall of 19.03 inches occurred on September 9, 1921. The study area is located within a hydrologic province experiencing vigorous cold fronts and tropical storms that result in some of the highest rainfall rates in the United States. Peak flood flows in tributary streams in the Austin area are some of the highest flows for those stream types reported nationwide (US Army Corps of Engineers 1987).

Walnut Creek is one of the only perennial creeks in the Austin area. The creek exhibits constant flow, except during periods of severe drought. Springs, seeps and perennial pools occur along the main stem and some of the larger tributaries and provide permanent water sources for fish and wildlife (U.S. Army Corps of Engineers 1972).

The headwaters originate in the Edwards Plateau region, which is relatively flat compared to other areas of the Plateau. Numerous small tributaries drain this area and combine to form the main stem of the creek. The rock types of the northern section of Walnut Creek Basin are predominately limestone. Dolomitic limestone is found in the northwestern corner of the watershed and mixed and hard limestone are found to the east. Soil types in this area are in the Tarrant Association and are shallow, stony, calcareous, clayey soils overlying limestone (Figure 3).

Moving south along the main stem, the creek crosses the Balcones Escarpment and enters the Blackland Prairie region. This portion of the Blackland Prairie consists of

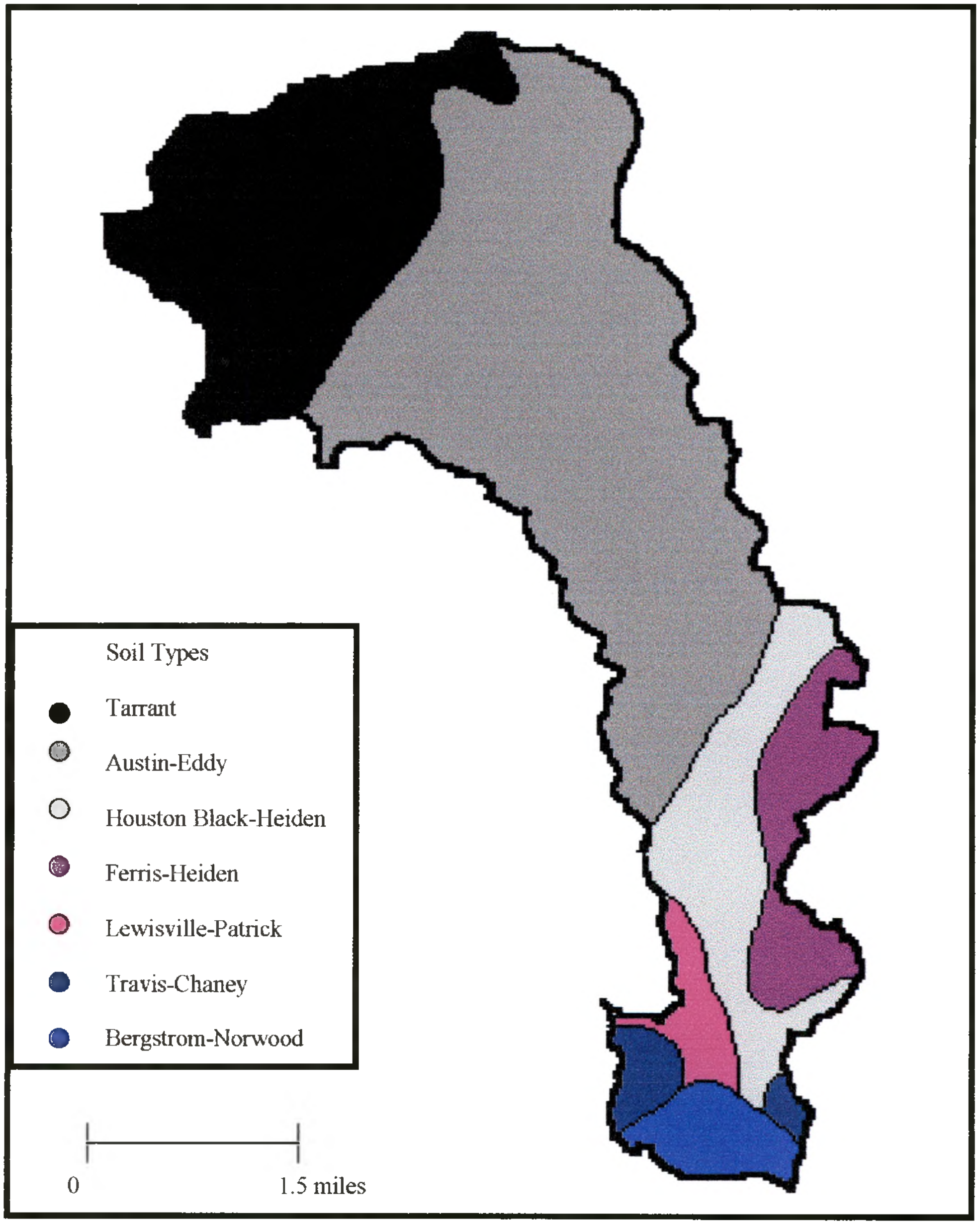


Figure 3. Soil Association Boundaries for Walnut Creek Basin

steeper slopes than are found in other sections of this region and exhibits rolling terrain except along the main stem and some tributaries where limestone bluffs are common. The rock types change to soft limestone. Soils are predominately of the Austin-Eddy Association, and are moderately deep and mostly clay loams (U.S. Army Corps of Engineers 1972).

The lower portion of the creek, immediately above the confluence with the Colorado River consists of deep, alluvial soils. Alluvial materials occur in floodplains throughout the watershed with clayey alluvium occurring along lower Walnut Creek. Sandy alluvium is found in areas where the creek and its tributaries flow through limestone areas. Sand and gravel deposited by the Colorado River and Walnut Creek occurs in terraces in the lower third of the watershed, below the study area (U.S. Army Corps of Engineers 1972).

POPULATION CHARACTERISTICS

The 1990 census tract boundaries for tracts contained within the Walnut Creek Basin are shown in Figure 4. Census tract data for the specific variables used in this study is shown in Table 1. The variability in income, percentage of home ownership and race of householders within the basin boundaries contributed to the selection of Walnut Creek Basin for this study.

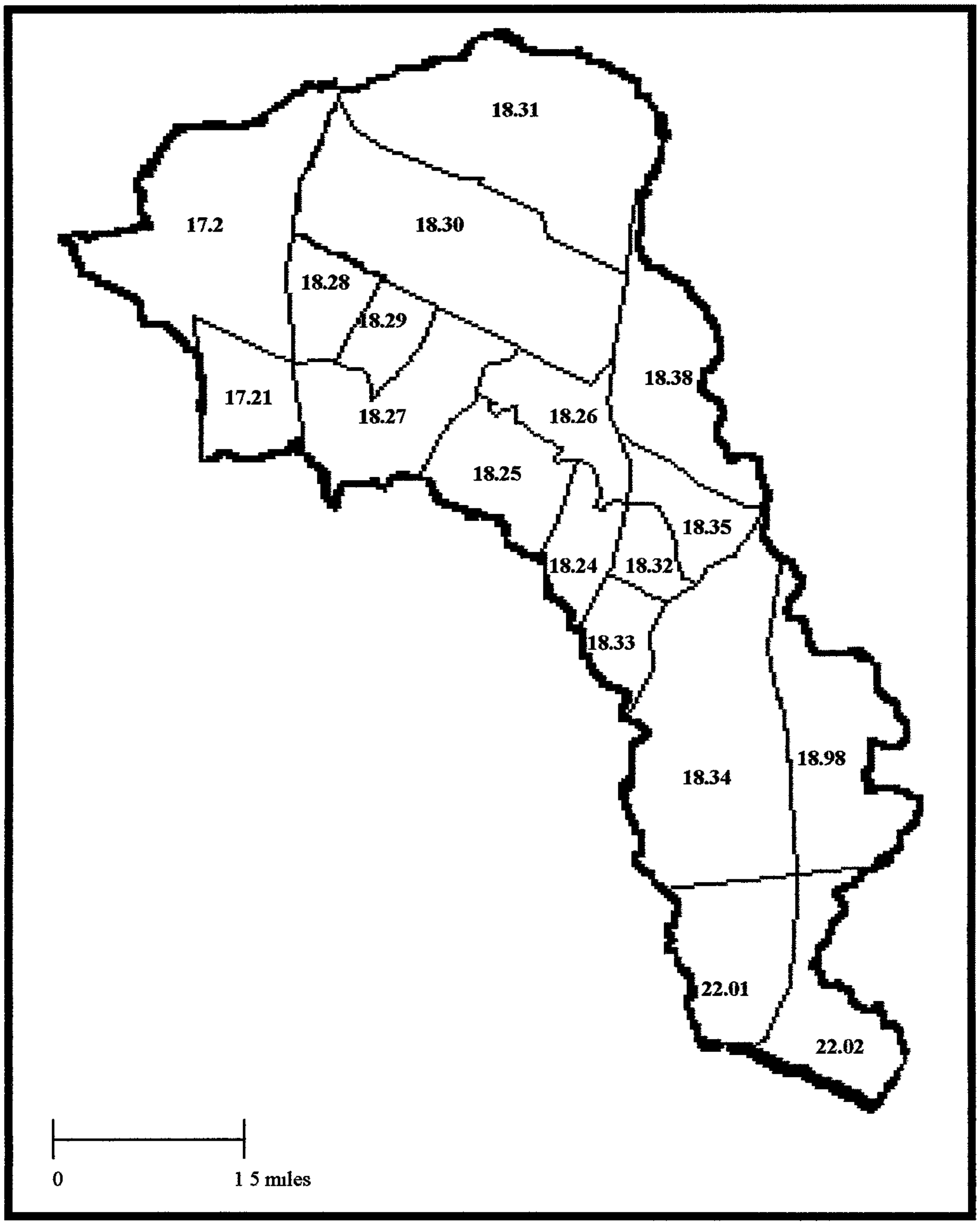


Figure 4. Census Tracts Within the Boundaries of Walnut Creek Basin

Table 1

Census Tract Data, Walnut Creek Basin, 1990

Control Point	Tract	White Homeowner	White Renter	White Householder	Non-white Homeowner	Non-white Renter	Non-white householder	Population Density (persons/sq mile)	Percent homeowners	Median Income
4	22.01	51	10	61	288	97	288	178.4	74.8	33077
4	22.02	55	21	76	338	274	338	1674.6	56.3	27222
4	18.34	143	456	599	27	353	27	1282.3	19.2	24670
4	18.98	33	9	42	11	5	11	177.7	76.5	61867
3	18.32	552	384	936	68	177	68	433.0	53.8	31719
3	18.35	677	206	883	315	100	315	315.2	76.1	38694
3	18.38	153	15	168	83	6	83	213.3	91.7	36136
3	18.23	340	817	1157	183	916	183	3976.0	25	23324
3	18.24	430	101	531	33	24	33	278.0	79.1	37125
2	18.25	668	722	1390	209	329	209	4128.2	47	34144
2	18.26	200	64	264	21	20	21	654.2	73.5	59558
2	18.27	35	238	273	13	88	13	168.1	12.5	27188
1	18.29	251	544	795	44	163	44	3120.0	29.9	33228
1	18.3	1123	388	1511	346	472	346	1679.7	72.4	42012
1	18.31	1	0	1	0	0	0	3.3	100	0
1	17.2	781	613	1394	169	178	169	1778.6	55.1	35932
1	17.21	855	897	1752	103	205	103	2029.1	47.4	37721

Source: U. S. Department of Commerce 1990

CHAPTER V

METHODOLOGY

The time periods for the site specific study were the census years between 1960 and 1990, inclusive. There are two reasons for selection of this time period. First, before 1960, land uses in the Walnut Creek Basin were primarily agricultural. Growth began slowly in the 1960s and rapidly accelerated in portions of the watershed in subsequent years. Second, the period of record for the USGS gaging station (Walnut Creek at Webberville Road, USGS gage 08158600) in this basin starts in the 1960s. Flood-hydrograph partial-record gages at Walnut Creek and FM 1325 (USGS gage 08158100) and Walnut Creek and Dessau Rd. (USGS gage 08158200) were active during the 1970s and 1980s.

Within the context of the Hazards of Place Model, identification of the degree of risk at specific locations is essential. To identify locations at risks from flood hazards in Walnut Creek Basin, the US Army Corps of Engineer's hydrologic simulation model, HEC-HMS (U. S. Army Corps of Engineers 1998) was used to generate storm hydrographs for the 25 year and 100 year storm events for 1960, 1970, 1980 and 1990 basin conditions. The HEC-HMS simulation model requires three data sets, the basin schematic model, rainfall input and control specifications (Hoggan 1989).

The basin schematic model contains parameter information (curve number, initial abstraction and impervious cover for each subwatershed) and basin connectivity (a representation of the drainage relationships of the subwatersheds). The City of Austin provided the data set (modified for this study) used for this simulation. The basin outlet was set at Control Point 4 (the confluence of the creek and Loyola Lane), the drainage point for the study area (see Figure 5, pg 47).

HEC-HMS allows user specification of simulation parameters. The City of Austin's model simulated runoff using the ModClark method. This method tracks rainfall and infiltration losses for each subbasin, lags rainfall excess (runoff) to the basin outlet and routes the rainfall excess through a linear reservoir. Values obtained from a HEC-2 simulation (U. S. Army Corps of Engineers model for determining water surface elevations) using gridded rainfall data produced the original Austin data set. The rainfall data set was unavailable for this study, therefore, in this simulation, subbasins were modeled using the SCS (Soil Conservation Service) curve number method.

The SCS method models runoff as a function of soil infiltration. The average curve number, a function of soil hydrologic type and land use, is generated for each subbasin based on values calculated by the Soil Conservation Service for small urban basins in the United States (U.S. Soil Conservation Service 1975). A 1991 ArcView land use coverage, obtained from the city of Austin, was used as a base data set for determination of curve numbers. This data set was assumed to represent 1990 basin conditions. ArcView land use coverages for earlier years were recreated from topographic maps, aerial photography, and land-use surveys available from the U.S. Geological Survey, Texas Natural Resource Information System, and the City of Austin. Following the method of Magilligan and Stamp (1997), land use coverages were overlain with soil coverages in ArcView GIS to calculate curve numbers for each subbasin for each year.

The percentage of impervious cover for each subbasin is also required for input into the model. Values for percent impervious cover were based on land use categories in accordance with the Drainage Criteria Manual (City of Austin 1974) as shown in Table 2.

The SCS method generates the total excess for a storm and the incremental excess. The HEC-HMS model calculates the difference between rainfall and infiltration loss for each time step as the difference between the excess at the end of the time step and the excess at the end of the previous time step. The simulation model then computes infiltration losses for each subbasin as a function of an initial loss and the curve number of the subbasin. Initial loss was calculated using the following formula with 1000 and 10 held constant in the equation:

$$S = (1000/CN) - 10$$

where S = potential maximum retention after runoff begins
CN = curve number

The initial abstraction (I) or loss, input for each subbasin in the model was then approximated by the equation: $I = 0.2S$

HEC/HMS allows user designation of various rainfall scenarios. The Frequency Based Design Storm option was selected for this study. The Frequency Based Design Storm can generate values for peak flow in excess of observed values because the rainfall event occurs simultaneously and in equal magnitude in all parts of the basin. However, use of this option allowed an examination of the effects of land use on peak discharge independent of the effects of rainfall distribution within the watershed. The Frequency Based Design Storm option represents a single exceedance probability. Model input parameters are the exceedance probability of the storm, the storm area in square miles, the duration of the maximum intensity of the storm, the total storm duration and a table of

Table 2.

Land Use and Percent Impervious Cover

Land Use	Percent Imperviousness
"A" Residence District	25
"AA" Residence District	25
"B" Residence District	50
"BB" Residence District	45
"C" Commercial District	95
"C-2" Commercial District	95
"D" Industrial Distrcit	70
"DL" Light Industrial District	70
"E" Heavy Industrial District	70
"GR" General Retail District	80
"L" Lake Development District	60
"LR" Local Retail District	75
"MH" Residence District	40
"O" Office District	50
"SR" Suburban Residence District	20

storm duration and precipitation depth. Values for maximum storm intensity, exceedance probability and precipitation depth were obtained from TP-40 (National Weather Service 1961). The author recognizes that the actual precipitation data for the region suggests that the precipitation values in TP-40 are probably too low. These values were employed so that the results of this study would be consistent with other studies that utilize TP-40 (Slade 1986).

The final set of data are control specifications, the time-related information required for simulation. This study assumed a twenty-four hour time interval with data points calculated at five-minute intervals. The twenty-four hour time interval generates sufficient values for both the rising and receding limbs of the hydrograph to generate an accurate representation of basin response to the storm event. Calculation of discharge at five minute intervals provides a more detailed representation of hydrograph shape including secondary peaks associated with inputs from subbasins routed into the main channel behind the primary storm surge (see Figures 14-17 and 20-23).

Model output for four Control Points corresponding to the intersection of the creek with transportation nodes was evaluated. Gage data is available for two of the Control Points (Control Points 1 and 3), allowing comparison of model results to actual discharge data. Control Point 1 is located at the intersection of the main stem of the creek, Burnet Road and MoPac (FM 1325). The USGS maintained a partial recording gage at this location during the early study period (1975-1986). This location is also the confluence of the major tributaries in the northern portion of the watershed that meet to form the main stem of the creek. Control Point 2 is located at the intersection of the creek and Lamar Boulevard, a major transportation route. Control Point 3 is located at the intersection of the main stem of the creek and Dessau Road. The USGS maintained a partial recording gage at this location during some years of the study period (1975 to 1986). Control Point 4, representing the basin outlet is located at the intersection of Loyola Lane and the main stem of the creek (Figure 5). The control points are located at the confluence of creek and transportation nodes and are easily identifiable.

Examination of spatial changes in development distribution for the various time periods indicates that development in the study area was not evenly distributed over time (Figure 6a-6d). Land use in the basin in the 1960s was predominately agricultural with minimal development evident along transportation routes. Between 1960 and 1970, development occurred primarily in the lower portions of the watershed with some development in subbasins contributing to Control Points 2 and 4. Between 1970 and 1980 and 1980 and 1990, development increased rapidly and affected subbasins contributing flow to all control points.

1990 Census Tract data aggregated by drainage area above each Control Point is shown in Figures 7-11 and illustrates the social characteristics of householders within the drainage areas. Figure 7 shows the percentage of home ownership within the basin boundaries. Although there are several tracts in the lower basin that have home ownership rates in excess of 57%, these areas are also less densely populated (Figure 8). In general, there is a higher percentage of home owners in the basin above control point 1 as compared to the lower basin. Figures 9 and 10 show the percentage of white and non-white householders within the basin boundaries. The householders in the northern portions of the watershed are predominately white and those in the lower portions of the basin are predominately non-white. Figure 11 depicts the median income of populations

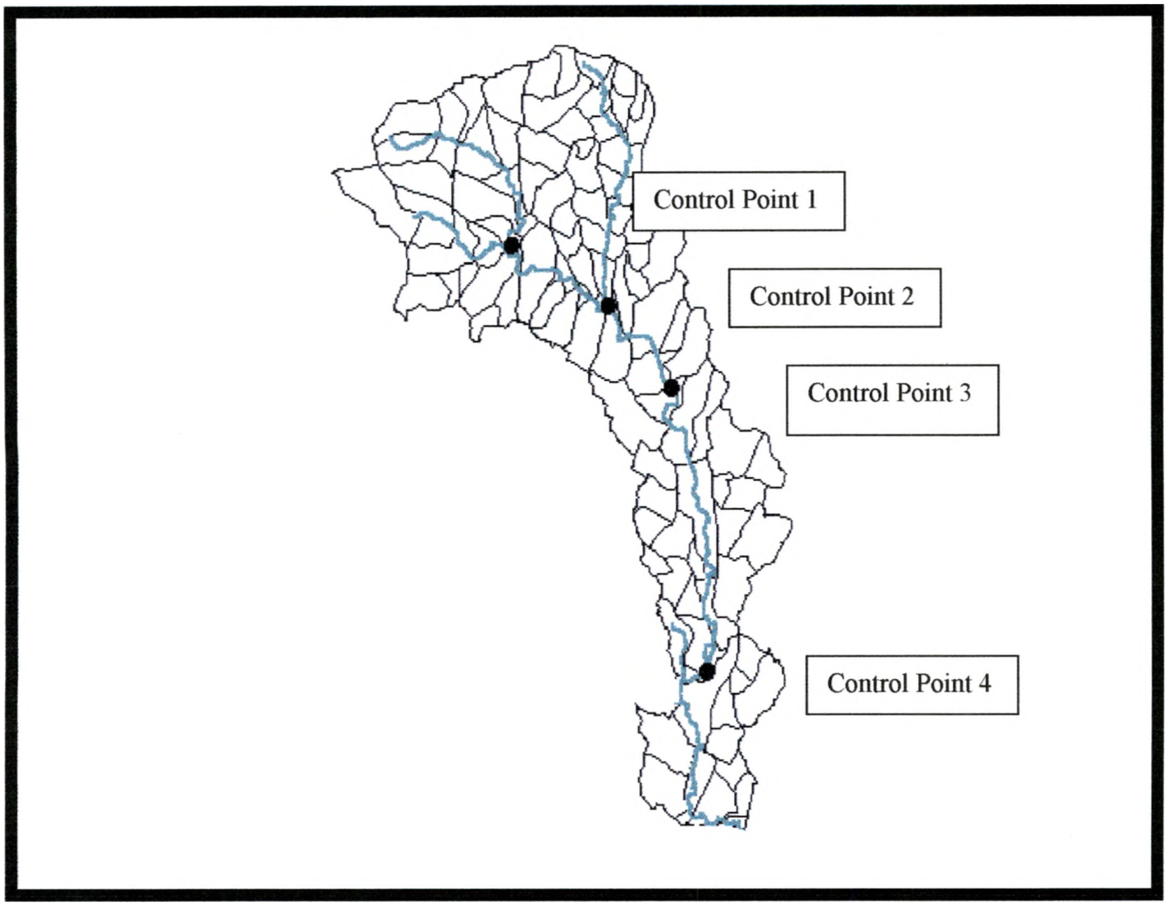


Figure 5. Control Point Locations

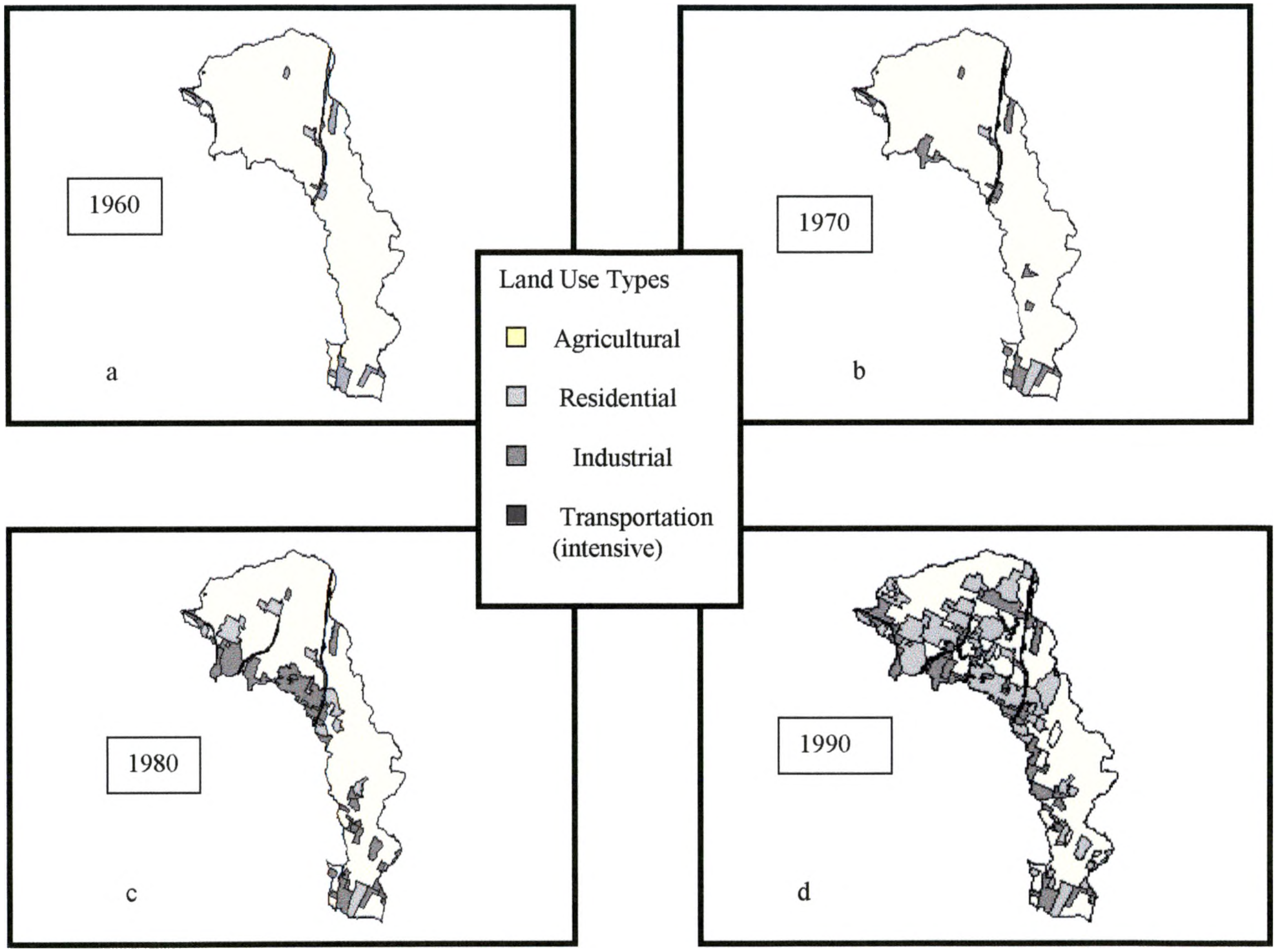


Figure 6. Land Use Change in Walnut Creek Basin, 1960-1990

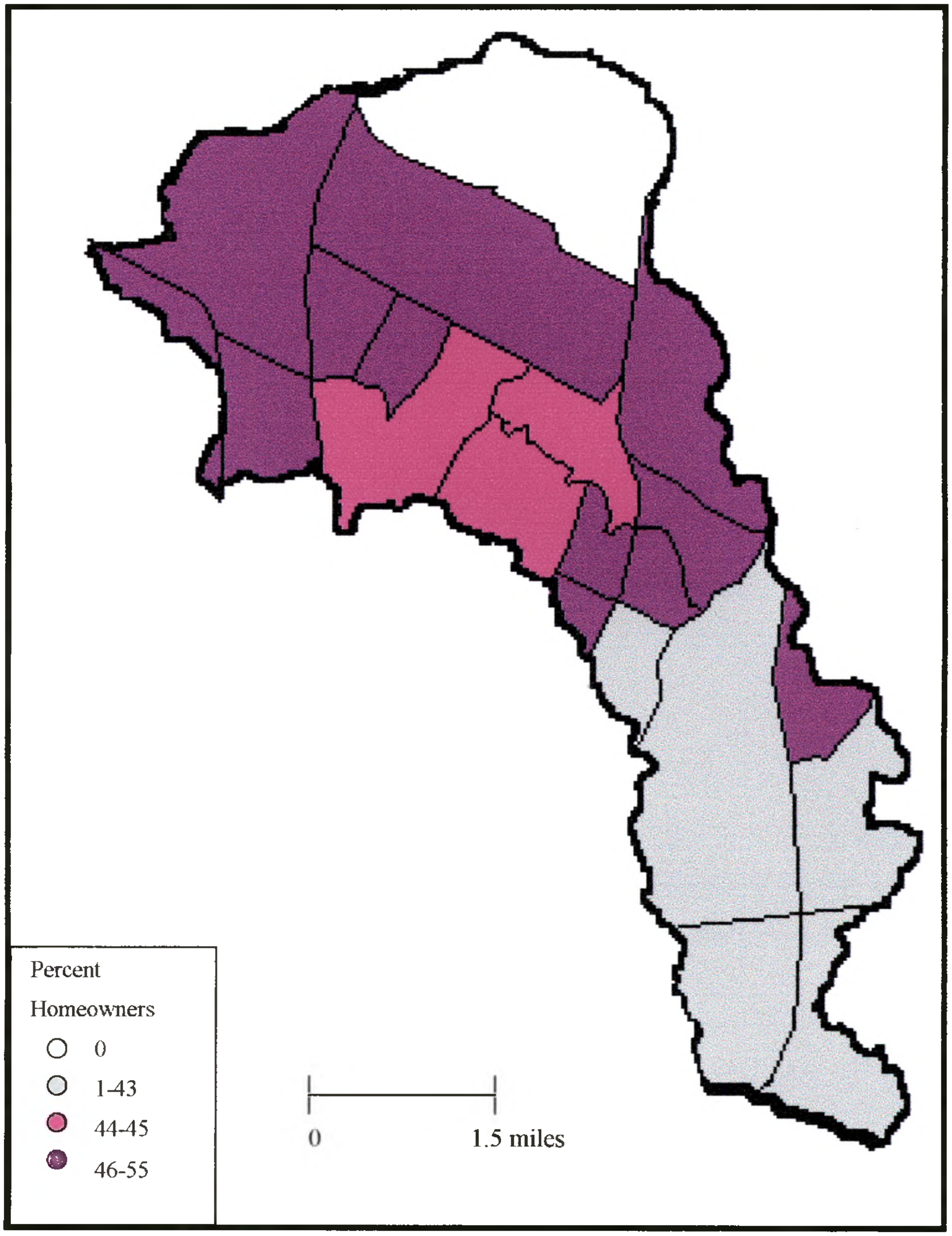


Figure 7. Percentage Homeownership in Walnut Creek Basin

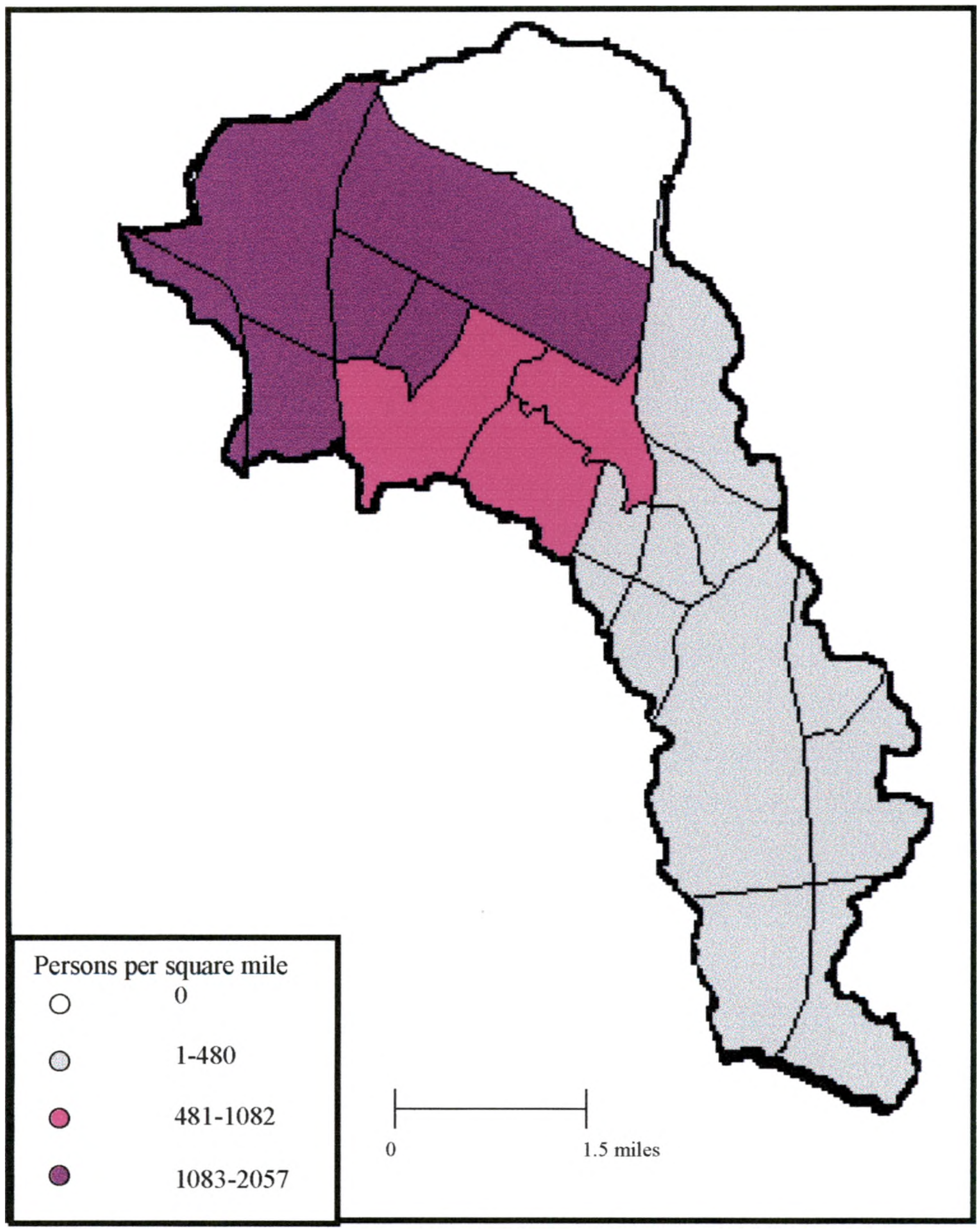


Figure 8. Population Density

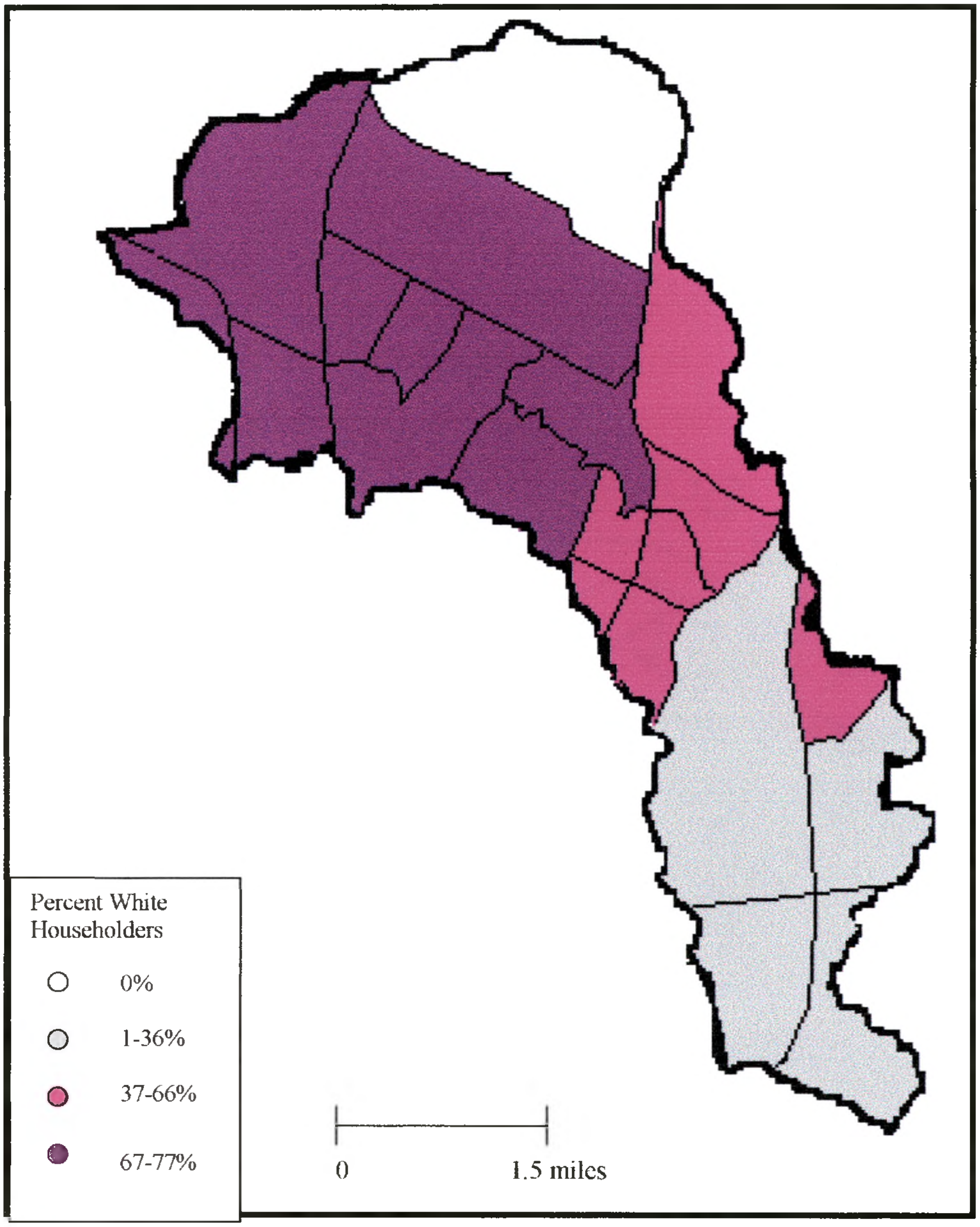


Figure 9. Percentage of White Householders

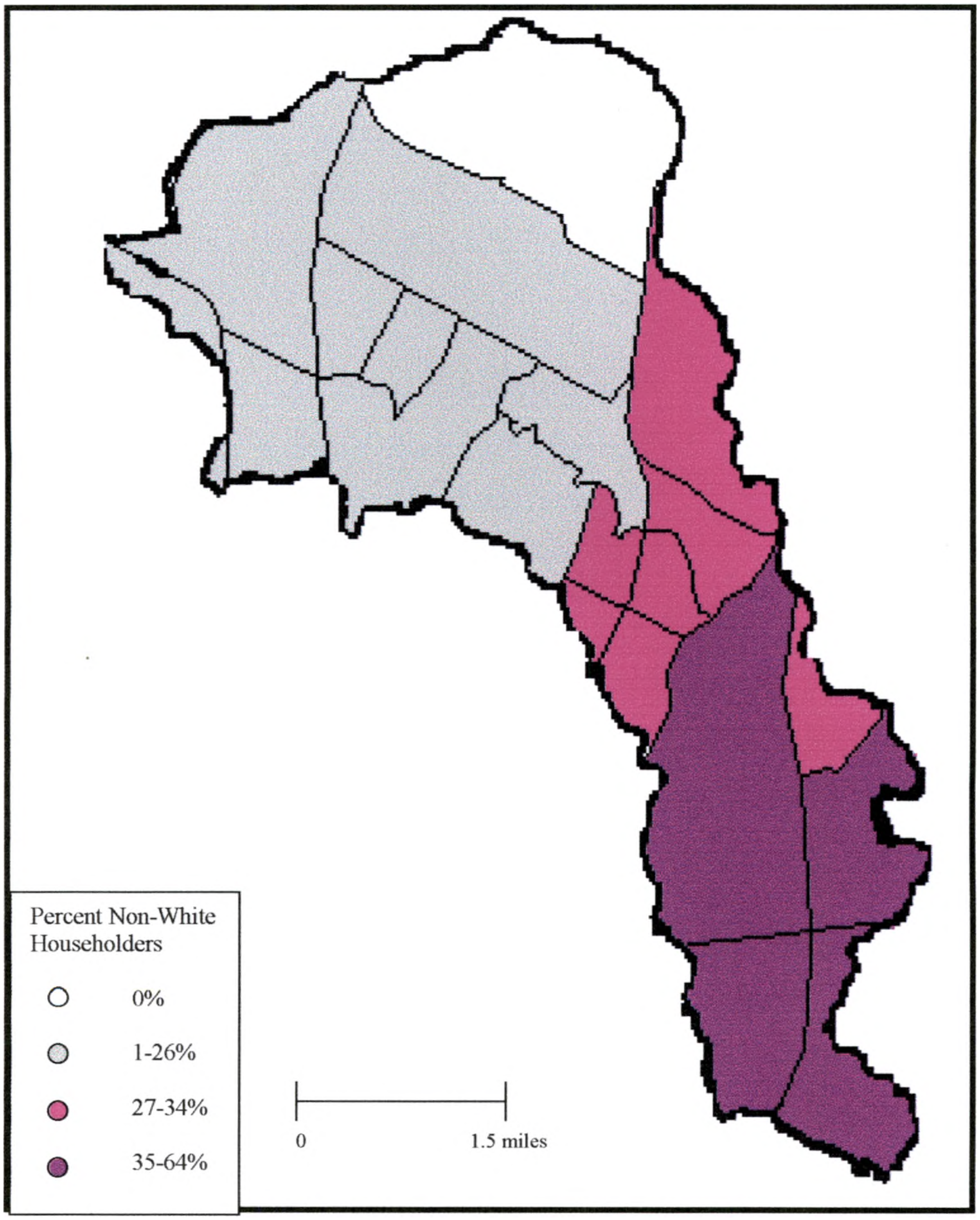


Figure 10. Percentage non-white householders

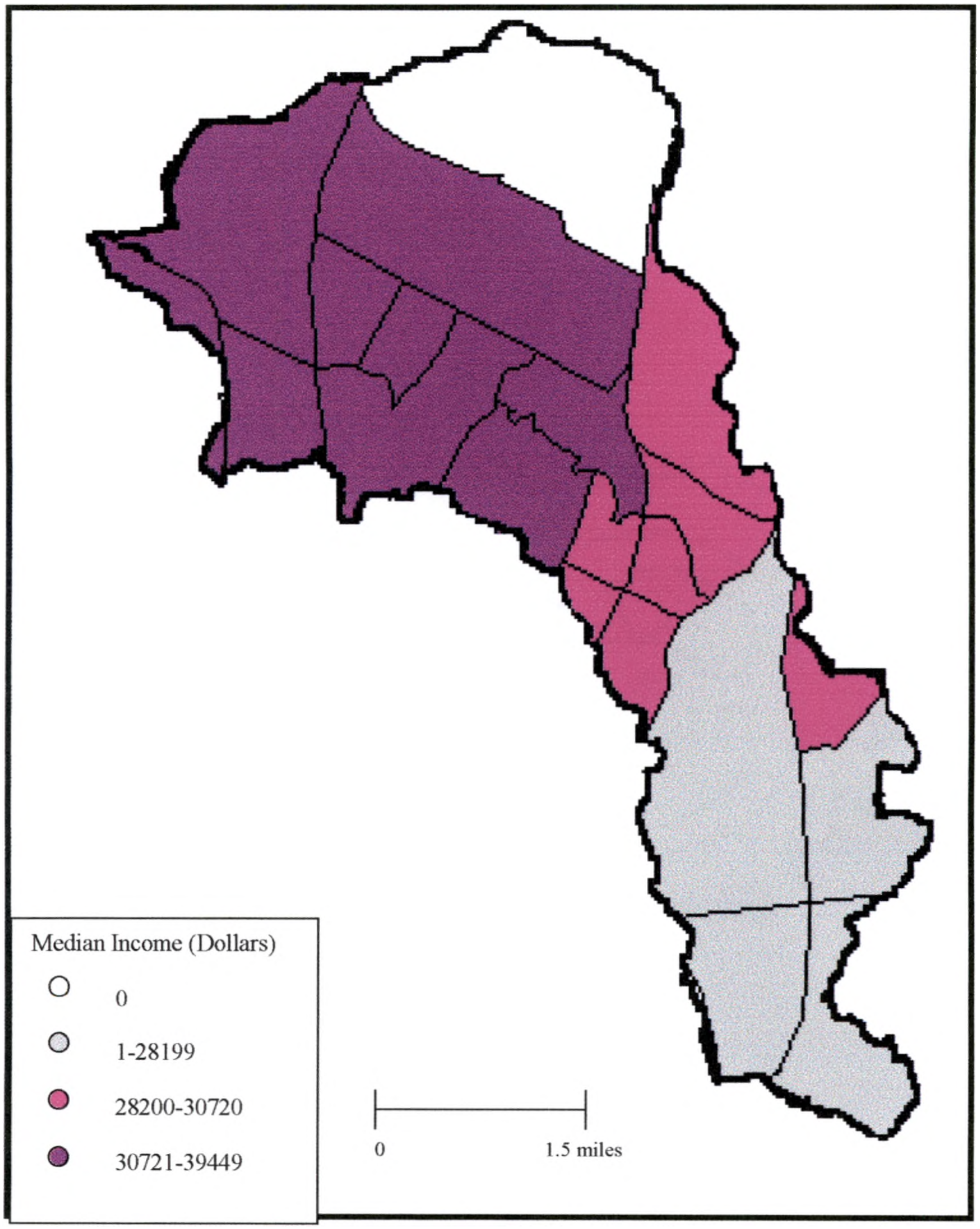


Figure 11. Median Income (Dollars)

within the basin boundaries aggregated by drainage areas above each of the control points. Median income in the basin tends to be greater in the upper portion of the basin than in the lower.

Table 3 summarizes the population characteristics used to evaluate social vulnerability in this study. Not only are the median incomes of populations in the drainage area between control points 3 and 4 less than median incomes of populations above control points 1 and 2, the median income of the population above Control Point 4 is less than the median income of the Austin population as a whole. Home-ownership rates above Control Point 4 are also lower than those in the rest of the basin and Austin as a whole.

TABLE 3

CENSUS TRACT DATA FOR WALNUT CREEK BASIN COMPARED TO AUSTIN AS A WHOLE

Location	Median Income	# owner occupied homes	% owner occupied homes
Control Point 1	$39,442	4908	58
Control Point 2	$36,119	3889	45
Control Point 3	$30,720	1334	51
Control Point 4	$28,199	845	43
Austin	$28,474	303,871	49.6

Source: U. S. Department of Commerce 1990

The following five hypotheses guided the evaluation of the data generated in the site specific study of Walnut Creek Basin. As the flood peak moves downstream, peak discharge increases. The greatest increase in peak discharge over time should occur at

Control Point 4 because of the cumulative contribution of all drainage areas above that control point, leading to the first hypothesis:

1. The locations experiencing the highest percentage increase in discharge during the study period changes over time with the highest overall increase occurring at the most downstream control point (Control Point 4).

The spatial distribution of development in the watershed should result in changes to the characteristics of storm response over time. The relative contribution of upstream areas, the timing of flood peaks and the time of concentration of the flood peak within the channel (the time base of the storm hydrograph) should change as impervious cover increases unevenly along basin tributaries, leading to the second hypothesis:

2. The location of the greatest differences in the shape and the time base of the storm hydrograph change over time with the greatest overall impact at the most downstream control point (Control Point 4).

Cannon (1993, 99) suggests that livelihood vulnerability is a function of age, race and class position. Livelihood vulnerability is an indication of the ability of populations to recover from a hazard. For the purposes of this study, percent owner occupied homes and median family income are surrogates for class position. According to Cutter's Hazards of Place model (Cutter 1996), the intersection of social and physical vulnerability determines place vulnerability. Comparing the determinants of livelihood vulnerability and the locations of the greatest risk from flood hazards led to the formulation of the remaining hypotheses:

3. Populations with the lowest median incomes are found in areas with the greatest exposure to flood hazards.

4. Populations with the lowest percentage of owner occupied homes are found in areas with the greatest exposure to flood hazards.
5. Populations with the lowest percentage of white householders are found in areas with the greatest exposure to flood hazards.

CHAPTER VI

SIMULATION RESULTS

As previously mentioned, use of the frequency based design storm option often results in discharge values in excess of actual gaging station values. Historical gage records from stations located at Walnut Creek and Dessau Road (Control Point 3) and Walnut Creek at FM 1325 (Control Point 1) were compared to values obtained from the simulation. Plots of precipitation vs. discharge, including data points generated by the simulation (Figures 12 and 13), for the two gaging stations indicate that values obtained from the simulation are consistent with actual values. For the gage at Walnut Creek and FM 1325, the R squared value of 0.3292 is fairly low. The low R squared is partly due to the storm event of May 13, 1982 in which 5.06 inches of rain occurred during a 9 hour period resulting in a discharge of 9540 cfs. This relatively high actual discharge value in the upper portion of the watershed indicates that the study results may underestimate flood peaks at this location. The comparison between actual and observed values for the gage at Walnut Creek and Dessau Road generated an R squared value of 0.6793. The results of the comparison indicate that the HEC/HMS simulation model constructed for this study generates values at the two control points that are consistent with observed values. Because of the relatively good fit of the values for headwater and mid-basin control points, it appears that the simulation results approximate basin conditions with a reasonable degree of accuracy.

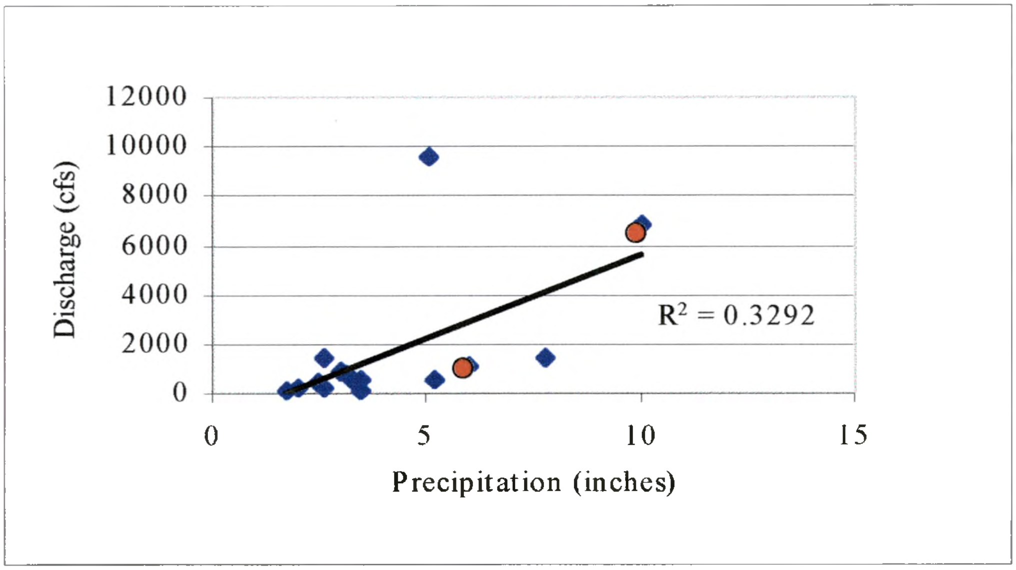
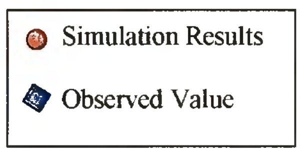


Figure 12. Precipitation vs. Discharge at USGS gage 08158100, Walnut Creek at FM 1325



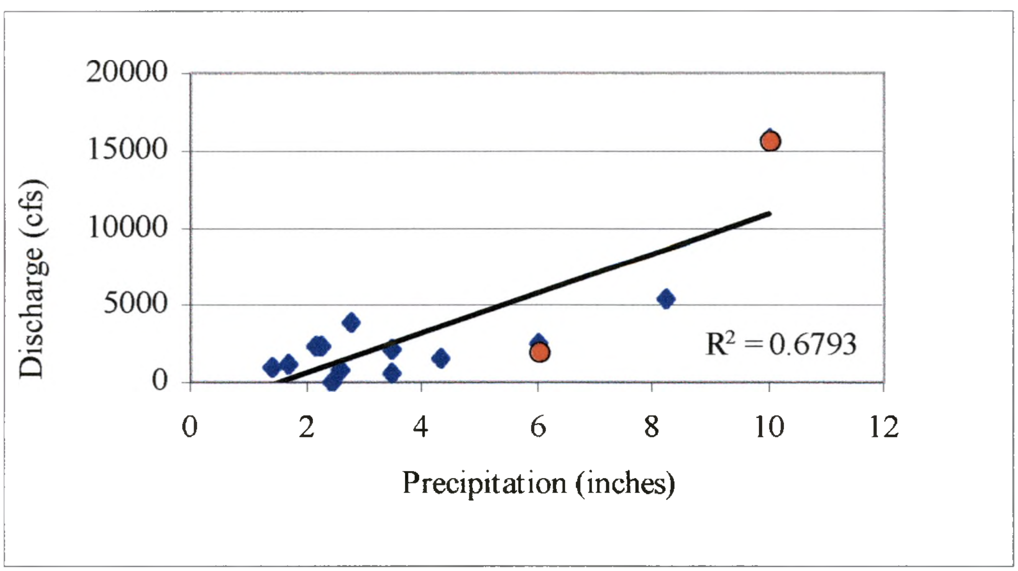


Figure 13. Precipitation vs. Discharge at USGS gage 08158200, Walnut Creek at Dessau Road

The summary of results generated by the simulation for each control point for both flood events is included in Appendix A. Hydrographs for the 25 year storm event (Figures 14-17) indicate that the impact of development over time was most severe between 1980 and 1990. The rising limb of the hydrograph rose more sharply and rapidly in 1990 than in previous years at all control points. This result indicates that the onset of the flood event occurs more quickly than in previous years with a proportionally higher discharge rate. The difference between peak discharges for 1960 and 1970 basin conditions were greatest at Control Point 4 (Table 4). The simulation indicates similar differences between 1970 and 1980 basin conditions with the greatest change observed at Control Point 4. However, after 1980, the simulation results indicate that the greatest increase in peak discharge occurs at Control Point 1. Control Point 1 also exhibits the highest overall increase for the study period.

TABLE 4

PERCENTAGE CHANGE IN PEAK DISCHARGE RATE
FOR THE 25 YEAR STORM EVENT

Control Point	1960-1970	1970-1980	1980-1990	1960-1990
1	26%	22%	185%	340%
2	106%	45%	116%	233%
3	116%	57%	54%	264%
4	126%	69%	88%	296%

Until 1970, the simulation results provide evidence in support of Hypothesis 1 (page 55) After 1980, simulation results do not provide evidence in support of Hypothesis 1. The results indicate that the populations above Control Point 1 have the greatest degree of

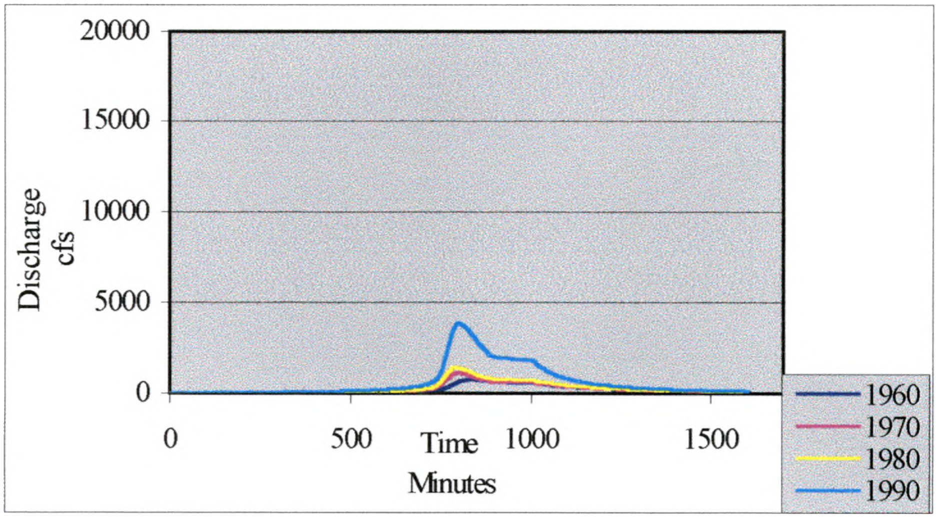


Figure 14. Storm Hydrograph at Control Point 1, 25 Year Storm Event

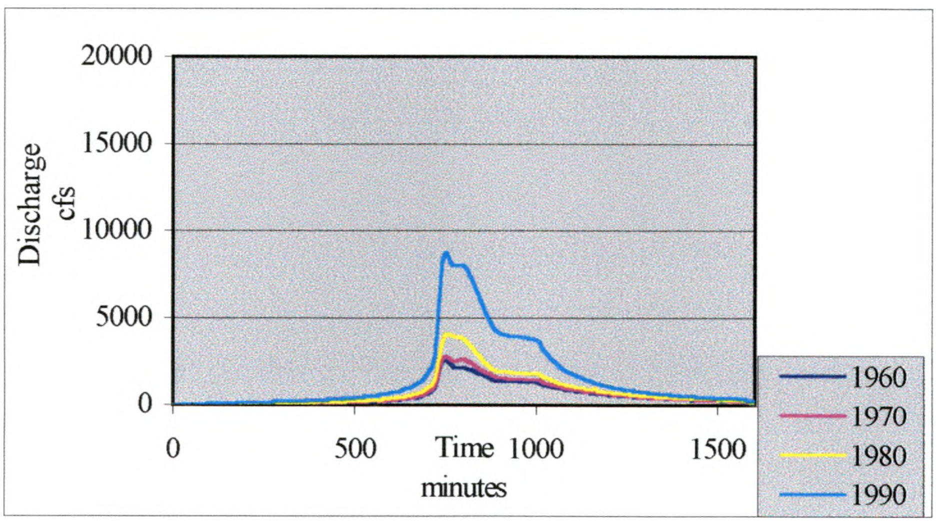


Figure 15. Storm Hydrograph at Control Point 2, 25 Year Storm Event

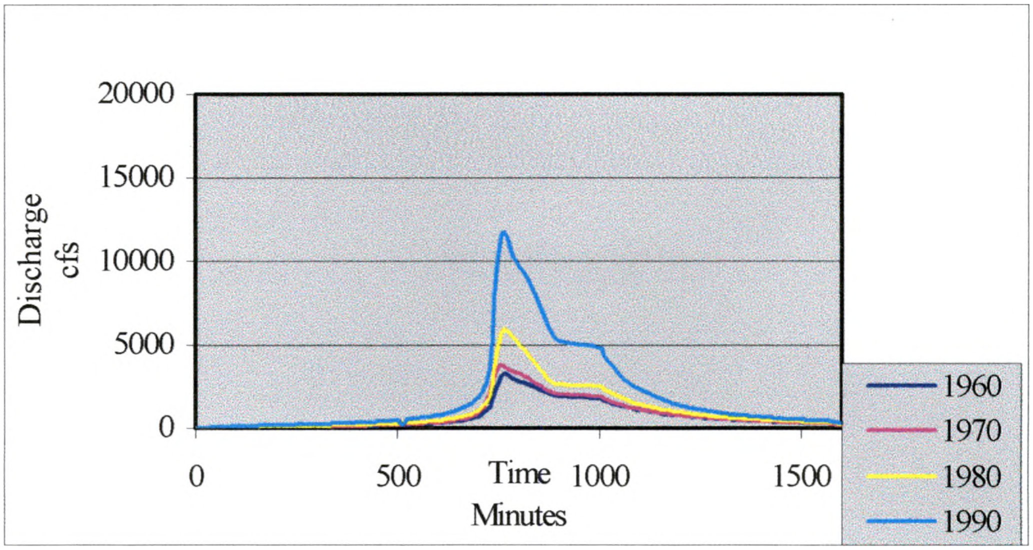


Figure 16. Storm Hydrograph at Control Point 3, 25 Year Storm Event

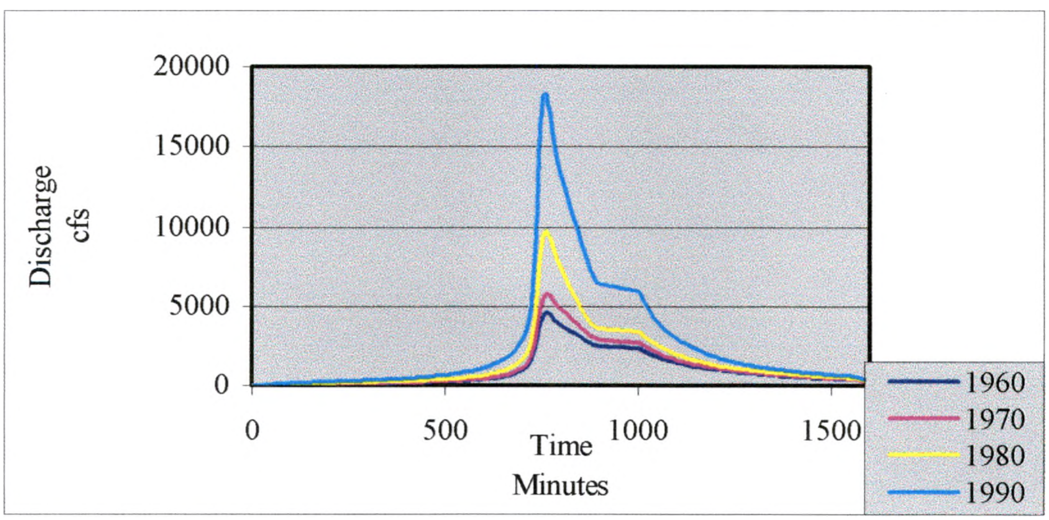


Figure 17. Storm Hydrograph at Control Point 4, 25 Year Storm Event

exposure to increased flood hazards as measured by peak discharge rates. It should be noted that one of the deaths from the 1981 flood event occurred at Control Point 1.

Information about losses resulting from the May 1981 flood event (Austin American Statesman 1981a-h) and later flood events (Austin American Statesman 1998) suggests that populations inhabiting the drainage area between Control Points 3 and 4 experience significant exposure to flood hazards because of significantly higher discharge rates at this location and more rapid onset of flood events. Figures 18 and 19 compare simulation results for the 25 year storm event for the years 1980 and 1990 at all control points. As the flood peak moves downstream, the hydrograph rises more rapidly and the time base of the hydrograph increases. Additionally, the flood peak does not recede as rapidly at Control Point 4 as it does at Control Point 1. Comparison of the storm hydrographs for each of the control points indicates that the greatest exposure to flood events occurs at Control Point 4. This result provides evidence in support of Hypothesis 2, i.e Control Point 4 experiences the greatest exposure to flood hazards if the indicator is characteristics of the storm hydrograph.

Figures 20-23 (storm hydrographs for the 100 year storm event) indicate some change from non-developed to developed basin conditions. However, peak discharge rates for the 100 year storm event do not exhibit the higher proportional increase between 1960 and 1990 conditions as indicated in Table 4 for the 25 year event. The impact of development on flood peaks for the 100 year storm event was consistent across all control points (see Table 5). The data supports conclusions of a previous study (Hollis 1975) that urbanization has the greatest impact on floods of smaller recurrence intervals. Results of the simulation for the 100 year rainfall event indicate that although onset of the flood

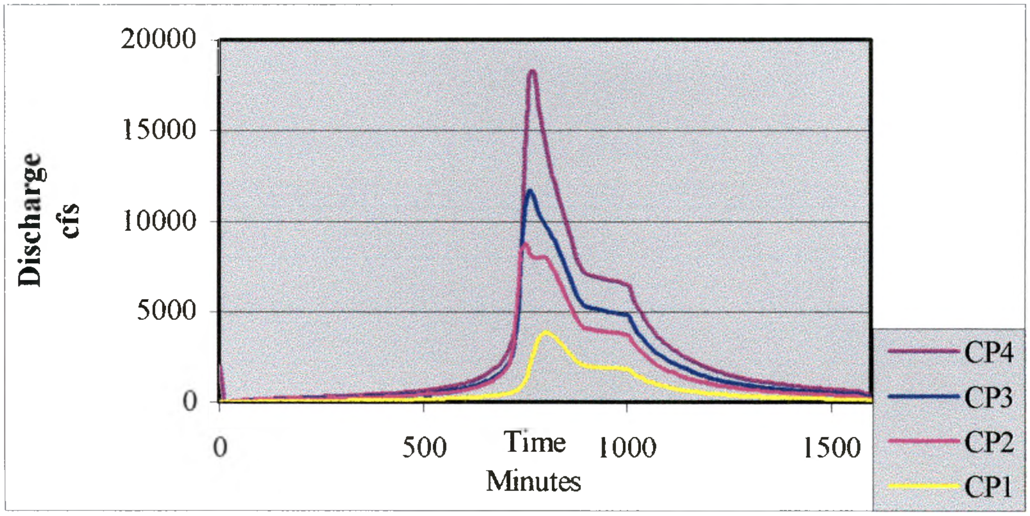


Figure 18. Comparison of Hydrographs for the 25 Year Storm Event in 1990 for all Control Points

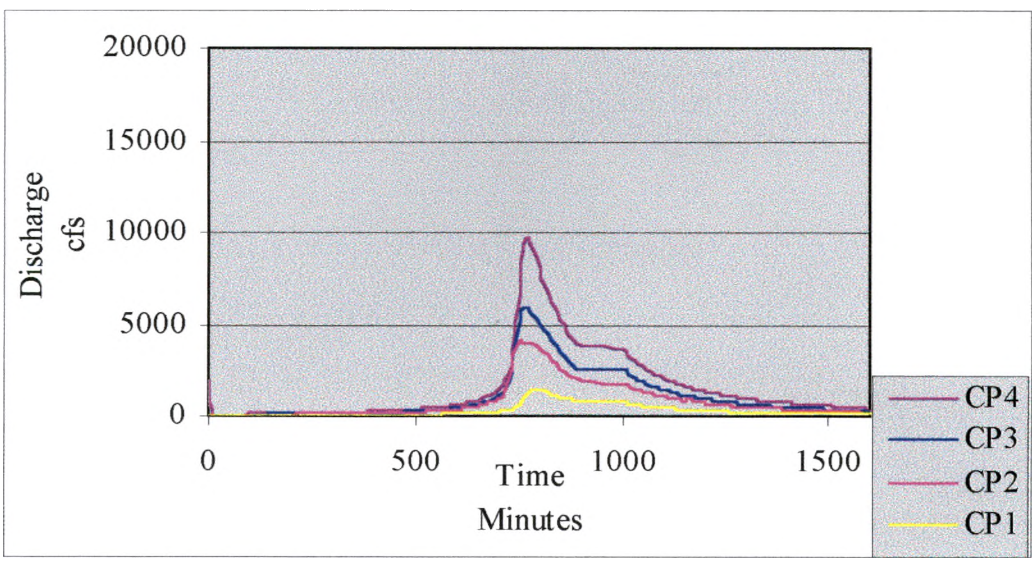


Figure 19. Comparison of Hydrographs for the 25 Year Storm Event in 1980 for all Control Points

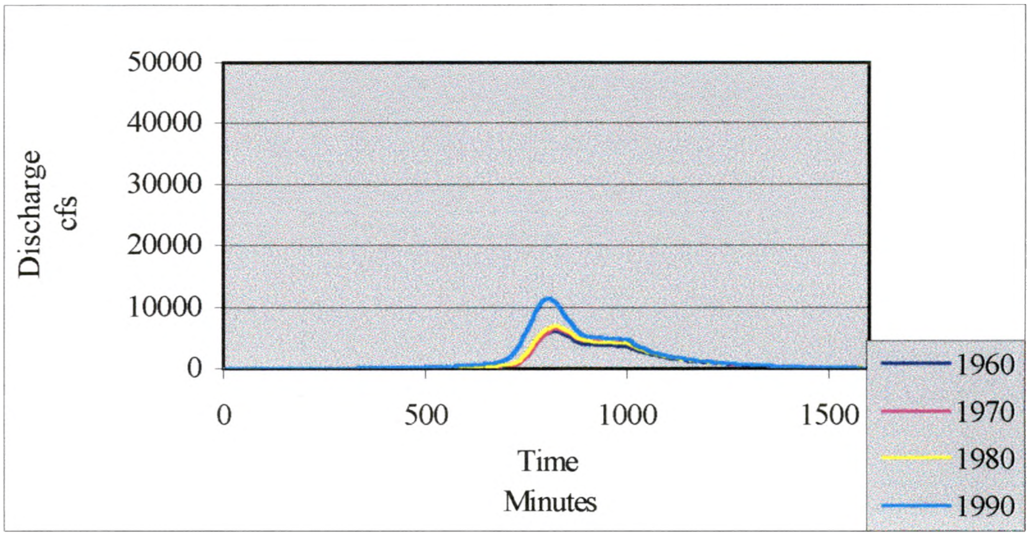


Figure 19. Storm Hydrograph at Control Point 1 for the 100 Year Storm Event

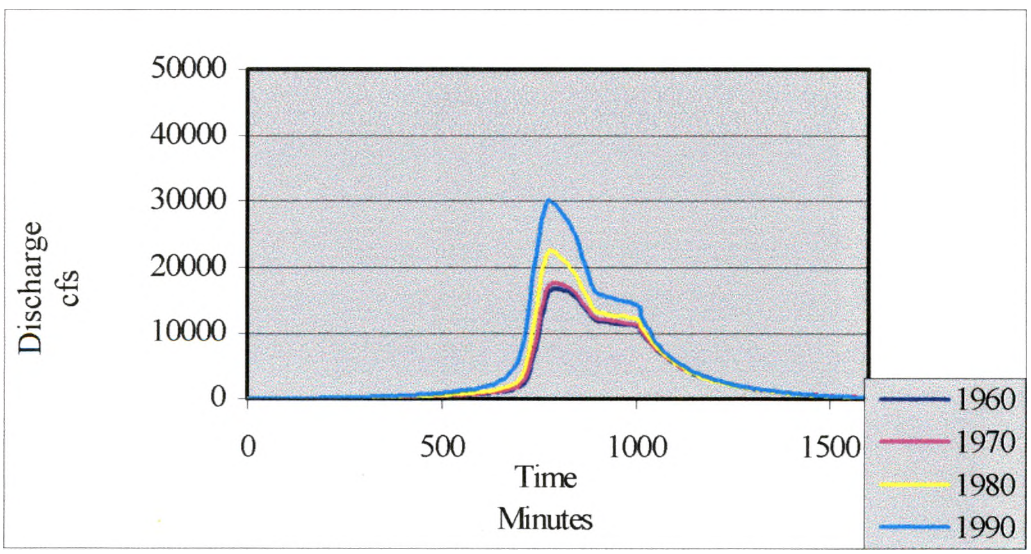


Figure 20. Storm Hydrograph at Control Point 2 for the 100 Year Storm Event

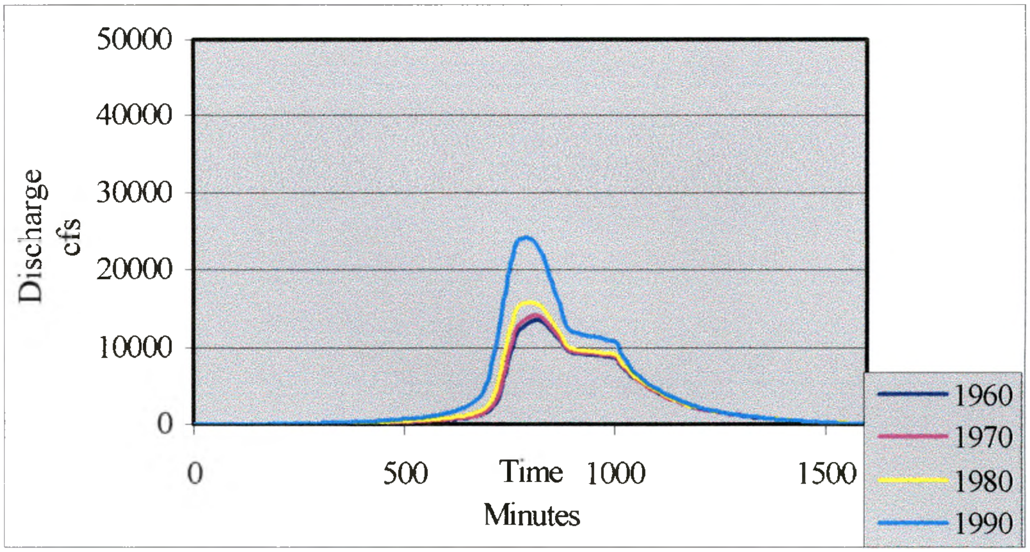


Figure 22. Storm Hydrograph at Control Point 3, 100 Year Storm Event

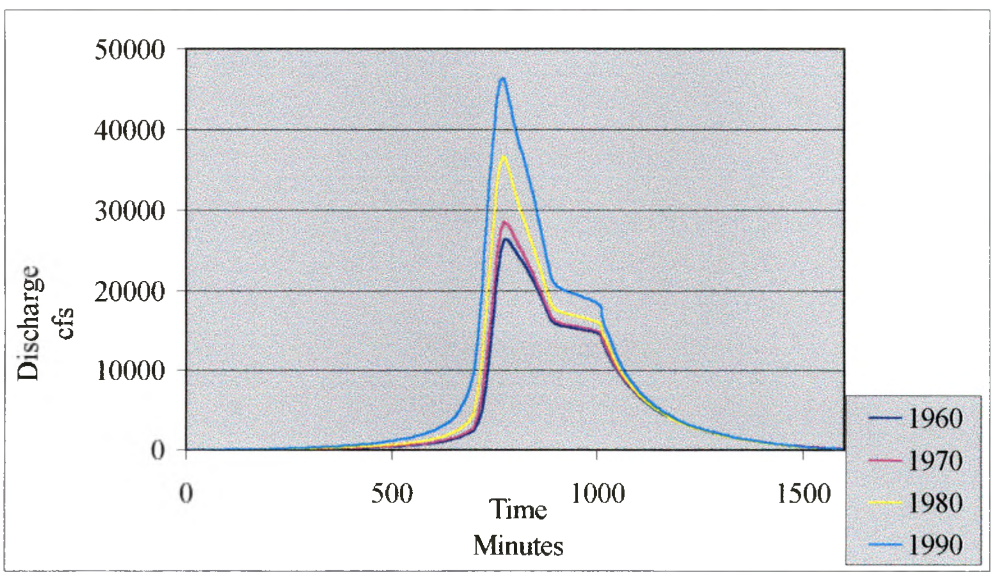


Figure 23. Storm Hydrograph at Control Point 4 for the 100 Year Storm Event

event occurs more rapidly in all subbasins, the storm hydrographs did not show much variation among the control points. Peak onset occurred 15 to 30 minutes earlier in 1990 than in 1960 at all control points. Whether or not a change of this magnitude indicates an increased risk to populations in these areas is unknown. The percentage increase in peak discharge at each of the control points was similar indicating no significant differential impact among the subwatersheds evaluated in this study as a result of increased rainfall amounts associated with the 100 year storm event.

TABLE 5

PERCENTAGE CHANGE IN PEAK DISCHARGE RATE FOR THE 100 YEAR STORM EVENT

Control Point	1960-1990
1	86%
2	79%
3	78%
4	76%

The census tract data clearly shows differences between the populations above Control Point 1 and the populations above Control Point 4. Median incomes decrease, home ownership rates decrease and the percentage of white householders decreases from the headwaters of the creek to the lower reaches. Because the study results do not conclusively identify a single location where physical vulnerability exists, hypotheses 3, 4 and 5 cannot be evaluated to determine if any basin populations are differentially affected.

CHAPTER VII

CONCLUSION

The physical and social factors which create place vulnerability, and the underlying process which causes it, are extremely complex issues. The difficulty of determining vulnerability is increased because there is no consensus about what vulnerability "really" means. Definitions of vulnerability depend on the focus of the individual researcher and the definition that is chosen often influences the outcome of the research.

This research used the Hazards of Place Model to examine the vulnerability of populations to flood hazards. An underlying assumption of the Hazards of Place Model is that there is an identifiable place where hazard potential exists. The methodology used in the site specific study did not clearly identify one location with a high risk potential. This suggests that modification of the methodology of the site specific study may be necessary in order to answer the underlying question of whether or not the Hazards of Place Model is a valid method for evaluating flood hazards.

The simulation results indicate that exposure to flood hazards exists in both the headwaters of the basin and in the lower reaches depending on which indicator is used to identify risk. If the indicator of risk is an increase in peak discharge over time, the population above Control Point 1 has the greatest exposure to flood hazards. This contradicts the assumption of Hypothesis 1 that increases in peak discharge would be greater at Control Point 4. Reasons for this result are probably related to both the geography at this location and to the dramatic increase in development above this control point between 1980 and 1990. The stream network is more dense in the area above Control Point 1 than in the lower reaches. The soils are thinner and infiltration rates are lower so more rainfall appears as runoff. Additionally, increased development in the 1980s and the associated increase in impervious cover during the study period also contributed to higher runoff volumes.

If change in the characteristics of the storm hydrograph is used as an indicator of increased exposure to flood hazards, the risk is greatest for the populations above Control Point 4. This result supports the assumptions of Hypothesis 2. There are several possible reasons for the conflict in identification of the location with the greatest degree of exposure to flood hazards in the basin. First, although the Frequency Based Design Storm does allow an evaluation of the effects of land use change on basin hydrology, the underlying assumptions of this option (uniform rainfall occurring simultaneously at all points within the watershed) may conceal other effects of urbanization on basin hydrology. Use of a non-uniform set of rainfall parameters in the simulation, may allow investigation of changes in lag times caused by urbanization. Second, the choice of scale may have impeded identification of hazardous locations. The basin model contains 92 hydrologic units which were consolidated into only four drainage areas for purposes of evaluation. The HEC/HMS simulation generates data for all hydrologic units. A more in-depth examination of peak discharge values for all subbasins may provide a clearer indication of the locations which experience the greatest risk from flood events in the basin.

Even if the simulation model is modified as suggested in the preceding paragraph and generates data that identifies a location with a high hazard potential, additional information may be necessary to evaluate the degree of risk at that location. Higher peak discharges and an increase in the time base of the flood hydrograph may not be sufficient indicators of the degree of risk. These factors do not provide evidence of whether or not flood volumes exceed channel capacity. Additional data such as channel cross sections and channel capacity at identified hazard locations may provide more conclusive evidence about the magnitude of risk.

The census tract data clearly indicate differences among basin populations. The effect of these differences cannot be evaluated using the methodology of this study. Tract level data does give a clear indication that social disparities exist among basin populations, however the scale of the data does not allow identification of those populations in close proximity to flood hazard areas. If future studies can clearly identify the location where the risk from flood hazards is greatest, use of block level data may provide a better indication of the characteristics of vulnerable populations.

Although the attempt to identify and quantify physical and social vulnerability in the Walnut Creek Basin generated inconclusive results, the study results do indicate that urbanization in this basin has significantly affected basin hydrology and basin populations in several locations may suffer increasing risk from future flood events. Mitigation of risks associated with the flood hazard has not significantly reduced these risks and losses continue to occur. One reason mitigation efforts may not reduce risks is the tendency of planners to focus on regulatory solutions alone.

Flooding is inherently an environmental issue yet policy solutions tend to address people and property. Regulatory measures traditionally focus on environmental impacts on human beings rather than human impacts on the environment. Most governmental action to mitigate flood damage is either to move floods away from people or people away from floods. Structural controls move floods away from people, through a variety of methods, i.e. dams, levees, channelization and detention ponds. These options are often cost prohibitive and can cause environmental damage. Restricting future development or buyouts of flood prone land are techniques for moving people away from floods. This option may cause an undue financial burden on low income populations.

The restoration of the natural functions of floodplains and recognition of the impacts of grading and fill on small tributaries outside the regulatory floodway are usually not part of the dialog about flood control and floodplain management. Movement at the federal level towards incorporation of environmental issues into floodplain management did not result in legislation, but there is some evidence that this trend towards consideration of environmental issues is present at the local level. The environmental community in Austin did have an impact on flood control policies. Unfortunately, the opposing agendas of the development community and the environmentalists during the 1970s and 1980s resulted in a stalemate. The opposition of the environmental community to more stringent ordinances protected Austin's creeks from further damage, but the next step, restoration of natural waterways and their flood plains did not occurr. The Walnut Creek Greenway Partnership is attempting to shift the focus of mitigation efforts toward environmental solutions, however, as yet, there are no discernable results.

A brief examination of the extent to which the population of Walnut Creek Basin participates in the dialog about flood control policy at the local level reveals little evidence that these populations are included in the discussions about flood hazard mitigation. With the exception of reports published by the USGS and the U.S. Army Corps of Engineers, reports of the 1981 flood event rarely mentioned the impact of this event in the Walnut Creek Basin. There was no evidence that the basin population was represented on the City of Austin's Floodplain Task Force. Further investigation into this issue is warranted. A determination of the extent to which exclusion of the basin population from the decision making process affects efforts to mitigate flood hazards in the Walnut Creek Basin may provide insight into the underlying causes of increased vulnerability.

APPENDIX

HMS * Summary of Results

Project : thesis   Run Name : Run 4

Start of Simulation : 01Jan00 2400   Basin Model : 1960wal
End of Simulation : 03Jan00 0055   Precip Model : Precip 25
Execution Time : 29Sep01 1014   Control Specs : wln100ex.ihl.basin

Hydrologic Element	Discharge Peak (cfs)	Time of Peak	Total Volume (ac ft)	Drainage Area (sq mi)
W-A1	30.201	02 Jan 00 1220	6.6537	0.270
W-A2	30.097	02 Jan 00 1220	6.3582	0.258
28	60.298	02 Jan 00 1220	13.012	0.528
Reservoir-1	48.104	02 Jan 00 1230	13.004	0.528
W-B	104.85	02 Jan 00 1220	28.597	0.642
19	146.71	02 Jan 00 1220	41.601	1.170
27	125.61	02 Jan 00 1230	41.579	1.170
W-C	62.272	02 Jan 00 1225	15.423	0.626
12	185.34	02 Jan 00 1230	57.002	1.796
Reservoir-2	179.88	02 Jan 00 1235	56.986	1.796
T17-A	39.575	02 Jan 00 1220	9.1912	0.373
15	212.85	02 Jan 00 1230	66.177	2.169
26	149.33	02 Jan 00 1255	65.716	2.169
W-D	69.931	02 Jan 00 1225	17.320	0.703
Junction-1	187.63	02 Jan 00 1240	83.035	2.872
Reservoir-3	169.62	02 Jan 00 1305	82.600	2.872
T9-A	61.723	02 Jan 00 1225	15.496	0.629
73	46.393	02 Jan 00 1240	15.451	0.629
T9-B	47.107	02 Jan 00 1220	10.941	0.444
14	83.970	02 Jan 00 1230	26.391	1.073
25	225.39	02 Jan 00 1250	108.99	3.945
Reservoir-5	220.52	02 Jan 00 1300	108.72	3.945
W-E	72.930	02 Jan 00 1220	12.474	0.326
Junction-2	242.24	02 Jan 00 1255	121.19	4.271
Reservoir-6	239.95	02 Jan 00 1300	120.93	4.271
T8-A	33.518	02 Jan 00 1220	7.1714	0.291
T8-B	50.533	02 Jan 00 1220	10.597	0.430
3	84.051	02 Jan 00 1220	17.769	0.721
T8-C2	24.329	02 Jan 00 1215	4.7281	0.099
T8-C3	65.829	02 Jan 00 1220	14.184	0.297

Hydrologic Element	Discharge Peak (cfs)	Time of Peak	Total Volume (ac ft)	Drainage Area (sq mi)
72	88.835	02 Jan 00 1215	18.912	0.396
T8-C1	43.886	02 Jan 00 1220	9.4560	0.198
Junction-3	131.88	02 Jan 00 1220	28.368	0.594
Reservoir-7	84.294	02 Jan 00 1235	28.309	0.594
8	154.89	02 Jan 00 1220	46.078	1.315
T8-D1	79.825	02 Jan 00 1220	17.502	0.273
T8-D2	29.425	02 Jan 00 1215	5.8340	0.091
Junction-4	107.44	02 Jan 00 1215	23.336	0.364
17	261.64	02 Jan 00 1220	69.413	1.679
71	180.74	02 Jan 00 1240	69.179	1.679
T8-E	213.02	02 Jan 00 1220	41.538	0.551
87	355.47	02 Jan 00 1225	110.72	2.230
70	302.04	02 Jan 00 1245	110.47	2.230
T8-F	108.35	02 Jan 00 1225	24.938	0.347
21	391.11	02 Jan 00 1235	135.41	2.577
Reservoir-8	362.28	02 Jan 00 1255	135.11	2.577
T8-G	48.229	02 Jan 00 1220	11.409	0.463
Junction-5	381.52	02 Jan 00 1250	146.52	3.040
24	619.66	02 Jan 00 1255	267.45	7.311
Reservoir-10	592.17	02 Jan 00 1315	266.40	7.311
W-F	11.332	02 Jan 00 1220	2.5382	0.103
34	594.44	02 Jan 00 1315	268.94	7.414
T7-A	366.08	02 Jan 00 1230	71.909	0.682
69	224.64	02 Jan 00 1255	71.233	0.682
T7-B	64.704	02 Jan 00 1230	18.341	0.745
Junction-6	269.71	02 Jan 00 1250	89.574	1.427
Junction-7	840.74	02 Jan 00 1305	358.51	8.841
23	779.15	02 Jan 00 1330	356.38	8.841
W-G	25.893	02 Jan 00 1225	6.2583	0.254
35	783.94	02 Jan 00 1330	362.64	9.095
T6-A	96.229	02 Jan 00 1225	24.879	1.010
65	51.199	02 Jan 00 1255	24.495	1.010
T6-B	398.33	02 Jan 00 1235	82.448	0.724
Junction-8	442.97	02 Jan 00 1235	106.94	1.734
64	375.61	02 Jan 00 1250	106.91	1.734
T6-C	65.129	02 Jan 00 1235	19.049	0.774
33	429.55	02 Jan 00 1245	125.96	2.508
T6T1-A	325.18	02 Jan 00 1225	61.331	0.561

Hydrologic Element	Discharge Peak (cfs)	Time of Peak	Total Volume (ac ft)	Drainage Area (sq mi)
67	318.12	02 Jan 00 1230	61.326	0.561
T6T1-B	19.482	02 Jan 00 1215	3.7954	0.154
45	329.82	02 Jan 00 1230	65.121	0.715
66	261.13	02 Jan 00 1245	65.008	0.715
T6T1-C	13.021	02 Jan 00 1220	3.0801	0.125
43	268.22	02 Jan 00 1245	68.088	0.840
Junction-9	697.78	02 Jan 00 1245	194.04	3.348
63	657.08	02 Jan 00 1300	193.64	3.348
T6-D	192.87	02 Jan 00 1230	37.946	0.340
36	783.91	02 Jan 00 1255	231.58	3.688
Junction-10	1485.1	02 Jan 00 1310	594.22	12.783
22	1441.8	02 Jan 00 1325	592.04	12.783
W-H	66.886	02 Jan 00 1225	17.047	0.692
39	1457.1	02 Jan 00 1325	609.08	13.475
T5-A	23.638	02 Jan 00 1215	4.8304	0.196
62	17.537	02 Jan 00 1230	4.8266	0.196
T5-B	29.345	02 Jan 00 1225	7.5870	0.308
46	46.773	02 Jan 00 1225	12.414	0.504
Junction-11	1469.0	02 Jan 00 1325	621.50	13.979
Reservoir-11	1454.5	02 Jan 00 1330	620.33	13.979
W-I1	498.70	02 Jan 00 1220	64.273	0.450
9	433.59	02 Jan 00 1225	64.273	0.450
W-I2	459.38	02 Jan 00 1225	66.983	0.469
Junction-12	892.97	02 Jan 00 1225	131.26	0.919
38	1608.8	02 Jan 00 1325	751.58	14.898
T16-A	34.251	02 Jan 00 1215	6.9991	0.284
20	1613.5	02 Jan 00 1325	758.58	15.182
W-J	25.828	02 Jan 00 1215	5.1508	0.209
Junction-13	1616.8	02 Jan 00 1325	763.73	15.391
T15-A	161.92	02 Jan 00 1220	33.656	0.465
93	1718.2	02 Jan 00 1230	797.39	15.856
W-K	9.2468	02 Jan 00 1215	1.7005	0.069
95	1722.9	02 Jan 00 1230	799.09	15.925
TB-A	27.735	02 Jan 00 1220	5.8161	0.236
61	17.788	02 Jan 00 1230	5.7999	0.236
TB-B	36.945	02 Jan 00 1230	11.102	0.192
Junction-14	54.734	02 Jan 00 1230	16.902	0.428
60	41.836	02 Jan 00 1300	16.823	0.428

Hydrologic Element	Discharge Peak (cfs)	Time of Peak	Total Volume (ac ft)	Drainage Area (sq mi)
TB-C	154.85	02 Jan 00 1225	30.163	0.278
91	185.40	02 Jan 00 1230	46.986	0.706
Junction-15	1908.3	02 Jan 00 1230	846.07	16.631
W-L	68.428	02 Jan 00 1305	27.498	0.607
50	1971.0	02 Jan 00 1230	873.57	17.238
WB-A	31.356	02 Jan 00 1215	6.4077	0.260
55	22.801	02 Jan 00 1230	6.4015	0.260
WB-B	39.919	02 Jan 00 1215	8.1575	0.331
4	59.556	02 Jan 00 1220	14.559	0.591
54	47.974	02 Jan 00 1230	14.542	0.591
WB-C1	15.650	02 Jan 00 1215	2.9821	0.121
Reservoir-15	12.840	02 Jan 00 1220	2.9818	0.121
WB-C2	15.650	02 Jan 00 1215	2.9821	0.121
Junction-16	27.101	02 Jan 00 1220	5.9639	0.242
16	70.126	02 Jan 00 1225	20.506	0.833
WB-T2A	27.559	02 Jan 00 1215	5.4958	0.223
58	20.159	02 Jan 00 1225	5.4919	0.223
WB-T2B	22.932	02 Jan 00 1220	4.9780	0.202
Junction-17	41.566	02 Jan 00 1220	10.470	0.425
10	30.306	02 Jan 00 1240	10.437	0.425
Junction-18	97.151	02 Jan 00 1230	30.943	1.258
WB-T3A	271.09	02 Jan 00 1220	31.593	0.161
59	244.58	02 Jan 00 1225	31.591	0.161
WB-T3B	115.08	02 Jan 00 1220	23.035	0.273
11	357.01	02 Jan 00 1225	54.625	0.434
Junction-19	453.05	02 Jan 00 1225	85.568	1.692
WB-D	56.554	02 Jan 00 1220	12.100	0.491
Junction-20	504.47	02 Jan 00 1225	97.669	2.183
WB-E	43.769	02 Jan 00 1220	9.3647	0.380
Junction-21	544.26	02 Jan 00 1225	107.03	2.563
WB-F	27.147	02 Jan 00 1220	5.6929	0.231
31	568.04	02 Jan 00 1225	112.73	2.794
WB-T1A	11.253	02 Jan 00 1215	2.1441	0.087
57	8.5112	02 Jan 00 1225	2.1434	0.087
WB-T1B	44.047	02 Jan 00 1220	15.289	0.388
88	52.235	02 Jan 00 1220	17.433	0.475
56	39.805	02 Jan 00 1235	17.414	0.475
WB-T1C	39.262	02 Jan 00 1220	13.831	0.351

Hydrologic Element	Discharge Peak (cfs)	Time of Peak	Total Volume (ac ft)	Drainage Area (sq mi)
29	74.458	02 Jan 00 1225	31.245	0.826
Junction-22	642.50	02 Jan 00 1225	143.97	3.620
WB-G	42.685	02 Jan 00 1220	13.550	0.376
90	682.07	02 Jan 00 1225	157.52	3.996
WB-H	33.633	02 Jan 00 1220	7.1961	0.292
92	712.65	02 Jan 00 1225	164.72	4.288
Junction-23	2662.2	02 Jan 00 1225	1038.3	21.526
Reservoir-20	2388.8	02 Jan 00 1240	1035.6	21.526
WB-M	342.59	02 Jan 00 1215	61.568	0.709
Junction-24	2590.0	02 Jan 00 1240	1097.2	22.235
T4-A	360.78	02 Jan 00 1220	55.398	0.437
48	269.74	02 Jan 00 1235	55.367	0.437
T4-B	21.380	02 Jan 00 1215	4.2636	0.173
40	280.61	02 Jan 00 1235	59.631	0.610
T4-C	208.41	02 Jan 00 1225	49.567	0.793
Junction-25	488.18	02 Jan 00 1230	109.20	1.403
T4-D	74.893	02 Jan 00 1215	14.568	0.207
42	541.47	02 Jan 00 1230	123.77	1.610
T4-E	112.19	02 Jan 00 1225	25.965	0.369
41	649.55	02 Jan 00 1230	149.73	1.979
Junction-26	3177.2	02 Jan 00 1235	1246.9	24.214
Reservoir-22	3062.4	02 Jan 00 1245	1244.7	24.214
T13-A	96.335	02 Jan 00 1225	23.284	0.945
44	3118.7	02 Jan 00 1245	1268.0	25.159
T3-A1	17.125	02 Jan 00 1215	3.4996	0.142
T3-A2	15.884	02 Jan 00 1220	3.4993	0.142
Junction-27	32.646	02 Jan 00 1220	6.9989	0.284
Junction-28	3132.1	02 Jan 00 1245	1274.9	25.443
W-N	65.486	02 Jan 00 1215	24.603	0.543
Junction-29	3191.6	02 Jan 00 1245	1299.6	25.986
T2-A	70.371	02 Jan 00 1305	28.223	0.623
Junction-30	3256.0	02 Jan 00 1245	1327.8	26.609
W-O	45.977	02 Jan 00 1220	9.9807	0.405
Junction-31	3276.0	02 Jan 00 1245	1337.8	27.014
T14-A	106.20	02 Jan 00 1220	24.666	1.001
Junction-32	3331.5	02 Jan 00 1245	1362.4	28.015
W-P	90.608	02 Jan 00 1220	21.044	0.854
Junction-33	3378.9	02 Jan 00 1245	1383.5	28.869

Hydrologic Element	Discharge Peak (cfs)	Time of Peak	Total Volume (ac ft)	Drainage Area (sq mi)
T18-A	48.593	02 Jan 00 1220	11.286	0.458
Junction-34	3404.3	02 Jan 00 1245	1394.8	29.327
W-Q	98.183	02 Jan 00 1230	26.034	1.057
Junction-35	3476.5	02 Jan 00 1245	1420.8	30.384
FB-A	68.095	02 Jan 00 1225	22.334	0.398
Reservoir-28	60.839	02 Jan 00 1300	22.306	0.398
FB-B	60.259	02 Jan 00 1255	21.386	0.428
Junction-36	121.07	02 Jan 00 1300	43.692	0.826
Reservoir-29	120.65	02 Jan 00 1305	43.684	0.826
FB-T1A	76.165	02 Jan 00 1235	18.294	0.278
Junction-37	186.56	02 Jan 00 1250	61.977	1.104
FB-C	118.95	02 Jan 00 1240	29.544	0.449
Junction-38	303.76	02 Jan 00 1245	91.521	1.553
FB-D	40.723	02 Jan 00 1235	9.6077	0.146
Junction-39	342.36	02 Jan 00 1245	101.13	1.699
Junction-40	3818.8	02 Jan 00 1245	1521.9	32.083
W-R	46.360	02 Jan 00 1220	10.571	0.429
Junction-41	3844.9	02 Jan 00 1240	1532.5	32.512
T11-A	64.747	02 Jan 00 1215	9.7800	0.177
Reservoir-33	55.229	02 Jan 00 1225	9.7794	0.177
T11-B	128.23	02 Jan 00 1225	28.200	0.365
Junction-42	183.46	02 Jan 00 1225	37.980	0.542
T11-C	45.729	02 Jan 00 1220	8.0401	0.245
96	224.24	02 Jan 00 1225	46.020	0.787
Junction-43	4021.1	02 Jan 00 1240	1578.5	33.299
T1-A	44.047	02 Jan 00 1220	15.289	0.388
Reservoir-36	34.618	02 Jan 00 1230	15.279	0.388
T1-B	44.388	02 Jan 00 1220	14.091	0.391
Junction-44	74.409	02 Jan 00 1225	29.370	0.779
T1-T1A	83.455	02 Jan 00 1225	20.425	0.829
T1-T1B	47.310	02 Jan 00 1230	10.858	0.165
Junction-45	128.63	02 Jan 00 1225	31.283	0.994
Junction-46	203.04	02 Jan 00 1225	60.653	1.773
Reservoir-38	142.66	02 Jan 00 1245	60.426	1.773
T1-C	104.70	02 Jan 00 1240	25.335	0.385
Junction-47	245.09	02 Jan 00 1240	85.761	2.158
T1-T2A	89.348	02 Jan 00 1305	35.834	0.791
Junction-48	326.46	02 Jan 00 1245	121.60	2.949

Hydrologic Element	Discharge Peak (cfs)	Time of Peak	Total Volume (ac ft)	Drainage Area (sq mi)
Subbasin-1	198.43	02 Jan 00 1225	43.864	0.674
Junction-49	497.60	02 Jan 00 1230	165.46	3.623
Reservoir-40	407.00	02 Jan 00 1305	164.84	3.623
74	4382.8	02 Jan 00 1240	1743.3	36.922
W-S	164.75	02 Jan 00 1225	33.708	0.515
98	4508.9	02 Jan 00 1240	1777.1	37.437
W-T	117.46	02 Jan 00 1225	27.825	0.532
97	4598.9	02 Jan 00 1240	1804.9	37.969
Junction-50	4598.9	02 Jan 00 1240	1804.9	37.969

HMS * Summary of Results

Project : thesis   Run Name : Run 2

Start of Simulation : 01Jan00 2400   Basin Model : 1970wal
End of Simulation : 03Jan00 0055   Precip Model : Precip 25
Execution Time : 27Sep01 1335   Control Specs : wln100ex.ih1.basin

Hydrologic Element	Discharge Peak (cfs)	Time of Peak	Total Volume (ac ft)	Drainage Area (sq mi)
W-A1	30.201	02 Jan 00 1220	6.6537	0.270
W-A2	30.097	02 Jan 00 1220	6.3582	0.258
28	60.298	02 Jan 00 1220	13.012	0.528
Reservoir-1	48.104	02 Jan 00 1230	13.004	0.528
W-B	104.85	02 Jan 00 1220	28.597	0.642
19	146.71	02 Jan 00 1220	41.601	1.170
27	125.61	02 Jan 00 1230	41.579	1.170
W-C	62.272	02 Jan 00 1225	15.423	0.626
12	185.34	02 Jan 00 1230	57.002	1.796
Reservoir-2	179.88	02 Jan 00 1235	56.986	1.796
T17-A	39.575	02 Jan 00 1220	9.1912	0.373
15	212.85	02 Jan 00 1230	66.177	2.169
26	149.33	02 Jan 00 1255	65.716	2.169
W-D	69.931	02 Jan 00 1225	17.320	0.703
Junction-1	187.63	02 Jan 00 1240	83.035	2.872
Reservoir-3	169.62	02 Jan 00 1305	82.600	2.872
T9-A	61.723	02 Jan 00 1225	15.496	0.629
73	46.393	02 Jan 00 1240	15.451	0.629
T9-B	47.107	02 Jan 00 1220	10.941	0.444
14	83.970	02 Jan 00 1230	26.391	1.073
25	225.39	02 Jan 00 1250	108.99	3.945
Reservoir-5	220.52	02 Jan 00 1300	108.72	3.945
W-E	512.81	02 Jan 00 1220	62.328	0.326
Junction-2	648.27	02 Jan 00 1225	171.04	4.271
Reservoir-6	593.16	02 Jan 00 1230	170.79	4.271
T8-A	33.518	02 Jan 00 1220	7.1714	0.291
T8-B	50.533	02 Jan 00 1220	10.597	0.430
3	84.051	02 Jan 00 1220	17.769	0.721
T8-C2	24.329	02 Jan 00 1215	4.7281	0.099
T8-C3	65.829	02 Jan 00 1220	14.184	0.297

Hydrologic Element	Discharge Peak (cfs)	Time of Peak		Total Volume (ac ft)	Drainage Area (sq mi)
72	88.835	02 Jan 00	1215	18.912	0.396
T8-C1	43.886	02 Jan 00	1220	9.4560	0.198
Junction-3	131.88	02 Jan 00	1220	28.368	0.594
Reservoir-7	84.294	02 Jan 00	1235	28.309	0.594
8	154.89	02 Jan 00	1220	46.078	1.315
T8-D1	79.825	02 Jan 00	1220	17.502	0.273
T8-D2	29.425	02 Jan 00	1215	5.8340	0.091
Junction-4	107.44	02 Jan 00	1215	23.336	0.364
17	261.64	02 Jan 00	1220	69.413	1.679
71	180.74	02 Jan 00	1240	69.179	1.679
T8-E	213.02	02 Jan 00	1220	41.538	0.551
87	355.47	02 Jan 00	1225	110.72	2.230
70	302.04	02 Jan 00	1245	110.47	2.230
T8-F	108.35	02 Jan 00	1225	24.938	0.347
21	391.11	02 Jan 00	1235	135.41	2.577
Reservoir-8	362.28	02 Jan 00	1255	135.11	2.577
T8-G	48.229	02 Jan 00	1220	11.409	0.463
Junction-5	381.52	02 Jan 00	1250	146.52	3.040
24	942.56	02 Jan 00	1235	317.30	7.311
Reservoir-10	844.05	02 Jan 00	1255	316.23	7.311
W-F	11.332	02 Jan 00	1220	2.5382	0.103
34	847.92	02 Jan 00	1255	318.77	7.414
T7-A	530.69	02 Jan 00	1235	94.753	0.682
69	362.63	02 Jan 00	1300	93.923	0.682
T7-B	64.704	02 Jan 00	1230	18.341	0.745
Junction-6	403.27	02 Jan 00	1255	112.26	1.427
Junction-7	1251.2	02 Jan 00	1255	431.03	8.841
23	1149.0	02 Jan 00	1315	428.79	8.841
W-G	25.893	02 Jan 00	1225	6.2583	0.254
35	1155.3	02 Jan 00	1315	435.04	9.095
T6-A	96.229	02 Jan 00	1225	24.879	1.010
65	51.199	02 Jan 00	1255	24.495	1.010
T6-B	398.33	02 Jan 00	1235	82.448	0.724
Junction-8	442.97	02 Jan 00	1235	106.94	1.734
64	375.61	02 Jan 00	1250	106.91	1.734
T6-C	65.129	02 Jan 00	1235	19.049	0.774
33	429.55	02 Jan 00	1245	125.96	2.508
T6T1-A	325.18	02 Jan 00	1225	61.331	0.561

Hydrologic Element	Discharge Peak (cfs)	Time of Peak	Total Volume (ac ft)	Drainage Area (sq mi)
67	318.12	02 Jan 00 1230	61.326	0.561
T6T1-B	19.482	02 Jan 00 1215	3.7954	0.154
45	329.82	02 Jan 00 1230	65.121	0.715
66	261.13	02 Jan 00 1245	65.008	0.715
T6T1-C	13.021	02 Jan 00 1220	3.0801	0.125
43	268.22	02 Jan 00 1245	68.088	0.840
Junction-9	697.78	02 Jan 00 1245	194.04	3.348
63	657.08	02 Jan 00 1300	193.64	3.348
T6-D	372.74	02 Jan 00 1230	58.379	0.340
36	880.08	02 Jan 00 1245	252.02	3.688
Junction-10	1940.7	02 Jan 00 1310	687.06	12.783
22	1876.4	02 Jan 00 1320	684.78	12.783
W-H	66.886	02 Jan 00 1225	17.047	0.692
39	1893.5	02 Jan 00 1320	701.82	13.475
T5-A	23.638	02 Jan 00 1215	4.8304	0.196
62	17.537	02 Jan 00 1230	4.8266	0.196
T5-B	29.345	02 Jan 00 1225	7.5870	0.308
46	46.773	02 Jan 00 1225	12.414	0.504
Junction-11	1906.8	02 Jan 00 1320	714.24	13.979
Reservoir-11	1889.2	02 Jan 00 1325	713.01	13.979
W-I1	498.70	02 Jan 00 1220	64.273	0.450
9	433.59	02 Jan 00 1225	64.273	0.450
W-I2	459.38	02 Jan 00 1225	66.983	0.469
Junction-12	892.97	02 Jan 00 1225	131.26	0.919
38	2055.7	02 Jan 00 1320	844.27	14.898
T16-A	34.251	02 Jan 00 1215	6.9991	0.284
20	2060.7	02 Jan 00 1320	851.27	15.182
W-J	25.828	02 Jan 00 1215	5.1508	0.209
Junction-13	2064.3	02 Jan 00 1320	856.42	15.391
T15-A	161.92	02 Jan 00 1220	33.656	0.465
93	2129.7	02 Jan 00 1320	890.07	15.856
W-K	9.2468	02 Jan 00 1215	1.7005	0.069
95	2130.8	02 Jan 00 1320	891.77	15.925
TB-A	27.735	02 Jan 00 1220	5.8161	0.236
61	17.788	02 Jan 00 1230	5.7999	0.236
TB-B	75.227	02 Jan 00 1240	15.704	0.192
Junction-14	92.380	02 Jan 00 1240	21.504	0.428
60	69.297	02 Jan 00 1305	21.415	0.428

Hydrologic Element	Discharge Peak (cfs)	Time of Peak	Total Volume (ac ft)	Drainage Area (sq mi)
TB-C	154.85	02 Jan 00 1225	30.163	0.278
91	188.39	02 Jan 00 1230	51.578	0.706
Junction-15	2261.7	02 Jan 00 1320	943.35	16.631
W-L	68.428	02 Jan 00 1305	27.498	0.607
50	2327.9	02 Jan 00 1320	970.85	17.238
WB-A	31.356	02 Jan 00 1215	6.4077	0.260
55	22.801	02 Jan 00 1230	6.4015	0.260
WB-B	39.919	02 Jan 00 1215	8.1575	0.331
4	59.556	02 Jan 00 1220	14.559	0.591
54	47.974	02 Jan 00 1230	14.542	0.591
WB-C1	15.650	02 Jan 00 1215	2.9821	0.121
Reservoir-15	12.840	02 Jan 00 1220	2.9818	0.121
WB-C2	15.650	02 Jan 00 1215	2.9821	0.121
Junction-16	27.101	02 Jan 00 1220	5.9639	0.242
16	70.126	02 Jan 00 1225	20.506	0.833
WB-T2A	27.559	02 Jan 00 1215	5.4958	0.223
58	20.159	02 Jan 00 1225	5.4919	0.223
WB-T2B	22.932	02 Jan 00 1220	4.9780	0.202
Junction-17	41.566	02 Jan 00 1220	10.470	0.425
10	30.306	02 Jan 00 1240	10.437	0.425
Junction-18	97.151	02 Jan 00 1230	30.943	1.258
WB-T3A	271.09	02 Jan 00 1220	31.593	0.161
59	244.58	02 Jan 00 1225	31.591	0.161
WB-T3B	115.08	02 Jan 00 1220	23.035	0.273
11	357.01	02 Jan 00 1225	54.625	0.434
Junction-19	453.05	02 Jan 00 1225	85.568	1.692
WB-D	56.554	02 Jan 00 1220	12.100	0.491
Junction-20	504.47	02 Jan 00 1225	97.669	2.183
WB-E	43.769	02 Jan 00 1220	9.3647	0.380
Junction-21	544.26	02 Jan 00 1225	107.03	2.563
WB-F	27.147	02 Jan 00 1220	5.6929	0.231
31	568.04	02 Jan 00 1225	112.73	2.794
WB-T1A	11.253	02 Jan 00 1215	2.1441	0.087
57	8.5112	02 Jan 00 1225	2.1434	0.087
WB-T1B	44.047	02 Jan 00 1220	15.289	0.388
88	52.235	02 Jan 00 1220	17.433	0.475
56	39.805	02 Jan 00 1235	17.414	0.475
WB-T1C	39.262	02 Jan 00 1220	13.831	0.351

Hydrologic Element	Discharge Peak (cfs)	Time of Peak	Total Volume (ac ft)	Drainage Area (sq mi)
29	74.458	02 Jan 00 1225	31.245	0.826
Junction-22	642.50	02 Jan 00 1225	143.97	3.620
WB-G	42.685	02 Jan 00 1220	13.550	0.376
90	682.07	02 Jan 00 1225	157.52	3.996
WB-H	33.633	02 Jan 00 1220	7.1961	0.292
92	712.65	02 Jan 00 1225	164.72	4.288
Junction-23	2787.4	02 Jan 00 1230	1135.6	21.526
Reservoir-20	2586.4	02 Jan 00 1240	1132.7	21.526
WB-M	342.59	02 Jan 00 1215	61.568	0.709
Junction-24	2787.7	02 Jan 00 1240	1194.3	22.235
T4-A	360.78	02 Jan 00 1220	55.398	0.437
48	269.74	02 Jan 00 1235	55.367	0.437
T4-B	21.380	02 Jan 00 1215	4.2636	0.173
40	280.61	02 Jan 00 1235	59.631	0.610
T4-C	208.41	02 Jan 00 1225	49.567	0.793
Junction-25	488.18	02 Jan 00 1230	109.20	1.403
T4-D	184.18	02 Jan 00 1220	27.040	0.207
42	647.67	02 Jan 00 1225	136.24	1.610
T4-E	307.65	02 Jan 00 1230	52.113	0.369
41	953.23	02 Jan 00 1225	188.35	1.979
Junction-26	3636.6	02 Jan 00 1235	1382.7	24.214
Reservoir-22	3504.9	02 Jan 00 1245	1380.3	24.214
T13-A	96.335	02 Jan 00 1225	23.284	0.945
44	3561.1	02 Jan 00 1245	1403.6	25.159
T3-A1	40.144	02 Jan 00 1235	9.3446	0.142
T3-A2	38.615	02 Jan 00 1240	9.3442	0.142
Junction-27	78.661	02 Jan 00 1235	18.689	0.284
Junction-28	3636.1	02 Jan 00 1245	1422.3	25.443
W-N	65.486	02 Jan 00 1215	24.603	0.543
Junction-29	3695.6	02 Jan 00 1245	1446.9	25.986
T2-A	70.371	02 Jan 00 1305	28.223	0.623
Junction-30	3760.0	02 Jan 00 1245	1475.1	26.609
W-O	110.96	02 Jan 00 1235	26.651	0.405
Junction-31	3867.3	02 Jan 00 1245	1501.8	27.014
T14-A	208.82	02 Jan 00 1245	58.927	1.001
Junction-32	4076.1	02 Jan 00 1245	1560.7	28.015
W-P	227.96	02 Jan 00 1240	56.194	0.854
Junction-33	4301.5	02 Jan 00 1245	1616.9	28.869

Hydrologic Element	Discharge Peak (cfs)	Time of Peak	Total Volume (ac ft)	Drainage Area (sq mi)
T18-A	48.593	02 Jan 00 1220	11.286	0.458
Junction-34	4326.9	02 Jan 00 1245	1628.2	29.327
W-Q	98.183	02 Jan 00 1230	26.034	1.057
Junction-35	4399.0	02 Jan 00 1245	1654.2	30.384
FB-A	68.095	02 Jan 00 1225	22.334	0.398
Reservoir-28	60.839	02 Jan 00 1300	22.306	0.398
FB-B	60.259	02 Jan 00 1255	21.386	0.428
Junction-36	121.07	02 Jan 00 1300	43.692	0.826
Reservoir-29	120.65	02 Jan 00 1305	43.684	0.826
FB-T1A	76.165	02 Jan 00 1235	18.294	0.278
Junction-37	186.56	02 Jan 00 1250	61.977	1.104
FB-C	118.95	02 Jan 00 1240	29.544	0.449
Junction-38	303.76	02 Jan 00 1245	91.521	1.553
FB-D	40.723	02 Jan 00 1235	9.6077	0.146
Junction-39	342.36	02 Jan 00 1245	101.13	1.699
Junction-40	4741.4	02 Jan 00 1245	1755.4	32.083
W-R	280.06	02 Jan 00 1225	49.592	0.429
Junction-41	4925.8	02 Jan 00 1245	1805.0	32.512
T11-A	64.747	02 Jan 00 1215	9.7800	0.177
Reservoir-33	55.229	02 Jan 00 1225	9.7794	0.177
T11-B	128.23	02 Jan 00 1225	28.200	0.365
Junction-42	183.46	02 Jan 00 1225	37.980	0.542
T11-C	151.67	02 Jan 00 1225	25.245	0.245
96	335.12	02 Jan 00 1225	63.224	0.787
Junction-43	5197.8	02 Jan 00 1240	1868.2	33.299
T1-A	44.047	02 Jan 00 1220	15.289	0.388
Reservoir-36	34.618	02 Jan 00 1230	15.279	0.388
T1-B	44.388	02 Jan 00 1220	14.091	0.391
Junction-44	74.409	02 Jan 00 1225	29.370	0.779
T1-T1A	83.455	02 Jan 00 1225	20.425	0.829
T1-T1B	47.310	02 Jan 00 1230	10.858	0.165
Junction-45	128.63	02 Jan 00 1225	31.283	0.994
Junction-46	203.04	02 Jan 00 1225	60.653	1.773
Reservoir-38	142.66	02 Jan 00 1245	60.426	1.773
T1-C	104.70	02 Jan 00 1240	25.335	0.385
Junction-47	245.09	02 Jan 00 1240	85.761	2.158
T1-T2A	89.348	02 Jan 00 1305	35.834	0.791
Junction-48	326.46	02 Jan 00 1245	121.60	2.949

Hydrologic Element	Discharge Peak (cfs)	Time of Peak	Total Volume (ac ft)	Drainage Area (sq mi)
Subbasin-1	198.43	02 Jan 00 1225	43.864	0.674
Junction-49	497.60	02 Jan 00 1230	165.46	3.623
Reservoir-40	407.00	02 Jan 00 1305	164.84	3.623
74	5559.5	02 Jan 00 1240	2033.0	36.922
W-S	164.75	02 Jan 00 1225	33.708	0.515
98	5685.5	02 Jan 00 1240	2066.7	37.437
W-T	117.46	02 Jan 00 1225	27.825	0.532
97	5775.6	02 Jan 00 1240	2094.5	37.969
Junction-50	5775.6	02 Jan 00 1240	2094.5	37.969

HMS * Summary of Results

Project : thesis   Run Name : Run 3

Start of Simulation : 01Jan00 2400   Basin Model   : 1980wal
End of Simulation   : 03Jan00 0055   Precip Model   : Precip 25
Execution Time   : 27Sep01 1446   Control Specs : wln100ex.ih1.basin

Hydrologic Element	Discharge Peak (cfs)	Time of Peak	Total Volume (ac ft)	Drainage Area (sq mi)
W-A1	30.201	02 Jan 00 1220	6.6537	0.270
W-A2	30.097	02 Jan 00 1220	6.3582	0.258
28	60.298	02 Jan 00 1220	13.012	0.528
Reservoir-1	48.104	02 Jan 00 1230	13.004	0.528
W-B	104.85	02 Jan 00 1220	28.597	0.642
19	146.71	02 Jan 00 1220	41.601	1.170
27	125.61	02 Jan 00 1230	41.579	1.170
W-C	62.272	02 Jan 00 1225	15.423	0.626
12	185.34	02 Jan 00 1230	57.002	1.796
Reservoir-2	179.88	02 Jan 00 1235	56.986	1.796
T17-A	39.575	02 Jan 00 1220	9.1912	0.373
15	212.85	02 Jan 00 1230	66.177	2.169
26	149.33	02 Jan 00 1255	65.716	2.169
W-D	139.88	02 Jan 00 1225	36.724	0.703
Junction-1	247.09	02 Jan 00 1235	102.44	2.872
Reservoir-3	221.83	02 Jan 00 1305	101.98	2.872
T9-A	61.723	02 Jan 00 1225	15.496	0.629
73	46.393	02 Jan 00 1240	15.451	0.629
T9-B	94.215	02 Jan 00 1220	23.197	0.444
14	130.03	02 Jan 00 1225	38.648	1.073
25	309.69	02 Jan 00 1250	140.63	3.945
Reservoir-5	305.54	02 Jan 00 1305	140.34	3.945
W-E	512.81	02 Jan 00 1220	62.328	0.326
Junction-2	720.13	02 Jan 00 1225	202.67	4.271
Reservoir-6	663.12	02 Jan 00 1235	202.39	4.271
T8-A	33.518	02 Jan 00 1220	7.1714	0.291
T8-B	50.533	02 Jan 00 1220	10.597	0.430
3	84.051	02 Jan 00 1220	17.769	0.721
T8-C3	65.829	02 Jan 00 1220	14.184	0.297
T8-C2	24.329	02 Jan 00 1215	4.7281	0.099

Hydrologic Element	Discharge Peak (cfs)	Time of Peak		Total Volume (ac ft)	Drainage Area (sq mi)
72	88.835	02 Jan 00	1215	18.912	0.396
T8-C1	43.886	02 Jan 00	1220	9.4560	0.198
Junction-3	131.88	02 Jan 00	1220	28.368	0.594
Reservoir-7	83.211	02 Jan 00	1235	28.304	0.594
8	153.59	02 Jan 00	1220	46.073	1.315
T8-D1	79.825	02 Jan 00	1220	17.502	0.273
T8-D2	29.425	02 Jan 00	1215	5.8340	0.091
Junction-4	107.44	02 Jan 00	1215	23.336	0.364
17	260.34	02 Jan 00	1220	69.408	1.679
71	179.90	02 Jan 00	1245	69.171	1.679
T8-E	213.02	02 Jan 00	1220	41.538	0.551
87	354.79	02 Jan 00	1225	110.71	2.230
70	301.35	02 Jan 00	1245	110.47	2.230
T8-F	108.35	02 Jan 00	1225	24.938	0.347
21	390.55	02 Jan 00	1235	135.40	2.577
Reservoir-8	361.67	02 Jan 00	1255	135.10	2.577
T8-G	111.89	02 Jan 00	1220	26.092	0.463
Junction-5	420.42	02 Jan 00	1250	161.19	3.040
24	1066.2	02 Jan 00	1235	363.58	7.311
Reservoir-10	960.91	02 Jan 00	1255	362.45	7.311
W-F	11.332	02 Jan 00	1220	2.5382	0.103
34	964.78	02 Jan 00	1255	364.99	7.414
T7-A	730.61	02 Jan 00	1230	115.09	0.682
69	499.22	02 Jan 00	1255	114.20	0.682
T7-B	64.704	02 Jan 00	1230	18.341	0.745
Junction-6	544.04	02 Jan 00	1250	132.54	1.427
Junction-7	1506.2	02 Jan 00	1255	497.53	8.841
23	1403.5	02 Jan 00	1315	495.13	8.841
W-G	93.714	02 Jan 00	1225	20.618	0.254
35	1451.1	02 Jan 00	1310	515.75	9.095
T6-A	134.72	02 Jan 00	1225	34.694	1.010
65	71.680	02 Jan 00	1255	34.240	1.010
T6-B	398.33	02 Jan 00	1235	82.448	0.724
Junction-8	460.82	02 Jan 00	1235	116.69	1.734
64	388.47	02 Jan 00	1255	116.65	1.734
T6-C	156.40	02 Jan 00	1235	41.968	0.774
33	523.06	02 Jan 00	1245	158.61	2.508
T6T1-A	384.32	02 Jan 00	1225	67.771	0.561

Hydrologic Element	Discharge Peak (cfs)	Time of Peak	Total Volume (ac ft)	Drainage Area (sq mi)
67	376.43	02 Jan 00 1230	67.765	0.561
T6T1-B	214.33	02 Jan 00 1220	25.790	0.154
45	542.40	02 Jan 00 1225	93.555	0.715
66	439.40	02 Jan 00 1240	93.427	0.715
T6T1-C	138.89	02 Jan 00 1225	18.970	0.125
43	548.78	02 Jan 00 1235	112.40	0.840
Junction-9	1067.7	02 Jan 00 1240	271.01	3.348
63	991.90	02 Jan 00 1255	270.53	3.348
T6-D	372.74	02 Jan 00 1230	58.379	0.340
36	1245.0	02 Jan 00 1245	328.91	3.688
Junction-10	2558.5	02 Jan 00 1300	844.67	12.783
22	2466.7	02 Jan 00 1315	842.16	12.783
W-H	712.69	02 Jan 00 1230	113.57	0.692
39	2760.5	02 Jan 00 1310	955.73	13.475
T5-A	61.458	02 Jan 00 1215	11.752	0.196
62	45.630	02 Jan 00 1230	11.746	0.196
T5-B	29.345	02 Jan 00 1225	7.5870	0.308
46	74.668	02 Jan 00 1230	19.333	0.504
Junction-11	2796.4	02 Jan 00 1310	975.06	13.979
Reservoir-11	2774.0	02 Jan 00 1315	973.70	13.979
W-I1	498.70	02 Jan 00 1220	64.273	0.450
9	433.59	02 Jan 00 1225	64.273	0.450
W-I2	459.38	02 Jan 00 1225	66.983	0.469
Junction-12	892.97	02 Jan 00 1225	131.26	0.919
38	2979.9	02 Jan 00 1310	1105.0	14.898
T16-A	34.251	02 Jan 00 1215	6.9991	0.284
20	2985.9	02 Jan 00 1310	1112.0	15.182
W-J	60.439	02 Jan 00 1215	11.179	0.209
Junction-13	3004.6	02 Jan 00 1310	1123.1	15.391
T15-A	243.97	02 Jan 00 1225	46.610	0.465
93	3113.8	02 Jan 00 1310	1169.7	15.856
W-K	9.2468	02 Jan 00 1215	1.7005	0.069
95	3115.1	02 Jan 00 1310	1171.4	15.925
TB-A	27.947	02 Jan 00 1220	10.693	0.236
61	24.882	02 Jan 00 1320	10.668	0.236
TB-B	75.227	02 Jan 00 1240	15.704	0.192
Junction-14	95.339	02 Jan 00 1245	26.372	0.428
60	76.219	02 Jan 00 1315	26.262	0.428

Hydrologic Element	Discharge Peak (cfs)	Time of Peak	Total Volume (ac ft)	Drainage Area (sq mi)
TB-C	71.456	02 Jan 00 1235	19.321	0.278
91	134.29	02 Jan 00 1300	45.583	0.706
Junction-15	3246.6	02 Jan 00 1310	1217.0	16.631
W-L	68.428	02 Jan 00 1305	27.498	0.607
50	3314.7	02 Jan 00 1310	1244.5	17.238
WB-A	31.356	02 Jan 00 1215	6.4077	0.260
55	22.801	02 Jan 00 1230	6.4015	0.260
WB-B	39.919	02 Jan 00 1215	8.1575	0.331
4	59.556	02 Jan 00 1220	14.559	0.591
54	47.974	02 Jan 00 1230	14.542	0.591
WB-C1	15.650	02 Jan 00 1215	2.9821	0.121
Reservoir-15	12.840	02 Jan 00 1220	2.9818	0.121
WB-C2	15.650	02 Jan 00 1215	2.9821	0.121
Junction-16	27.101	02 Jan 00 1220	5.9639	0.242
16	70.126	02 Jan 00 1225	20.506	0.833
WB-T2A	27.559	02 Jan 00 1215	5.4958	0.223
58	20.159	02 Jan 00 1225	5.4919	0.223
WB-T2B	22.932	02 Jan 00 1220	4.9780	0.202
Junction-17	41.566	02 Jan 00 1220	10.470	0.425
10	30.306	02 Jan 00 1240	10.437	0.425
Junction-18	97.151	02 Jan 00 1230	30.943	1.258
WB-T3A	271.09	02 Jan 00 1220	31.593	0.161
59	244.58	02 Jan 00 1225	31.591	0.161
WB-T3B	115.08	02 Jan 00 1220	23.035	0.273
11	357.01	02 Jan 00 1225	54.625	0.434
Junction-19	453.05	02 Jan 00 1225	85.568	1.692
WB-D	56.554	02 Jan 00 1220	12.100	0.491
Junction-20	504.47	02 Jan 00 1225	97.669	2.183
WB-E	87.538	02 Jan 00 1220	19.855	0.380
Junction-21	584.08	02 Jan 00 1225	117.52	2.563
WB-F	84.883	02 Jan 00 1220	16.604	0.231
31	659.39	02 Jan 00 1225	134.13	2.794
WB-T1A	94.194	02 Jan 00 1220	12.444	0.087
57	73.372	02 Jan 00 1230	12.443	0.087
WB-T1B	88.095	02 Jan 00 1220	20.273	0.388
88	153.78	02 Jan 00 1225	32.715	0.475
56	122.02	02 Jan 00 1240	32.691	0.475
WB-T1C	39.262	02 Jan 00 1220	13.831	0.351

Hydrologic Element	Discharge Peak (cfs)	Time of Peak	Total Volume (ac ft)	Drainage Area (sq mi)
29	149.46	02 Jan 00 1230	46.523	0.826
Junction-22	802.68	02 Jan 00 1225	180.65	3.620
WB-G	245.58	02 Jan 00 1220	42.831	0.376
90	1047.0	02 Jan 00 1225	223.48	3.996
WB-H	122.38	02 Jan 00 1220	23.921	0.292
92	1161.3	02 Jan 00 1225	247.40	4.288
Junction-23	4075.1	02 Jan 00 1235	1491.9	21.526
Reservoir-20	3942.6	02 Jan 00 1245	1488.7	21.526
WB-M	342.59	02 Jan 00 1215	61.568	0.709
Junction-24	4125.8	02 Jan 00 1245	1550.3	22.235
T4-A	360.78	02 Jan 00 1220	55.398	0.437
48	269.74	02 Jan 00 1235	55.367	0.437
T4-B	217.78	02 Jan 00 1220	27.608	0.173
40	444.11	02 Jan 00 1225	82.975	0.610
T4-C	617.61	02 Jan 00 1230	108.57	0.793
Junction-25	1049.0	02 Jan 00 1230	191.54	1.403
T4-D	311.02	02 Jan 00 1220	36.722	0.207
42	1303.3	02 Jan 00 1225	228.26	1.610
T4-E	637.24	02 Jan 00 1225	85.388	0.369
41	1940.5	02 Jan 00 1225	313.65	1.979
Junction-26	5796.0	02 Jan 00 1235	1864.0	24.214
Reservoir-22	5581.2	02 Jan 00 1245	1861.3	24.214
T13-A	96.335	02 Jan 00 1225	23.284	0.945
44	5637.4	02 Jan 00 1245	1884.6	25.159
T3-A1	40.144	02 Jan 00 1235	9.3446	0.142
T3-A2	38.615	02 Jan 00 1240	9.3442	0.142
Junction-27	78.661	02 Jan 00 1235	18.689	0.284
Junction-28	5712.4	02 Jan 00 1245	1903.3	25.443
W-N	65.486	02 Jan 00 1215	24.603	0.543
Junction-29	5771.9	02 Jan 00 1245	1927.9	25.986
T2-A	120.31	02 Jan 00 1225	37.100	0.623
Junction-30	5881.8	02 Jan 00 1245	1965.0	26.609
W-O	110.96	02 Jan 00 1235	26.651	0.405
Junction-31	5989.2	02 Jan 00 1245	1991.7	27.014
T14-A	317.66	02 Jan 00 1235	75.039	1.001
Junction-32	6288.9	02 Jan 00 1245	2066.7	28.015
W-P	227.96	02 Jan 00 1240	56.194	0.854
Junction-33	6514.2	02 Jan 00 1245	2122.9	28.869

Hydrologic Element	Discharge Peak (cfs)	Time of Peak	Total Volume (ac ft)	Drainage Area (sq mi)
T18-A	48.593	02 Jan 00 1220	11.286	0.458
Junction-34	6539.6	02 Jan 00 1245	2134.2	29.327
W-Q	98.183	02 Jan 00 1230	26.034	1.057
Junction-35	6611.8	02 Jan 00 1245	2160.2	30.384
FB-A	476.11	02 Jan 00 1225	58.792	0.398
Reservoir-28	340.06	02 Jan 00 1240	58.752	0.398
FB-B	245.46	02 Jan 00 1230	46.060	0.428
Junction-36	568.00	02 Jan 00 1235	104.81	0.826
Reservoir-29	562.36	02 Jan 00 1240	104.80	0.826
FB-T1A	201.58	02 Jan 00 1225	32.774	0.278
Junction-37	727.75	02 Jan 00 1235	137.57	1.104
FB-C	498.91	02 Jan 00 1225	68.140	0.449
Junction-38	1197.3	02 Jan 00 1230	205.71	1.553
FB-D	136.40	02 Jan 00 1220	18.973	0.146
Junction-39	1319.3	02 Jan 00 1230	224.69	1.699
Junction-40	7801.8	02 Jan 00 1240	2384.9	32.083
W-R	350.74	02 Jan 00 1225	57.482	0.429
Junction-41	8066.1	02 Jan 00 1240	2442.4	32.512
T11-A	161.80	02 Jan 00 1220	23.718	0.177
Reservoir-33	140.97	02 Jan 00 1225	23.717	0.177
T11-B	177.45	02 Jan 00 1220	34.053	0.365
Junction-42	317.68	02 Jan 00 1225	57.770	0.542
T11-C	269.23	02 Jan 00 1220	34.893	0.245
96	581.26	02 Jan 00 1225	92.662	0.787
Junction-43	8501.2	02 Jan 00 1235	2535.0	33.299
T1-A	63.471	02 Jan 00 1220	21.297	0.388
Reservoir-36	59.373	02 Jan 00 1300	21.284	0.388
T1-B	374.34	02 Jan 00 1225	53.090	0.391
Junction-44	422.27	02 Jan 00 1225	74.375	0.779
T1-T1A	83.455	02 Jan 00 1225	20.425	0.829
T1-T1B	47.310	02 Jan 00 1230	10.858	0.165
Junction-45	128.63	02 Jan 00 1225	31.283	0.994
Junction-46	550.90	02 Jan 00 1225	105.66	1.773
Reservoir-38	371.43	02 Jan 00 1245	105.39	1.773
T1-C	270.19	02 Jan 00 1225	45.665	0.385
Junction-47	577.60	02 Jan 00 1235	151.06	2.158
T1-T2A	344.26	02 Jan 00 1225	67.557	0.791
Junction-48	894.70	02 Jan 00 1230	218.61	2.949

Hydrologic Element	Discharge Peak (cfs)	Time of Peak	Total Volume (ac ft)	Drainage Area (sq mi)
Subbasin-1	198.43	02 Jan 00 1225	43.864	0.674
Junction-49	1087.4	02 Jan 00 1230	262.48	3.623
Reservoir-40	868.02	02 Jan 00 1250	261.77	3.623
74	9320.2	02 Jan 00 1240	2796.8	36.922
W-S	283.24	02 Jan 00 1230	56.180	0.515
98	9569.3	02 Jan 00 1240	2853.0	37.437
W-T	149.72	02 Jan 00 1235	39.172	0.532
97	9717.2	02 Jan 00 1240	2892.2	37.969
Junction-50	9717.2	02 Jan 00 1240	2892.2	37.969

HMS * Summary of Results

Project : thesis   Run Name : Run 5

Start of Simulation : 01Jan00 2400   Basin Model   : 1990wal
End of Simulation   : 03Jan00 0055   Precip Model   : Precip 25
Execution Time   : 29Sep01 1236   Control Specs : wln100ex.ihl.basin

Hydrologic Element	Discharge Peak (cfs)	Time of Peak	Total Volume (ac ft)	Drainage Area (sq mi)
W-A1	579.91	02 Jan 00 1220	68.008	0.270
W-A2	579.28	02 Jan 00 1220	64.986	0.258
28	1159.2	02 Jan 00 1220	132.99	0.528
Reservoir-1	921.26	02 Jan 00 1230	132.97	0.528
W-B	314.99	02 Jan 00 1220	54.836	0.642
19	1176.0	02 Jan 00 1225	187.81	1.170
27	1047.6	02 Jan 00 1235	187.76	1.170
W-C	311.36	02 Jan 00 1225	49.527	0.626
12	1316.6	02 Jan 00 1235	237.29	1.796
Reservoir-2	1285.2	02 Jan 00 1240	237.26	1.796
T17-A	39.575	02 Jan 00 1220	9.1912	0.373
15	1309.9	02 Jan 00 1240	246.45	2.169
26	958.85	02 Jan 00 1305	245.71	2.169
W-D	419.60	02 Jan 00 1225	72.839	0.703
Junction-1	1142.5	02 Jan 00 1255	318.55	2.872
Reservoir-3	1059.7	02 Jan 00 1315	317.86	2.872
T9-A	308.62	02 Jan 00 1225	49.763	0.629
73	231.97	02 Jan 00 1240	49.703	0.629
T9-B	282.64	02 Jan 00 1220	46.007	0.444
14	464.50	02 Jan 00 1225	95.710	1.073
25	1308.7	02 Jan 00 1305	413.57	3.945
Reservoir-5	1292.1	02 Jan 00 1315	413.15	3.945
W-E	508.42	02 Jan 00 1220	65.394	0.326
Junction-2	1433.6	02 Jan 00 1300	478.54	4.271
Reservoir-6	1428.0	02 Jan 00 1310	478.14	4.271
T8-A	167.59	02 Jan 00 1220	23.026	0.291
T8-B	64.879	02 Jan 00 1240	20.522	0.430
3	224.67	02 Jan 00 1220	43.548	0.721
T8-C2	61.864	02 Jan 00 1220	10.111	0.099
T8-C3	172.92	02 Jan 00 1225	30.333	0.297

Hydrologic Element	Discharge Peak (cfs)	Time of Peak	Total Volume (ac ft)	Drainage Area (sq mi)
72	231.02	02 Jan 00 1225	40.444	0.396
T8-C1	115.28	02 Jan 00 1225	20.222	0.198
Junction-3	346.30	02 Jan 00 1225	60.666	0.594
Reservoir-7	239.09	02 Jan 00 1245	60.581	0.594
8	398.70	02 Jan 00 1230	104.13	1.315
T8-D1	411.89	02 Jan 00 1220	50.059	0.273
T8-D2	149.52	02 Jan 00 1215	16.687	0.091
Junction-4	556.52	02 Jan 00 1220	66.746	0.364
17	933.00	02 Jan 00 1220	170.87	1.679
71	650.72	02 Jan 00 1245	170.53	1.679
T8-E	699.34	02 Jan 00 1220	95.154	0.551
87	1220.3	02 Jan 00 1225	265.69	2.230
70	1072.1	02 Jan 00 1240	265.34	2.230
T8-F	454.55	02 Jan 00 1230	61.998	0.347
21	1468.8	02 Jan 00 1235	327.34	2.577
Reservoir-8	1353.8	02 Jan 00 1250	326.90	2.577
T8-G	508.71	02 Jan 00 1225	72.809	0.463
Junction-5	1695.1	02 Jan 00 1240	399.71	3.040
24	3061.1	02 Jan 00 1245	877.85	7.311
Reservoir-10	2907.3	02 Jan 00 1300	876.25	7.311
W-F	73.705	02 Jan 00 1220	11.766	0.103
34	2934.9	02 Jan 00 1300	888.02	7.414
T7-A	1044.8	02 Jan 00 1230	147.64	0.682
69	684.25	02 Jan 00 1250	146.69	0.682
T7-B	301.45	02 Jan 00 1245	68.683	0.745
Junction-6	977.26	02 Jan 00 1250	215.37	1.427
Junction-7	3868.4	02 Jan 00 1300	1103.4	8.841
23	3736.7	02 Jan 00 1310	1100.1	8.841
W-G	229.60	02 Jan 00 1225	37.939	0.254
35	3828.4	02 Jan 00 1310	1138.0	9.095
T6-A	1171.3	02 Jan 00 1230	176.31	1.010
65	624.85	02 Jan 00 1300	175.39	1.010
T6-B	398.33	02 Jan 00 1235	82.448	0.724
Junction-8	931.02	02 Jan 00 1250	257.84	1.734
64	874.42	02 Jan 00 1305	257.76	1.734
T6-C	643.56	02 Jan 00 1240	118.57	0.774
33	1361.5	02 Jan 00 1255	376.33	2.508
T6T1-A	810.90	02 Jan 00 1225	105.56	0.561

Hydrologic Element	Discharge Peak (cfs)	Time of Peak	Total Volume (ac ft)	Drainage Area (sq mi)
67	785.85	02 Jan 00 1230	105.55	0.561
T6T1-B	373.87	02 Jan 00 1215	38.756	0.154
45	1059.1	02 Jan 00 1225	144.31	0.715
66	858.10	02 Jan 00 1235	144.16	0.715
T6T1-C	171.30	02 Jan 00 1225	22.108	0.125
43	1002.5	02 Jan 00 1235	166.27	0.840
Junction-9	2204.4	02 Jan 00 1250	542.60	3.348
63	2075.3	02 Jan 00 1300	541.89	3.348
T6-D	372.74	02 Jan 00 1230	58.379	0.340
36	2284.3	02 Jan 00 1255	600.26	3.688
Junction-10	6026.5	02 Jan 00 1305	1738.3	12.783
22	5814.2	02 Jan 00 1315	1734.8	12.783
W-H	874.58	02 Jan 00 1230	133.72	0.692
39	6123.6	02 Jan 00 1315	1868.5	13.475
T5-A	185.79	02 Jan 00 1220	26.042	0.196
62	139.38	02 Jan 00 1235	26.033	0.196
T5-B	146.73	02 Jan 00 1225	27.955	0.308
46	282.82	02 Jan 00 1230	53.988	0.504
Junction-11	6255.7	02 Jan 00 1315	1922.5	13.979
Reservoir-11	6146.4	02 Jan 00 1325	1920.6	13.979
W-I1	498.70	02 Jan 00 1220	64.273	0.450
9	433.59	02 Jan 00 1225	64.273	0.450
W-I2	459.38	02 Jan 00 1225	66.983	0.469
Junction-12	892.97	02 Jan 00 1225	131.26	0.919
38	6316.3	02 Jan 00 1320	2051.9	14.898
T16-A	34.251	02 Jan 00 1215	6.9991	0.284
20	6321.3	02 Jan 00 1320	2058.9	15.182
W-J	267.48	02 Jan 00 1220	30.803	0.209
Junction-13	6378.9	02 Jan 00 1320	2089.7	15.391
T15-A	307.43	02 Jan 00 1220	53.754	0.465
93	6480.8	02 Jan 00 1320	2143.5	15.856
W-K	9.2468	02 Jan 00 1215	3.1265	0.069
95	6488.0	02 Jan 00 1320	2146.6	15.925
TB-A	138.67	02 Jan 00 1220	18.674	0.236
61	88.941	02 Jan 00 1230	18.652	0.236
TB-B	18.020	02 Jan 00 1225	4.7293	0.192
Junction-14	106.94	02 Jan 00 1230	23.382	0.428
60	80.500	02 Jan 00 1255	23.303	0.428

Hydrologic Element	Discharge Peak (cfs)	Time of Peak	Total Volume (ac ft)	Drainage Area (sq mi)
TB-C	144.20	02 Jan 00 1230	28.389	0.278
91	211.51	02 Jan 00 1235	51.692	0.706
Junction-15	6626.2	02 Jan 00 1320	2198.3	16.631
W-L	68.428	02 Jan 00 1305	27.498	0.607
50	6692.4	02 Jan 00 1320	2225.8	17.238
WB-A	31.356	02 Jan 00 1215	6.4077	0.260
55	22.801	02 Jan 00 1230	6.4015	0.260
WB-B	199.84	02 Jan 00 1215	32.810	0.331
4	217.61	02 Jan 00 1220	39.212	0.591
54	173.36	02 Jan 00 1230	39.191	0.591
WB-C1	197.59	02 Jan 00 1215	20.108	0.121
Reservoir-15	132.00	02 Jan 00 1230	20.107	0.121
WB-C2	197.59	02 Jan 00 1215	20.108	0.121
Junction-16	318.71	02 Jan 00 1220	40.215	0.242
16	472.76	02 Jan 00 1220	79.406	0.833
WB-T2A	141.22	02 Jan 00 1220	23.671	0.223
58	109.42	02 Jan 00 1230	23.664	0.223
WB-T2B	116.78	02 Jan 00 1225	20.852	0.202
Junction-17	222.65	02 Jan 00 1225	44.516	0.425
10	113.22	02 Jan 00 1315	44.452	0.425
Junction-18	558.07	02 Jan 00 1220	123.86	1.258
WB-T3A	291.54	02 Jan 00 1220	34.267	0.161
59	265.24	02 Jan 00 1225	34.265	0.161
WB-T3B	280.15	02 Jan 00 1225	40.250	0.273
11	545.39	02 Jan 00 1225	74.515	0.434
Junction-19	1096.7	02 Jan 00 1225	198.37	1.692
WB-D	524.45	02 Jan 00 1220	72.392	0.491
Junction-20	1615.3	02 Jan 00 1225	270.77	2.183
WB-E	656.83	02 Jan 00 1220	78.255	0.380
Junction-21	2256.0	02 Jan 00 1220	349.02	2.563
WB-F	507.33	02 Jan 00 1220	54.486	0.231
31	2763.3	02 Jan 00 1220	403.51	2.794
WB-T1A	116.41	02 Jan 00 1215	14.569	0.087
57	89.169	02 Jan 00 1225	14.567	0.087
WB-T1B	209.44	02 Jan 00 1220	35.815	0.388
88	291.30	02 Jan 00 1220	50.382	0.475
56	227.80	02 Jan 00 1235	50.355	0.475
WB-T1C	469.83	02 Jan 00 1225	56.980	0.351

Hydrologic Element	Discharge Peak (cfs)	Time of Peak		Total Volume (ac ft)	Drainage Area (sq mi)
29	675.96	02 Jan 00	1225	107.34	0.826
Junction-22	3409.6	02 Jan 00	1220	510.84	3.620
WB-G	738.54	02 Jan 00	1220	82.942	0.376
90	4148.1	02 Jan 00	1220	593.78	3.996
WB-H	402.05	02 Jan 00	1220	49.955	0.292
92	4550.2	02 Jan 00	1220	643.74	4.288
Junction-23	8814.8	02 Jan 00	1225	2869.5	21.526
Reservoir-20	8346.4	02 Jan 00	1235	2865.1	21.526
WB-M	793.92	02 Jan 00	1220	107.18	0.709
Junction-24	8884.2	02 Jan 00	1235	2972.3	22.235
T4-A	360.78	02 Jan 00	1220	55.398	0.437
48	269.74	02 Jan 00	1235	55.367	0.437
T4-B	343.47	02 Jan 00	1215	36.602	0.173
40	552.50	02 Jan 00	1220	91.969	0.610
T4-C	927.18	02 Jan 00	1230	141.21	0.793
Junction-25	1426.5	02 Jan 00	1230	233.18	1.403
T4-D	323.96	02 Jan 00	1220	38.321	0.207
42	1715.4	02 Jan 00	1225	271.50	1.610
T4-E	637.24	02 Jan 00	1225	85.388	0.369
41	2352.7	02 Jan 00	1225	356.89	1.979
Junction-26	11027	02 Jan 00	1230	3329.2	24.214
Reservoir-22	10497	02 Jan 00	1240	3325.7	24.214
T13-A	1160.3	02 Jan 00	1225	153.40	0.945
44	11412	02 Jan 00	1240	3479.1	25.159
T3-A1	40.144	02 Jan 00	1235	9.3446	0.142
T3-A2	38.615	02 Jan 00	1240	9.3442	0.142
Junction-27	78.661	02 Jan 00	1235	18.689	0.284
Junction-28	11490	02 Jan 00	1240	3497.8	25.443
W-N	78.679	02 Jan 00	1250	27.136	0.543
Junction-29	11565	02 Jan 00	1240	3524.9	25.986
T2-A	176.55	02 Jan 00	1225	43.837	0.623
Junction-30	11713	02 Jan 00	1240	3568.7	26.609
W-O	110.96	02 Jan 00	1235	26.651	0.405
Junction-31	11824	02 Jan 00	1240	3595.4	27.014
T14-A	607.32	02 Jan 00	1225	111.73	1.001
Junction-32	12314	02 Jan 00	1240	3707.1	28.015
W-P	227.96	02 Jan 00	1240	56.194	0.854
Junction-33	12542	02 Jan 00	1240	3763.3	28.869

Hydrologic Element	Discharge Peak (cfs)	Time of Peak	Total Volume (ac ft)	Drainage Area (sq mi)
T18-A	388.74	02 Jan 00 1220	54.952	0.458
Junction-34	12784	02 Jan 00 1240	3818.3	29.327
W-Q	1800.0	02 Jan 00 1230	248.84	1.057
Junction-35	14442	02 Jan 00 1235	4067.1	30.384
FB-A	567.72	02 Jan 00 1225	65.244	0.398
Reservoir-28	415.55	02 Jan 00 1235	65.203	0.398
FB-B	245.46	02 Jan 00 1230	46.060	0.428
Junction-36	651.37	02 Jan 00 1235	111.26	0.826
Reservoir-29	641.20	02 Jan 00 1240	111.25	0.826
FB-T1A	201.58	02 Jan 00 1225	32.774	0.278
Junction-37	810.43	02 Jan 00 1235	144.03	1.104
FB-C	571.99	02 Jan 00 1225	72.887	0.449
Junction-38	1333.5	02 Jan 00 1230	216.91	1.553
FB-D	119.85	02 Jan 00 1225	17.913	0.146
Junction-39	1442.5	02 Jan 00 1230	234.83	1.699
Junction-40	15839	02 Jan 00 1235	4301.9	32.083
W-R	530.28	02 Jan 00 1225	70.378	0.429
Junction-41	16274	02 Jan 00 1235	4372.3	32.512
T11-A	161.80	02 Jan 00 1220	23.718	0.177
Reservoir-33	140.97	02 Jan 00 1225	23.717	0.177
T11-B	177.45	02 Jan 00 1220	34.053	0.365
Junction-42	317.68	02 Jan 00 1225	57.770	0.542
T11-C	363.96	02 Jan 00 1220	40.331	0.245
96	671.16	02 Jan 00 1220	98.100	0.787
Junction-43	16800	02 Jan 00 1235	4470.4	33.299
T1-A	187.85	02 Jan 00 1220	36.599	0.388
Reservoir-36	155.43	02 Jan 00 1235	36.585	0.388
T1-B	613.16	02 Jan 00 1220	72.616	0.391
Junction-44	733.87	02 Jan 00 1220	109.20	0.779
T1-T1A	459.00	02 Jan 00 1225	71.234	0.829
T1-T1B	113.45	02 Jan 00 1220	18.418	0.165
Junction-45	561.84	02 Jan 00 1225	89.652	0.994
Junction-46	1295.2	02 Jan 00 1225	198.85	1.773
Reservoir-38	949.57	02 Jan 00 1240	198.53	1.773
T1-C	270.19	02 Jan 00 1225	45.665	0.385
Junction-47	1168.1	02 Jan 00 1235	244.20	2.158
T1-T2A	344.26	02 Jan 00 1225	67.557	0.791
Junction-48	1458.6	02 Jan 00 1230	311.75	2.949

Hydrologic Element	Discharge Peak (cfs)	Time of Peak	Total Volume (ac ft)	Drainage Area (sq mi)
Subbasin-1	198.43	02 Jan 00 1225	43.864	0.674
Junction-49	1651.2	02 Jan 00 1230	355.62	3.623
Reservoir-40	1407.3	02 Jan 00 1250	354.82	3.623
74	18052	02 Jan 00 1235	4825.2	36.922
W-S	283.24	02 Jan 00 1230	56.180	0.515
98	18323	02 Jan 00 1235	4881.4	37.437
W-T	149.72	02 Jan 00 1235	39.172	0.532
97	18473	02 Jan 00 1235	4920.6	37.969
Junction-50	18473	02 Jan 00 1235	4920.6	37.969

HMS * Summary of Results

Project : thesis   Run Name : Run 6

Start of Simulation : 01Jan00 2400   Basin Model : 1960wal
End of Simulation : 03Jan00 0055   Precip Model : Precip 100
Execution Time : 29Sep01 1251   Control Specs : wln100ex.ih1.basin

Hydrologic Element	Discharge Peak (cfs)	Time of Peak	Total Volume (ac ft)	Drainage Area (sq mi)
W-A1	256.44	02 Jan 00 1245	48.225	0.270
W-A2	252.41	02 Jan 00 1240	46.082	0.258
28	506.76	02 Jan 00 1240	94.307	0.528
Reservoir-1	446.20	02 Jan 00 1255	94.304	0.528
W-B	810.91	02 Jan 00 1240	140.97	0.642
19	1187.1	02 Jan 00 1245	235.27	1.170
27	1104.2	02 Jan 00 1255	235.26	1.170
W-C	558.07	02 Jan 00 1250	111.81	0.626
12	1651.2	02 Jan 00 1255	347.07	1.796
Reservoir-2	1627.9	02 Jan 00 1300	347.07	1.796
T17-A	346.30	02 Jan 00 1245	66.622	0.373
15	1943.5	02 Jan 00 1255	413.69	2.169
26	1585.7	02 Jan 00 1325	413.45	2.169
W-D	626.72	02 Jan 00 1250	125.56	0.703
Junction-1	2042.3	02 Jan 00 1320	539.02	2.872
Reservoir-3	1981.2	02 Jan 00 1330	538.76	2.872
T9-A	556.60	02 Jan 00 1250	112.34	0.629
73	489.00	02 Jan 00 1305	112.33	0.629
T9-B	412.21	02 Jan 00 1245	79.303	0.444
14	842.51	02 Jan 00 1300	191.63	1.073
25	2677.9	02 Jan 00 1325	730.39	3.945
Reservoir-5	2640.0	02 Jan 00 1335	730.23	3.945
W-E	326.93	02 Jan 00 1240	64.009	0.326
Junction-2	2821.7	02 Jan 00 1330	794.24	4.271
Reservoir-6	2798.0	02 Jan 00 1335	794.08	4.271
T8-A	281.46	02 Jan 00 1240	51.976	0.291
T8-B	424.96	02 Jan 00 1240	76.803	0.430
3	706.42	02 Jan 00 1240	128.78	0.721
T8-C2	126.79	02 Jan 00 1235	21.784	0.099
T8-C3	365.50	02 Jan 00 1240	65.352	0.297

Hydrologic Element	Discharge Peak (cfs)	Time of Peak	Total Volume (ac ft)	Drainage Area (sq mi)
72	488.92	02 Jan 00 1240	87.135	0.396
T8-C1	243.67	02 Jan 00 1240	43.568	0.198
Junction-3	732.59	02 Jan 00 1240	130.70	0.594
Reservoir-7	598.75	02 Jan 00 1255	130.68	0.594
8	1262.1	02 Jan 00 1245	259.46	1.315
T8-D1	377.48	02 Jan 00 1235	67.620	0.273
T8-D2	131.05	02 Jan 00 1235	22.540	0.091
Junction-4	508.53	02 Jan 00 1235	90.160	0.364
17	1734.2	02 Jan 00 1245	349.62	1.679
71	1433.5	02 Jan 00 1305	349.52	1.679
T8-E	775.71	02 Jan 00 1240	144.07	0.551
87	2017.4	02 Jan 00 1255	493.59	2.230
70	1932.9	02 Jan 00 1305	493.48	2.230
T8-F	457.38	02 Jan 00 1245	89.242	0.347
21	2296.4	02 Jan 00 1300	582.73	2.577
Reservoir-8	2240.7	02 Jan 00 1315	582.58	2.577
T8-G	426.05	02 Jan 00 1245	82.697	0.463
Junction-5	2576.5	02 Jan 00 1310	665.28	3.040
24	5137.6	02 Jan 00 1330	1459.4	7.311
Reservoir-10	4998.6	02 Jan 00 1340	1458.7	7.311
W-F	97.166	02 Jan 00 1245	18.397	0.103
34	5049.5	02 Jan 00 1340	1477.1	7.414
T7-A	950.04	02 Jan 00 1245	203.38	0.682
69	746.42	02 Jan 00 1310	202.97	0.682
T7-B	612.82	02 Jan 00 1300	133.06	0.745
Junction-6	1344.3	02 Jan 00 1305	336.03	1.427
Junction-7	6155.2	02 Jan 00 1335	1813.1	8.841
23	6016.4	02 Jan 00 1345	1811.6	8.841
W-G	229.26	02 Jan 00 1250	45.367	0.254
35	6141.0	02 Jan 00 1345	1857.0	9.095
T6-A	878.84	02 Jan 00 1250	180.39	1.010
65	552.01	02 Jan 00 1340	180.08	1.010
T6-B	1113.3	02 Jan 00 1245	229.01	0.724
Junction-8	1423.3	02 Jan 00 1250	409.10	1.734
64	1383.9	02 Jan 00 1305	409.07	1.734
T6-C	625.12	02 Jan 00 1300	138.24	0.774
33	2007.9	02 Jan 00 1300	547.31	2.508
T6T1-A	904.88	02 Jan 00 1240	174.44	0.561

Hydrologic Element	Discharge Peak (cfs)	Time of Peak	Total Volume (ac ft)	Drainage Area (sq mi)
67	896.14	02 Jan 00 1240	174.44	0.561
T6T1-B	155.78	02 Jan 00 1240	27.506	0.154
45	1051.9	02 Jan 00 1240	201.94	0.715
66	955.65	02 Jan 00 1255	201.91	0.715
T6T1-C	115.02	02 Jan 00 1245	22.326	0.125
43	1067.0	02 Jan 00 1250	224.24	0.840
Junction-9	3047.6	02 Jan 00 1300	771.55	3.348
63	2852.8	02 Jan 00 1315	771.34	3.348
T6-D	536.98	02 Jan 00 1240	106.63	0.340
36	3220.2	02 Jan 00 1310	877.97	3.688
Junction-10	8872.1	02 Jan 00 1335	2735.0	12.783
22	8742.1	02 Jan 00 1345	2733.4	12.783
W-H	607.10	02 Jan 00 1250	123.60	0.692
39	9094.5	02 Jan 00 1345	2857.0	13.475
T5-A	195.50	02 Jan 00 1240	35.008	0.196
62	163.28	02 Jan 00 1255	35.007	0.196
T5-B	268.00	02 Jan 00 1250	55.011	0.308
46	430.03	02 Jan 00 1255	90.018	0.504
Junction-11	9357.9	02 Jan 00 1345	2947.0	13.979
Reservoir-11	9247.5	02 Jan 00 1355	2946.1	13.979
W-I1	693.83	02 Jan 00 1235	151.08	0.450
9	520.81	02 Jan 00 1255	151.08	0.450
W-I2	696.29	02 Jan 00 1240	157.46	0.469
Junction-12	1201.8	02 Jan 00 1240	308.53	0.919
38	9846.0	02 Jan 00 1345	3254.6	14.898
T16-A	283.28	02 Jan 00 1240	50.726	0.284
20	9971.3	02 Jan 00 1345	3305.4	15.182
W-J	210.08	02 Jan 00 1240	37.330	0.209
Junction-13	10063	02 Jan 00 1345	3342.7	15.391
T15-A	643.41	02 Jan 00 1240	119.88	0.465
93	10317	02 Jan 00 1345	3462.6	15.856
W-K	72.027	02 Jan 00 1235	12.324	0.069
95	10346	02 Jan 00 1345	3474.9	15.925
TB-A	233.23	02 Jan 00 1240	42.152	0.236
61	168.16	02 Jan 00 1305	42.145	0.236
TB-B	237.21	02 Jan 00 1245	46.086	0.192
Junction-14	396.15	02 Jan 00 1250	88.231	0.428
60	333.44	02 Jan 00 1320	88.194	0.428

Hydrologic Element	Discharge Peak (cfs)	Time of Peak	Total Volume (ac ft)	Drainage Area (sq mi)
TB-C	430.27	02 Jan 00 1240	85.492	0.278
91	653.24	02 Jan 00 1250	173.69	0.706
Junction-15	10818	02 Jan 00 1345	3648.6	16.631
W-L	754.14	02 Jan 00 1245	136.41	0.607
50	11159	02 Jan 00 1345	3785.0	17.238
WB-A	259.34	02 Jan 00 1240	46.439	0.260
55	212.94	02 Jan 00 1255	46.437	0.260
WB-B	330.16	02 Jan 00 1240	59.120	0.331
4	516.90	02 Jan 00 1245	105.56	0.591
54	476.55	02 Jan 00 1300	105.55	0.591
WB-C1	123.06	02 Jan 00 1240	21.612	0.121
Reservoir-15	113.14	02 Jan 00 1245	21.612	0.121
WB-C2	123.06	02 Jan 00 1240	21.612	0.121
Junction-16	231.51	02 Jan 00 1240	43.224	0.242
16	681.17	02 Jan 00 1255	148.77	0.833
WB-T2A	224.15	02 Jan 00 1240	39.830	0.223
58	191.26	02 Jan 00 1250	39.829	0.223
WB-T2B	192.85	02 Jan 00 1245	36.079	0.202
Junction-17	375.96	02 Jan 00 1250	75.908	0.425
10	218.28	02 Jan 00 1340	75.893	0.425
Junction-18	829.93	02 Jan 00 1300	224.67	1.258
WB-T3A	328.70	02 Jan 00 1230	67.596	0.161
59	326.10	02 Jan 00 1235	67.596	0.161
WB-T3B	399.73	02 Jan 00 1240	75.170	0.273
11	721.99	02 Jan 00 1240	142.77	0.434
Junction-19	1463.0	02 Jan 00 1245	367.43	1.692
WB-D	474.90	02 Jan 00 1240	87.698	0.491
Junction-20	1933.9	02 Jan 00 1245	455.13	2.183
WB-E	367.54	02 Jan 00 1240	67.872	0.380
Junction-21	2298.3	02 Jan 00 1245	523.00	2.563
WB-F	228.29	02 Jan 00 1240	41.259	0.231
31	2520.9	02 Jan 00 1245	564.26	2.794
WB-T1A	88.478	02 Jan 00 1240	15.539	0.087
57	76.539	02 Jan 00 1250	15.539	0.087
WB-T1B	476.93	02 Jan 00 1240	82.725	0.388
88	547.16	02 Jan 00 1240	98.264	0.475
56	491.73	02 Jan 00 1255	98.259	0.475
WB-T1C	428.13	02 Jan 00 1240	74.836	0.351

Hydrologic Element	Discharge Peak (cfs)	Time of Peak	Total Volume (ac ft)	Drainage Area (sq mi)
29	891.15	02 Jan 00 1245	173.09	0.826
Junction-22	3412.0	02 Jan 00 1245	737.36	3.620
WB-G	440.28	02 Jan 00 1240	77.209	0.376
90	3841.7	02 Jan 00 1245	814.57	3.996
WB-H	282.43	02 Jan 00 1240	52.155	0.292
92	4121.7	02 Jan 00 1245	866.72	4.288
Junction-23	13506	02 Jan 00 1335	4651.7	21.526
Reservoir-20	13414	02 Jan 00 1345	4649.7	21.526
WB-M	1082.8	02 Jan 00 1235	197.32	0.709
Junction-24	13810	02 Jan 00 1340	4847.0	22.235
T4-A	685.61	02 Jan 00 1240	141.69	0.437
48	643.51	02 Jan 00 1245	141.68	0.437
T4-B	173.89	02 Jan 00 1240	30.900	0.173
40	810.01	02 Jan 00 1245	172.58	0.610
T4-C	948.94	02 Jan 00 1245	191.79	0.793
Junction-25	1759.0	02 Jan 00 1245	364.37	1.403
T4-D	295.93	02 Jan 00 1235	52.857	0.207
42	2030.2	02 Jan 00 1245	417.23	1.610
T4-E	486.59	02 Jan 00 1245	94.222	0.369
41	2516.8	02 Jan 00 1245	511.45	1.979
Junction-26	15152	02 Jan 00 1330	5358.5	24.214
Reservoir-22	15138	02 Jan 00 1335	5356.8	24.214
T13-A	852.97	02 Jan 00 1250	168.79	0.945
44	15686	02 Jan 00 1325	5525.5	25.159
T3-A1	141.64	02 Jan 00 1240	25.363	0.142
T3-A2	134.87	02 Jan 00 1245	25.363	0.142
Junction-27	275.41	02 Jan 00 1240	50.726	0.284
Junction-28	15847	02 Jan 00 1325	5576.3	25.443
W-N	729.23	02 Jan 00 1235	122.03	0.543
Junction-29	16214	02 Jan 00 1315	5698.3	25.986
T2-A	778.05	02 Jan 00 1245	140.01	0.623
Junction-30	16750	02 Jan 00 1310	5838.3	26.609
W-O	386.66	02 Jan 00 1245	72.338	0.405
Junction-31	17032	02 Jan 00 1310	5910.6	27.014
T14-A	929.34	02 Jan 00 1245	178.79	1.001
Junction-32	17801	02 Jan 00 1305	6089.4	28.015
W-P	792.86	02 Jan 00 1245	152.53	0.854
Junction-33	18488	02 Jan 00 1300	6242.0	28.869

Hydrologic Element	Discharge Peak (cfs)	Time of Peak	Total Volume (ac ft)	Drainage Area (sq mi)
T18-A	425.21	02 Jan 00 1245	81.804	0.458
Junction-34	18863	02 Jan 00 1300	6323.8	29.327
W-Q	906.31	02 Jan 00 1255	188.79	1.057
Junction-35	19750	02 Jan 00 1300	6512.6	30.384
FB-A	546.69	02 Jan 00 1240	96.012	0.398
Reservoir-28	474.41	02 Jan 00 1255	96.005	0.398
FB-B	561.55	02 Jan 00 1240	100.08	0.428
Junction-36	1015.8	02 Jan 00 1245	196.08	0.826
Reservoir-29	1012.8	02 Jan 00 1250	196.08	0.826
FB-T1A	423.54	02 Jan 00 1235	72.218	0.278
Junction-37	1401.7	02 Jan 00 1245	268.30	1.104
FB-C	667.93	02 Jan 00 1240	116.64	0.449
Junction-38	2055.3	02 Jan 00 1245	384.94	1.553
FB-D	225.84	02 Jan 00 1235	37.927	0.146
Junction-39	2264.5	02 Jan 00 1245	422.86	1.699
Junction-40	21771	02 Jan 00 1255	6935.4	32.083
W-R	401.70	02 Jan 00 1245	76.624	0.429
Junction-41	22144	02 Jan 00 1255	7012.0	32.512
T11-A	211.62	02 Jan 00 1235	39.594	0.177
Reservoir-33	205.21	02 Jan 00 1240	39.594	0.177
T11-B	580.17	02 Jan 00 1235	99.733	0.365
Junction-42	773.11	02 Jan 00 1240	139.33	0.542
T11-C	248.14	02 Jan 00 1240	46.367	0.245
96	1021.3	02 Jan 00 1240	185.69	0.787
Junction-43	22963	02 Jan 00 1255	7197.7	33.299
T1-A	476.93	02 Jan 00 1240	82.725	0.388
Reservoir-36	435.92	02 Jan 00 1250	82.722	0.388
T1-B	457.85	02 Jan 00 1240	80.289	0.391
Junction-44	874.55	02 Jan 00 1245	163.01	0.779
T1-T1A	743.54	02 Jan 00 1250	148.07	0.829
T1-T1B	261.44	02 Jan 00 1235	42.863	0.165
Junction-45	965.87	02 Jan 00 1245	190.93	0.994
Junction-46	1840.4	02 Jan 00 1245	353.94	1.773
Reservoir-38	1489.9	02 Jan 00 1305	353.85	1.773
T1-C	583.82	02 Jan 00 1240	100.01	0.385
Junction-47	1897.8	02 Jan 00 1300	453.86	2.158
T1-T2A	987.87	02 Jan 00 1245	177.76	0.791
Junction-48	2818.9	02 Jan 00 1250	631.62	2.949

Hydrologic Element	Discharge Peak (cfs)	Time of Peak	Total Volume (ac ft)	Drainage Area (sq mi)
Subbasin-1	831.39	02 Jan 00 1245	165.15	0.674
Junction-49	3635.2	02 Jan 00 1250	796.78	3.623
Reservoir-40	2695.7	02 Jan 00 1325	796.51	3.623
74	25302	02 Jan 00 1255	7994.2	36.922
W-S	615.57	02 Jan 00 1245	124.76	0.515
98	25882	02 Jan 00 1255	8119.0	37.437
W-T	608.66	02 Jan 00 1245	120.10	0.532
97	26460	02 Jan 00 1255	8239.1	37.969
Junction-50	26460	02 Jan 00 1255	8239.1	37.969

HMS * Summary of Results

Project : thesis Run Name : Run 7

Start of Simulation : 01Jan00 2400 Basin Model : 1970wal
End of Simulation : 03Jan00 0055 Precip Model : Precip 100
Execution Time : 29Sep01 1318 Control Specs : wln100ex.ih1.basin

Hydrologic Element	Discharge Peak (cfs)	Time of Peak	Total Volume (ac ft)	Drainage Area (sq mi)
W-A1	256.44	02 Jan 00 1245	48.225	0.270
W-A2	252.41	02 Jan 00 1240	46.082	0.258
28	506.76	02 Jan 00 1240	94.307	0.528
Reservoir-1	446.20	02 Jan 00 1255	94.304	0.528
W-B	810.91	02 Jan 00 1240	140.97	0.642
19	1187.1	02 Jan 00 1245	235.27	1.170
27	1104.2	02 Jan 00 1255	235.26	1.170
W-C	558.07	02 Jan 00 1250	111.81	0.626
12	1651.2	02 Jan 00 1255	347.07	1.796
Reservoir-2	1627.9	02 Jan 00 1300	347.07	1.796
T17-A	346.30	02 Jan 00 1245	66.622	0.373
15	1943.5	02 Jan 00 1255	413.69	2.169
26	1585.7	02 Jan 00 1325	413.45	2.169
W-D	626.72	02 Jan 00 1250	125.56	0.703
Junction-1	2042.3	02 Jan 00 1320	539.02	2.872
Reservoir-3	1981.2	02 Jan 00 1330	538.76	2.872
T9-A	556.60	02 Jan 00 1250	112.34	0.629
73	489.00	02 Jan 00 1305	112.33	0.629
T9-B	412.21	02 Jan 00 1245	79.303	0.444
14	842.51	02 Jan 00 1300	191.63	1.073
25	2677.9	02 Jan 00 1325	730.39	3.945
Reservoir-5	2640.0	02 Jan 00 1335	730.23	3.945
W-E	660.56	02 Jan 00 1235	135.33	0.326
Junction-2	2893.9	02 Jan 00 1330	865.56	4.271
Reservoir-6	2871.7	02 Jan 00 1335	865.40	4.271
T8-A	281.46	02 Jan 00 1240	51.976	0.291
T8-B	424.96	02 Jan 00 1240	76.803	0.430
3	706.42	02 Jan 00 1240	128.78	0.721
T8-C2	126.79	02 Jan 00 1235	21.784	0.099
T8-C3	365.50	02 Jan 00 1240	65.352	0.297

Hydrologic Element	Discharge Peak (cfs)	Time of Peak	Total Volume (ac ft)	Drainage Area (sq mi)
72	488.92	02 Jan 00 1240	87.135	0.396
T8-C1	243.67	02 Jan 00 1240	43.568	0.198
Junction-3	732.59	02 Jan 00 1240	130.70	0.594
Reservoir-7	598.75	02 Jan 00 1255	130.68	0.594
8	1262.1	02 Jan 00 1245	259.46	1.315
T8-D1	377.48	02 Jan 00 1235	67.620	0.273
T8-D2	131.05	02 Jan 00 1235	22.540	0.091
Junction-4	508.53	02 Jan 00 1235	90.160	0.364
17	1734.2	02 Jan 00 1245	349.62	1.679
71	1433.5	02 Jan 00 1305	349.52	1.679
T8-E	775.71	02 Jan 00 1240	144.07	0.551
87	2017.4	02 Jan 00 1255	493.59	2.230
70	1932.9	02 Jan 00 1305	493.48	2.230
T8-F	457.38	02 Jan 00 1245	89.242	0.347
21	2296.4	02 Jan 00 1300	582.73	2.577
Reservoir-8	2240.7	02 Jan 00 1315	582.58	2.577
T8-G	426.05	02 Jan 00 1245	82.697	0.463
Junction-5	2576.5	02 Jan 00 1310	665.28	3.040
24	5222.2	02 Jan 00 1325	1530.7	7.311
Reservoir-10	5098.1	02 Jan 00 1340	1530.0	7.311
W-F	97.166	02 Jan 00 1245	18.397	0.103
34	5149.0	02 Jan 00 1340	1548.4	7.414
T7-A	1172.1	02 Jan 00 1240	239.52	0.682
69	932.97	02 Jan 00 1305	239.09	0.682
T7-B	612.82	02 Jan 00 1300	133.06	0.745
Junction-6	1540.9	02 Jan 00 1300	372.15	1.427
Junction-7	6400.6	02 Jan 00 1335	1920.6	8.841
23	6279.6	02 Jan 00 1345	1919.0	8.841
W-G	229.26	02 Jan 00 1250	45.367	0.254
35	6404.2	02 Jan 00 1345	1964.4	9.095
T6-A	878.84	02 Jan 00 1250	180.39	1.010
65	552.01	02 Jan 00 1340	180.08	1.010
T6-B	1113.3	02 Jan 00 1245	229.01	0.724
Junction-8	1423.3	02 Jan 00 1250	409.10	1.734
64	1383.9	02 Jan 00 1305	409.07	1.734
T6-C	625.12	02 Jan 00 1300	138.24	0.774
33	2007.9	02 Jan 00 1300	547.31	2.508
T6T1-A	904.88	02 Jan 00 1240	174.44	0.561

Hydrologic Element	Discharge Peak (cfs)	Time of Peak	Total Volume (ac ft)	Drainage Area (sq mi)
67	896.14	02 Jan 00 1240	174.44	0.561
T6T1-B	155.78	02 Jan 00 1240	27.506	0.154
45	1051.9	02 Jan 00 1240	201.94	0.715
66	955.65	02 Jan 00 1255	201.91	0.715
T6T1-C	115.02	02 Jan 00 1245	22.326	0.125
43	1067.0	02 Jan 00 1250	224.24	0.840
Junction-9	3047.6	02 Jan 00 1300	771.55	3.348
63	2852.8	02 Jan 00 1315	771.34	3.348
T6-D	633.54	02 Jan 00 1240	132.50	0.340
36	3260.6	02 Jan 00 1310	903.84	3.688
Junction-10	9227.6	02 Jan 00 1330	2868.3	12.783
22	9099.5	02 Jan 00 1345	2866.7	12.783
W-H	607.10	02 Jan 00 1250	123.60	0.692
39	9464.0	02 Jan 00 1340	2990.3	13.475
T5-A	195.50	02 Jan 00 1240	35.008	0.196
62	163.28	02 Jan 00 1255	35.007	0.196
T5-B	268.00	02 Jan 00 1250	55.011	0.308
46	430.03	02 Jan 00 1255	90.018	0.504
Junction-11	9742.4	02 Jan 00 1340	3080.3	13.979
Reservoir-11	9628.7	02 Jan 00 1350	3079.4	13.979
W-I1	693.83	02 Jan 00 1235	151.08	0.450
9	520.81	02 Jan 00 1255	151.08	0.450
W-I2	696.29	02 Jan 00 1240	157.46	0.469
Junction-12	1201.8	02 Jan 00 1240	308.53	0.919
38	10284	02 Jan 00 1345	3387.9	14.898
T16-A	283.28	02 Jan 00 1240	50.726	0.284
20	10409	02 Jan 00 1345	3438.7	15.182
W-J	210.08	02 Jan 00 1240	37.330	0.209
Junction-13	10500	02 Jan 00 1345	3476.0	15.391
T15-A	643.41	02 Jan 00 1240	119.88	0.465
93	10755	02 Jan 00 1345	3595.9	15.856
W-K	72.027	02 Jan 00 1235	12.324	0.069
95	10784	02 Jan 00 1345	3608.2	15.925
TB-A	233.23	02 Jan 00 1240	42.152	0.236
61	168.16	02 Jan 00 1305	42.145	0.236
TB-B	297.19	02 Jan 00 1245	54.494	0.192
Junction-14	449.53	02 Jan 00 1250	96.639	0.428
60	384.74	02 Jan 00 1310	96.602	0.428

Hydrologic Element	Discharge Peak (cfs)	Time of Peak	Total Volume (ac ft)	Drainage Area (sq mi)
TB-C	430.27	02 Jan 00 1240	85.492	0.278
91	732.16	02 Jan 00 1250	182.09	0.706
Junction-15	11294	02 Jan 00 1340	3790.3	16.631
W-L	754.14	02 Jan 00 1245	136.41	0.607
50	11658	02 Jan 00 1340	3926.7	17.238
WB-A	259.34	02 Jan 00 1240	46.439	0.260
55	212.94	02 Jan 00 1255	46.437	0.260
WB-B	330.16	02 Jan 00 1240	59.120	0.331
4	516.90	02 Jan 00 1245	105.56	0.591
54	476.55	02 Jan 00 1300	105.55	0.591
WB-C1	123.06	02 Jan 00 1240	21.612	0.121
Reservoir-15	113.14	02 Jan 00 1245	21.612	0.121
WB-C2	123.06	02 Jan 00 1240	21.612	0.121
Junction-16	231.51	02 Jan 00 1240	43.224	0.242
16	681.17	02 Jan 00 1255	148.77	0.833
WB-T2A	224.15	02 Jan 00 1240	39.830	0.223
58	191.26	02 Jan 00 1250	39.829	0.223
WB-T2B	192.85	02 Jan 00 1245	36.079	0.202
Junction-17	375.96	02 Jan 00 1250	75.908	0.425
10	218.28	02 Jan 00 1340	75.893	0.425
Junction-18	829.93	02 Jan 00 1300	224.67	1.258
WB-T3A	328.70	02 Jan 00 1230	67.596	0.161
59	326.10	02 Jan 00 1235	67.596	0.161
WB-T3B	399.73	02 Jan 00 1240	75.170	0.273
11	721.99	02 Jan 00 1240	142.77	0.434
Junction-19	1463.0	02 Jan 00 1245	367.43	1.692
WB-D	474.90	02 Jan 00 1240	87.698	0.491
Junction-20	1933.9	02 Jan 00 1245	455.13	2.183
WB-E	367.54	02 Jan 00 1240	67.872	0.380
Junction-21	2298.3	02 Jan 00 1245	523.00	2.563
WB-F	228.29	02 Jan 00 1240	41.259	0.231
31	2520.9	02 Jan 00 1245	564.26	2.794
WB-T1A	88.478	02 Jan 00 1240	15.539	0.087
57	76.539	02 Jan 00 1250	15.539	0.087
WB-T1B	476.93	02 Jan 00 1240	82.725	0.388
88	547.16	02 Jan 00 1240	98.264	0.475
56	491.73	02 Jan 00 1255	98.259	0.475
WB-T1C	428.13	02 Jan 00 1240	74.836	0.351

Hydrologic Element	Discharge Peak (cfs)	Time of Peak	Total Volume (ac ft)	Drainage Area (sq mi)
29	891.15	02 Jan 00 1245	173.09	0.826
Junction-22	3412.0	02 Jan 00 1245	737.36	3.620
WB-G	440.28	02 Jan 00 1240	77.209	0.376
90	3841.7	02 Jan 00 1245	814.57	3.996
WB-H	282.43	02 Jan 00 1240	52.155	0.292
92	4121.7	02 Jan 00 1245	866.72	4.288
Junction-23	14104	02 Jan 00 1330	4793.4	21.526
Reservoir-20	14005	02 Jan 00 1340	4791.4	21.526
WB-M	1082.8	02 Jan 00 1235	197.32	0.709
Junction-24	14420	02 Jan 00 1335	4988.7	22.235
T4-A	685.61	02 Jan 00 1240	141.69	0.437
48	643.51	02 Jan 00 1245	141.68	0.437
T4-B	173.89	02 Jan 00 1240	30.900	0.173
40	810.01	02 Jan 00 1245	172.58	0.610
T4-C	948.94	02 Jan 00 1245	191.79	0.793
Junction-25	1759.0	02 Jan 00 1245	364.37	1.403
T4-D	374.27	02 Jan 00 1235	70.368	0.207
42	2087.6	02 Jan 00 1245	434.74	1.610
T4-E	645.50	02 Jan 00 1240	129.94	0.369
41	2725.2	02 Jan 00 1240	564.68	1.979
Junction-26	15918	02 Jan 00 1320	5553.4	24.214
Reservoir-22	15901	02 Jan 00 1325	5551.6	24.214
T13-A	852.97	02 Jan 00 1250	168.79	0.945
44	16494	02 Jan 00 1320	5720.4	25.159
T3-A1	222.58	02 Jan 00 1235	36.888	0.142
T3-A2	215.33	02 Jan 00 1240	36.888	0.142
Junction-27	437.19	02 Jan 00 1235	73.777	0.284
Junction-28	16712	02 Jan 00 1320	5794.2	25.443
W-N	729.23	02 Jan 00 1235	122.03	0.543
Junction-29	17110	02 Jan 00 1315	5916.2	25.986
T2-A	778.05	02 Jan 00 1245	140.01	0.623
Junction-30	17664	02 Jan 00 1310	6056.2	26.609
W-O	617.03	02 Jan 00 1235	105.21	0.405
Junction-31	18055	02 Jan 00 1305	6161.4	27.014
T14-A	1429.5	02 Jan 00 1240	248.73	1.001
Junction-32	19118	02 Jan 00 1300	6410.2	28.015
W-P	1277.6	02 Jan 00 1240	221.85	0.854
Junction-33	20122	02 Jan 00 1255	6632.0	28.869

Hydrologic Element	Discharge Peak (cfs)	Time of Peak	Total Volume (ac ft)	Drainage Area (sq mi)
T18-A	425.21	02 Jan 00 1245	81.804	0.458
Junction-34	20522	02 Jan 00 1255	6713.8	29.327
W-Q	906.31	02 Jan 00 1255	188.79	1.057
Junction-35	21428	02 Jan 00 1255	6902.6	30.384
FB-A	546.69	02 Jan 00 1240	96.012	0.398
Reservoir-28	474.41	02 Jan 00 1255	96.005	0.398
FB-B	561.55	02 Jan 00 1240	100.08	0.428
Junction-36	1015.8	02 Jan 00 1245	196.08	0.826
Reservoir-29	1012.8	02 Jan 00 1250	196.08	0.826
FB-T1A	423.54	02 Jan 00 1235	72.218	0.278
Junction-37	1401.7	02 Jan 00 1245	268.30	1.104
FB-C	667.93	02 Jan 00 1240	116.64	0.449
Junction-38	2055.3	02 Jan 00 1245	384.94	1.553
FB-D	225.84	02 Jan 00 1235	37.927	0.146
Junction-39	2264.5	02 Jan 00 1245	422.86	1.699
Junction-40	23500	02 Jan 00 1255	7325.5	32.083
W-R	689.07	02 Jan 00 1240	135.55	0.429
Junction-41	24070	02 Jan 00 1250	7461.0	32.512
T11-A	211.62	02 Jan 00 1235	39.594	0.177
Reservoir-33	205.21	02 Jan 00 1240	39.594	0.177
T11-B	580.17	02 Jan 00 1235	99.733	0.365
Junction-42	773.11	02 Jan 00 1240	139.33	0.542
T11-C	423.68	02 Jan 00 1235	75.516	0.245
96	1195.5	02 Jan 00 1235	214.84	0.787
Junction-43	25088	02 Jan 00 1250	7675.9	33.299
T1-A	476.93	02 Jan 00 1240	82.725	0.388
Reservoir-36	435.92	02 Jan 00 1250	82.722	0.388
T1-B	457.85	02 Jan 00 1240	80.289	0.391
Junction-44	874.55	02 Jan 00 1245	163.01	0.779
T1-T1A	743.54	02 Jan 00 1250	148.07	0.829
T1-T1B	261.44	02 Jan 00 1235	42.863	0.165
Junction-45	965.87	02 Jan 00 1245	190.93	0.994
Junction-46	1840.4	02 Jan 00 1245	353.94	1.773
Reservoir-38	1489.9	02 Jan 00 1305	353.85	1.773
T1-C	583.82	02 Jan 00 1240	100.01	0.385
Junction-47	1897.8	02 Jan 00 1300	453.86	2.158
T1-T2A	987.87	02 Jan 00 1245	177.76	0.791
Junction-48	2818.9	02 Jan 00 1250	631.62	2.949

Hydrologic Element	Discharge Peak (cfs)	Time of Peak	Total Volume (ac ft)	Drainage Area (sq mi)
Subbasin-1	831.39	02 Jan 00 1245	165.15	0.674
Junction-49	3635.2	02 Jan 00 1250	796.78	3.623
Reservoir-40	2695.7	02 Jan 00 1325	796.51	3.623
74	27319	02 Jan 00 1255	8472.4	36.922
W-S	615.57	02 Jan 00 1245	124.76	0.515
98	27902	02 Jan 00 1250	8597.1	37.437
W-T	608.66	02 Jan 00 1245	120.10	0.532
97	28504	02 Jan 00 1250	8717.2	37.969
Junction-50	28504	02 Jan 00 1250	8717.2	37.969

HMS * Summary of Results

Project : thesis Run Name : Run 8

Start of Simulation : 01Jan00 2400 Basin Model : 1980wal
End of Simulation : 03Jan00 0055 Precip Model : Precip 100
Execution Time : 29Sep01 1353 Control Specs : wln100ex.ih1.basin

Hydrologic Element	Discharge Peak (cfs)	Time of Peak	Total Volume (ac ft)	Drainage Area (sq mi)
W-A1	256.44	02 Jan 00 1245	48.225	0.270
W-A2	252.41	02 Jan 00 1240	46.082	0.258
28	506.76	02 Jan 00 1240	94.307	0.528
Reservoir-1	446.20	02 Jan 00 1255	94.304	0.528
W-B	810.91	02 Jan 00 1240	140.97	0.642
19	1187.1	02 Jan 00 1245	235.27	1.170
27	1104.2	02 Jan 00 1255	235.26	1.170
W-C	558.07	02 Jan 00 1250	111.81	0.626
12	1651.2	02 Jan 00 1255	347.07	1.796
Reservoir-2	1627.9	02 Jan 00 1300	347.07	1.796
T17-A	346.30	02 Jan 00 1245	66.622	0.373
15	1943.5	02 Jan 00 1255	413.69	2.169
26	1585.7	02 Jan 00 1325	413.45	2.169
W-D	839.78	02 Jan 00 1245	161.07	0.703
Junction-1	2127.0	02 Jan 00 1320	574.53	2.872
Reservoir-3	2074.6	02 Jan 00 1330	574.27	2.872
T9-A	556.60	02 Jan 00 1250	112.34	0.629
73	489.00	02 Jan 00 1305	112.33	0.629
T9-B	548.26	02 Jan 00 1240	101.73	0.444
14	939.19	02 Jan 00 1255	214.06	1.073
25	2836.7	02 Jan 00 1320	788.33	3.945
Reservoir-5	2810.4	02 Jan 00 1330	788.16	3.945
W-E	660.56	02 Jan 00 1235	135.33	0.326
Junction-2	3082.8	02 Jan 00 1325	923.49	4.271
Reservoir-6	3066.1	02 Jan 00 1330	923.33	4.271
T8-A	281.46	02 Jan 00 1240	51.976	0.291
T8-B	424.96	02 Jan 00 1240	76.803	0.430
3	706.42	02 Jan 00 1240	128.78	0.721
T8-C3	365.50	02 Jan 00 1240	65.352	0.297
T8-C2	126.79	02 Jan 00 1235	21.784	0.099

Hydrologic Element	Discharge Peak (cfs)	Time of Peak	Total Volume (ac ft)	Drainage Area (sq mi)
72	488.92	02 Jan 00 1240	87.135	0.396
T8-C1	243.67	02 Jan 00 1240	43.568	0.198
Junction-3	732.59	02 Jan 00 1240	130.70	0.594
Reservoir-7	601.42	02 Jan 00 1255	130.68	0.594
8	1264.8	02 Jan 00 1245	259.46	1.315
T8-D1	377.48	02 Jan 00 1235	67.620	0.273
T8-D2	131.05	02 Jan 00 1235	22.540	0.091
Junction-4	508.53	02 Jan 00 1235	90.160	0.364
17	1736.8	02 Jan 00 1245	349.62	1.679
71	1433.7	02 Jan 00 1305	349.52	1.679
T8-E	775.71	02 Jan 00 1240	144.07	0.551
87	2016.8	02 Jan 00 1255	493.59	2.230
70	1931.8	02 Jan 00 1305	493.48	2.230
T8-F	457.38	02 Jan 00 1245	89.242	0.347
21	2294.7	02 Jan 00 1300	582.72	2.577
Reservoir-8	2239.6	02 Jan 00 1315	582.58	2.577
T8-G	573.68	02 Jan 00 1240	108.44	0.463
Junction-5	2643.9	02 Jan 00 1310	691.02	3.040
24	5564.9	02 Jan 00 1320	1614.4	7.311
Reservoir-10	5419.8	02 Jan 00 1335	1613.7	7.311
W-F	97.166	02 Jan 00 1245	18.397	0.103
34	5473.7	02 Jan 00 1335	1632.1	7.414
T7-A	1273.3	02 Jan 00 1240	265.08	0.682
69	1030.0	02 Jan 00 1300	264.65	0.682
T7-B	612.82	02 Jan 00 1300	133.06	0.745
Junction-6	1642.8	02 Jan 00 1300	397.71	1.427
Junction-7	6856.9	02 Jan 00 1325	2029.8	8.841
23	6713.4	02 Jan 00 1340	2028.3	8.841
W-G	357.90	02 Jan 00 1240	68.958	0.254
35	6874.1	02 Jan 00 1340	2097.2	9.095
T6-A	987.63	02 Jan 00 1250	198.94	1.010
65	636.54	02 Jan 00 1330	198.62	1.010
T6-B	1113.3	02 Jan 00 1245	229.01	0.724
Junction-8	1497.0	02 Jan 00 1255	427.63	1.734
64	1458.4	02 Jan 00 1305	427.61	1.734
T6-C	817.80	02 Jan 00 1255	176.62	0.774
33	2263.4	02 Jan 00 1300	604.23	2.508
T6T1-A	944.60	02 Jan 00 1240	183.28	0.561

Hydrologic Element	Discharge Peak (cfs)	Time of Peak	Total Volume (ac ft)	Drainage Area (sq mi)
67	939.27	02 Jan 00 1240	183.28	0.561
T6T1-B	303.41	02 Jan 00 1230	59.458	0.154
45	1222.7	02 Jan 00 1240	242.74	0.715
66	1137.3	02 Jan 00 1250	242.71	0.715
T6T1-C	237.65	02 Jan 00 1235	46.230	0.125
43	1357.2	02 Jan 00 1245	288.94	0.840
Junction-9	3554.4	02 Jan 00 1255	893.16	3.348
63	3290.9	02 Jan 00 1310	892.95	3.348
T6-D	633.54	02 Jan 00 1240	132.50	0.340
36	3721.5	02 Jan 00 1305	1025.5	3.688
Junction-10	10181	02 Jan 00 1330	3122.7	12.783
22	10033	02 Jan 00 1340	3121.0	12.783
W-H	1273.1	02 Jan 00 1240	263.77	0.692
39	10581	02 Jan 00 1335	3384.8	13.475
T5-A	261.51	02 Jan 00 1235	46.780	0.196
62	235.68	02 Jan 00 1245	46.779	0.196
T5-B	268.00	02 Jan 00 1250	55.011	0.308
46	502.23	02 Jan 00 1250	101.79	0.504
Junction-11	10895	02 Jan 00 1335	3486.6	13.979
Reservoir-11	10770	02 Jan 00 1345	3485.7	13.979
W-I1	693.83	02 Jan 00 1235	151.08	0.450
9	520.81	02 Jan 00 1255	151.08	0.450
W-I2	696.29	02 Jan 00 1240	157.46	0.469
Junction-12	1201.8	02 Jan 00 1240	308.53	0.919
38	11487	02 Jan 00 1340	3794.2	14.898
T16-A	283.28	02 Jan 00 1240	50.726	0.284
20	11620	02 Jan 00 1340	3845.0	15.182
W-J	266.98	02 Jan 00 1235	47.490	0.209
Junction-13	11726	02 Jan 00 1340	3892.5	15.391
T15-A	728.05	02 Jan 00 1240	138.42	0.465
93	12012	02 Jan 00 1340	4030.9	15.856
W-K	72.027	02 Jan 00 1235	12.324	0.069
95	12043	02 Jan 00 1340	4043.2	15.925
TB-A	313.73	02 Jan 00 1235	53.036	0.236
61	214.01	02 Jan 00 1305	53.028	0.236
TB-B	297.19	02 Jan 00 1245	54.494	0.192
Junction-14	496.47	02 Jan 00 1245	107.52	0.428
60	435.54	02 Jan 00 1310	107.48	0.428

Hydrologic Element	Discharge Peak (cfs)	Time of Peak	Total Volume (ac ft)	Drainage Area (sq mi)
TB-C	394.85	02 Jan 00 1240	72.595	0.278
91	765.25	02 Jan 00 1255	180.08	0.706
Junction-15	12612	02 Jan 00 1335	4223.3	16.631
W-L	754.14	02 Jan 00 1245	136.41	0.607
50	13000	02 Jan 00 1335	4359.7	17.238
WB-A	259.34	02 Jan 00 1240	46.439	0.260
55	212.94	02 Jan 00 1255	46.437	0.260
WB-B	330.16	02 Jan 00 1240	59.120	0.331
4	516.90	02 Jan 00 1245	105.56	0.591
54	476.55	02 Jan 00 1300	105.55	0.591
WB-C1	123.06	02 Jan 00 1240	21.612	0.121
Reservoir-15	113.14	02 Jan 00 1245	21.612	0.121
WB-C2	123.06	02 Jan 00 1240	21.612	0.121
Junction-16	231.51	02 Jan 00 1240	43.224	0.242
16	681.17	02 Jan 00 1255	148.77	0.833
WB-T2A	224.15	02 Jan 00 1240	39.830	0.223
58	191.26	02 Jan 00 1250	39.829	0.223
WB-T2B	192.85	02 Jan 00 1245	36.079	0.202
Junction-17	375.96	02 Jan 00 1250	75.908	0.425
10	218.28	02 Jan 00 1340	75.893	0.425
Junction-18	829.93	02 Jan 00 1300	224.67	1.258
WB-T3A	328.70	02 Jan 00 1230	67.596	0.161
59	326.10	02 Jan 00 1235	67.596	0.161
WB-T3B	399.73	02 Jan 00 1240	75.170	0.273
11	721.99	02 Jan 00 1240	142.77	0.434
Junction-19	1463.0	02 Jan 00 1245	367.43	1.692
WB-D	474.90	02 Jan 00 1240	87.698	0.491
Junction-20	1933.9	02 Jan 00 1245	455.13	2.183
WB-E	487.38	02 Jan 00 1240	87.067	0.380
Junction-21	2401.9	02 Jan 00 1245	542.20	2.563
WB-F	328.69	02 Jan 00 1235	59.410	0.231
31	2707.9	02 Jan 00 1240	601.61	2.794
WB-T1A	163.49	02 Jan 00 1230	30.958	0.087
57	154.55	02 Jan 00 1240	30.958	0.087
WB-T1B	494.49	02 Jan 00 1240	88.900	0.388
88	649.05	02 Jan 00 1240	119.86	0.475
56	597.70	02 Jan 00 1250	119.85	0.475
WB-T1C	428.13	02 Jan 00 1240	74.836	0.351

Hydrologic Element	Discharge Peak (cfs)	Time of Peak	Total Volume (ac ft)	Drainage Area (sq mi)
29	1009.5	02 Jan 00 1245	194.69	0.826
Junction-22	3717.0	02 Jan 00 1245	796.30	3.620
WB-G	626.46	02 Jan 00 1235	118.94	0.376
90	4317.4	02 Jan 00 1240	915.24	3.996
WB-H	431.34	02 Jan 00 1235	79.535	0.292
92	4747.6	02 Jan 00 1240	994.77	4.288
Junction-23	15839	02 Jan 00 1315	5354.5	21.526
Reservoir-20	15753	02 Jan 00 1330	5352.4	21.526
WB-M	1082.8	02 Jan 00 1235	197.32	0.709
Junction-24	16234	02 Jan 00 1325	5549.7	22.235
T4-A	685.61	02 Jan 00 1240	141.69	0.437
48	643.51	02 Jan 00 1245	141.68	0.437
T4-B	333.40	02 Jan 00 1230	65.052	0.173
40	943.51	02 Jan 00 1240	206.74	0.610
T4-C	1372.9	02 Jan 00 1240	276.67	0.793
Junction-25	2316.4	02 Jan 00 1240	483.41	1.403
T4-D	413.43	02 Jan 00 1230	82.430	0.207
42	2708.2	02 Jan 00 1240	565.84	1.610
T4-E	766.67	02 Jan 00 1235	169.65	0.369
41	3465.6	02 Jan 00 1240	735.49	1.979
Junction-26	18488	02 Jan 00 1300	6285.2	24.214
Reservoir-22	18424	02 Jan 00 1310	6283.4	24.214
T13-A	852.97	02 Jan 00 1250	168.79	0.945
44	19150	02 Jan 00 1305	6452.2	25.159
T3-A1	222.58	02 Jan 00 1235	36.888	0.142
T3-A2	215.33	02 Jan 00 1240	36.888	0.142
Junction-27	437.19	02 Jan 00 1235	73.777	0.284
Junction-28	19427	02 Jan 00 1305	6526.0	25.443
W-N	729.23	02 Jan 00 1235	122.03	0.543
Junction-29	19893	02 Jan 00 1305	6648.0	25.986
T2-A	837.98	02 Jan 00 1240	152.88	0.623
Junction-30	20575	02 Jan 00 1300	6800.9	26.609
W-O	617.03	02 Jan 00 1235	105.21	0.405
Junction-31	21017	02 Jan 00 1300	6906.1	27.014
T14-A	1523.4	02 Jan 00 1240	270.82	1.001
Junction-32	22241	02 Jan 00 1255	7176.9	28.015
W-P	1277.6	02 Jan 00 1240	221.85	0.854
Junction-33	23318	02 Jan 00 1255	7398.8	28.869

Hydrologic Element	Discharge Peak (cfs)	Time of Peak	Total Volume (ac ft)	Drainage Area (sq mi)
T18-A	425.21	02 Jan 00 1245	81.804	0.458
Junction-34	23717	02 Jan 00 1255	7480.6	29.327
W-Q	906.31	02 Jan 00 1255	188.79	1.057
Junction-35	24624	02 Jan 00 1255	7669.4	30.384
FB-A	769.73	02 Jan 00 1235	145.91	0.398
Reservoir-28	724.93	02 Jan 00 1245	145.90	0.398
FB-B	702.99	02 Jan 00 1240	133.27	0.428
Junction-36	1424.3	02 Jan 00 1240	279.17	0.826
Reservoir-29	1416.7	02 Jan 00 1245	279.17	0.826
FB-T1A	486.53	02 Jan 00 1235	90.434	0.278
Junction-37	1894.3	02 Jan 00 1240	369.60	1.104
FB-C	853.63	02 Jan 00 1235	166.06	0.449
Junction-38	2739.5	02 Jan 00 1240	535.66	1.553
FB-D	270.31	02 Jan 00 1235	50.025	0.146
Junction-39	3001.4	02 Jan 00 1240	585.69	1.699
Junction-40	27322	02 Jan 00 1250	8255.1	32.083
W-R	745.04	02 Jan 00 1235	146.73	0.429
Junction-41	27977	02 Jan 00 1250	8401.8	32.512
T11-A	317.42	02 Jan 00 1235	60.538	0.177
Reservoir-33	313.28	02 Jan 00 1235	60.537	0.177
T11-B	596.57	02 Jan 00 1235	106.61	0.365
Junction-42	909.86	02 Jan 00 1235	167.15	0.542
T11-C	465.57	02 Jan 00 1235	87.739	0.245
96	1375.4	02 Jan 00 1235	254.89	0.787
Junction-43	29109	02 Jan 00 1250	8656.7	33.299
T1-A	537.46	02 Jan 00 1240	93.025	0.388
Reservoir-36	497.08	02 Jan 00 1250	93.022	0.388
T1-B	724.08	02 Jan 00 1235	136.54	0.391
Junction-44	1185.7	02 Jan 00 1240	229.56	0.779
T1-T1A	743.54	02 Jan 00 1250	148.07	0.829
T1-T1B	261.44	02 Jan 00 1235	42.863	0.165
Junction-45	965.87	02 Jan 00 1245	190.93	0.994
Junction-46	2133.5	02 Jan 00 1240	420.49	1.773
Reservoir-38	1761.1	02 Jan 00 1300	420.40	1.773
T1-C	658.77	02 Jan 00 1235	124.80	0.385
Junction-47	2249.9	02 Jan 00 1255	545.19	2.158
T1-T2A	1102.2	02 Jan 00 1240	216.51	0.791
Junction-48	3297.1	02 Jan 00 1245	761.70	2.949

Hydrologic Element	Discharge Peak (cfs)	Time of Peak	Total Volume (ac ft)	Drainage Area (sq mi)
Subbasin-1	831.39	02 Jan 00 1245	165.15	0.674
Junction-49	4128.5	02 Jan 00 1245	926.86	3.623
Reservoir-40	3047.0	02 Jan 00 1325	926.58	3.623
74	31694	02 Jan 00 1250	9583.3	36.922
W-S	788.57	02 Jan 00 1240	158.74	0.515
98	32448	02 Jan 00 1250	9742.0	37.437
W-T	752.99	02 Jan 00 1245	141.54	0.532
97	33178	02 Jan 00 1250	9883.5	37.969
Junction-50	33178	02 Jan 00 1250	9883.5	37.969

HMS * Summary of Results

Project : thesis Run Name : Run 7

Start of Simulation : 01Jan00 2400 Basin Model : 1990wal
End of Simulation : 03Jan00 0055 Precip Model : Precip 100
Execution Time : 29Sep01 1522 Control Specs : wln100ex.ih1.basin

Hydrologic Element	Discharge Peak (cfs)	Time of Peak	Total Volume (ac ft)	Drainage Area (sq mi)
W-A1	640.09	02 Jan 00 1230	133.59	0.270
W-A2	614.64	02 Jan 00 1230	127.66	0.258
28	1254.7	02 Jan 00 1230	261.25	0.528
Reservoir-1	1213.0	02 Jan 00 1240	261.25	0.528
W-B	1054.0	02 Jan 00 1235	182.57	0.642
19	2264.6	02 Jan 00 1235	443.82	1.170
27	2144.5	02 Jan 00 1245	443.81	1.170
W-C	798.67	02 Jan 00 1245	162.58	0.626
12	2943.2	02 Jan 00 1245	606.40	1.796
Reservoir-2	2898.4	02 Jan 00 1250	606.40	1.796
T17-A	400.91	02 Jan 00 1245	70.244	0.373
15	3287.1	02 Jan 00 1250	676.64	2.169
26	2998.1	02 Jan 00 1305	676.48	2.169
W-D	1090.2	02 Jan 00 1240	213.33	0.703
Junction-1	3878.9	02 Jan 00 1300	889.81	2.872
Reservoir-3	3781.5	02 Jan 00 1305	889.62	2.872
T9-A	797.33	02 Jan 00 1245	163.36	0.629
73	731.11	02 Jan 00 1255	163.35	0.629
T9-B	711.36	02 Jan 00 1240	134.74	0.444
14	1365.6	02 Jan 00 1245	298.09	1.073
25	4974.6	02 Jan 00 1300	1187.7	3.945
Reservoir-5	4910.6	02 Jan 00 1310	1187.6	3.945
W-E	725.86	02 Jan 00 1235	142.22	0.326
Junction-2	5298.7	02 Jan 00 1305	1329.8	4.271
Reservoir-6	5264.5	02 Jan 00 1310	1329.7	4.271
T8-A	398.00	02 Jan 00 1240	75.578	0.291
T8-B	624.84	02 Jan 00 1235	99.017	0.430
3	1017.2	02 Jan 00 1235	174.60	0.721
T8-C2	189.74	02 Jan 00 1235	31.290	0.099
T8-C3	559.13	02 Jan 00 1235	93.870	0.297

Hydrologic Element	Discharge Peak (cfs)	Time of Peak	Total Volume (ac ft)	Drainage Area (sq mi)
T18-A	694.68	02 Jan 00 1240	143.48	0.458
Junction-34	34142	02 Jan 00 1250	10118	29.327
W-Q	2400.9	02 Jan 00 1235	504.41	1.057
Junction-35	36355	02 Jan 00 1250	10623	30.384
FB-A	874.06	02 Jan 00 1235	158.40	0.398
Reservoir-28	827.38	02 Jan 00 1240	158.40	0.398
FB-B	779.36	02 Jan 00 1240	138.02	0.428
Junction-36	1606.7	02 Jan 00 1240	296.41	0.826
Reservoir-29	1599.9	02 Jan 00 1240	296.41	0.826
FB-T1A	539.54	02 Jan 00 1235	93.542	0.278
Junction-37	2128.2	02 Jan 00 1240	389.95	1.104
FB-C	961.12	02 Jan 00 1235	176.99	0.449
Junction-38	3075.4	02 Jan 00 1240	566.94	1.553
FB-D	292.19	02 Jan 00 1235	50.215	0.146
Junction-39	3358.7	02 Jan 00 1235	617.16	1.699
Junction-40	39566	02 Jan 00 1245	11240	32.083
W-R	915.51	02 Jan 00 1235	169.43	0.429
Junction-41	40410	02 Jan 00 1245	11409	32.512
T11-A	351.74	02 Jan 00 1235	62.519	0.177
Reservoir-33	347.55	02 Jan 00 1235	62.519	0.177
T11-B	665.42	02 Jan 00 1235	110.61	0.365
Junction-42	1013.0	02 Jan 00 1235	173.13	0.542
T11-C	539.43	02 Jan 00 1230	97.445	0.245
96	1550.9	02 Jan 00 1235	270.57	0.787
Junction-43	41798	02 Jan 00 1245	11680	33.299
T1-A	678.77	02 Jan 00 1235	117.00	0.388
Reservoir-36	642.63	02 Jan 00 1245	116.99	0.388
T1-B	869.66	02 Jan 00 1230	164.52	0.391
Junction-44	1476.0	02 Jan 00 1235	281.52	0.779
T1-T1A	1088.9	02 Jan 00 1245	222.70	0.829
T1-T1B	313.06	02 Jan 00 1235	53.570	0.165
Junction-45	1376.6	02 Jan 00 1240	276.27	0.994
Junction-46	2851.5	02 Jan 00 1240	557.79	1.773
Reservoir-38	2399.6	02 Jan 00 1255	557.73	1.773
T1-C	731.39	02 Jan 00 1235	129.08	0.385
Junction-47	2990.9	02 Jan 00 1250	686.82	2.158
T1-T2A	1237.1	02 Jan 00 1240	224.94	0.791
Junction-48	4194.6	02 Jan 00 1245	911.76	2.949

Hydrologic Element	Discharge Peak (cfs)	Time of Peak	Total Volume (ac ft)	Drainage Area (sq mi)
29	1472.0	02 Jan 00 1240	286.34	0.826
Junction-22	6218.3	02 Jan 00 1235	1303.4	3.620
WB-G	873.46	02 Jan 00 1230	173.26	0.376
90	7086.7	02 Jan 00 1235	1476.7	3.996
WB-H	633.16	02 Jan 00 1235	117.60	0.292
92	7719.9	02 Jan 00 1235	1594.3	4.288
Junction-23	24063	02 Jan 00 1305	7485.1	21.526
Reservoir-20	23761	02 Jan 00 1325	7483.4	21.526
WB-M	1472.5	02 Jan 00 1235	266.91	0.709
Junction-24	24335	02 Jan 00 1320	7750.3	22.235
T4-A	764.63	02 Jan 00 1235	146.46	0.437
48	717.20	02 Jan 00 1245	146.45	0.437
T4-B	400.59	02 Jan 00 1230	77.881	0.173
40	1072.3	02 Jan 00 1240	224.33	0.610
T4-C	1654.1	02 Jan 00 1240	325.56	0.793
Junction-25	2726.4	02 Jan 00 1240	549.89	1.403
T4-D	458.76	02 Jan 00 1230	86.595	0.207
42	3166.7	02 Jan 00 1235	636.49	1.610
T4-E	840.49	02 Jan 00 1235	173.99	0.369
41	4007.2	02 Jan 00 1235	810.48	1.979
Junction-26	26961	02 Jan 00 1255	8560.8	24.214
Reservoir-22	26889	02 Jan 00 1305	8559.3	24.214
T13-A	2008.7	02 Jan 00 1235	372.50	0.945
44	28305	02 Jan 00 1300	8931.8	25.159
T3-A1	249.15	02 Jan 00 1235	38.424	0.142
T3-A2	240.37	02 Jan 00 1235	38.424	0.142
Junction-27	489.52	02 Jan 00 1235	76.847	0.284
Junction-28	28655	02 Jan 00 1255	9008.7	25.443
W-N	863.58	02 Jan 00 1235	132.69	0.543
Junction-29	29273	02 Jan 00 1255	9141.3	25.986
T2-A	967.32	02 Jan 00 1240	167.65	0.623
Junction-30	30105	02 Jan 00 1255	9309.0	26.609
W-O	691.04	02 Jan 00 1235	109.59	0.405
Junction-31	30632	02 Jan 00 1255	9418.6	27.014
T14-A	1805.7	02 Jan 00 1240	324.99	1.001
Junction-32	32224	02 Jan 00 1250	9743.6	28.015
W-P	1426.1	02 Jan 00 1240	231.08	0.854
Junction-33	33509	02 Jan 00 1250	9974.7	28.869

Hydrologic Element	Discharge Peak (cfs)	Time of Peak	Total Volume (ac ft)	Drainage Area (sq mi)
TB-C	497.22	02 Jan 00 1240	87.865	0.278
91	727.26	02 Jan 00 1250	185.29	0.706
Junction-15	19467	02 Jan 00 1330	5748.1	16.631
W-L	848.62	02 Jan 00 1240	142.73	0.607
50	19916	02 Jan 00 1325	5890.8	17.238
WB-A	300.93	02 Jan 00 1240	48.964	0.260
55	244.56	02 Jan 00 1255	48.963	0.260
WB-B	580.84	02 Jan 00 1235	100.61	0.331
4	773.84	02 Jan 00 1240	149.57	0.591
54	730.45	02 Jan 00 1245	149.57	0.591
WB-C1	270.23	02 Jan 00 1230	48.332	0.121
Reservoir-15	196.32	02 Jan 00 1250	48.332	0.121
WB-C2	270.23	02 Jan 00 1230	48.332	0.121
Junction-16	456.18	02 Jan 00 1235	96.665	0.242
16	1142.1	02 Jan 00 1240	246.24	0.833
WB-T2A	409.81	02 Jan 00 1235	70.391	0.223
58	368.76	02 Jan 00 1245	70.390	0.223
WB-T2B	376.92	02 Jan 00 1235	64.103	0.202
Junction-17	738.07	02 Jan 00 1240	134.49	0.425
10	454.99	02 Jan 00 1310	134.48	0.425
Junction-18	1523.3	02 Jan 00 1245	380.72	1.258
WB-T3A	366.60	02 Jan 00 1230	72.411	0.161
59	363.24	02 Jan 00 1235	72.411	0.161
WB-T3B	561.89	02 Jan 00 1235	102.03	0.273
11	925.13	02 Jan 00 1235	174.44	0.434
Junction-19	2400.4	02 Jan 00 1240	555.16	1.692
WB-D	1020.5	02 Jan 00 1235	183.50	0.491
Junction-20	3388.0	02 Jan 00 1240	738.66	2.183
WB-E	856.79	02 Jan 00 1230	168.02	0.380
Junction-21	4221.5	02 Jan 00 1235	906.68	2.563
WB-F	547.54	02 Jan 00 1230	110.41	0.231
31	4762.4	02 Jan 00 1235	1017.1	2.794
WB-T1A	186.05	02 Jan 00 1230	34.369	0.087
57	176.05	02 Jan 00 1240	34.369	0.087
WB-T1B	636.56	02 Jan 00 1235	113.62	0.388
88	811.93	02 Jan 00 1235	147.99	0.475
56	752.08	02 Jan 00 1245	147.99	0.475
WB-T1C	759.64	02 Jan 00 1235	138.36	0.351

Hydrologic Element	Discharge Peak (cfs)	Time of Peak	Total Volume (ac ft)	Drainage Area (sq mi)
67	1220.0	02 Jan 00 1235	237.09	0.561
T6T1-B	368.51	02 Jan 00 1230	76.169	0.154
45	1581.7	02 Jan 00 1235	313.25	0.715
66	1498.0	02 Jan 00 1245	313.24	0.715
T6T1-C	270.97	02 Jan 00 1235	51.272	0.125
43	1757.2	02 Jan 00 1240	364.51	0.840
Junction-9	5880.1	02 Jan 00 1250	1306.3	3.348
63	5456.5	02 Jan 00 1305	1306.1	3.348
T6-D	696.77	02 Jan 00 1240	136.40	0.340
36	5957.0	02 Jan 00 1300	1442.5	3.688
Junction-10	17018	02 Jan 00 1315	4492.6	12.783
22	16394	02 Jan 00 1330	4491.3	12.783
W-H	1462.9	02 Jan 00 1235	295.11	0.692
39	17069	02 Jan 00 1325	4786.4	13.475
T5-A	399.08	02 Jan 00 1235	69.689	0.196
62	385.07	02 Jan 00 1240	69.688	0.196
T5-B	453.65	02 Jan 00 1245	88.538	0.308
46	833.35	02 Jan 00 1240	158.23	0.504
Junction-11	17512	02 Jan 00 1325	4944.7	13.979
Reservoir-11	17353	02 Jan 00 1330	4943.9	13.979
W-I1	777.31	02 Jan 00 1235	155.93	0.450
9	540.73	02 Jan 00 1255	155.93	0.450
W-I2	777.89	02 Jan 00 1240	162.51	0.469
Junction-12	1308.3	02 Jan 00 1240	318.44	0.919
38	18209	02 Jan 00 1330	5262.4	14.898
T16-A	328.71	02 Jan 00 1240	53.484	0.284
20	18363	02 Jan 00 1330	5315.8	15.182
W-J	449.31	02 Jan 00 1230	78.676	0.209
Junction-13	18511	02 Jan 00 1330	5394.5	15.391
T15-A	835.62	02 Jan 00 1235	152.03	0.465
93	18851	02 Jan 00 1330	5546.5	15.856
W-K	109.20	02 Jan 00 1235	16.225	0.069
95	18891	02 Jan 00 1330	5562.8	15.925
TB-A	325.49	02 Jan 00 1235	61.294	0.236
61	224.21	02 Jan 00 1300	61.289	0.236
TB-B	191.51	02 Jan 00 1250	36.158	0.192
Junction-14	412.06	02 Jan 00 1255	97.447	0.428
60	359.20	02 Jan 00 1320	97.424	0.428

Hydrologic Element	Discharge Peak (cfs)	Time of Peak	Total Volume (ac ft)	Drainage Area (sq mi)
72	748.87	02 Jan 00 1235	125.16	0.396
T8-C1	372.75	02 Jan 00 1235	62.580	0.198
Junction-3	1121.6	02 Jan 00 1235	187.74	0.594
Reservoir-7	1027.8	02 Jan 00 1245	187.73	0.594
8	2037.8	02 Jan 00 1240	362.32	1.315
T8-D1	600.59	02 Jan 00 1230	113.67	0.273
T8-D2	202.86	02 Jan 00 1230	37.891	0.091
Junction-4	803.46	02 Jan 00 1230	151.56	0.364
17	2796.3	02 Jan 00 1240	513.89	1.679
71	2426.4	02 Jan 00 1250	513.82	1.679
T8-E	1172.7	02 Jan 00 1235	221.65	0.551
87	3433.4	02 Jan 00 1245	735.48	2.230
70	3283.1	02 Jan 00 1255	735.40	2.230
T8-F	748.51	02 Jan 00 1235	143.34	0.347
21	3938.2	02 Jan 00 1250	878.75	2.577
Reservoir-8	3831.5	02 Jan 00 1300	878.65	2.577
T8-G	964.00	02 Jan 00 1235	178.79	0.463
Junction-5	4574.4	02 Jan 00 1255	1057.4	3.040
24	9576.5	02 Jan 00 1305	2387.1	7.311
Reservoir-10	9342.5	02 Jan 00 1315	2386.6	7.311
W-F	175.28	02 Jan 00 1240	32.935	0.103
34	9436.1	02 Jan 00 1315	2419.6	7.414
T7-A	1509.1	02 Jan 00 1235	310.99	0.682
69	1238.6	02 Jan 00 1300	310.64	0.682
T7-B	1222.7	02 Jan 00 1245	226.87	0.745
Junction-6	2430.4	02 Jan 00 1250	537.51	1.427
Junction-7	11594	02 Jan 00 1310	2957.1	8.841
23	11161	02 Jan 00 1320	2955.8	8.841
W-G	490.82	02 Jan 00 1240	94.272	0.254
35	11409	02 Jan 00 1320	3050.1	9.095
T6-A	2105.9	02 Jan 00 1240	410.71	1.010
65	1701.1	02 Jan 00 1300	410.43	1.010
T6-B	1232.8	02 Jan 00 1245	237.01	0.724
Junction-8	2865.4	02 Jan 00 1250	647.45	1.734
64	2800.0	02 Jan 00 1300	647.43	1.734
T6-C	1465.6	02 Jan 00 1245	294.36	0.774
33	4187.0	02 Jan 00 1255	941.78	2.508
T6T1-A	1227.9	02 Jan 00 1235	237.09	0.561

Hydrologic Element	Discharge Peak (cfs)	Time of Peak	Total Volume (ac ft)	Drainage Area (sq mi)
Subbasin-1	936.53	02 Jan 00 1245	172.18	0.674
Junction-49	5131.1	02 Jan 00 1245	1083.9	3.623
Reservoir-40	3704.4	02 Jan 00 1320	1083.8	3.623
74	44797	02 Jan 00 1245	12763	36.922
W-S	877.69	02 Jan 00 1240	164.38	0.515
98	45665	02 Jan 00 1245	12928	37.437
W-T	840.47	02 Jan 00 1240	147.27	0.532
97	46504	02 Jan 00 1245	13075	37.969
Junction-50	46504	02 Jan 00 1245	13075	37.969

BIBLIOGRAPHY

Austin American Statesman. 1981a. *Homeowners flee storm's flooding.* May 25, morning edition. A1.

_________. 1981b. *10 dead, 9 missing as flooding leaves home and business damage in millions.* May 25, evening edition. A1.

_________. 1981c. *Flash floods turn families into refugees.* May 25, evening edition. B1.

_________. 1981d. *Disaster aid sought in aftermath of flood.* May 26, evening edition. A1.

_________. 1981e. *As flood waters recede, a grim count is taken.* May 26, evening edition. B2.

_________. 1981f. *Businesses insured, but most homes aren't.* May 26, evening edition. B3.

_________. 1981g. *City lack system to provide early alert of flooding threat.* May 27, evening edition. A14.

_________. 1981h. *Losses reached 35.5 million, city reports.* May 28, evening edition. B1.

_________. 1998. *Austin pushes forward all 12 bond propositions.* November 4. A1.

Austin Metropolitan Trails Council. 1997. *Walnut Creek Greenway: A Partnership approach.* Austin, TX: Austin Metropolitan Trails Council.

Baker, V. R. 1977. Stream-channel response to floods with examples from central Texas. *Geological Society of America Bulletin* 88: 1057-1071.

Boyer, A. D. 1992. What is the true 100-year flood plain elevation? in *Multi-Objective approaches to flood plain management: Proceedings of the sixteenth annual conference of the Association of State Floodplain Managers, May 18-22, 1992, Grand Rapids Michigan.*

Brown, D. W. chairman. 1997. *City of Austin Floodplain Task Force's Report to Council.* Austin, TX: City of Austin.

Burby, R., French, S., Ciglar, B., Kaiser, E., Moreau, D., and B. Stiffel. 1981. *Flood plain land use management: A National assessment.* Studies in Water Policy and Management, No. 5. Boulder, CO: Westview Press.

Burby, R. J. and S. P. French. 1981. Coping with floods: The Land use management paradox. *Journal of the American Planning Association* 47(3): 289-300.

Cannon, T. 1993. A Hazard need not a disaster make: Vulnerability and the causes of 'natural' disasters. In *Natural disasters: Protecting vulnerable communities. Proceedings of the conference held in London, October 13-15, 1993*, edited by P. A. Merriman and C. W. A. Browitt, 92-105. London: Thomas Telford.

Cheatham, L. 1977. *An Analysis of the effectiveness of land use regulations required for flood insurance eligibility.* State College, MI: Water Research Institute, Mississippi State University.

City of Austin. 1967. *Austin City Code.* Austin, TX.

City of Austin. 1974a. *Drainage Criteria.* Austin, TX: Engineering Department.

City of Austin. 1974b. *Creek Ordinance*. Ordinance No. 740307-I. March 7, 1974.

City of Austin. 1975a. *Floodplain Ordinance.* Ordinance No. 750313-D. March 13, 1975.

City of Austin. 1975b. *Floodplain Ordinance.* Ordinance No. 750313-C. March 13, 1975.

City of Austin, 1979. *Austin Tomorrow Comprehensive Plan.* Austin, TX: Department of Planning.

City of Austin. 1981. *Austin City Code.* Austin, TX.

City of Austin. 1983a. Ordinance No. 830915-L. September 15, 1983.

City of Austin. 1983b. Ordinance No. 830915-M. September 15, 1983.

Colten, C. E. 1991. A Historical perspective on industrial wastes and groundwater contamination. *Geographical Review* 81:215-228.

Costa, J. E. 1978. The Dilemma of flood control in the United States. *Environmental Management* 2(4): 313-322.

Coxe, M. A. F. 1992. Spatial interpretation of urban flood hazards and public policy in the Bayou Fountain Basin, Louisiana. unpublished Masters Thesis. Louisiana State University.

Cutter, S. L. 1996. Vulnerability to environmental hazards. *Progress in Human Geography* 20(4): 529-539.

Daly, S. F. and J. Peters. 1979. Determining peak discharge frequencies in an urbanizing watershed-a case study. *Proceedings of the International Symposium on Urban Runoff.* University of Kentucky, Lexington, July 1979.

Dow, K. Exploring differences in our common future(s): The Meaning of vulnerability to global environmental change. *Human Dimensions Quarterly* 1:3-5.

Dunne, T. and L. Leopold. 1978. *Water in environmental planning*. San Francisco: W. H. Freeman and Company.

Earl, R. and Kimmel, T. 1995. Means and extremes: The Weather and climate of South-Central Texas. In *A Geographic Glimpse of Central Texas and the Borderlands: Prepared for the 80th meeting of the National Council for Geographic Education in San Antonio, Texas, October 25-28, 1995.* Edited by James F. Petersen and Julie A. Tuason. 31-40. Pathways in Geography: The National Council for Geographic Education.

Flood Control Act. Statutes at large. 1936. PL 738, chapter 688. Vol. 49.

Flood Control Act. Statutes at large. 1938. PL 761, chapter 795. Vol. 52.

Flood Control Act. Statutes at large. 1944. PL 352, chapter 275. Vol. 58.

Flood Control Act. Statutes at large. 1948. PL 858, chapter 771. Vol. 62.

Flood Control Act. Statutes at large. 1960. PL 86-645, Title II. Vol. 74.

Flood Control Act. Statutes at large. 1970. PL 91-611, Title II. Vol. 84.

Flood Disaster Protection Act. 1973. PL 93-234. http://thomas.loc.gov. accessed 9/17/98.

Florence Dolan, Petitioner v. City of Tigard. 1994. 114 S. Ct. 2309, No. 93-518.

Funk, J. W. 1969. The flood potential and future flood problems. in *Flood plain management: Iowa's experience*. ed. M.D. Dougal, 37-49. Ames, Iowa: Iowa State University Press.

Galloway, G. 1980. *Nonstructural measures in flood damage reduction activities.* Washington, DC: U. S. Water Resources Council.

Graf, W. 1976. *The effect of suburbanization on flood peaks.* Iowa City: University of Iowa. Department of Geography Research Paper No. 21.

Green, C. H., Tunstall, S. M., and M. H. Fordham.1991. The risks from flooding: Which risks and whose perception? *Disasters* 15(3): 227-236.

Hoggan, D. 1989. *Computer assisted floodplain hydrology and hydraulics.* New York NY: McGraw-Hill Publishing Company.

Hollis, G. E. 1975. The Effect of urbanization on floods of different recurrence interval. *Water Resources Research* 11(3): 431-435.

Kates, Robert W. 1962. *Hazard and choice perception in flood plain management.* Department of Geography Research Paper No. 78. Chicago: University of Chicago Press.

Knox, J. C. 1977. Human impacts on Wisconsin stream channels. *Annals of the Association of American Geographers* 67(3): 323-342.

Kunreuther, H. C. and G. F. White. 1994. The Role of the National Flood Insurance Program in reducing losses and promoting wise use of floodplains. *Water Resources Update* 95: 31-35.

Leopold, L. B. 1994. Flood hydrology and the floodplain. *Water Resources Update* 95:11-14.

Lord, W. B. 1994. Flood hazard delineation: The One percent standard. *Water Resources Update* 95: 36-39.

Magilligan, F. J. 1985. Historical floodplain sedimentation in the Galena River Basin, Wisconsin and Illinois. *Annals of the Association of American Geographers* 75(4): 583-594.

________ 1992. Thresholds and the spatial variability of flood power during extreme floods. *Geomorphology* 5:373-390.

________ and M. L. Stamp. 1997. Historical land-cover changes and hydrogeomorphic adjustment in a small Georgia watershed. *Annals of the Association of American Geographers* 87(4): 614-635.

Montz, B. and E. C. Gruntfest. 1986. Changes in urban floodplain occupancy since 1958: The Experience of nine cities. *Applied Geography* 6: 325-338.

Moore, Jamie and Dorothy Moore. 1989. *The Army Corps of Engineers and the evolution of federal floodplain management policy.* Program on Environment and Behavior Special Publication No. 20. Boulder, CO: Institute of Behavioral Science, University of Colorado.

Moore, W., Cook, E., Gooch, R. S., and C. Nordin. 1982. *The Austin, Texas flood of May 24-25, 1981.* Prepared for the Committee on Natural Disasters, National Research Council. Washington, DC: National Academy Press.

Murphy, Francis. 1958. *Regulating flood plain development.* Department of Geography Research Paper No. 56. Chicago: University of Chicago Press.

National Flood Insurance Act. Statutes at large. 1968. PL 90-448. Vol. 82.

National Flood Insurance Act. Statutes at large. 1969. PL 91-152. Vol. 83.

National Weather Service. 1961. *Rainfall frequency atlas of the United States.* Washington, DC: Department of Commerce. TP-40.

Parker, Dennis. 1995. Floods in cities: Increasing exposure and rising impact potential. *Built Environment* 21(2/3): 114-125.

_______ and E. C. Penning-Roswell. 1983. Flood hazard research in Britain. *Progress in Human Geography* 7(2): 182-202.

Potter, K. 1991. Hydrological impacts of changing land management practices in a moderate-sized agricultural catchment. *Water Resources Research* 27(5): 845-855.

Pulido, L. , Sidawi, S. and R. Vos. 1996. An Archeology of environmental racism in Los Angeles. *Urban Geography* 17(5):419-439.

Sidawi, S. 1997. Planning environmental racism: The Construction of the industrial suburban ideal in Los Angeles County in the early twentieth century. *Historical Geography* 25:83-99.

Slade, Raymond M. 1986. Large rainstorms along the Balcones Escarpment in Central Texas. In *The Balcones Escaprment, Geological Society of America Annual Meeting Guidebook*, ed. Abbott, P. L. and C. M. Woodruff, Jr.. Boulder, CO: Geological Society of America.

Sussman, P., O'Keefe, P. and B. Wisner. 1984. Global disasters: A Radical interpretation. In Hewitt, K., editor, *Interpretations of Calamity*. Boston, MA: Allen and Unwin. 264-283.

Timmerman, P. 1981. *Vulnerability, resilience and the collapse of society. Environmental Monograph 1.* Toronto: Institute for Environmental Studies.

U. S. Army Corps of Engineers. 1972. *Flood plain information, Big and Little Walnut Creeks, Austin, Texas.* Fort Worth, TX: U. S. Army Corps of Engineers, Fort Worth District.

_______. 1980. *Walnut Creek, expanded floodplain information study, City of Austin and Travis County, Texas, General Report.* Volume 1. Fort Worth, TX: U. S. Army Corps of Engineers, Fort Worth District.

_______. 1987. *Little Walnut Creek, Austin, Texas, Detailed Project Report.* Fort Worth, TX: U. S. Army Corps of Engineers, Fort Worth District.

________. 1998. *HEC-HMS Hydrologic Modeling System, user's manual.* Version 1.0, March 1998. Davis, CA: U. S. Army Corps of Engineers.

U. S. Congress. Senate. Committee on Interior and Insular Affairs. 1956. *Hearings before the Committee on Interior and Insular Affairs on S. Res. 281.* 84th Cong., 2d sess., July.

U. S. Department of Commerce. Economics and Statistics Administration. Bureau of the Census. 1990. *1990 Census of population and housing, population and housing Characteristics for census tracts and block numbering areas, Austin, Texas MSA.* Washington, DC.

United States Geological Survey. 1981. *Water resources data, Texas, water year 1981.* Austin, TX: U. S. Geological Survey.

U. S. President. 1977. *Public papers of the presidents of the Unites States.* Washington, DC: Office of the *Federal Register*, National Archives and Records Service. Jimmy Carter.

U. S. Soil Conservation Service. 1975. *Urban hydrology for small watersheds.* Washington, DC: Technical Release No. 55.

U. S. Water Resources Council. 1970. *Regulation of flood hazard areas to reduce flood losses*. Volume 1. Washington, DC: U. S. Water Resources Council.

U. S. Water Resources Council. 1971. *Regulation of flood hazard areas to reduce flood losses.* Volume 2. Washington, DC: U. S. Water Resources Council.

U. S. Water Resources Council. 1973, *Principles and standards for planning of water and land related resources.* Washington, DC: U. S. Water Resources Council.

Waananen, G. L. 1977. *Floodprone areas and landuse planning: Selected examples from the San Francisco Bay area*. Washington, DC: U.S. Government Printing Office. U. S. Geological Survey Professional Paper No. 942.

White, G. F. 1942. *Human adjustment to floods, a geographical approach to the flood problem in the United States.* Chicago: University of Chicago. Department of Geography Research Paper No. 29.

_______ et al. 1958. *Changes in urban occupance of floodplains in the United States.* Chicago: University of Chicago Press. Department of Geography Research Paper No. 57.

Woltemade, C. J. 1994. Form and process: Fluvial geomorphology and flood flow interaction, Grant River, Wisconsin. *Annals of the Association of American Geographers* 84(1): 462-479.

_______ and K. W. Potter. 1994. A Watershed modeling analysis of fluvial geomorphologic influences on flood peak attenuation. *Water Resources Research* 30(6):1933-1942.

Wright, J. M. 1994. Evolution of floodplain management. *Water Resources Update* 95: 5-10.

VITA

Kathy Ann Alexander was born in Phoenix, Arizona, on November 2, 1956. She is the daughter of Lt. Col. Baird M. Martin. USAF, Ret. and Betty J. Martin of Houston, Texas. After graduating from Clear Lake High School in Houston, Texas, in 1974, she attended the University of Texas at Austin where she studied Chemical Engineering and Chemistry. She was employed by the United States Postal Service from 1979 until 1995 and graduated from the University of Texas with a BA in History in May of 1997. She entered the Graduate Program in Applied Geography at Southwest Texas State University in San Marcos, Texas, in the fall of 1997. She is currently employed by the Texas Natural Resource Conservation Commission in Austin, Texas, as a Hydrologist.