

## MEGGINNIS ARM BASIN DIAGNOSIS --- A DISTRIBUTED WATERSHED MODEL USING XP-SWMM32™

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### ABSTRACT

Urban development in the 2,230-acre Megginnis Arm basin of the Lake Jackson watershed in the recent decades has resulted in serious water quality and aquatic habitat degradation. Increases in impervious land surface led to increased stormwater runoff volume and pollutant overloading which also contributed to water quality problems.

The study area mainly includes the Megginnis Creek sub-watershed that is the most intensively developed portion of the Lake Jackson Basin. Flows through the Megginnis Creek sub-basins are from south to north through a well-defined drainage system. A total of three facilities are discussed: the NFWFMD's Megginnis Arm Stormwater Treatment Facility, the City of Tallahassee's John Knox Road Facilities, and the City of Tallahassee's Boone Boulevard facility. From 1994 to 1996, a water quality monitoring program was undertaken to monitor the effectiveness of these facilities and data compiled from this program are expected to be used in our SWMM model development. The aim of this work is to develop a distributed watershed model to evaluate the effectiveness of the stormwater management facilities for the Megginnis Arm Basin based on the current conditions. This model is built via XP-SWMM32 (Version 6.02) which utilizes the mathematical engine of EPA SWMM 4.04. The RUNOFF layer is used to simulate the hydrologic responses of the basin and subsequently generates outflow hydrographs. These hydrographs are then routed by the TRANSPORT layer downstream through the drainage network. Our model is carefully calibrated and verified with the hydrologic data and concurrent rainfall data for 23 sub-catchments in the study area.

### INTRODUCTION

The Lake Jackson basin is situated in the Tallahassee Hills upland area in northern Tallahassee and west central Leon County, Florida. With an estimated drainage area of approximately 28,000 acres, the drainage basin consists of Lake Jackson, Lake Carr, Mallard Pond, Holley Pond, and land areas that drain into these lakes. Soils are predominately sandy loams to clay loams and most of the northern portions of the basin are heavily vegetated forests and pasturelands. The southern portion of the Lake Jackson have been the main receiving waters for most of the stormwater which runs off the more densely populated areas in the basin.

Lake Jackson is the largest lake in the Basin with a surface area of approximately 4,000 acres

at a water elevation of 87 feet. Lake Jackson water level elevations have historically ranged from 75 feet NGVD with most of the lake bottom exposed to 96 feet NGVD at the highest flood stage observed. These water level fluctuations have been a critical factor in the management of the lake environment and flood control of the basin. It is believed that the lake stage fluctuations are primarily dominated by climatic conditions and sinkhole activity caused by a series of underlying geological processes and the interactions with groundwater at the bottom of the lake. Statistical analysis on the historical records of climatic data and lake level data reveals a strong positive correlation that can be used to derive future likelihood of lake response with respect to climatic conditions.

Lake Jackson has been considered a priority water body under the Northwest Florida Water Management District's SWIM Program and is classified by the State of Florida as an Outstanding Florida Waterbody (OFW) and an Aquatic Preserve. However, urban and suburban developments in the southern portions of the Lake Jackson watershed, including Megginis Creek and its tributaries, have resulted in significant contributions of stormwater pollution. Poor water quality was frequently detected along with increased sedimentation, contamination of bottom sediments by heavy metals and other pollutants, and increased nit&cation of the lake as a result of stream pollution. Since late 1970s, the lake has been given lake protection status under the Tallahassee-Leon County 20 10 Comprehensive Plan and local environmental ordinances. Several stormwater management facilities were installed, including the City-owned Boone Boulevard pond and the John Knox Road facilities, and the I- 10 pond and the Stormwater Treatment Facility managed by the District. The District facility was further enlarged in the late 1980s to accommodate more runoff. It is expected that these facilities help attenuate peak runoff flow during large storms events while providing longer detention time to improve water quality.

Previous study on water quality and quantity in the Lake Jackson basin can be obtained from the Storm Water Management Plan for the Lake Jackson Basin developed by the NFWFMD (Bartel et al., 1991) for the City of Tallahassee and Leon County. The District further developed the Lake Jackson Regional Stormwater Retrofit Plan (Bartel et al., 1992) in 1992. Hydrologic models were also developed for the watershed using EPA SWMM in conjunction with HEC-2's backwater analysis. While these models provided calibrated hydrologic parameters for the basin, most of them were built from later 1970s to early 1980s, whose conditions differ drastically from the post-development conditions.

The goal of this work is to develop a comprehensive hydrologic-hydraulic model for the diagnosis of the Megginis Arm sub-basin under current post-development conditions. Both field observations and previous modeling results indicated that the Megginis Arm sub-basin was the flashiest sub-basin with the highest peak flow rates and storm volumes (Bartel et al. 1991). Because of the change of the urbanization characteristics of the basin, its hydrology as well as the drainage network in the area needs to be reexamined. The inclusion of John Knox ponds is expected to attenuate the peak runoff flow downstream and we hope to quantify the efficiency of these ponds statistically against the measured stage levels of the District's Storm Water Treatment Facility, and eventually be able to determine how often water tends to bypass the District pond. The model is expected to perform both flow and pollutant routing effectively while taking advantage of field measurements of stage/discharge and water quality in calibration and verification. Utilizing the XP-

SWMM32™ graphic interface, this model incorporates SWMM's RUNOFF, TRANSPORT, and EXTRAN layers interactively.

Reported in this paper is the model development in its early phase. A two-layer model, e.g., RUNOFF-TRANSPORT, has been developed and successfully applied in both storm-event and long-term simulations. Model hydrology is carefully calibrated and verified against measured data.

## Study Site

Drainage in the 2,230-acre Megginis Arm basin is controlled to various degrees by ditches, paved channels and detention ponds managed by the City of Tallahassee and the Northwest Florida Water Management District. The sub-basin has historically exhibited higher peak flow rates and relatively greater stormwater volumes than elsewhere in the Lake Jackson basin. It is also the site of a multimillion-dollar experimental water quality control facility consisting of detention ponds and an artificial marsh.

Land uses characters for Megginis Arm Basin are delineated as Low-medium density residential to High density residential with a significant amount of land for commercial uses. Modern day land uses information is available in the form of digital maps based upon 1989 remote sensing data according to Level III of the Florida Land Use Cover and Forms Classification System (FLUCCS) developed by the Florida Department of Transportation. It is highly urbanized (almost 90 percent), consisting of residential areas, apartment complexes, office parks, commercial areas (including three large shopping malls), and two schools. Interstate 10 traverses the sub-basin of the tributaries, contributing additional amounts of stormwater runoff to the system.

The sub-basin water budget consists of a balance of the volumes of water associated with each of the components of the hydrologic cycle. Generally speaking, the total volume of surface water runoff from the catchment is a direct function of precipitation, evapotranspiration, land infiltration, and ground water inflow and groundwater outflow. Evapotranspiration and rainfall are temporal variables that are related to the climatic changes over time. Statistics derived from long-term precipitation data (1958-1999) collected at hourly intervals at the Tallahassee Municipal Airport indicate an annual average rainfall of 64.59 inches. On a monthly basis, July is the wettest month and has the most intense rainstorms on average. On the contrary, the month of October is the driest and December is the month with the lowest average rainfall intensities. Long-term daily pan evaporation data available from the Jim Woodruff Dam, northeast of Tallahassee, for the period from 1959 to 1976 indicates an annual average pan evaporation of 65.86 inches. June was the month with highest average pan evaporation of 7.8 inches, whereas December the lowest at 2.5 inches. Actual evapotranspiration (ET) is defined as the total amount of water removed from an area by transpiration and evaporation. Actual ET is commonly estimated from pan evaporation through a factor or factors that reflect(s) the general properties of the land and vegetative covers. For this area., long-term estimates of average annual evapotranspiration losses have been estimated to range from 35 to 45 inches per year depending upon soil types and vegetative covers.

Previous modeling studies indicate that only about 10 percent of the total volume of water entering the system became direct runoff into Lake Jackson. The remaining 90 percent are lost to evaporation and infiltration. For this study, a number of rainstorms in the late 1970s and early 1980s

were used in model calibration and verification. The hydrologic model was also applied to a ten-year rainfall record from 1991 to 1999.

## Hydrologic Model Description

The model of the Megginis Arm sub-basin is a quantitative description of the basin hydrology and drainage network hydraulics. It is an assemblage of tremendous amount of data either gathered directly from existing database such as rainfall, flow measurements, and evaporation, or indirectly derived from analysis of the characteristics of the basin. The aim of the assemblage is intended for the model to be a principal tool for stormwater management in the area. The hydrologic/hydraulic model is developed and calibrated using the XP-SWMM32TM (version 6.02) that utilizes the U.S. EPA's Stormwater Management Model (SWMM) as its mathematical engine. Figure 1 shows the basin delineation as well as its location relative to the city. Figure 2 shows the station network for the Lake Jackson Stormwater Monitoring Project. Stage/discharge measurements obtained at some of the stations were utilized in model calibration and verification. In particular, station S64 provides stage measurements for the NFWFMD's facility in 5- to 10-minute time intervals. The model starts at the weir (cross-section number 3680) of the NFWFMD's Facility. The simulated hydrographs at this location are hence the inflow hydrographs to the facility and are hydraulically correlated to the stage fluctuations in the facility.

Figure 3 schematically depicts the runoff elements, major channels, and storage elements configured in the SWMM model. The basin is divided into 23 runoff sub-catchments. SWMM RUNOFF layer reads rainfall data and calculates runoff for each sub-catchments. The TRANSPORT layer subsequently routes flow down stream through the drainage network. Megginis Arm Tributary 1 begins at the confluence with Megginis Creek just south of Sharer Road. It crosses North Monroe Street and extends north through the Town and Country neighborhood. The second tributary to Megginis Creek originates behind Northwood shopping center and runs along Boone Boulevard where the Boone Boulevard stormwater facility is located. Inflow to and outflow from the facility were measured along with the stage measurements for a number of years. These data were used to calibrate the hydrologic model at this location. The SWMM model reported in this paper is two-layer (RUNOFF- TRANSPORT). Inclusion of the EXTREN layer is currently under testing.

Table 1 lists the major parameters used in the hydrologic model. Most of these parameters were assembled from existing information such as physiographic, land use, and climatic data, and from regional regression equations for ungaged sub-basins (Bartel et al., 1991).

**Table 1.** Runoff layer parameters for Megginnis Arm Basin.

PARAMETERS	VALUE
Area (total)	2,230 acre
Percent imperviousness (average)	29.77
Slope (average)	0.02936
Manning's roughness (average)	
Impervious	0.0175
Pervious	0.30
Depression storage (average)	
Impervious	0.02 in.
Pervious	0.30 in.
Green-Ampt parameters (average)	
Suction	6.1509 in.
Saturated hydraulic conductivity	0.2259 in/hr
Initial moisture deficit	0.35

The Green-Ampt infiltration model was assumed to simulate infiltration and the necessary parameters were estimated by identifying the soils in the basin (primarily sandy) from a county soil survey map. Hydraulic conductivity and capillary suction data for each soil were obtained from published data by Carlisle et al. (1981) and work by Bedient and Huber (1988). Manning's  $n$  values were selected from charts based on average type of ground cover.

## RESULTS AND DISCUSSIONS

Rainfall-runoff data for calibration and verification were obtained from records gathered at NFWFMD's weather and rainfall stations. Eight major storms were selected in the late 1970s and early 80s. Figure 4 shows a verification run for a storm on 12/06/1979 at cross-section 3680 under pre-development conditions. Rainfall record for the storm is also shown in the figure. It is noted the cross-section 3680 is located at the very downstream of the entire simulated basin and is the weir of the NFWFMD's Stormwater Treatment Facility. Figure 5 compares the simulated hydrographs at this location for the same storm under pre- and post-development conditions. Statistics for these hydrographs are listed in Table 2. The hydrologic simulation reveals that a 24.4 percent attenuation in peak flow was resulted due to the addition of the stormwater management facilities in the basin.

**Table 2. Summary** of the statistics of the simulated hydrographs at cross-section 3680 for storm on 12/06/1 979 under pre- and post-development conditions.

	Pre-development	Post-development
Average flow (cfs)	100.187	99.945
Flow standard deviation (cfs)	8.327	7.516
Maximum Flow (cfs)	441.935	334.286
Runoff Vol. (cubic feet)	5.68 10 <sup>6</sup>	5.67 10 <sup>6</sup>

In Figure 6, a 12-month continuous simulation for the year of 1991 was performed and the simulated hydrograph at cross-section 3680 is plotted against rainfall. Also plotted is the measured stage record at station S64. The elevation of the top of the emergency spillway is at 10 1 feet NGVD. The figure indicates a strong correlation between rainfall, the inflow at section 3680 and the stage level. Frequency analysis on the hydrographs will be conducted and is believed to be of great importance to the management of the functioning of the facilities.

## CONCLUSIONS

A distributed stormwater management model has been developed for the Megginnis Arm Basin and the framework is demonstrated in this paper. Preliminary results presented here indicate that the hydrologic/hydraulic model functioned correctly in both event-based and long-term continuous simulations. The study quantitatively verified that the installation of the stormwater treatment facilities effectively attenuates the peak flow during major storm events. One of the future tasks is to perform additional statistical analysis on the simulated hydrologic time series. Such analysis is necessary to the discovery of important cross-correlation between the hydrologic response of the system and the climatic conditions, which is informatively useful to the stormwater management of the basin.

## ACKNOWLEDGMENTS

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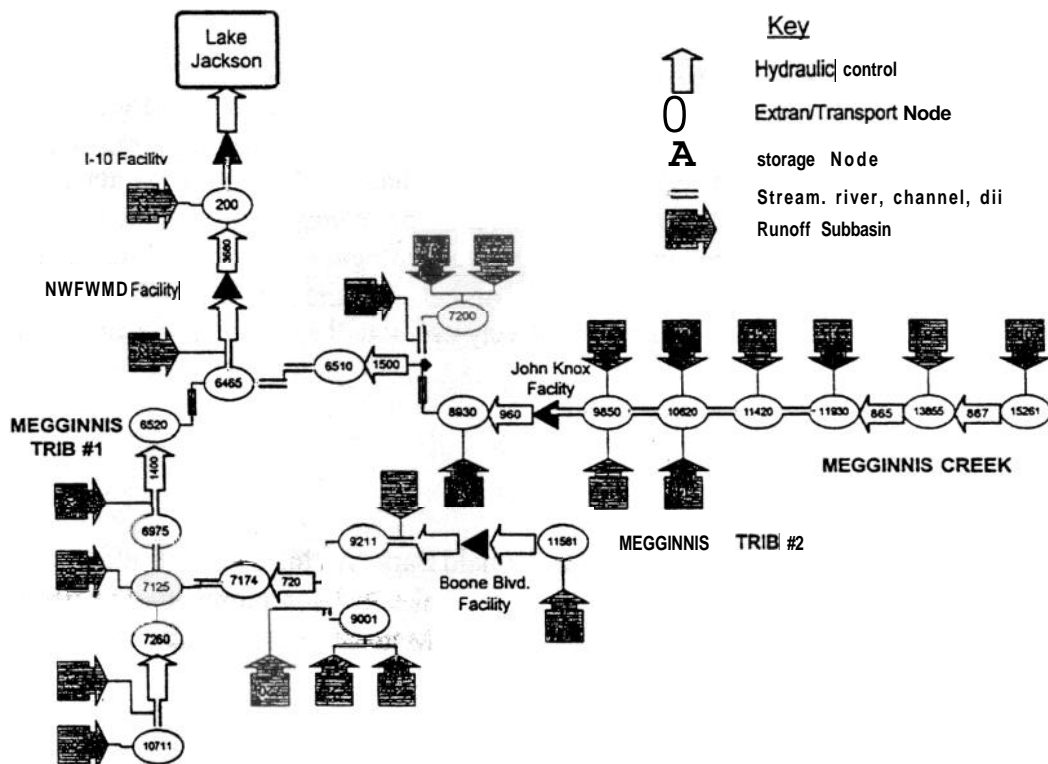


Figure 3. XP-SWMM32 model diagram for Megginnis Arm Basin

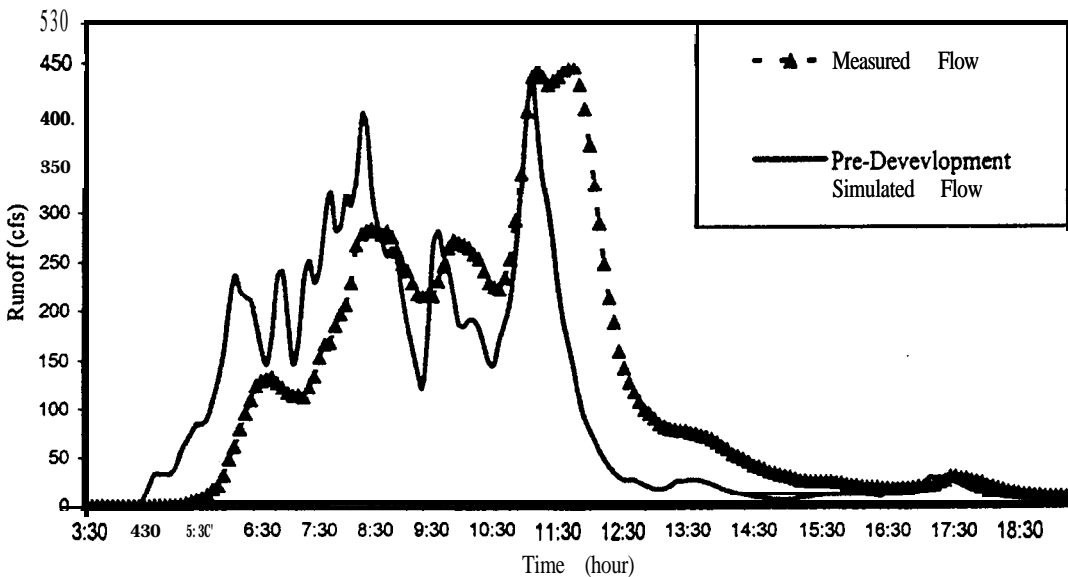
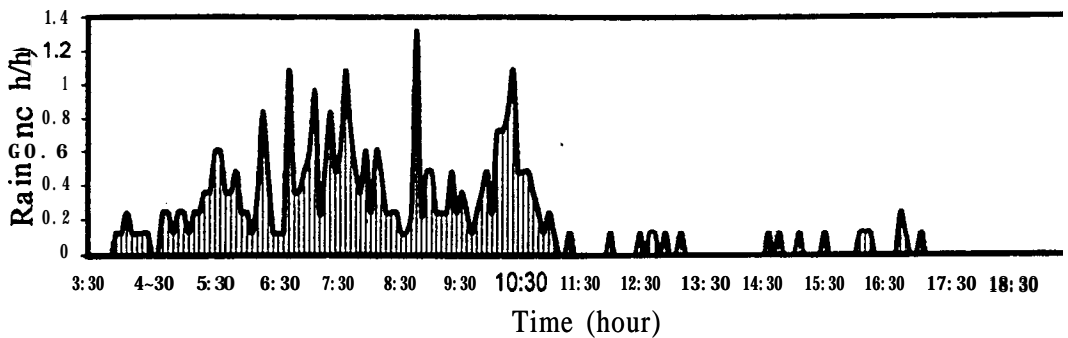


Figure 4. Verification run for storm on 12/06/79 at cross-section 3680, storm Starts at 03:25.

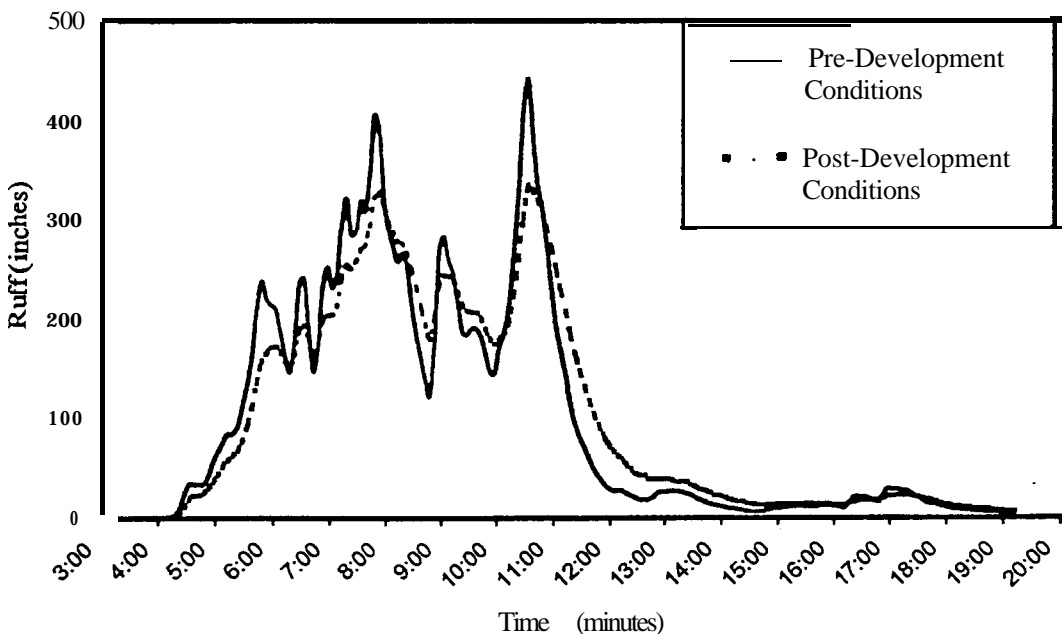
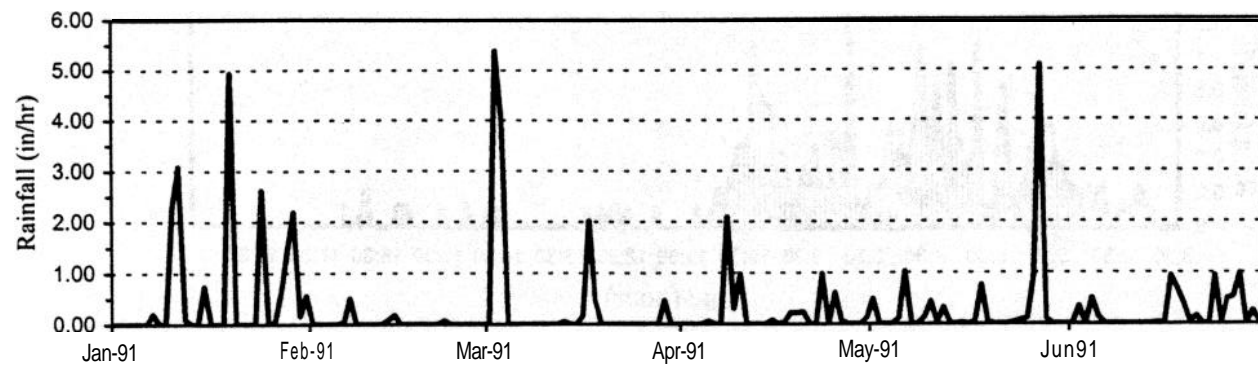


Figure 5. Comparison of simulated hydrographs at cross-section 3680 for storm on 12/06/79 under pre- and post-development conditions, storm starts at 03:25.



S64 Stage Data for January 1991 to June 1991

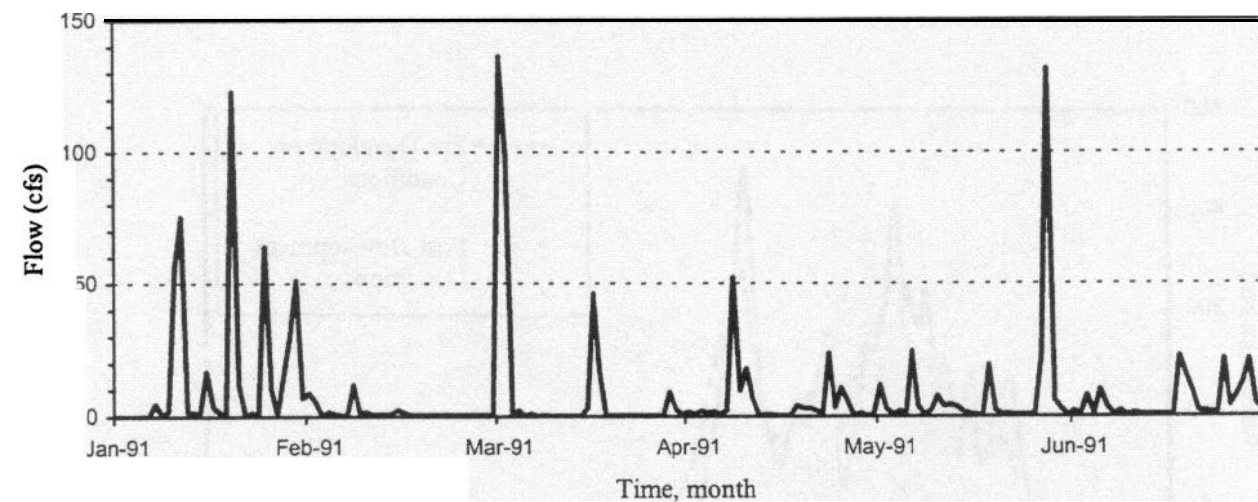
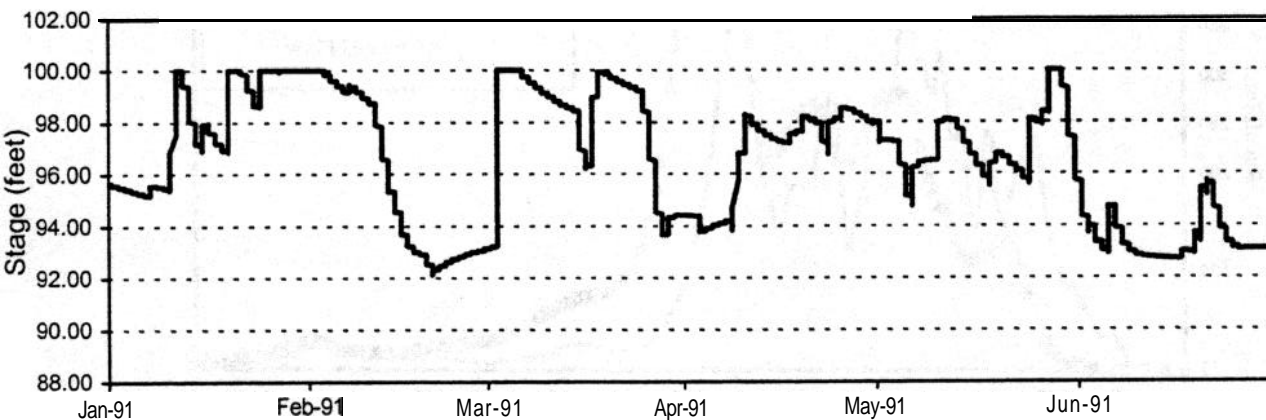


Figure 6. Simulated storm hydrograph for cross section 3680 from January 1991 to June 1991