Watershed Modeling and Calibration for Spring Creek Sub-basin in the Flint River Basin of Georgia Using the EPA BASINS/HSPF Modeling Tool

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Abstract. Heavy groundwater pumping in the Lower Flint River Basin, especially in Spring Creek Basin for agriculture irrigation plus surface water withdrawal has led to the record low flow conditions in recent drought years during summer. To evaluate possible effects of human activities on stream flow and analyzing future impact of these practices on flow conditions, a hydrological model to simulate the stream flow in Spring Creek has been developed by utilizing EPA BASINS/HSPF watershed modeling tool. The model was calibrated by using observed gage flow during a period of 1982 to 1995. In this paper, the process of data collection, model development and calibration is discussed. The simulation of flow in Spring Creek shows a good match between simulated flow and observed flow. The goal of this research is to provide an accurate modeling tool to simulate stream flow in Spring Creek, and therefore to provide technical support for management decision.

INTRODUCTION

With the rapid growth in water use, especially by agriculture, and its possible impacts on water resources in the Flint River Basin (FRB), the Flint River Regional Conservation and Development Plan was initiated in June 1998 to address this critical issue, and to attempt a comprehensive analysis of water resources in the FRB (GA EPD, 1998). To achieve this goal, mathematical models and computer analysis tools need to be developed to simulate this complex water resources system and evaluate the impacts of human activities on water resources in FRB, and therefore, to provide a strong technical support and valuable information to management decision.

To develop the water resources management model for FRB, the natural stream flow conditions are important input to the model, therefore need to be quantified. Although USGS stream flow gage data provides important information for this purpose, the number of gage stations is limited. More stream flow data in ungaged places of interest needs be calculated to develop detail water resources management model.

The WINHSPF modeling tool was selected to develop a hydrological model in this study. WINHSPF is a comprehensive, continuous watershed model, which is designed to simulate hydrology and associated water quality processes on pervious and impervious land surfaces and in river reach streams and well-mixed lakes, reservoirs and impoundments (Duda etc, 2001). Spring Creek basin was selected for the study area because of the importance in the FRB. This study is our first effort to develop a hydrological model for Spring Creek basin to simulate stream flow in any place of interest based on the rainfall data. The next step will be to establish the regional hydrological model for FRB.

DESCRIPTION OF STUDY AREA

Spring Creek is located in the Lower Flint Basin (USGS Hydrological Code # 03130010) and is one of three major tributaries of the Flint River in the Lower Flint Basin. Spring Creek joins the Flint River in Lake Seminole approximately 20 miles below Bainbridge, GA, and its watershed has a drainage area of 788 square miles. Due to the shallow depth and prolific nature of the Floridan aquifer in the area, groundwater pumpage for agricultural irrigation is extremely heavy in the Spring Creek watershed, while surface water withdrawals are relatively insignificant (McDowell, R. J., 2004). Groundwater usage consists of more than 89% of permitted agriculture withdrawals in the watershed. Considering the close interaction between the streams and the Upper Floridan Aquifer which supplies the water for pumping, therefore, Spring Creek is strongly influenced by groundwater withdrawal.

Spring Creek sub-basin is located almost entirely in Subarea 4 which is an area of ground water model targeting the Upper Flroidan (Torak, L.J. et al, 1996). It has several major tributaries including Aycocks Creek in western Miller county, Big Drain in eastern Miller County, Fishpond Drain in Seminole County, and Dry Creek in Miller and Early Counties (Fig.1). Five USGS stream gage records exist within the basin, but two have very short periods of stream flow record and were

terminated long time ago. Other two started just recently. Only stream gage near Iron City has a long period of record and its drainage area is 485 square mile. Therefore, this gage record will be used for model calibration.

DATA

Data required for the HSPF model includes geographic, meteorological, hydraulic and hydrological data as well as watershed data. Geographic data includes the Digital Elevation Model (DEM), and soil and land use etc. Hydrological and hydraulic data includes stream flow gage data, stage-discharge relationship at cross-sections, and channel characteristics. Meteorological data required for hydrological simulation includes rainfall and potential evaporation (PEVT) data.

Met Stations

Three weather stations exist in Spring Creek basin but only two have an adequate period of record: one is Colquitt 2W station located near the middle of the basin, and another is Blakely station located at the upper-left boundary of the basin, as shown in Fig. 1. Both weather stations have only daily rainfall data. Colquitt has rainfall data from the year 1956 to 1999 and the Blakely station has rainfall data from 1930 to 1992. The nearest weather station with hourly rainfall data is Edison station, which is located near the upper-right corner of Spring Creek within Ichawaynochaway basin, and has a rainfall record from 1970 to 1996. Three Met stations cover well the upper half of Spring Creek basin, where the calibration is implemented. The simulation period for calibration was selected from 1982 to 1995. This period covers normal, wet and dry years. The time step for the model is an hour so that hourly rainfall data is critical to the modeling results. Since only daily precipitation available at Colquitt 2W and Blakely stations, their hourly rainfall values were computed based on the hourly distribution at Edison station.

Other input data required by the model is potential evaporation (PEVT). Since there is no PEVT available at Colquitt and Blakely stations, the maximum and minimum temperatures at these two stations were used to calculate their daily PEVT and then, hourly distribution of PEVT at Edison was used to calculate the hourly values of the two stations by using the WDMUtil tool in BASINS.

Hydrological and Hydraulic Data

As mentioned in the Introduction, although there are five USGS stream flow gage records in the area, only the gaging station near Iron City (USGS 02357000) has an adequate period of record from 1935 to 1970 and then from 1982 to 2003 with missing data from 1970 to 1982. Thus, only the observed stream flow at this gaging station

can be used for model calibration. There is another gaging station (USGS 0235698) just upstream of the station near
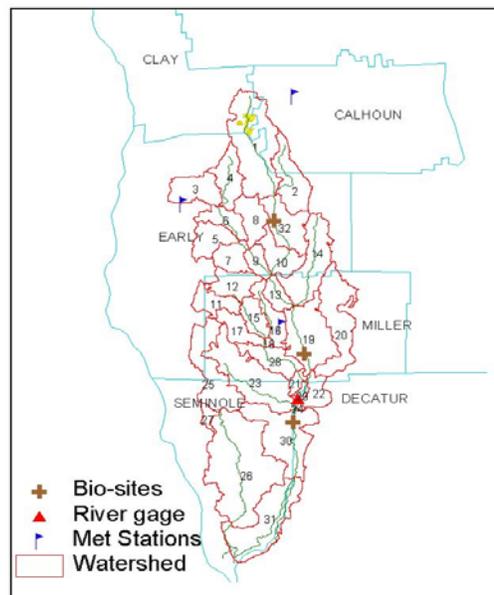
Figure 1. Spring Creek Watershed.

Iron City, which has a period of record from 1993 to 1995. It can be used to validate calibrated parameters.

The channel geometry required by the HSPF model such as channel cross-sections, river reach length, channel slope and roughness coefficient was generated automatically by ARCVIEW GIS and the Spatial Analyst tool in BASINS 3.1 based on the DEM data, river network data collected by USGS. More accurate data can be obtained by field surveys, but they were not conducted in this study. Rating curves representing the stage-discharge-storage relationships of channels at the sub-basin outlets were also obtained automatically in BASINS 3.1. A more accurate relationship can be obtained by using hydrodynamic simulation software such as Hec_Ras. Rating curves can also be adjusted during the calibration process.

Watershed Data

Land use and soil property data required by the model was collected by ARCVIEW GIS in BASINS 3.1 based on currently available land use and soil information within GIS coverage. This land use information indicates that about 58% of land in the Spring Creek basin is agriculture land, about 30% is forest, and the rest water, wetlands, barren and urban. It should be noted that the land use data obtained in current BASINS 3.1's GIS coverage were generated in the 1970s and 1980s. Land use may be significantly changed over the time in some area due to

the development. If this is the case, the most recent updated land use data should be used, of course, depending on its availability. In this case, the land use in Spring Creek basin did not have significant changes.

Based on the USGS 12-digit hydrologic units (Huc 12), and critical nodes in the basin, Spring Creek basin is delineated into 32 sub-basins, as shown in Fig. 1. Flow can be generated in each outlet of these sub-basins.

WATERSHED MODEL AND ANALYSIS

Subbasin Delineation and Data Preparation

As mentioned earlier, WinHSPF was selected to build the hydrological model for Spring Creek. To develop the model using WinHSPF, the study area needs to be delineated into a number of sub-basins and the data described above needs to be collected as model input.

The delineation and data collection were conducted in BASIN 3.1 platform based ARCVIEW GIS. The study area was delineated into 32 sub-basins based on Huc12, with consideration of the calibration and validation gaging stations and some critical nodes with possible flow requirement such as federally protected locations for freshwater mussels. Then geographic, watershed, landuse, soil, and channel geometry data was collected and prepared also by BASINS 3.1. These data were then input into WINHSPF to construct the watershed model for Spring Creek.

Simulation Period and Calibration Period

In HSPF, simulation is done on an hourly basis. Since the available hourly weather station at Edison only has precipitation and evaporation records from 1970 to 1995, the simulation was conducted during this period. However since stream flow gage data at Iron City Station has been missed from 1970 to 1982, although it has a long period of records in other years, calibration can be conducted only during 1982 to 1995.

Model Calibration

The purpose of calibration is to "tune" the model so that the simulated flow resembles the observed flow as closely as possible (Aqua Terra et al, 2004). This is completed by adjusting various input parameters within the WinHSPF, and several indices including correlation coefficient, coefficient of determination and Nash-sutcliffe coefficient were used to measure "the goodness of fit" between the simulated flow and observed flow at the calibration station.

For this calibration, the following steps were used. First, the water balance computation was conducted to examine the total runoff volume error. The analysis was performed for annual, seasonal and storm periods. The parameters such as lower zone storage nominal (LZSN),

upper zone storage nominal (UZSN) were adjusted to achieve the water balance. Then, various calibration parameters were adjusted to test how well the simulated flow matches observed stream flow at Spring Creek gage station near Iron City. These parameters include soil infiltration rate (INFILT), groundwater recession rate (AGWRC), LZSN, UZSN, coefficient measuring transition from surface water detention storage to interflow (INTFW), the interflow recession coefficient (IRC), groundwater recession flow parameter (KVARY), etc. Then, the detailed watershed summary report and water balance report were generated to show the distribution of precipitation among the components of the water balance including surface water runoff, baseflow and interflow, etc on an annual and span-of-the-run basis, so that a comparison could be made with other knowledge of the study area's hydrology. During the calibration, the expert system (HSPEXP) was also used to provide advice for the direction of parameter adjustment and reasons for the adjustment so that the calibration could be done in a more physical sense.

Analysis of Results

The calibrated parameters and their values are shown in Table 1, and calibration indices are shown in Table 2. Most of parameters are within the normal range of the parameters with INTFW, IRC and UZSN reaching the high values. This could mean the interflow has relatively higher weight than surface runoff and is the dominant source of runoff. Table 2 shows the calibration indices have relative high values meaning that the match between the simulated flow and observed flow is quite good. Fig. 2 shows flow duration curves between simulated and observed match very well with the observed flow having slightly higher values in both peak and low flow ends compared with the simulated flow. Fig. 3 shows two time series of the flows during 1985 and 1986 as an example. The two flow series also match satisfactorily with just a couple of mismatches for the rainfall process.

SUMMARY

In this study, the WINHSPF model has been used to establish a hydrological model for Spring Creek sub-basin. The model was calibrated by using observed gage flow during a period of 1982 to 1995 at gaging station near Iron City. The detail process of data collection, model development and calibration is discussed. The model simulation shows that the simulated result matches the observed result quite well, therefore, satisfactory results have been achieved for this purpose. The model can be used to simulate the stream flow at any point of interest within the sub-basin. The model

can also be used to generate umimpaired flow for our Flint River surface water model, and therefore provides valuable hydrological information to the surface water model. This model will also provide a basis for the development of future regional hydrological model for the FRB.

**Table 1. Calibrated Parameter Values**

Parameter Name	Parameter Value (unit)	Typical Low	Typical High
LZSN	6.6 (in)	3.0	8.0
INFILT	0.17 (in/hr)	0.01	0.25
LSUR	400.0 (ft)	200	500
SLSUR	0.008 (-)	0.01	0.15
KVARY	0.8 (1/in)	0.0	3.0
AGWRC	0.984 (1/day)	0.92	0.99
DEEPER	0.02	0.0	0.20
BASETP	0.04	0.0	0.05
AGWETP	0.0	0.0	0.05
CEPSC	0.1	0.03	0.20
UZSN	1.1	0.10	1.0
NSUR	0.2	0.15	0.35
INTFW	5.0	1.0	3.0
IRC	0.7	0.5	0.7
LZETP	monthly	0.2	0.7

Table 2. Calibration indices for Spring Creek

Calibration Period	Correlation Coefficient	Coef. of Determination	Nash-Sutcliffe Coefficient	Location
7/1/1982 – 12/31/1995	0.84	0.71	0.64	Spring at Iron
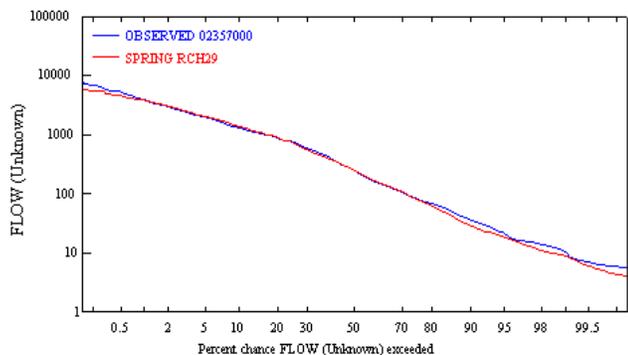
Figure 2. Duration Curves of Simulated and Observed Flow.
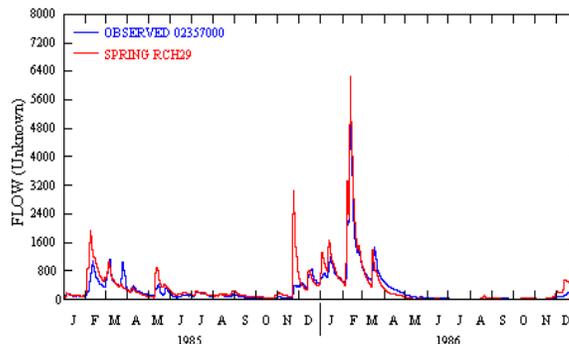
Figure 3. Hydrographs of Simulated and Observed Flow.

LITERATURE CITED

Aqua Terra Inc. and Utah State University, 2004. BASINS/HSPF Training Handbook.

BASINS Technical Note 6, 1999. Estimating Hydrology Parameters for NPSM/HSPF.

Donigian, Jr., A.S., 2000. HSPF Training Workshop Handbook and CD. For US EPA Water of Office.

Duda, P.B., J.L. Kittle, Jr., and R.S. Kinerson. 2001. WinHSPF - An Independent, Fully-Integrated Component of a Comprehensive Modeling System. Proceedings of the Annual Spring Specialty Conference. April 30 - May 2, 2001, San Antonio, TX. American Water Resources Association.

GA EPD, 1998. Flint River Regional Conservation and Development Plan.

McDowell, R. J., 2004 Spring Creek Watershed "Strawman" Development and Conservation Plan.

Torak, L. J.; McDowell, R. J., 1996 Ground-water resources of the lower Apalachicola-Chattahoochee-Flint River Basin in parts of Alabama, Florida, and Georgia; Subarea 4 of the Apalachicola-Chattahoochee-Flint & Alabama-Coosa-TallaPoosa river basins.