Appendix D
Model Configuration, Calibration and Validation

Basin: Apalachicola-Chattahoochee-Flint (ACF)

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Watershed Background

The Apalachicola-Chattahoochee-Flint (ACF) River basin lies in Georgia, Alabama, and Florida, empties into the Gulf of Mexico at Apalachicola Bay (Figure 1). It is comprised of 12 HUC8 cataloging units, and stretches across parts of three geological physiographic provinces. The ACF basin, along with the Alabama-Coosa-Tallapoosa (ACT) River basin, are the central focus of water war that has been ongoing for over 20 years. The states of Georgia, Alabama, and Florida are locked in courtroom controversy over the fair management of the waters that these states share (Alabama River Alliance 2007).

The watershed is underlain by five major aquifer systems: crystalline rock aquifers in the Blue Ridge and Piedmont physiographic provinces, and four aquifer systems in the Coastal Plain physiographic province. Watershed hydrology is influenced by 16 reservoirs, 13 of which are on the Chattahoochee River. These reservoirs play a major role in controlling flow and influencing the quality of water in the watershed (Couch 1993).

Water Body Characteristics

Chattahoochee River

The Chattahoochee River is 430 miles long, drains an area of 8,770 mi^2, and has an average discharge of 11,500 cubic feet per second (cfs). The river begins in the Blue Ridge Province in the mountainous region of northeast Georgia, which is characterized by steep topography and relatively high precipitation and runoff. Annual precipitation ranges from 53 to 70 inches and annual runoff from 27 to 37 inches. The part of the Chattahoochee River watershed in the Blue Ridge Province is underlain by crystalline rock, and surface water in the area is siliceous and low in natural mineral content (Couch 1993).

Thirteen of 16 dams on mainstem locations in the ACF River basin are on the Chattahoochee River. Dam construction in the watershed began in the early 1800s on the Chattahoochee River above the Fall Line at Columbus, Georgia, to take advantage of natural gradients for power production. Pronounced decreases in the frequency of high and low flows have occurred since the start of operation of Buford Dam, which forms Lake Sidney Lanier. Lake Sidney Lanier, West Point Lake, and Lake Walter F. George provide most water storage available to regulate flows in the watershed. Lake Sidney Lanier alone provides 65 percent of conservation storage, although it drains only 5 percent of the ACF River basin. In addition, West Point Lake and Lake Walter F. George provide 18 and 14 percent, respectively, of the watershed's conservation storage (USGS 2008).

Throughout most of its length, the Chattahoochee River is controlled by hydropeaking hydroelectric plants, which contribute to power supply during peak periods of electric demand. From Cornelia, Georgia all the way down to Lake Seminole, the hydrograph shows the influence of hydropeaking operations and these operations can result in daily stage fluctuations of 4 feet or more (USGS 2008).

In contrast to the mainstem Chattahoochee River, many tributaries remain free flowing. Flows of tributaries in forested watersheds are represented by Snake Creek and flows typical of urban watersheds are represented by Peachtree Creek. Similar to most Piedmont streams, both streams have higher sustained flows during winter months and show response to storm events throughout the year. However, sharper peaks in the hydrography of Peachtree Creek reflect greater influence of impervious land cover in the urban watershed (USGS 2008).

Flint River

The Flint River, which is 340 miles long and drains an area of 8,460 mi^2, has an average discharge of 9,800 cfs and begins in the Piedmont Province near Atlanta's Hartsfield International Airport. In the upper part of the Flint River watershed annual precipitation ranges from 44 to 59 inches, and annual runoff ranges from 10 to 39 inches.

The upper part of the Flint River watershed is characterized by both broad and narrow ridges separated by narrow valleys. Natural surface water quality in the part of the watershed in the Piedmont Province is similar to that in the Blue Ridge Province, but the water generally has higher concentrations of dissolved minerals and higher turbidity (Couch 1993, Cherry 1961).

Most of the larger tributaries in the ACF River basin are located in the Coastal Plain Province part of the Flint River watershed. These tributaries include Ichawaynochaway Creek, Chickasawhatchee Creek, Kinchafoonee Creek , and Muckalee Creek.

Apalachicola River

The Chattahoochee and Flint Rivers flow through the Piedmont and Coastal Plain Provinces to their confluence at Lake Seminole where they form the Apalachicola River. The parts of these river watersheds that lie in the Coastal Plain Province are underlain by unconsolidated sediments consisting of sand, gravel, and clay. Surface water tends to be siliceous in the upper part of the Coastal Plain Province but is predominantly carbonate in southwestern Georgia where it is in contact with limestone. Rainfall in the lower Chattahoochee and Flint River watersheds ranges from 43 to 55 inches, annually. Rainfall in this area is rapidly absorbed by the permeable soils, and annual runoff ranges from 12 to 28 inches (Couch 1993).

The Apalachicola River is 106 miles long and drains an area of about 2,400 mi^2 in the lower Coastal Plain Province. Because of the low gradient of the lower Coastal Plain Province, the channel of the Apalachicola River meanders through a wide, swampy floodplain. The floodplain ranges in width from 0.6 miles below Lake Seminole to 5 miles near its mouth, where the Apalachicola River flows through a system of distributaries to the Apalachicola Bay. The Apalachicola River has an average discharge of 26,000 cfs (Couch 1993).

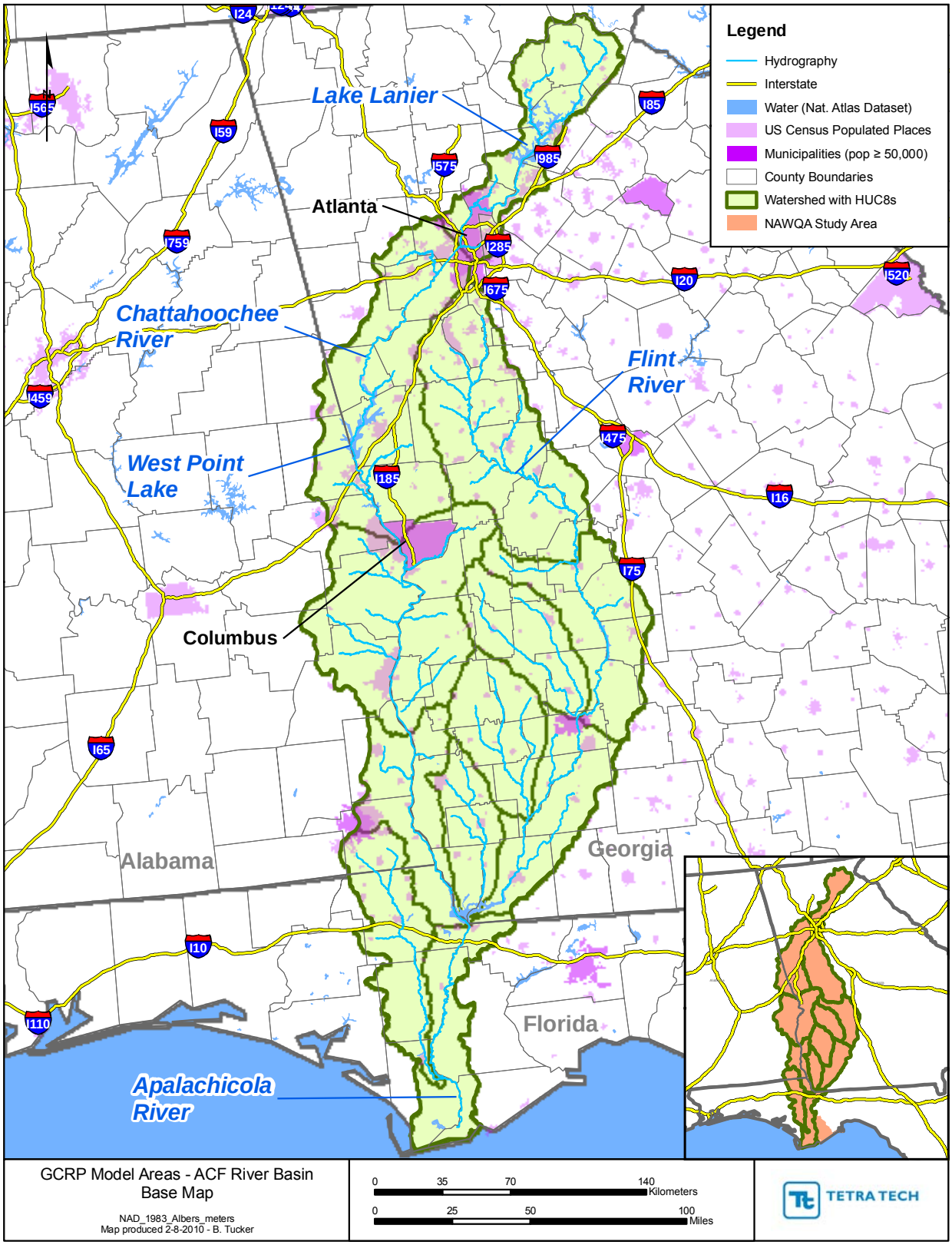

Figure 1. Location of the Apalachicola-Chattahoochee-Flint (ACF) River basin.

Soil Characteristics

The ACF River basin contains parts of the Blue Ridge, Piedmont, and Coastal Plain physiographic provinces that extend throughout the southeastern United States. Similar to much of the Southeast, the watershed's physiography reflects a geologic history of mountain building in the Appalachian Mountains, and long periods of repeated land submergence in the Coastal Plain Province. Physiography within the major provinces is not homogeneous and has been subdivided by the states of Alabama, Florida, and Georgia. Although similar physiography may extend across state boundaries, districts may be assigned different names by state geologists in each state (USGS 2008).

Three major soil orders, ultisols, entisols, and spodosols, and more than 50 soil series are present in the ACF River basin. Ultisols are characterized by sandy or loamy surface horizons and loamy or clayey subsurface horizons. These deeply weathered soils are derived from underlying acid crystalline and metamorphic rocks. Entisols are young soils with little or no change from parent material and with poorly developed subhorizons. These soils are frequently infertile and droughty because they are deep, sandy, well-drained, and subject to active erosion. Spodosols are characterized by a thin sandy subhorizon underlaying the A horizon. This sandy subhorizon is cemented by organic matter and aluminum. The ACF River basin is similar to much of the southeastern coastal plain in the dominance of ultisols. Entisols are found at and below the Fall Line and in the Dougherty Plain; and spodosols are found in the Gulf Coast Lowlands (USGS 2008).

The 20 Watershed study utilized STATSGO soil survey hydrologic soil group (HSG) information during model set-up. The descriptions of each hydrologic soil group are provided below.

<u>Group A Soils</u> Have low runoff potential and high infiltration rates even when thoroughly wetted. They consist chiefly of deep, well to excessively drained sands or gravels and have a high rate of water transmission.

<u>Group B Soils</u> Have moderate infiltration rates when wet and consist chiefly of soils that are moderately deep to deep, moderately well to well drained, and moderately fine to moderately course textures.

<u>Group C Soils</u> Have low infiltration rates when thoroughly wetted and consist chiefly of soils having a layer that impedes downward movement of water with moderately fine to fine structure.

<u>Group D Soils</u> Have high runoff potential, very low infiltration rates and consist chiefly of clay soils with high swelling potential, soils with a permanent water table, soils with a claypan or clay layer at or near the surface and shallow soils over nearly impervious material.

The ACF basin has all four HSGs in the watershed. The Upper and Middle Chattahoochee and most of the Upper Flint watersheds are dominated by hydrologic type B soils. As both rivers reach and cross over the Fall Line, the boundary between the Piedmont and Coastal Plain physiographic provinces, they flow through an area dominated by HSG A soils. As the two rivers come together near Lake Seminole the soil distribution is equally split between HSG A and B soils. The southernmost extents of the Apalachicola River are dominated by hydrologic soil type D.

Land Use Representation

Land use/cover in the watershed is based on the 2001 NLCD coverage (Figure 2). The 2001 NLCD land cover was used in order to generate consistency amongst all models for the 20 Watershed project.

Chattahoochee River Watershed

The Chattahoochee River watershed above Lake Sidney Lanier is dominated by forested land with a majority of the remaining land being pasture. As the Chattahoochee River flows out of Buford Dam to the southwest the dominant land use starts shifting to urban. As the Chattahoochee River nears and flows through the Atlanta metro

area, land use is almost entirely urban. After leaving the Atlanta Metro area, land use shifts back to forest dominance, but with a greater amount of pasture than the area above Lake Sidney Lanier. Continuing down the Chattahoochee and across the Fall Line, the dominant land use is still forest, but wetland areas begin to increase while pasture areas begin to decrease. After the Chattahoochee leaves Lake Walter F. George, agriculture and forest become equally dominant with wetlands still being prevalent. This land use/land cover pattern continues until the Chattahoochee empties into Lake Seminole.

Flint River Watershed

The most northern portions of the Flint River watershed are almost entirely urban. As the Flint River flows south the land use shifts to predominately pasture and then to forest. Once the Flint River crosses the Fall Line, agriculture become increasingly prevalent but there is still a good portion of forest and an increase in wetlands. The land uses of major tributaries to the Flint River are also chiefly comprised of agriculture, forest, and wetlands. The Flint River immediately above Lake Seminole is mostly agriculture with a small portion of pasture and forest.

Apalachicola River Watershed

The Apalachicola River immediately below Lake Seminole is comprised of mostly forest, scrub land and pasture. As the Apalachicola River flows south, the land use is almost entirely dominated by wetlands until the river empties into the Gulf of Mexico. The Chipola, a major tributary to the Apalachicola River, is chiefly comprised of pasture and barren lands to the north and forest and wetlands to the south.

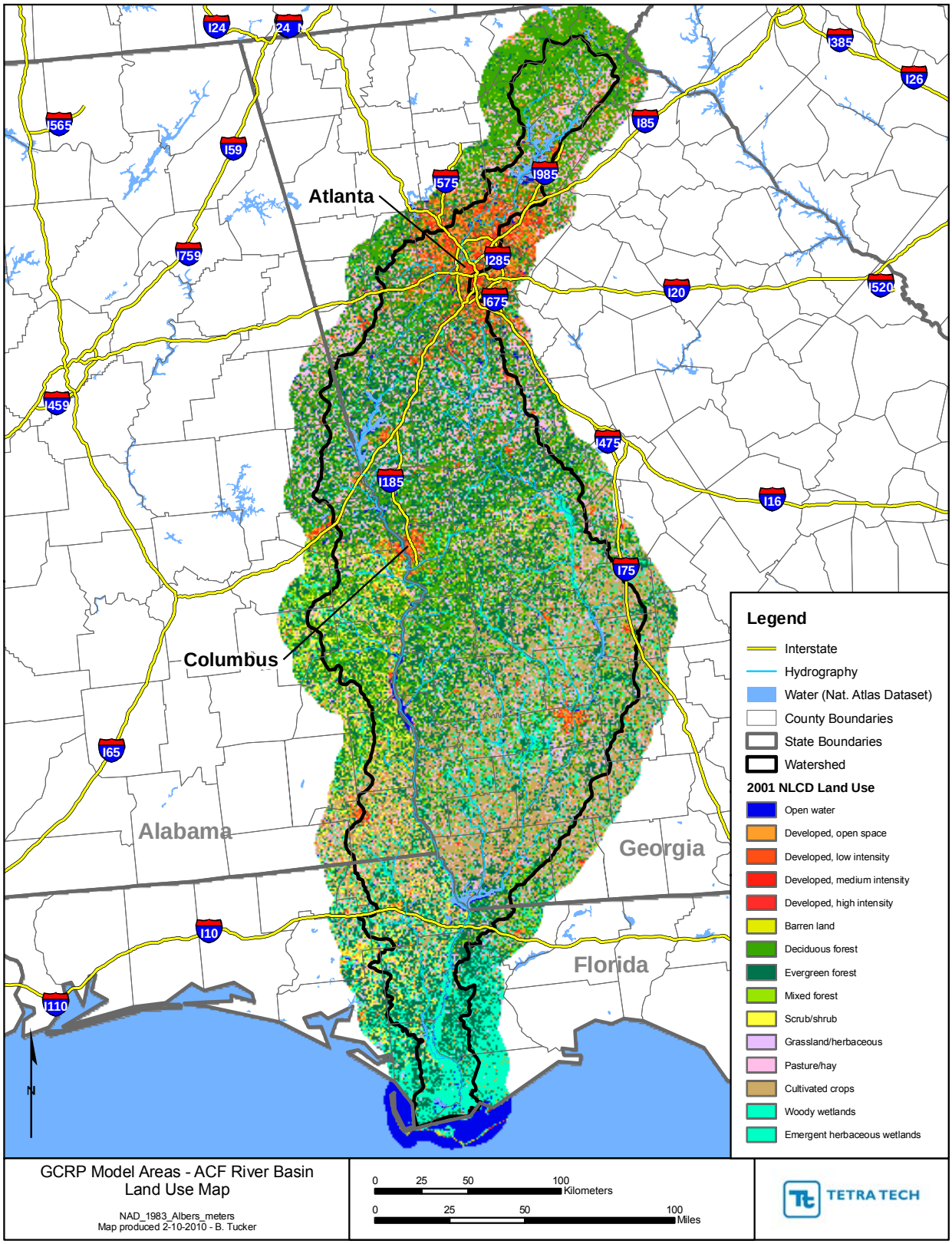

Figure 2. Land use in the ACF River basin.

NLCD land cover classes were aggregated according to the scheme shown in Table 1 for representation in the 20 Watershed model, and then overlain with the soils HSG grid. Pervious and impervious lands are specified separately for HSPF, so only one developed pervious class is used, along with an impervious class. HSPF simulates impervious land areas separately from pervious land. Impervious area distributions were also determined from the NLCD Urban Impervious data coverage. Specifically, percent impervious area was calculated over the entire watershed for each of the four developed land use classes. These percentages were then used to separate out impervious land. NLCD impervious area data products are known to underestimate total imperviousness in rural areas. However, the model requires properly connected impervious area, not total impervious area, and the NLCD tabulation is assumed to provide a reasonable approximation of connected impervious area. Different developed land classes are specified separately in SWAT. The WATER, BARREN, DEVPERV, and WETLAND classes are not subdivided by HSG in HSPF; SWAT uses the built-in HRU overlay mechanism in the ArcSWAT interface. The distribution of land use in the watershed is summarized in Table 2.

Table 1. Aggregation of NLCD land cover classes

NLCD Class	Comments	SWAT class	HSPF (after processing)
11 Water	Water surface area usually accounted for as reach area	WATR	WATER
12 Perennial ice/snow		WATR	BARREN, Assume HSG D
21 Developed open space		URLD	DEVPERV; IMPERV
22 Dev. Low Intensity		URMD	
23 Dev. Med. Intensity		URHD	
24 Dev. High Intensity		UIDU	
31 Barren Land		SWRN	BARREN (D)
41 Forest	Deciduous	FRSD	FOREST (A,B,C,D)
42 Forest	Evergreen	FRSE	
43 Forest	Mixed	FRST	
51-52 Shrubland		RNGB	SHRUB (A,B,C,D)
71-74 Herbaceous Upland		RNGE	GRASS (A,B,C,D), BARREN (D)
81 Pasture/Hay		HAY	GRASS (A,B,C,D)
82 Cultivated		AGRR	AGRI (A,B,C,D)
91-97 Wetland	Emergent & woody wetlands	WETF, WETL, WETN	WETLAND, Assume HSG D
98-99 Wetland	Aquatic bed wetlands (not emergent)	WATR	WATER

Table 2. Land use distribution for the ACF River basin (2001 NLCD) (mi^2)

HUC 8 watershed	Open water	Developed land[a]				Barren land	Forest	Shrubland	Pasture/Hay	Cultivated	Wetland	Total
		Open Space	Low density	Medium density	High density							
Lower Flint **03130008**	18.68	63.64	27.44	6.55	3.32	1.68	485.50	129.32	83.85	354.64	99.74	1,274.36
Spring[b] **03130010**	11.54	27.90	8.63	1.37	0.42	0.80	200.66	51.10	56.98	323.85	104.88	788.13
Middle Chattahoochee Walter F. George Reservoir **03130003**	75.90	116.45	56.69	14.76	6.02	9.75	1,707.28	384.98	157.72	142.74	164.22	2,836.52
Ichawaynochaway **03130009**	4.56	31.42	5.57	1.06	0.20	0.79	411.62	90.56	82.05	303.87	172.34	1,104.04
Apalachicola **03130011**	14.05	25.61	2.25	0.61	0.09	0.62	333.53	61.92	26.02	35.62	333.64	833.95
Lower Chattahoochee **03130004**	21.93	46.11	10.40	2.31	0.81	0.90	497.53	157.32	106.71	312.13	87.81	1,243.96
Kinchafoonee Muckalee **03130007**	4.01	40.35	13.08	3.11	1.51	0.81	506.78	97.07	83.95	232.69	117.76	1,101.12
Chipola **03130012**	9.91	66.91	7.43	2.13	0.58	0.99	407.96	227.81	99.09	192.57	248.09	1,263.47
Middle Flint **03130006**	17.33	62.41	20.79	3.86	1.54	1.66	619.38	126.89	120.44	416.28	166.93	1,557.50
Middle Chattahoochee Lake Harding **03130002**	82.79	218.52	127.04	29.88	15.65	22.97	1,809.39	246.54	388.08	1.28	98.74	3,040.89
Upper Chattahoochee **03130001**	66.64	226.45	149.88	53.78	30.45	10.83	804.58	56.76	175.98	0.11	9.47	1,584.94
Upper Flint **03130005**	28.26	143.33	79.35	21.80	14.97	16.31	1,452.89	227.02	376.03	79.34	190.22	2,629.53
Total	355.60	1,069.09	508.56	141.22	75.57	68.11	9,237.09	1,857.31	1,756.89	2,395.11	1,793.84	19,258.40

[a]The percent imperviousness applied to each of the developed land uses is as follows: open space (8.04%), low density (30.16%), medium density (60.71%), and high density(89.9%).
[b]Delineation for Lake Seminole crossed HUC8 boundaries so whole watershed is represented in Spring HUC8.

The HSPF model is set up on a hydrologic response unit (HRU) basis. For HSPF, HRUs were formed from an intersection of land use and hydrologic soil group, and then further subdivided by precipitation gage. Average slopes (which tend to correlate with soils) were calculated for each HRU. Slopes in most of the watershed are relatively mild (1-5 percent), therefore HSPF HRU's were not further subdivided by slope. The three HRUs above Lake Lanier have average slopes of 15-24 percent, but since there were already three HRU's for four delineated subwatersheds it was not further divided. The water land use area was adjusted to prevent double counting with area described in HSPF reaches. SWAT HRUs are formed from an intersection of land use and SSURGO major soils.

Point Sources

Facilities permitted under the National Pollutant Discharge Elimination System (NPDES) are, by definition, considered point sources. For all models in the 20 Watershed application, it was assumed that minor dischargers (below 1.0 MGD) were insignificant and, therefore, not included in the model setup and simulation. Data were sought from the PCS database for the major dischargers in the ACF River basin and reflect the time period from 1991-2006. Facilities that were missing total nitrogen, total phosphorus, or total suspended solids (TSS) concentrations were filled with a typical pollutant concentration value from literature based on Standard Industrial Classification (SIC) classification. For the 20 Watershed application, the assumption was to use constant point source flows and concentrations, for the entire simulation period, for each major discharge facility in the watershed. Figure 3 presents the locations of the major point sources included in the models.

During the water quality calibration, it was noticed that assumptions used for total phosphorus at some facilities were too high. An investigation into the point sources that had assumed values for total phosphorus was conducted. It was found that point sources with assumed values for total phosphorus, that were too high, were water pollution control plants (WPCP) and the assumed total phosphorus concentration for those facilities was 7 mg/L. A new assumed value was needed for these facilities. The new assumed value was 1.5 mg/L, which is an average of the total phosphorus concentration for WPCP's that do monitor for total phosphorus. It is assumed that 1.5 mg/L is a much better estimate of the true total phosphorus concentration coming out of WPCP's in the ACF basin. The new assumed value was also applied to the SWAT simulation. Both the HSPF and SWAT models used the exact same flows and concentrations for each of the major point sources included in the simulations for the ACF basin.

Table 3. Major point source discharges in the ACF River basin

NPDES ID	Name	Design flow (MGD)*	Observed flow (MGD) (1991-2006 average)
AL0000817	MEADWESTVACO COATED BOARD INC	40.00	22.34
AL0022209	PHENIX CITY WWTP	7.75	3.32
AL0022764	DOTHAN CITY OF OMUSSEE WWTP	7.12	3.97
AL0023159	LANETT CITY OF WWTP	5.00	1.90
AL0024619	SOUTHERN NUCLEAR OPERATNG CO	0.16	0.52
AL0024724	EAST AL WATER LOWER VALLEY WTP	4.00	2.83
AL0059218	OPELIKA CITY OF EASTSIDE WWTP	1.00	0.70
AL0061671	EUFAULA CITY OF	2.70	1.75
AL0072737	DOTHAN CITY CYPRESS WWTP NEW	3.00	1.32
FL0002283	GULF PWR SCHOLZ STEAM	129.60	3.24
FL0026867	BLOUNTSTOWN-STP	1.50	0.57
FL0031402	FL STATE HOSPITAL	1.30	0.71
GA0000973	COLUMBUS WATER WKS-FT.BENNING	4.60	11.71
GA0001112	SCOVILL FASTENERS, INC.		0.26
GA0001198	USAF PLT #6 - LOCKHEED MARTIN		1.63
GA0001201	GA. PACIFIC CORP (GREAT S.P)		32.60

NPDES ID	Name	Design flow (MGD)*	Observed flow (MGD) (1991-2006 average)
GA0001619	MERCK & CO -FLINT RVR PLNT		1.13
GA0020052	WEST POINT WPCP	1.00	0.64
GA0020079	THOMASTON-BELL CREEK WPCP	2.00	1.01
GA0020168	GAINESVILLE (LINWOOD DRIVE)	2.70	2.03
GA0020486	MONTEZUMA WPCP #2	1.95	0.30
GA0020516	COLUMBUS (SOUTH WPCP)	42.00	30.35
GA0021156	GAINESVILLE FLAT CR WPCP	10.20	6.45
GA0021326	DAWSON WPCP	2.50	1.29
GA0021458	ATLANTA (UTOY CREEK WRC)	40.00	29.50
GA0021482	ATLANTA (R.M. CLAYTON WPCP)	100.00	80.00
GA0021504	CORNELIA WPCP	3.00	2.33
GA0023167	BUFORD SOUTHSIDE WPCP	2.00	1.11
GA0024040	ATLANTA (SOUTH RIVER WRC)	48.00	35.31
GA0024333	FULTON CO-BIG CREEK WPCP	24.00	21.09
GA0024503	CORDELE WPCP	5.00	2.66
GA0024678	BAINBRIDGE WPCP	2.50	1.32
GA0025381	FULTON CO-CAMP CREEK WPCP	13.00	12.47
GA0025585	BLAKELY WPCP	1.32	1.01
GA0026077	DAHLONEGA WPCP	1.44	0.51
GA0026140	COBB CO-SUTTON WPCP	40.00	30.62
GA0026158	COBB CO.-SO. COBB WPCP	40.00	24.50
GA0026433	GWINNETT CO (CROOKED CRK WPCP)	36.00	23.52
GA0030121	THOMASTON-TOWN BRANCH WPCP	2.00	0.97
GA0030341	DOUGLASVILLE SOUTHSIDE WPCP	3.25	2.48
GA0030686	FULTON CO-JOHNS CREEK WPCP	7.00	5.73
GA0030791	GRIFFIN POTATO CR WPCP	2.00	1.41
GA0031721	NEWNAN WAHOO WPCP	3.00	1.66
GA0033511	DECATUR CO-IND. AIRPARK WPCP	1.50	0.38
GA0035777	PEACHTREE CTY (LINE CRK WPCP)	2.00	1.44
GA0035807	FAYETTEVILLE-WHITEWTER CR WPCP	3.75	1.88
GA0036951	LAGRANGE WPCP (LONG CANE CRK)	12.50	5.91
GA0037222	ALBANY (WPCP NO 2)	32.00	18.05
GA0038369	CLAYTON COUNTY (SHOAL CRK)	4.40	1.73
GA0046019	CUMMING WPCP	2.00	1.30
GA0046655	PEACHTREE CTY (ROCKAWAY WPCP)	4.00	1.66
GA0047201	DOUGLASVILLE (SWEETWATER CRK.)	3.00	1.39
GA0047767	AMERICUS MILL CRK, WPCP	4.40	2.73

*Note: Facilities that do not list a design flow are large industrial facilities. These industrial facilities have different permitting in the state of Georgia and these permits do not report a design flow.

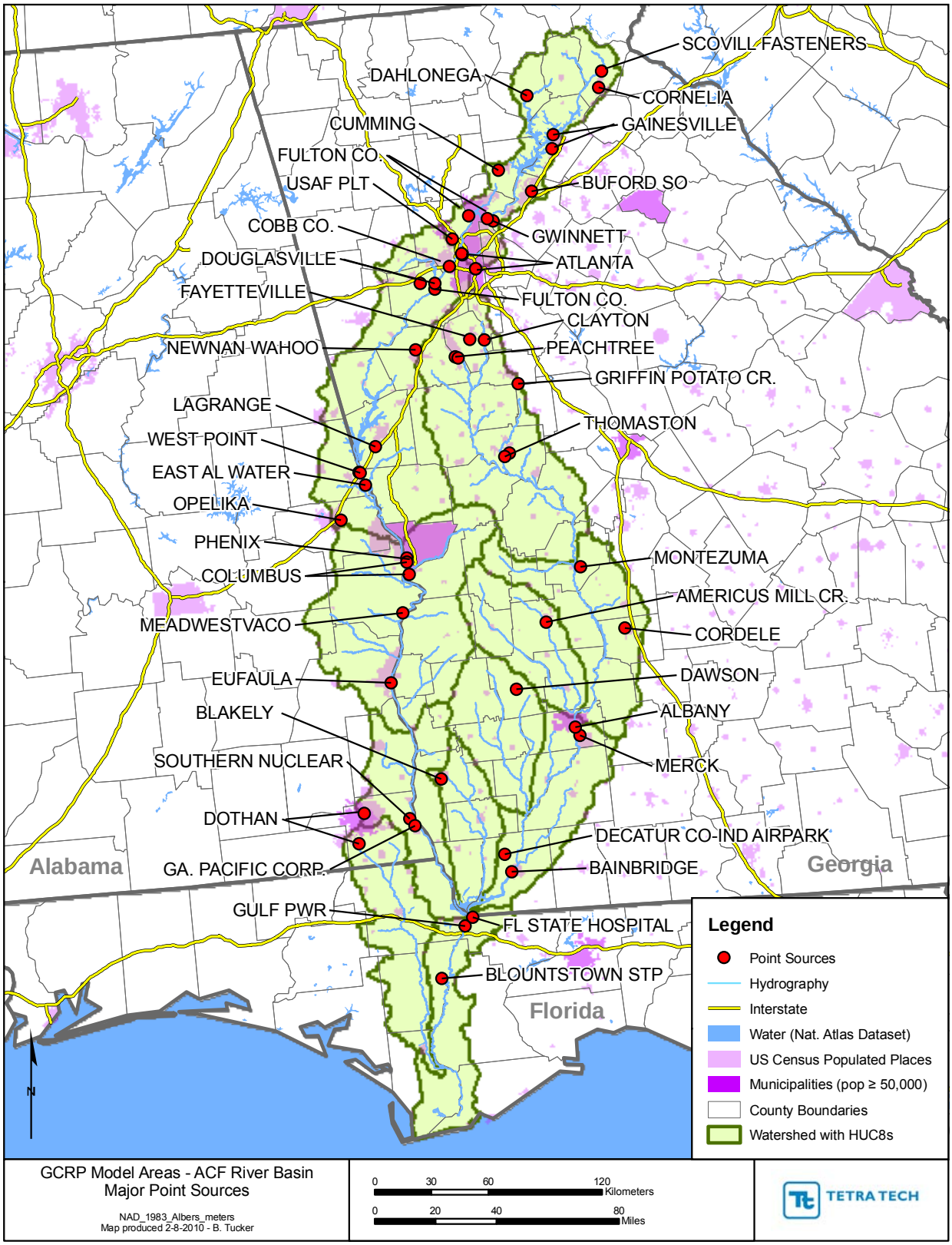

Figure 3. Major point sources in the ACF River basin.

Meteorological Data

The required meteorological data series for the 20 Watershed study are precipitation, air temperature, and potential evapotranspiration. The 20 Watershed model does not include water temperature or algal simulation and uses a degree-day method for snowmelt. These are drawn from the BASINS4 Meteorological Database (USEPA 2008), which provides a consistent, quality-assured set of nationwide data with gaps filled and records disaggregated. Scenario application will require simulation over 30 years, so the available stations are those with a common 30-year period of record (or one that can be filled from an approximately co-located station). A total of 37 precipitation stations were identified for use in the ACF basin model with a common period of record of 10/1/1972-9/30/2002 (Table 4 and Figure 4). Temperature records were sparse; where these were absent, temperature was taken from nearby stations with an elevation correction. For each weather station, Penman-Monteith reference evapo-transpiration was calculated for use in HSPF using observed precipitation and temperature coupled with SWAT weather generator estimates of solar radiation, wind movement, cloud cover, and relative humidity.

For the 20 Watershed model applications, SWAT uses daily meteorological data, while HSPF requires hourly data. It is important to note that a majority of the meteorological stations available for the ACF basin are Cooperative Summary of the Day stations that do not report sub-daily data. The BASINS4 dataset already has versions of the daily data that have been disaggregated to an hourly time step using template stations. For each daily station, this disaggregation was undertaken in reference to a single disaggregation template. Occasionally, this automated procedure provides undesirable results, particularly when the total rainfall for the day is very different between the subject station and the disaggregation template. This yields a small number of hourly precipitation intensity estimates that are unrealistically high (e.g., much greater than the 100-year 1-hour event for the region). This has only a small impact on the watershed-scale hydrologic calibration as gages are influenced by rainfall from multiple weather stations, but can introduce significant problems for the prediction of erosion and sediment loads.

Table 4. Precipitation stations for the ACF River basin model

COOP ID	Name	Latitude	Longitude	Temperature	Elevation (ft)
GA094230	HELEN	34.6997	-83.7261	Yes	1440
GA092283	CORNELIA	34.5181	-83.5286	Yes	1470
GA091998	CLERMONT 4 WSW	34.4503	-83.855	No	1281
GA092408	CUMMING 1 ENE	34.2214	-84.1222	No	1306
GA096407	NORCROSS	33.9483	-84.2219	No	1030
GA090444	ATLANTA BOLTON	33.8236	-84.4983	No	885
GA092791	DOUGLASVILLE 4 S	33.7006	-84.7303	No	1002
GA090451	ATLANTA HARTSFIELD INTERNATIONAL	33.63	-84.4417	Yes	1010
GA096335	NEWNAN 4NE	33.4428	-84.7886	Yes	920
GA093570	FRANKLIN	33.2758	-85.0992	No	790
GA094949	LA GRANGE	33.065	-85.0294	Yes	715
GA099506	WOODBURY	32.9839	-84.5889	No	790
GA099291	WEST POINT	32.8694	-85.1892	Yes	575
GA098661	THOMASTON 2 S	32.8664	-84.3175	Yes	672
GA098535	TALBOTTON	32.6856	-84.5192	Yes	686
GA091425	BUTLER	32.6525	-84.1858	No	446
GA092166	COLUMBUS METRO AP	32.5161	-84.9422	Yes	392
GA091372	BUENA VISTA	32.3178	-84.5203	No	646
GA095979	MONTEZUMA	32.2903	-84.0314	No	327
AL015397	MIDWAY	32.0597	-85.4953	No	556
GA090253	AMERICUS 3 SW	32.0503	-84.2753	Yes	490
GA095394	LUMPKIN 2 SE	32.0306	-84.7753	Yes	485
AL012730	EUFAULA WILDLIFE REF	32.0086	-85.0919	Yes	215

COOP ID	Name	Latitude	Longitude	Temperature	Elevation (ft)
GA092266	CORDELE	31.9847	-83.7758	Yes	308
GA092570	DAWSON	31.7819	-84.4497	No	355
GA092450	CUTHBERT	31.7672	-84.7931	Yes	461
AL010008	ABBEVILLE	31.5703	-85.2483	Yes	456
GA093028	EDISON	31.5664	-84.7339	Yes	294
GA090140	ALBANY 3 SE	31.5339	-84.1489	Yes	180
GA090979	BLAKELY	31.3811	-84.9508	Yes	268
AL012377	DOTHAN	31.1942	-85.3708	No	275
GA091500	CAMILLA 3 SE	31.1903	-84.2036	Yes	175
GA092153	COLQUITT 2 W	31.1681	-84.7664	Yes	153
GA090586	BAINBRIDGE INT PAPER	30.8228	-84.6175	No	190
FL081544	CHIPLEY	30.7836	-85.4847	Yes	130
FL089795	WOODRUFF DAM	30.7219	-84.8742	No	107
FL089566	WEWAHITCHKA	30.1192	-85.2042	Yes	42

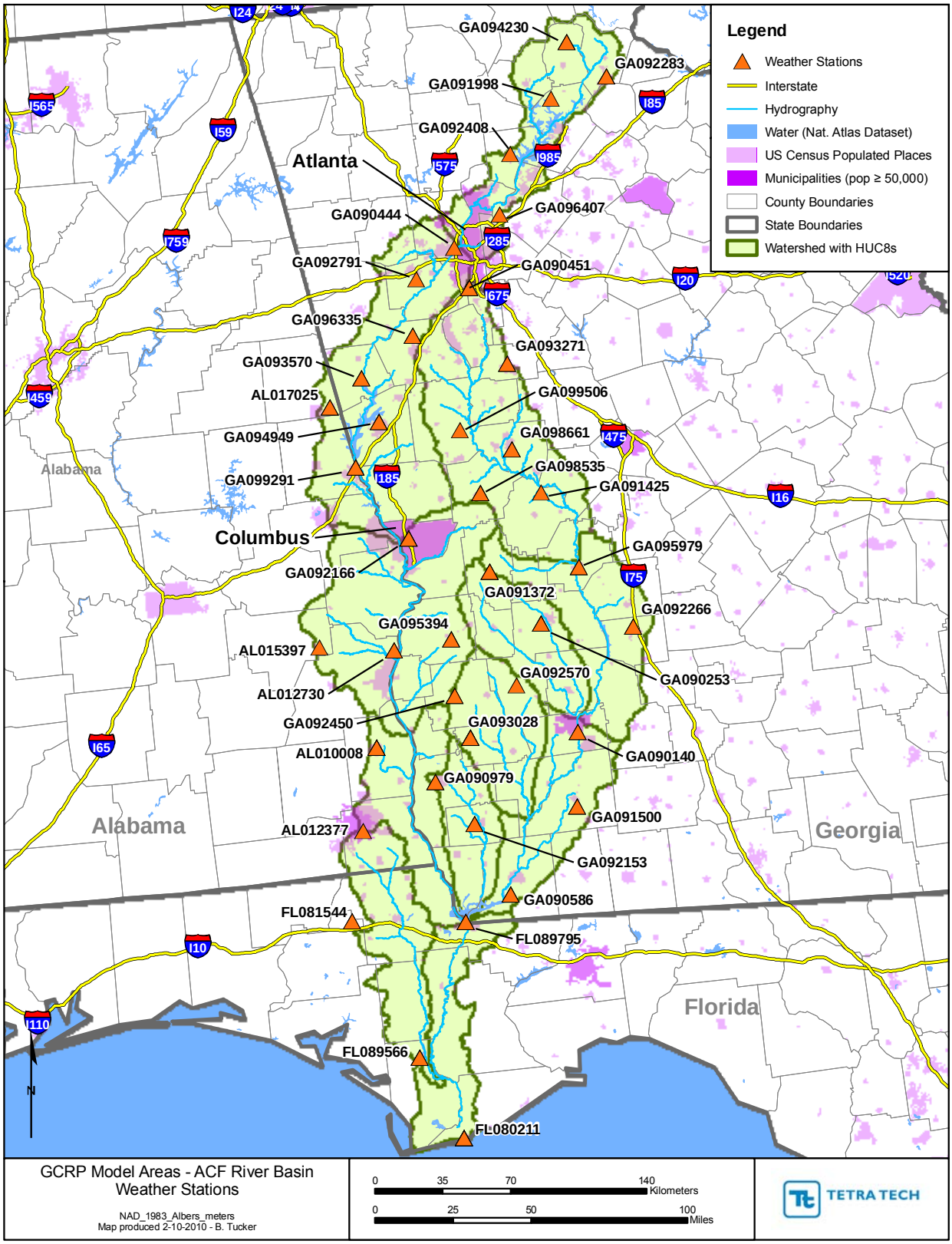

Figure 4. Weather stations for the ACF River basin model.

Watershed Segmentation

The ACF River basin was divided into 101 subwatersheds for the purposes of modeling (Figure 5). The initial calibration watershed (Upper Flint HUC) is highlighted. Each of the subwatershed delineations represents roughly a HUC 10 scale watershed. Each of the major reservoirs in the ACF basin was delineated so that the each dam outlet represents an individual watershed outlet. The delineations were done this way to ensure that any individual lake was contained in one watershed and that the watershed was only represented by one outlet. The ACF 20 Watershed model encompasses the complete watershed and does not require specification of any boundary conditions for application.

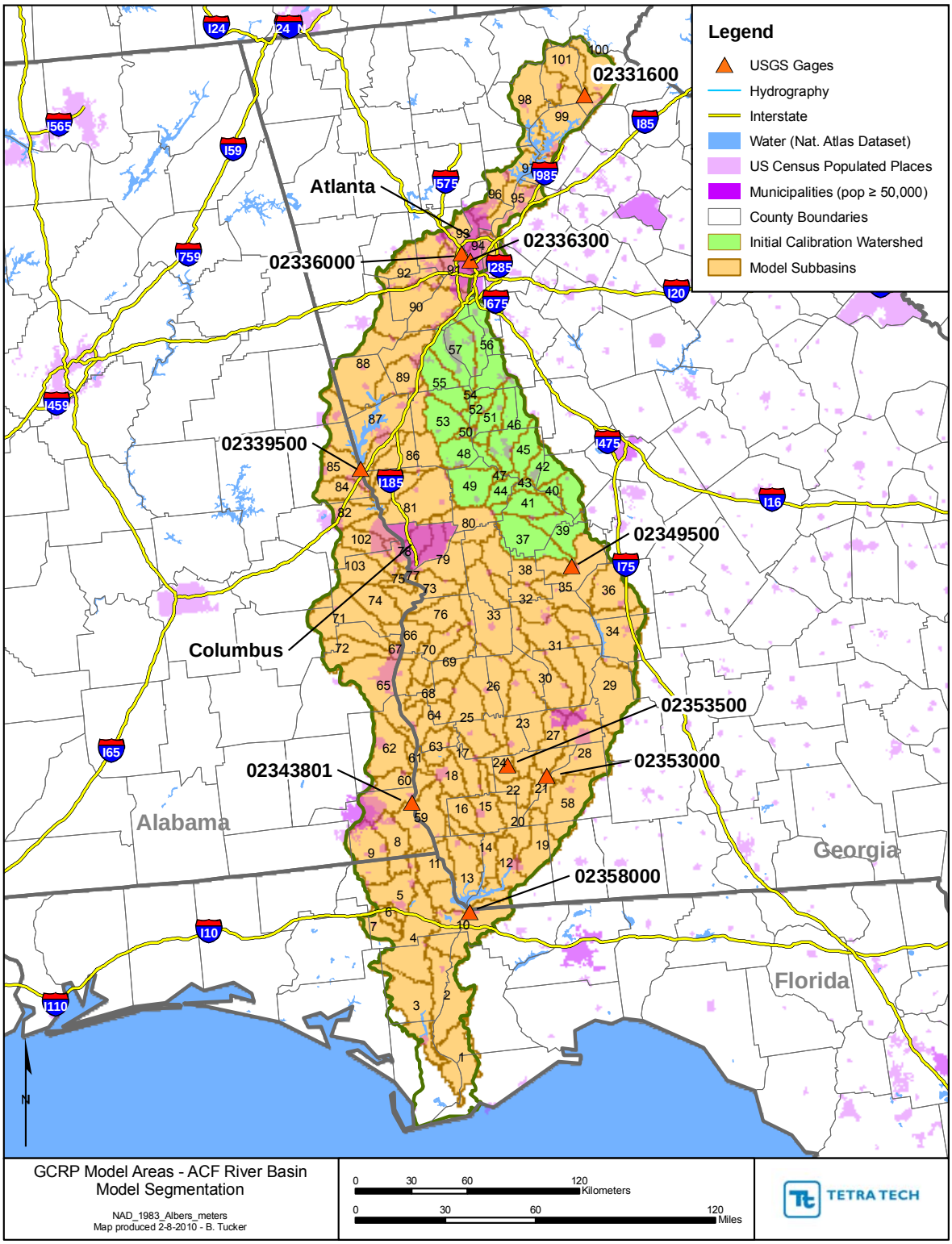

Figure 5. Model segmentation and USGS stations utilized for the ACF River basin.

Note: SWAT subwatershed numbering is shown; the HSPF model for this watershed uses the same subwatershed boundaries with an alternative internal numbering scheme.

Calibration Data and Locations

The ACF basin was selected as an early pilot site application because of previous modeling experience in parts of the watershed and the state of Georgia. The specific site chosen for initial calibration was the Flint River at GA 26, near Montezuma, Georgia (USGS 02349605) (Table 5). This is a flow and water quality monitoring location that approximately coincides with the pour point of the Upper Flint (03130005) 8-digit HUC (Figure 5). This location was selected for several reasons: 1) there is a good set of flow and water quality data available, 2) previous modeling efforts in nearby HUC8's were successful, and 3) investigations of land use, drainage area, and percentage of drainage area controlled by flow control structures, compared with other USGS gage locations in the ACF basin, identified this gage as the best possible choice.

There were an additional eight sites chosen for the whole ACF basin to check the performance of the model. These sites were chosen based on subwatershed delineation boundaries, land use, drainage area, flow control structures, data completeness and location. The eight additional sites are in Table 5 and shown spatially in Figure 5. The idea was to have some locations that were un-impacted by upstream flow control structures and additionally also have some locations downstream of major reservoirs to check the model performance of the reservoir simulation.

Three of the chosen sites were located at the outfall of two delineated subwatersheds. In reality, these gages are slightly downstream of a tributary joining the mainstem. These sites were Flint River at Montezuma, Georgia, Chattahoochee River near Cornelia, Georgia, and Flint River at Newton, Georgia. It is easy to add two flows together to get the theoretical flow at the sampling location but two water quality concentrations cannot be summed to get the theoretical concentration. In order to generate a theoretical concentration, constituent masses must be added together and then divide by the summed volumes to determine what the water quality concentration would be. Accordingly, in the SWAT application, constituent masses from two reaches were added together, and then divided by the summed volumes to determine constituent concentration. The HSPF application, dealt with this by combining the watersheds internally and generating one time series that represented the hydrology and water quality where these subwatersheds merge. This method makes the assumption that the main stem and tributary waters have fully mixed at the sampling location.

The gage for Peachtree Creek is not at the outlet of the subwatershed for Peachtree Creek. Both HSPF and SWAT applications utilized an area weighting approach for this gage. The USGS published drainage area was 66 percent of the drainage area of the subwatershed delineated for Peachtree Creek, so a multiplier of 0.66 was applied to the time series at the output of Peachtree Creek. Although this is not exact, theoretically it should be close to reality at the sampling location, because land use differences are insignificant for this watershed (90 percent urban).

The water quality data found in the NAWQA database for the chosen calibration and validation locations were limited in certain situations. Therefore, additional data were utilized from Georgia Environmental Protection Division (EPD). Due to earlier modeling work done in the state, these data were readily available, vetted and included in the water quality data for calibration and validation. While combining the NAWQA and EPD datasets there was some overlap on a few dates. The data from both datasets were compared and they always agreed on constituent values. It was decided to keep the NAWQA data and remove the EPD data. Georgia EPD submits their monitoring data to NAWQA and in general the additional EPD data contributed to lengthening the period of record available for calibration and validation.

Many of the locations chosen for calibration and validation did not specifically monitor for all constituents making up total nitrogen. Many times reported values were only for ammonia and nitrate+nitrite. The sum of those two constituents does not represent total nitrogen because it is missing the component for organic nitrogen. Because of this, the data available for total nitrogen were very limited. An approach was developed to bolster the amount of total nitrogen data available for calibration and validation. The NAWQA database was investigated for sampling dates that reported total nitrogen, ammonia, and nitrate+nitrite. These sampling dates and data were extracted and a regression analysis of total nitrogen vs. ammonia+nitrate+nitrite was performed. The regression

had an R^2 vale of 0.80. Because the fit was high, the regression was applied to the ammonia+nitrate+nitrite value and the result was an estimated value of total nitrogen based on two of the three components making up total nitrogen. For the 20 Watershed application, it was assumed that an estimated value for total nitrogen was better than having no value at all.

A database containing NAWQA, EPD, and calculated total nitrogen values was compiled and used in both the SWAT and HSPF modeling applications. This ensured the data that both models were calibrated to were consistent.

Table 5. Calibration and validation locations in the ACF River basin

Station Name	USGS ID	Drainage area (mi^2)	Hydrology calibration	Water quality calibration
FLINT RIVER AT MONTEZUMA, GA	USGS02349605	2,900.00	X	X
CHATTAHOOCHEE RIVER NEAR CORNELIA, GA	USGS02331600	315	X	X
PEACHTREE CREEK AT ATLANTA, GA	USGS02336300	86.8	X	X
CHATTAHOOCHEE RIVER AT ATLANTA, GA	USGS02336000	1,450	X	X
ICHAWAYNOCHAWAY CREEK AT MILFORD, GA	USGS02353500	620	X	X
CHATTAHOOCHEE RIVER AT WEST POINT, GA	USGS02339500	3,550	X	X
CHATTAHOOCHEE RIVER NEAR COLUMBIA, AL	USGS02343801	8,210	X	X
FLINT RIVER AT NEWTON, GA	USGS02353000	5,740	X	X
APALACHICOLA RIVER AT CHATTAHOOCHEE FLA	USGS02358000	17,200.00	X	

For hydrology, the model calibration period was set to calendar years 1993-2002 (from within the 30-year period of record for modeling). The end date is constrained by the common period of the set of 20 Watershed meteorological stations available for the watershed, and a ten year calibration period was desired. Hydrologic validation was then performed on Calendar Years 1983-1992. Water quality calibration used calendar years 1999-2002, because all gages had a decent set of data during that time period. Water quality validation was limited to 1986-1998, as very sparse data were available prior to 1986. Some of the stations didn't have observed water quality data prior to 1991. In these situations, the validation period represents all data available prior to January 1, 1999.

HSPF Modeling

Initial hydrologic parameterization for the Upper Flint calibration focus area came from a Loading Simulation Program – C++ (LSPC) model created for the Upper Oconee watershed in north central Georgia (HUC 03070101). LSPC is a comprehensive data management and modeling system that is capable of representing both flow and water quality loading from nonpoint and point sources and simulating in-stream processes. It is capable of simulating flow, sediment, metals, nutrients, pesticides, and other conventional pollutants, as well as temperature and pH for pervious and impervious lands and waterbodies. LSPC and HSPF use the same parameterization, therefore, an LSPC model was chosen for initial parameterization assignments.

The LSPC model used for initial parameterization and the HSPF model set up for the 20 Watershed study differed in land use representation as well as soils/HRU representation. The LSPC models utilized a much more detailed land use that was develop by the state of Georgia called Georgia Land Use Trends (GLUT). Additionally, in the LSPC model, subwatersheds were assigned to hydrologic soil groups by utilizing the hydrologic soil group that had the greatest area within the subwatershed. Using this method the Upper Oconee watershed did not have any hydrologic soil groups A or D. Therefore, the LSPC model was investigated to ensure the most representative land use and soil type parameterization was transferred to the HSPF 20 Watershed model. Technical Note 6 (USEPA 2000) was utilized to establish initial parameterization for infiltration rates in areas that had hydrologic soil groups A and D in the 20 Watershed application that.

Upon initial hydrologic parameterization of the focus area, both a model for the Upper Oconee watershed and a model for the Lake Lanier watershed were investigated as potential starting points. The Upper Oconee watershed parameterization did a much better job of representing measured flow than did those for the Lake Lanier watershed parameters. At this point it was realized that parameterization assigned to the calibration focus area probably will not work for all areas in the ACF basin.

The calibration focus area represents 7 HRUs. After calibrating the 7 HRUs, the calibrated parameterization was transferred to the remaining 30 HRUs. Three locations, un-affected by upstream impoundments, therefore only affected by parameterization, were selected to check the results with the focus area parameterization. These three locations were Chattahoochee River near Cornelia, Georgia (USGS 02331600), Peachtree Creek at Atlanta, Georgia (USGS 02336300), and Ichawaynochaway Creek at Milford, Georgia (USGS 02353500). All three of these locations had a poor simulation of the observed hydrology. Because of the poor hydrologic simulation, additional calibration was completed at each of the three locations.

The area contributing to Peachtree Creek at Atlanta, Georgia (USGS 02336300) was utilized as an urban area calibration. Land use at this location is roughly 79 percent urban. Since calibration at this location, entirely revolved around the urban land use, the calibrated results were transferred to all other urban areas throughout the ACF basin.

The area contributing to Chattahoochee River near Cornelia, Georgia (USGS 02331600) was parameterized with the Lake Lanier TMDL LSPC model, and is represented by two HRUs in the HSPF 20 Watershed model. The initial parameterization was adjusted slightly, to account for the indirect transfer of land use associated parameters, from the more detailed LSPC model to the 20 Watershed model. The calibrated parameters at this location were transferred to one more HRU, immediately downstream. The area represented by these parameters is closely associated with the area of the ACF basin that is in the Blue Ridge Geographic Province (Figure 6.)

The area contributing to Ichawaynochaway Creek at Milford, Georgia (USGS 02353500) was used to represent hydrologic conditions for the HRUs in the Coastal Plain Province. To calibrate the area contributing to this gage, the calibration focus area parameterization was adjusted until the simulated hydrology closely resembled the

observed hydrology. Since adjustment was needed for multiple parameters on multiple land uses it was decided that this gage would represent the hydrology of the Coastal Plain Province (Figure 6.)

The initial calibration focus area parameters were supplied for all other HRUs and this represents the Piedmont Province (Figure 6.)

In summary, after realizing that parameterization assigned to the calibration focus area will not work for all areas in the ACF basin an approach needed to be developed for assigning parameters for each HRU. After each area that wasn't influenced by major impoundments was calibrated separate of the others it was decided that each of the calibration areas would represent either the geologic province that each was contained in or in the case of the Peachtree Creek gage, the dominant land use. Essentially, there are three parameter groups assigned by geologic province and the urban land use is parameterized the same throughout the model.

After the parameter mapping was complete for all three geologic provinces the calibration turned to reservoir representation and operation. There is a more detailed discussion about the challenges faced during modeling reservoirs in the HSPF Assumptions section of this report.

Once the hydrology calibration was complete for the whole ACF basin, the focus turned to sediment and water quality representation. Initial parameterization for sediment and water quality simulation was taken from a LSPC model developed for the Lake Allatoona watershed. The Lake Allatoona TMDL model was utilized rather than the Lake Lanier TMDL or Upper Oconee watershed LSPC models because the Lake Allatoona model utilized the same general water quality approach that is utilized for the 20 Watershed application. The water quality simulation also generally reflected the need to assign parameters by geologic province, therefore, water quality was calibrated at the same locations as hydrology and the parameterization was transferred to the same HRUs as the hydrology parameters.

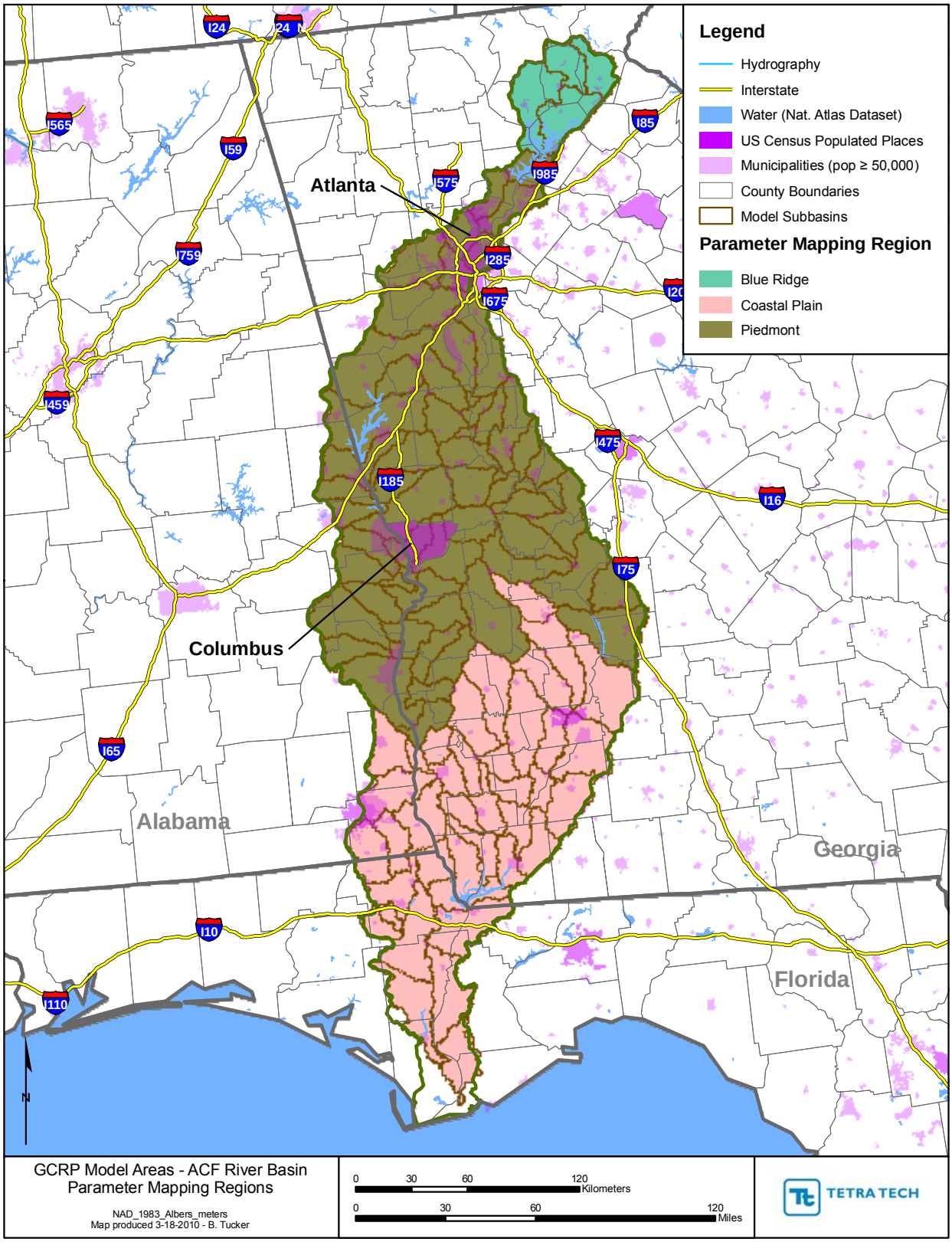

Figure 6. Parameter mapping utilized in the HSPF ACF River basin model.

Changes Made to Base Data Provided

No changes were made to the meteorological or land use base data. The impoundments of Lake Blackshear and Lake Seminole created an odd subwatershed connectivity when developed by BASINS. These two lakes both have large tributaries contributing to them and BASINS delineated the watersheds by having all of the individual tributaries pouring into the next downstream watershed. This made it difficult to represent the dam operation. The connectivity was modified so that there was only one watershed representing the outflow of each impoundment. The upstream subwatersheds, for all of the tributaries entering the lakes, were adjusted to pour into the subwatershed containing the lake. This change was also made in the SWAT model. Before this change was added, the HSPF model was in operation with the original connectivity, and BASINS generated f-tables. The simulation results below both of the lakes, for both original and updated connectivity, showed very similar results. This suggests that the update to the connectivity should not pose any problems.

As discussed earlier in the Point Sources section, an amendment was made to WPCP's that had default values assigned for total phosphorus. Additionally, as discussed earlier, GaEPD data were used to supplement the observed water quality data found in the NAWQA database.

Assumptions

Reservoirs

The Chattahoochee and the Flint Rivers represent two very different types if rivers. The Chattahoochee River has many impoundments while the Flint River has one of the longest unimpeded stretches of flow in the United States. The base data supplied point coverage for nine dams in the ACF basin and each was at the outlet of a delineated subwatershed. Three of those given dams were assumed to operate as run of the river (Oliver, Bartlett's Ferry, and George W. Andrews) and they were not included in the simulation. Table 6 identifies the dams and corresponding reservoirs represented in the ACF basin 20 Watershed model.

Table 6. Reservoirs represented in the ACF basin model

Dam Name	Other Name	River	Owner
Buford	Lake Sidney Lanier	Chattahoochee	USACE
West Point	West Point Lake	Chattahoochee	USACE
Walter F George Lock, Dam, Powerhouse	Eufala	Chattahoochee	USACE
Crisp County (Warwick)	Lake Blackshear	Flint	Crisp County Power Commission
Muckafoonee Creek Dam	Lake Worth	Flint	Georgia Power Company
Jim Woodruff Dam	Lake Seminole	Flint	USACE

All of the Army Corps of Engineers' (USACE) lakes simulated in the model have data published including elevation, inflow, discharge, and power generation, since the facility became operational (USACE 2010). The USACE has also made available a graph of the area capacity curve for each of the lakes. For the 20 Watershed application, it was assumed that the best representation of the reservoirs was to try to simulate them without supplying time series operations or boundary conditions. If time series operations were supplied, it would be difficult to predict what the boundary condition would be in the future. Therefore, the area-capacity curves were developed into an f-table, consistent with Technical Note 1 (USEPA 2007) and supplied for the subwatershed

containing the lake. By having the controlling feature on the lake be an f-table future climatic conditions will not be affected by boundary conditions of the past.

Elevation-Storage relationships were not available for Lake Blackshear and Lake Worth. Research was done to look for the average depth and average surface area for each of the lakes. This information was utilized to come up with a reservoir of similar size and storage by using the stage-storage-discharge relationships tool in the HSPF BMP Toolkit on the EPA website.

One of the biggest challenges was trying to represent reservoir operations with only an f-table. When the model was first set up, the focus was on calibrating to areas un-impacted by flow control devices, and the reservoirs simply had the f-table created by BASINS. The hydrology results at the gages used to check reservoir operations actually looked pretty decent considering lake storage and dam releases were not accounted for. F-tables were developed and inserted into the model for all reservoirs included in the simulation. The physical relationship between surface area and storage was left unchanged and reservoir calibration focused on assigning a discharge to a particular depth of water. When there were elevation and discharge data available, they were used as a guideline for assignment of the outflow for a particular depth. The results on the mainstem Flint River changed very little but the results on the mainstem Chattahoochee changed drastically and the simulation became very poor. Much work was done on the Chattahoochee River simulation to try to represent the reservoirs properly. Since the reservoirs are highly controlled by peaking hydro electric operations and targeted elevations based on the season, the approach used for the 20 Watershed application did not do a very good job at representing observed flows below the dams on the Chattahoochee River. Much of the error on the Chattahoochee can be attributed to the improper operation of Buford Dam. The discharges at Buford Dam impact the discharges at all other dams on the Chattahoochee and this is also the case in the 20 Watershed model.

Withdrawals

It is not known what water withdrawals by municipal and industrial facilities will look like in the future, therefore, they were not included in the 20 Watershed model application. Recent court rulings suggest that current withdrawals below Buford dam may change in as little as three years.

Irrigation

Irrigation in the Lower Flint, its tributaries, and the Lower Chattahoochee is used quite extensively when needed. The model, for the 20 Watershed application, is not using the irrigation module. HSPF requires that a land use be associated with irrigation and applying irrigation to all agricultural land may greatly over estimate the amount of irrigation that is actually taking place. Additionally, no one knows what agricultural irrigation may look like in the future. There have been numerous studies commissioned in the past decade to look into the amount of irrigation in the state of Georgia. A majority of the irrigation is from groundwater sources and this would represent new water to the HSPF model. It was assumed that an irrigation component would not benefit the model for the 20 Watershed application.

Snow Simulation

Previous modeling experience in Georgia did not utilize snow simulation. The model for the 20 Watershed application is to include snow simulation using the degree-day method for snowmelt. With no previous models to obtain initial parameters for snow simulation, the initial parameters needed to be developed. Technical Note 6 (USEPA 2000) was used as a guideline for parameterization. The parameters for the physical properties of each HRU are assigned by HRU but all other snow simulation parameters are the same for each HRU. These values are assumed to be appropriate and the initial parameterization was not adjusted.

Hydrology Calibration

As explained above, the starting parameters for ACF 20 Watershed application came from an LSPC model for the Upper Oconee watershed. Differences amongst the model set up between the LSPC application and HSPF 20 Watershed application meant that not all parameters in the LSPC application were directly transferrable to the HSPF 20 Watershed application. When it did not make sense to utilize parameters from the LSPC model, Technical Note 6 (USEPA 2000) was utilized to determine a good starting value. The parameters from the Upper Oconee watershed simulated flows in the range of the observed flows but minor adjustments needed to be made to better fit the simulated flows to the observed flows. Calibration adjustments focused on the following parameters:

- INFILT (index to mean soil infiltration rate): The LSPC model did not represent hydrologic soil groups A or D. A representative value was obtained from Technical Note 6 (USEPA 2000). Very minor modifications were made to these estimated values because the calibration focus area is dominated by B and C soils. Additionally, INFILT was adjusted slightly by land use to account for the land use differences between the LSPC model and the HSPF 20 Watershed model. INFILT values for the hydrologic soil groups are in the range of those stated in Technical note 6.
- AGWRC (Groundwater recession rate): Adjusted slightly in order to replicate groundwater recession in the observed data.
- LZSN (lower zone nominal soil moisture storage): This was increased slightly upward due to baseflow contributions severely tapering off during extreme dry weather. The changes to INFILT and AGWRC resulted in small modifications in this parameter.
- BASETP (ET by riparian vegetation): Even with the modifications mentioned above, simulation of low flows was not that good. It was assumed that the Flint River watershed has a greater amount of riparian vegetation than that of the Upper Oconee watershed. Slightly increasing the BASETP value made the simulation of low flows much better.

Initial calibrations were performed for the upper Flint River, comparing model results to data from USGS 02349605, and are summarized in Figures 7 through 13 and Tables 7 and 8. The model fit is of high quality but always simulates a little bit high. This could be because municipal and industrial withdrawals were not included in the in the simulation. None of the metrics fall out of those set for the 20 Watershed study. The model calibration period was set to calendar years 1993-2002.

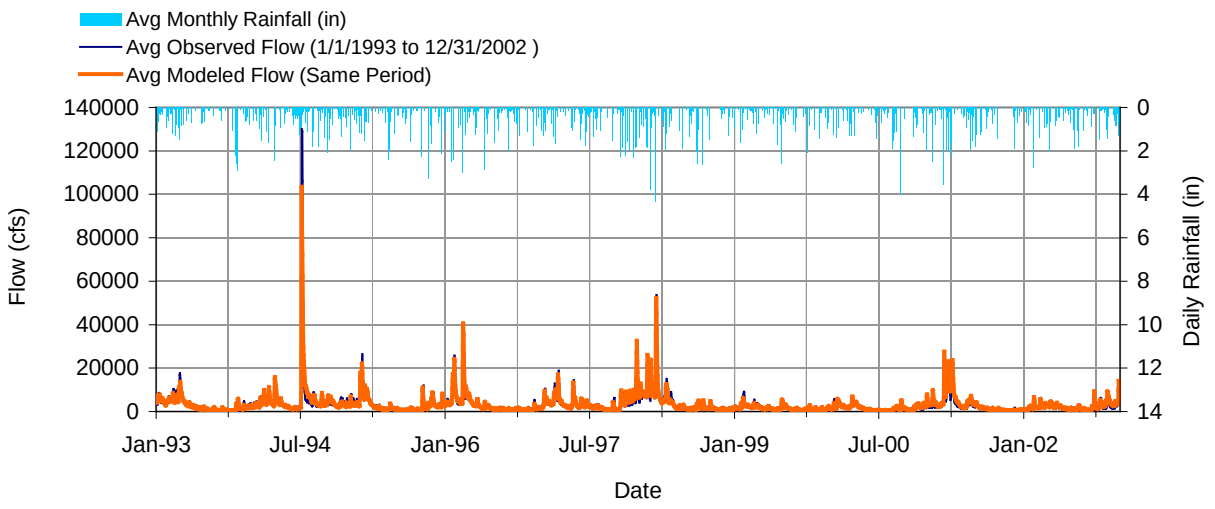

Figure 7. Mean daily flow at USGS 02349605 Flint River at Ga 26, near Montezuma, GA – calibration period (HSPF).

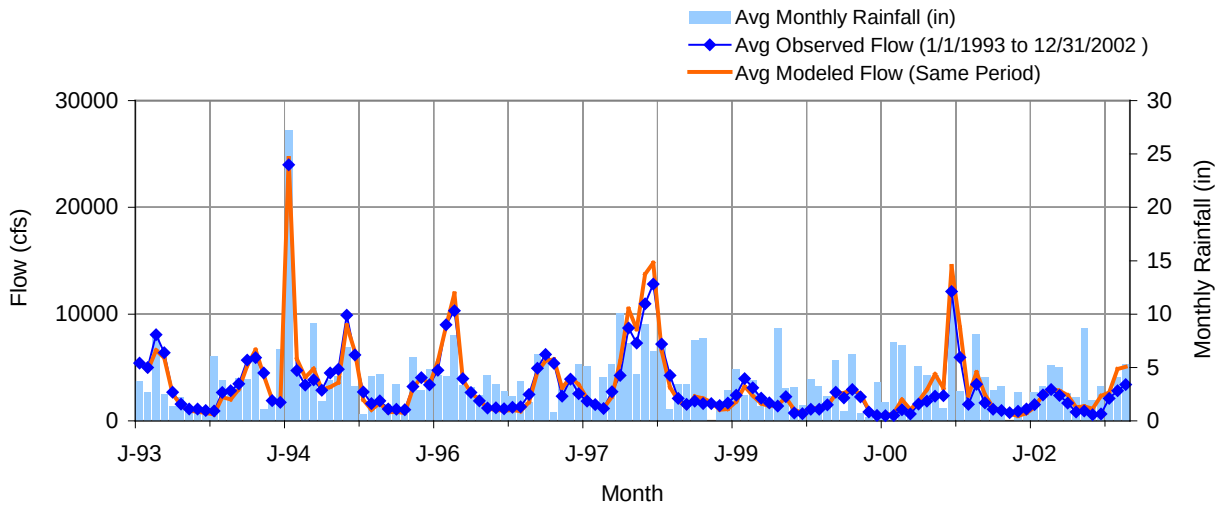

Figure 8. Mean monthly flow at USGS 02349605 Flint River at Ga 26, near Montezuma, GA – calibration period (HSPF).

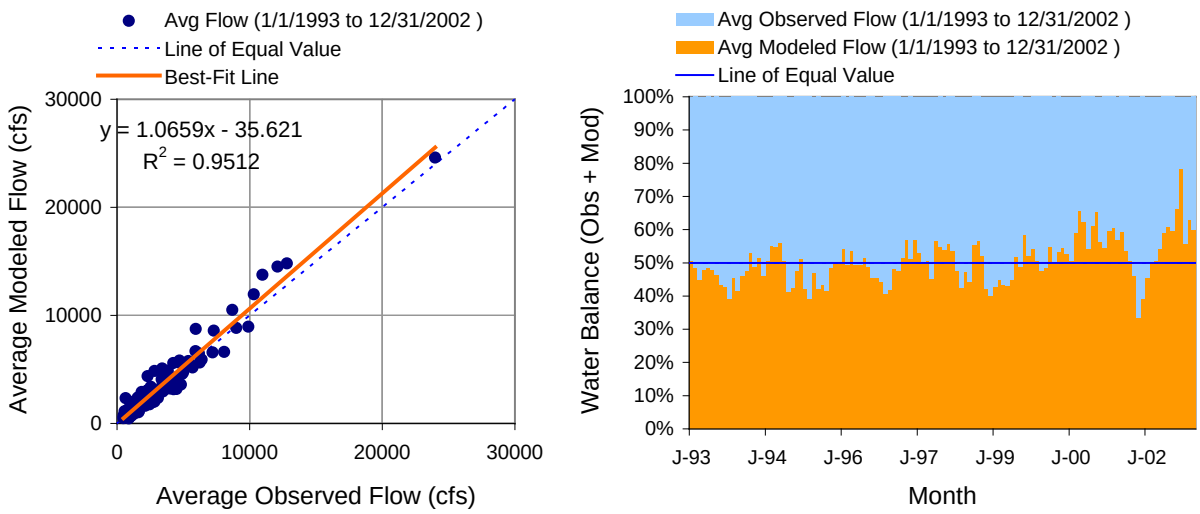

Figure 9. Monthly flow regression and temporal variation at USGS 02349605 Flint River at Ga 26, near Montezuma, GA – calibration period (HSPF).

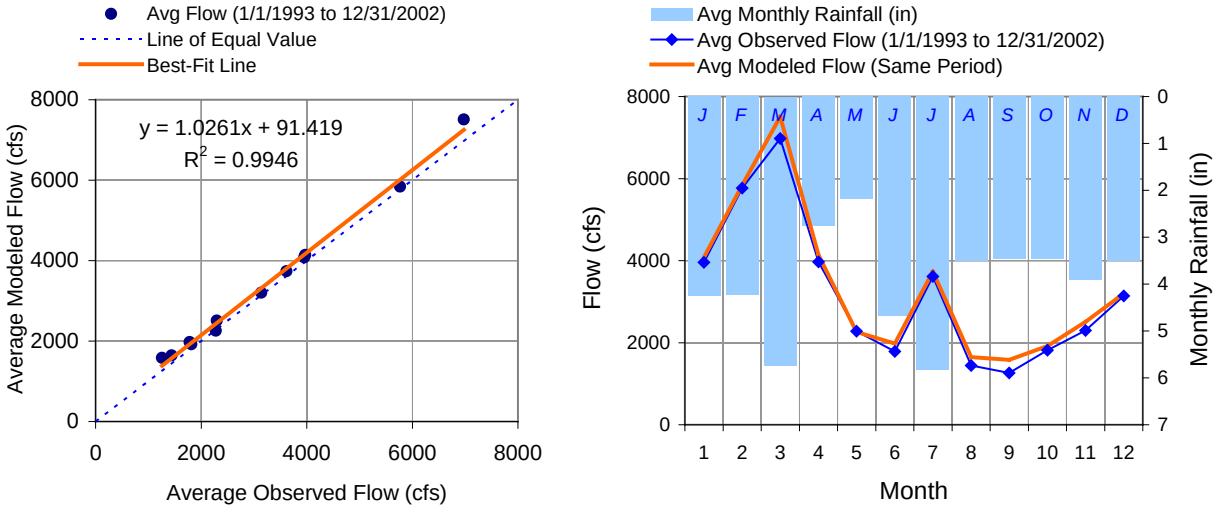

Figure 10. Seasonal regression and temporal aggregate at USGS 02349605 Flint River at Ga 26, near Montezuma, GA – calibration period (HSPF).

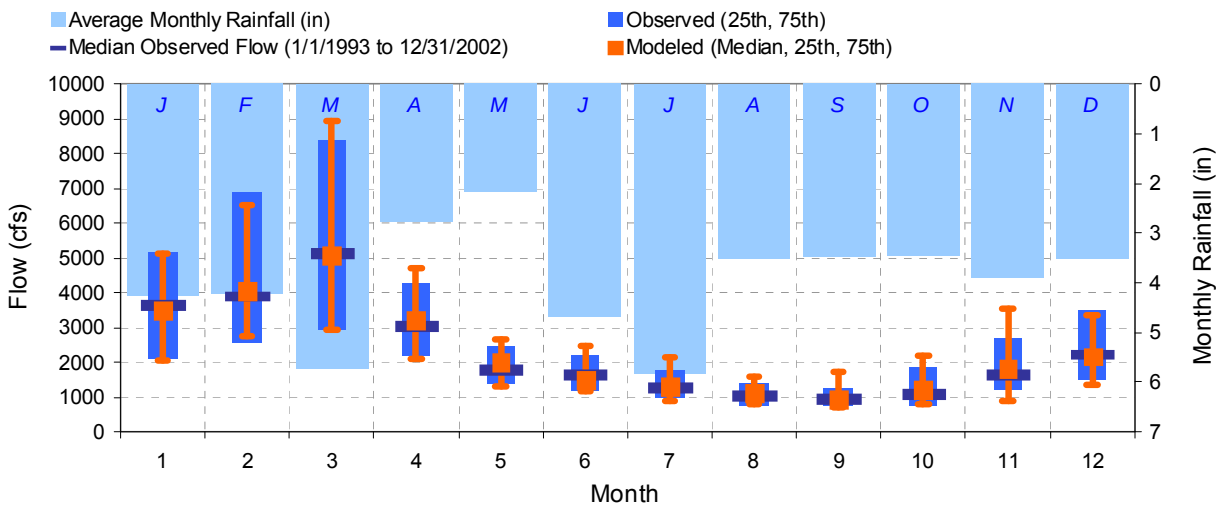

Figure 11. Seasonal medians and ranges at USGS 02349605 Flint River at Ga 26, near Montezuma, GA – calibration period (HSPF).

Table 7. Seasonal summary at USGS 02349605 Flint River At Ga 26, near Montezuma, GA – calibration period (HSPF)

MONTH	OBSERVED FLOW (CFS)				MODELED FLOW (CFS)			
	MEAN	MEDIAN	25TH	75TH	MEAN	MEDIAN	25TH	75TH
Jan	3955.13	3665.00	2110.00	5155.00	4080.88	3477.76	2037.87	5135.68
Feb	5767.27	3915.00	2572.50	6887.50	5840.28	4036.36	2764.25	6514.59
Mar	6976.42	5150.00	2932.50	8377.50	7509.10	5064.71	2921.96	8921.61
Apr	3970.93	3065.00	2210.00	4297.50	4138.24	3192.51	2099.52	4715.87
May	2277.06	1810.00	1400.00	2470.00	2259.06	2007.62	1330.76	2653.59
Jun	1783.49	1670.00	1180.00	2170.00	1976.13	1497.68	1168.42	2453.92
Jul	3617.54	1290.00	977.25	1765.00	3734.42	1309.40	880.28	2131.87
Aug	1440.71	1035.00	752.00	1420.00	1646.45	1108.31	803.03	1567.80
Sep	1260.28	964.00	770.50	1252.50	1584.54	917.93	712.46	1731.82
Oct	1816.83	1105.00	775.75	1855.00	1920.32	1202.58	785.75	2195.35
Nov	2297.06	1660.00	1220.00	2685.00	2506.66	1807.51	878.28	3533.72
Dec	3137.85	2240.00	1490.00	3497.50	3202.84	2167.47	1344.21	3347.46

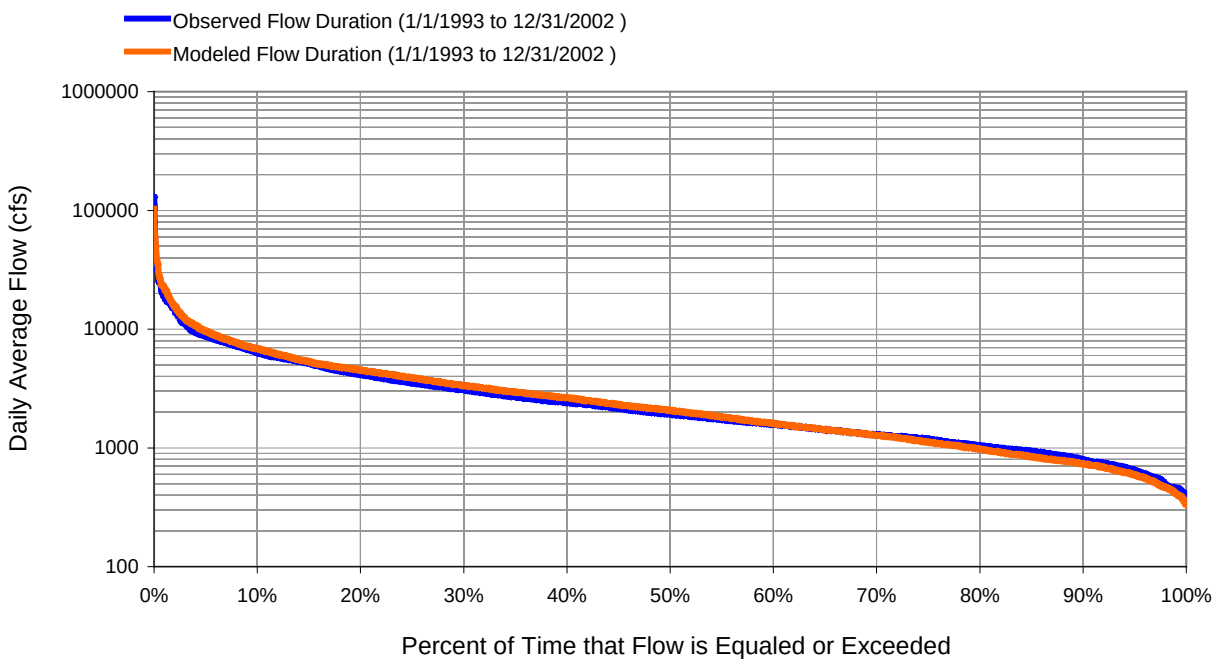

Figure 12. Flow exceedence at USGS 02349605 Flint River at Ga 26, near Montezuma, GA – calibration period (HSPF).

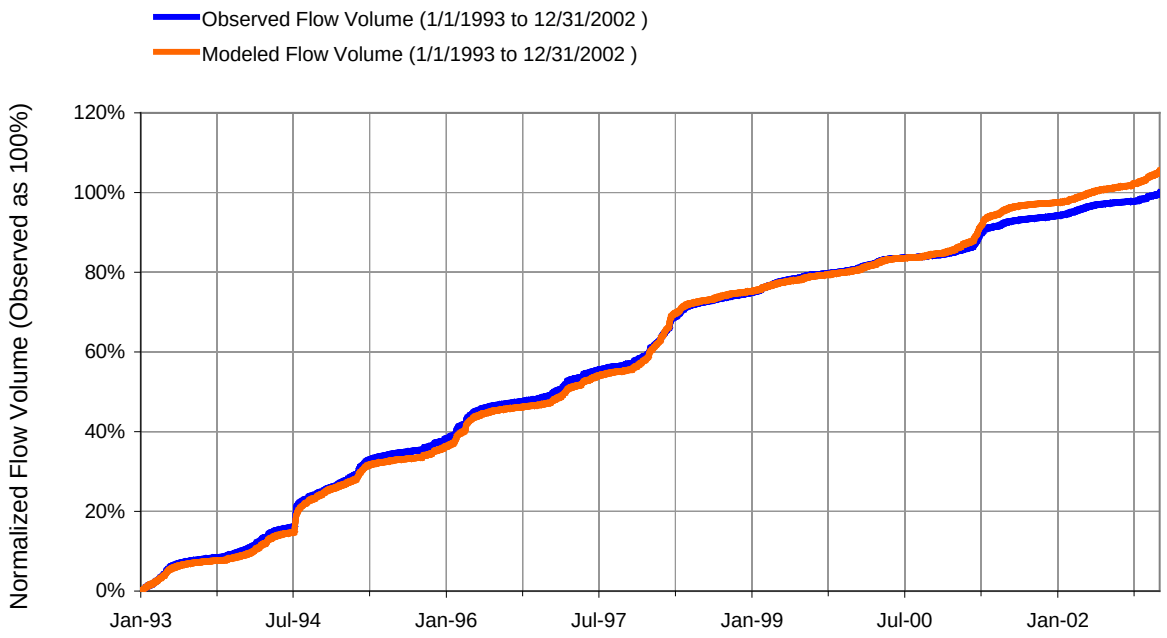

Figure 13. Flow accumulation at USGS 02349605 Flint River at Ga 26, near Montezuma, GA – calibration period (HSPF).

Table 8. Summary statistics at USGS 02349605 Flint River At Ga 26, near Montezuma, GA – calibration period (HSPF)

HSPF Simulated Flow		Observed Flow Gage	
REACH OUTFLOW FROM DSN 1001 10-Year Analysis Period: 1/1/1993 - 12/31/2002 Flow volumes are (inches/year) for upstream drainage area		USGS 02349605 FLINT RIVER AT GA 26, NEAR MONTEZUMA, GA Hydrologic Unit Code: 3130006 Latitude: 32.29305556 Longitude: -84.0436111 Drainage Area (sq-mi): 2920	
Total Simulated In-stream Flow:	**15.61**	Total Observed In-stream Flow:	**14.80**
Total of simulated highest 10% flows:	**6.10**	Total of Observed highest 10% flows:	**5.74**
Total of Simulated lowest 50% flows:	**2.71**	Total of Observed Lowest 50% flows:	**2.75**
Simulated Summer Flow Volume (months 7-9):	**2.73**	Observed Summer Flow Volume (7-9):	**2.48**
Simulated Fall Flow Volume (months 10-12):	**2.98**	Observed Fall Flow Volume (10-12):	**2.83**
Simulated Winter Flow Volume (months 1-3):	**6.67**	Observed Winter Flow Volume (1-3):	**6.39**
Simulated Spring Flow Volume (months 4-6):	**3.23**	Observed Spring Flow Volume (4-6):	**3.10**
Total Simulated Storm Volume:	**4.86**	Total Observed Storm Volume:	**4.80**
Simulated Summer Storm Volume (7-9):	**1.00**	Observed Summer Storm Volume (7-9):	**1.02**
Errors (Simulated-Observed)	*Error Statistics*	*Recommended Criteria*	
Error in total volume:	5.50	10	
Error in 50% lowest flows:	-1.49	10	
Error in 10% highest flows:	6.32	15	
Seasonal volume error - Summer:	10.14	30	
Seasonal volume error - Fall:	5.17	30	
Seasonal volume error - Winter:	4.48	30	
Seasonal volume error - Spring:	4.21	30	
Error in storm volumes:	1.25	20	
Error in summer storm volumes:	-2.14	50	
Nash-Sutcliffe Coefficient of Efficiency, E:	0.707	Model accuracy increases	
Baseline adjusted coefficient (Garrick), E':	0.568	as E or E' approaches 1.0	

Hydrology Validation

Validation for the Upper Flint calibration focus area was performed at the same location but for calendar years 1983-1992. Results are presented in Figures 14 through 20 and Tables 9 and 10. Similarly to the calibration years, the validation years' model fit is of high quality but always simulates a little bit high. None of the metrics fall out of the range set for the 20 Watershed study. The model validation period was set to calendar years 1983-1992.

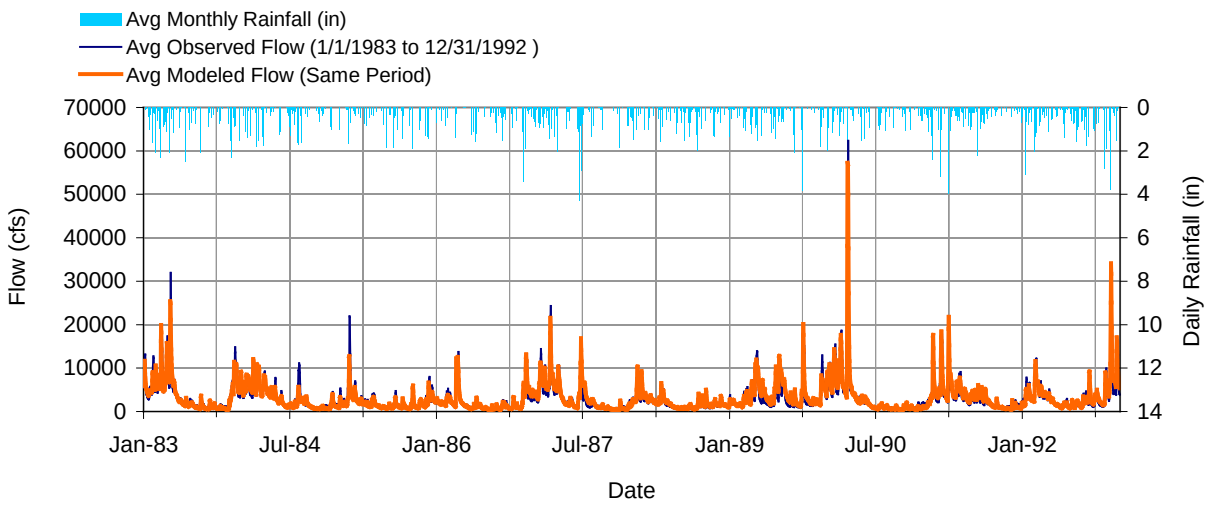

Figure 14. Mean daily flow at USGS 02349605 Flint River at Ga 26, near Montezuma, GA – validation period (HSPF).

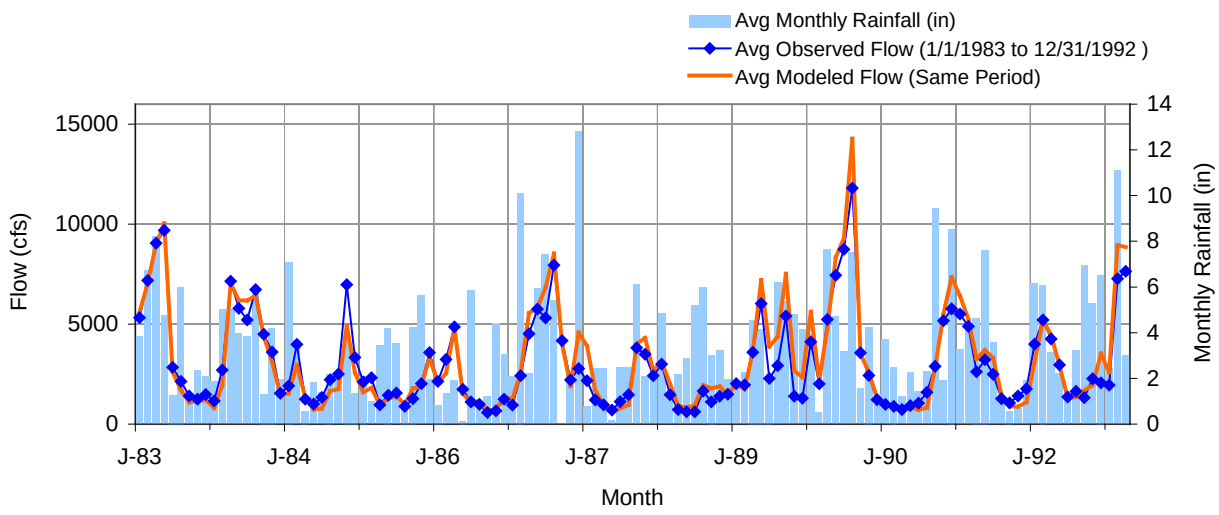

Figure 15. Mean monthly flow at USGS 02349605 Flint River at Ga 26, near Montezuma, GA – validation period (HSPF).

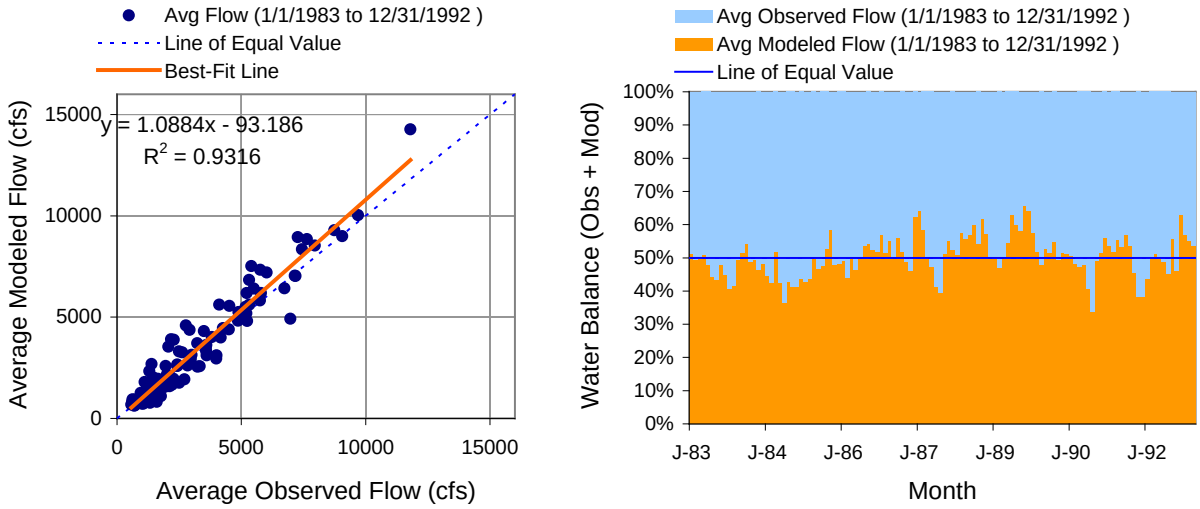

Figure 16. Monthly flow regression and temporal variation at USGS 02349605 Flint River at Ga 26, near Montezuma, GA – validation period (HSPF).

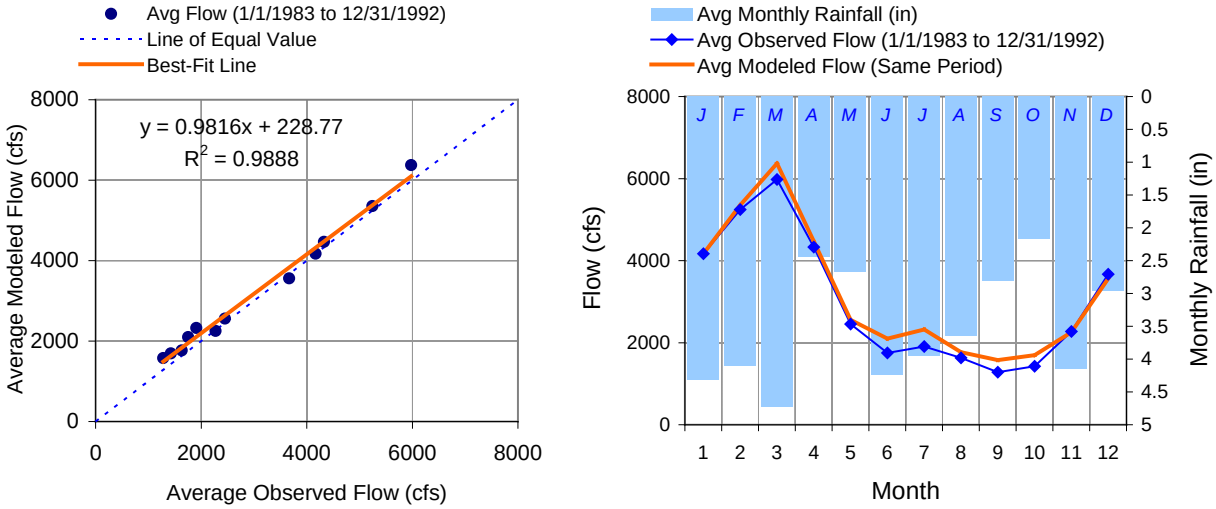

Figure 17. Seasonal regression and temporal aggregate at USGS 02349605 Flint River at Ga 26, near Montezuma, GA – validation period (HSPF).

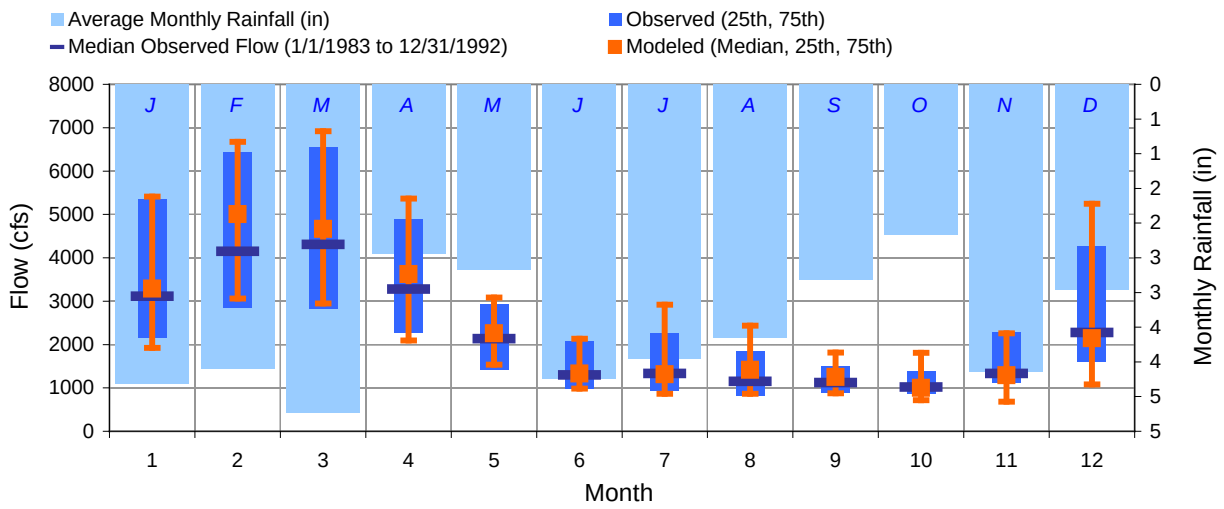

Figure 18. Seasonal medians and ranges at USGS 02349605 Flint River at Ga 26, near Montezuma, GA – validation period (HSPF).

Table 9. Seasonal summary at USGS 02349605 Flint River at Ga 26, near Montezuma, GA – validation period (HSPF)

MONTH	OBSERVED FLOW (CFS)				MODELED FLOW (CFS)			
	MEAN	MEDIAN	25TH	75TH	MEAN	MEDIAN	25TH	75TH
Jan	4168.00	3115.00	2152.50	5350.00	4169.05	3287.48	1922.32	5410.41
Feb	5242.97	4150.00	2850.00	6430.00	5353.14	5008.00	3062.19	6675.95
Mar	5976.65	4310.00	2830.00	6542.50	6371.53	4667.85	2944.79	6916.63
Apr	4328.17	3275.00	2277.50	4880.00	4468.43	3626.93	2094.33	5365.85
May	2451.47	2135.00	1420.00	2937.50	2557.55	2256.24	1533.87	3083.22
Jun	1753.24	1300.00	986.75	2072.50	2100.76	1331.44	985.52	2134.09
Jul	1908.70	1330.00	927.50	2257.50	2323.54	1314.50	866.44	2921.29
Aug	1632.54	1150.00	816.50	1830.00	1765.46	1414.88	867.56	2433.92
Sep	1283.93	1120.00	881.75	1500.00	1577.80	1249.76	876.51	1816.29
Oct	1425.06	1020.00	869.50	1390.00	1695.02	1001.13	717.97	1808.37
Nov	2275.14	1330.00	1120.00	2277.50	2252.76	1293.90	680.19	2259.65
Dec	3667.95	2275.00	1602.50	4277.50	3559.80	2145.93	1079.64	5244.57

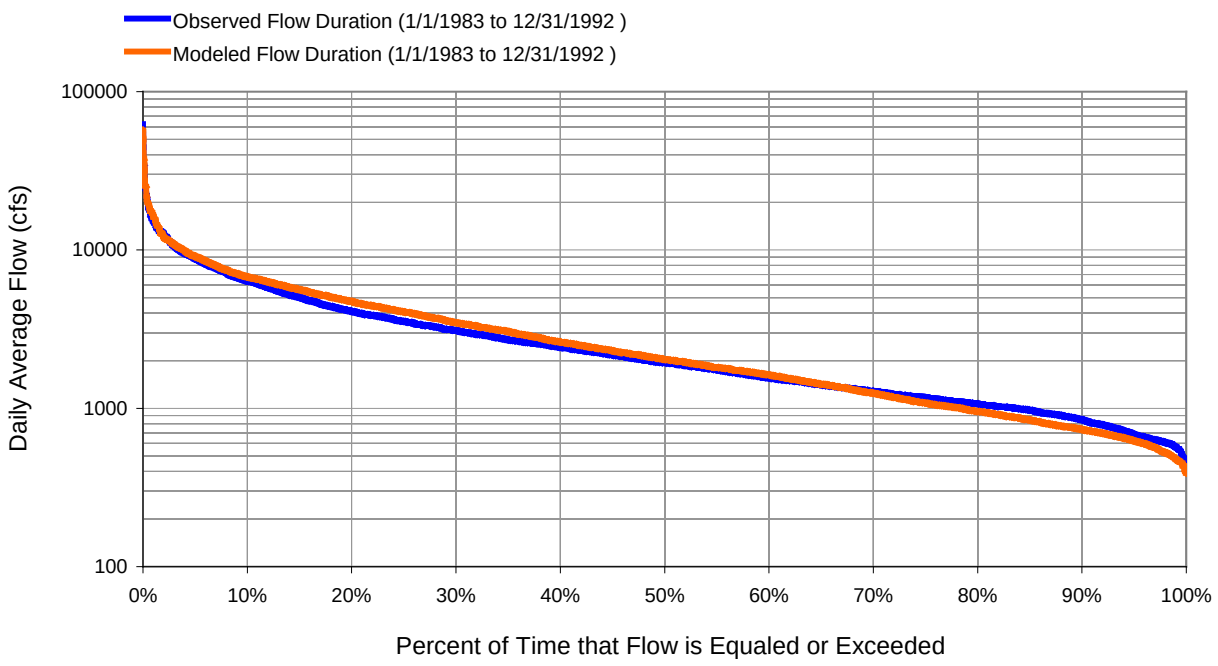

Figure 19. Flow exceedence at USGS 02349605 Flint River at Ga 26, near Montezuma, GA – validation period (HSPF).

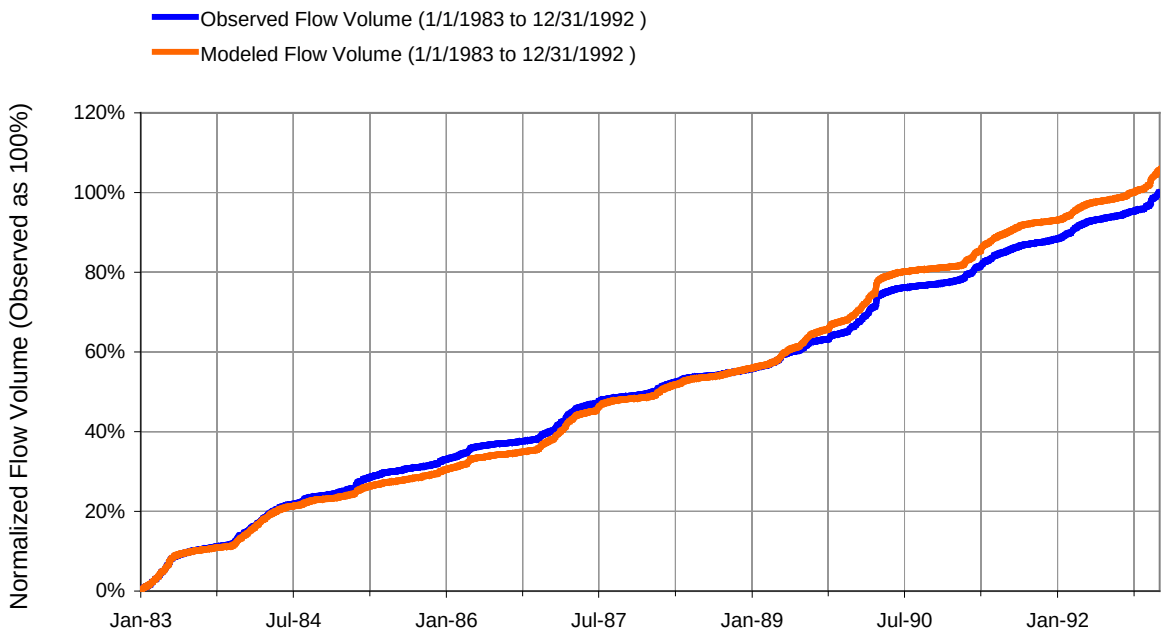

Figure 20. Flow accumulation at USGS 02349605 Flint River at Ga 26, near Montezuma, GA – validation period (HSPF).

Table 10. Summary statistics at USGS 02349605 Flint River at Ga 26, near Montezuma, GA – validation period (HSPF)

HSPF Simulated Flow		Observed Flow Gage	
REACH OUTFLOW FROM DSN 1001 10-Year Analysis Period: 1/1/1983 - 12/31/1992 Flow volumes are (inches/year) for upstream drainage area		USGS 02349605 FLINT RIVER AT GA 26, NEAR MONTEZUMA, GA Hydrologic Unit Code: 3130006 Latitude: 32.29305556 Longitude: -84.0436111 Drainage Area (sq-mi): 2920	
Total Simulated In-stream Flow:	**14.76**	Total Observed In-stream Flow:	**13.95**
Total of simulated highest 10% flows:	**5.05**	Total of Observed highest 10% flows:	**4.87**
Total of Simulated lowest 50% flows:	**2.70**	Total of Observed Lowest 50% flows:	**2.78**
Simulated Summer Flow Volume (months 7-9):	**2.22**	Observed Summer Flow Volume (7-9):	**1.89**
Simulated Fall Flow Volume (months 10-12):	**2.94**	Observed Fall Flow Volume (10-12):	**2.88**
Simulated Winter Flow Volume (months 1-3):	**6.09**	Observed Winter Flow Volume (1-3):	**5.89**
Simulated Spring Flow Volume (months 4-6):	**3.52**	Observed Spring Flow Volume (4-6):	**3.29**
Total Simulated Storm Volume:	**4.30**	Total Observed Storm Volume:	**4.42**
Simulated Summer Storm Volume (7-9):	**0.55**	Observed Summer Storm Volume (7-9):	**0.51**
Errors (Simulated-Observed)	*Error Statistics*	*Recommended Criteria*	
Error in total volume:	5.79	10	
Error in 50% lowest flows:	-3.16	10	
Error in 10% highest flows:	3.69	15	
Seasonal volume error - Summer:	17.40	30	
Seasonal volume error - Fall:	1.92	30	
Seasonal volume error - Winter:	3.33	30	
Seasonal volume error - Spring:	6.93	30	
Error in storm volumes:	-2.74	20	
Error in summer storm volumes:	9.14	50	
Nash-Sutcliffe Coefficient of Efficiency, E:	0.651	Model accuracy increases	
Baseline adjusted coefficient (Garrick), E':	0.551	as E or E' approaches 1.0	

Hydrology Results for Larger Watershed

As discussed above, the parameters from the calibration focus were not fully transferrable to other gages in the ACF basin. Therefore, at each of the gages un-impacted by flow control devices, an additional level of calibration was performed. Please refer to the discussion and Figure 6 for details on how the additional calibration areas' parameterization was assigned to the other areas in the watershed.

As stated above, the Upper Chattahoochee borrowed parameterization from a model done for the Lake Lanier TMDL. Due to careful transferring of parameters there wasn't any adjustment made to achieve calibration. The model fit was of high quality in the TMDL model and also has a very high goodness of fit in the 20 Watershed model. The statistics for Upper Chattahoochee gage are within the range defined for the 20 Watershed application. The calibration and validation results for this region are shown in Tables 11 and 12 (station 02331600).

The Ichawaynochaway Creek subwatershed did not have a model to borrow parameterization from. The calibrated results of the calibration focus area were assigned and then adjusted until the simulated flows closely matched the observed flows. All of the parameters adjusted were for the baseflow component of the simulation. Baseflow was being simulated too high so the goal was to lower the amount of baseflow reaching the stream. This was achieved through increasing the amount of ET satisfied by riparian vegetation and direct evaporation from groundwater. The model fit is fairly good except for the extreme low flows. The high simulation of the extreme low flows may be explained by not having simulated irrigation. The calibration and validation results for this region are shown in Tables 13 and 14 (station 02353500).

As discussed in the Assumptions section for Reservoirs, the simulation at all gages on the mainstem Chattahoochee, below Lake Lanier, is very poor. The approach taken to simulate the reservoirs in the ACF did not simulate Lake Lanier very well, but simulation of the other reservoirs was acceptable. This could be because the reservoirs other than Lake Lanier are mostly managed as inflow equals outflow and the discharges at Lake Lanier usually control most of the inflow. Once the Chattahoochee and Flint converge and leave Lake Seminole, the simulation and model fit is once again of high quality and shown for the calibration period in Figures 21 through 27 and Tables 11 and 12.

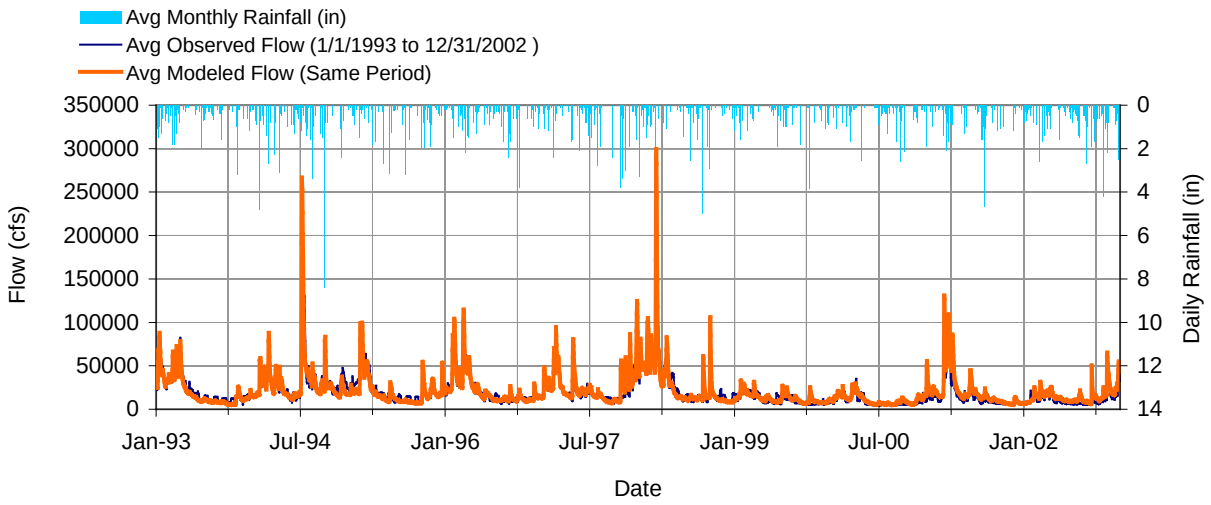

Figure 21. Mean daily flow: Model DSN 9001 vs. USGS 02358000 Apalachicola River At Chattahoochee, FL– calibration period (HSPF).

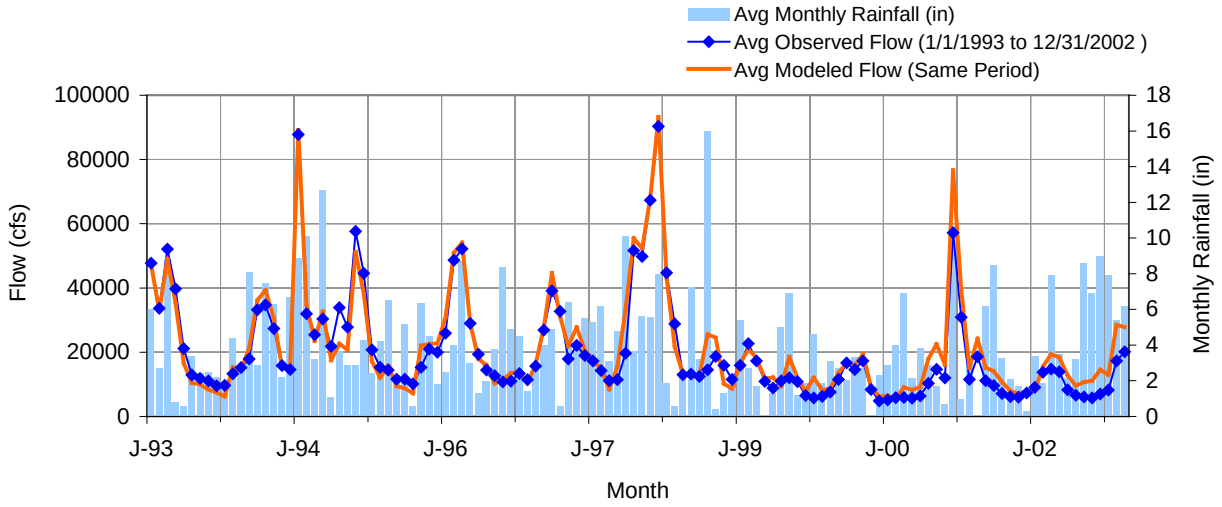

Figure 22. Mean monthly flow: Model DSN 9001 vs. USGS 02358000 Apalachicola River At Chattahoochee, FL– calibration period (HSPF).

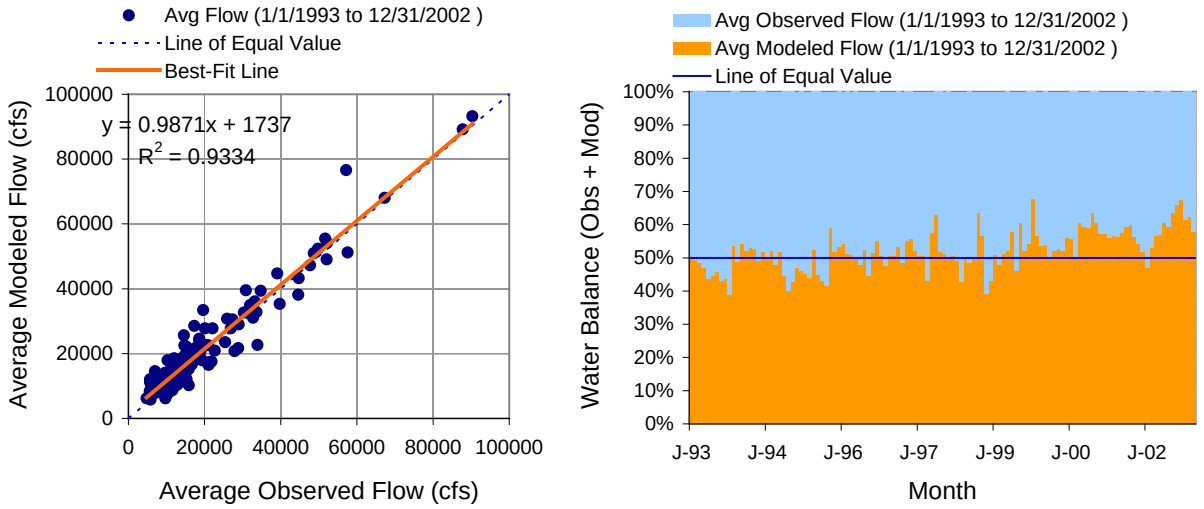

Figure 23. Monthly flow regression and temporal variation: Model DSN 9001 vs. USGS 02358000 Apalachicola River At Chattahoochee, FL– calibration period (HSPF).

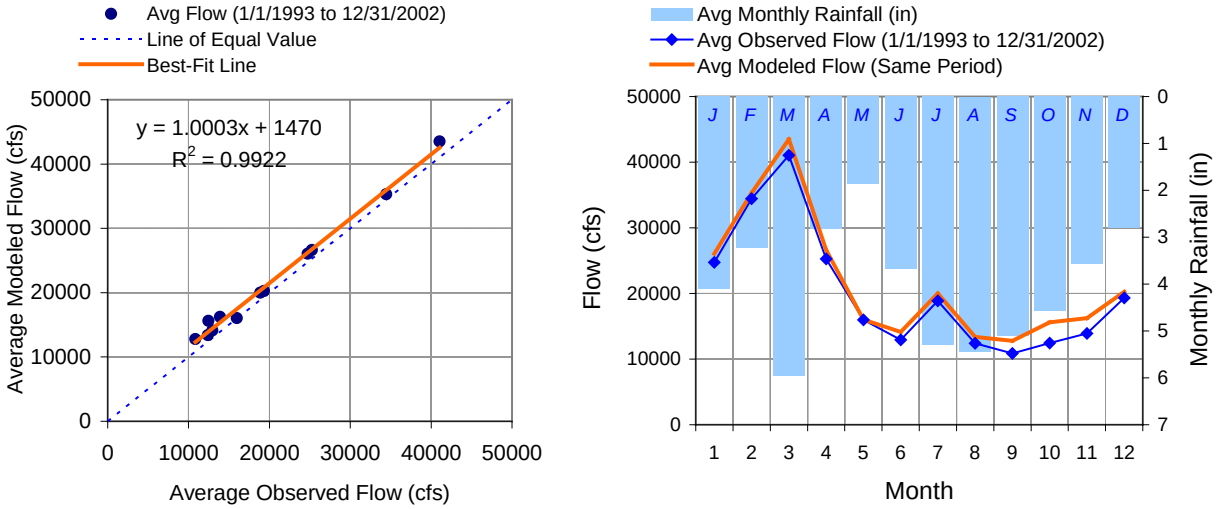

Figure 24. Seasonal regression and temporal aggregate: Model DSN 9001 vs. USGS 02358000 Apalachicola River At Chattahoochee, FL– calibration period (HSPF).

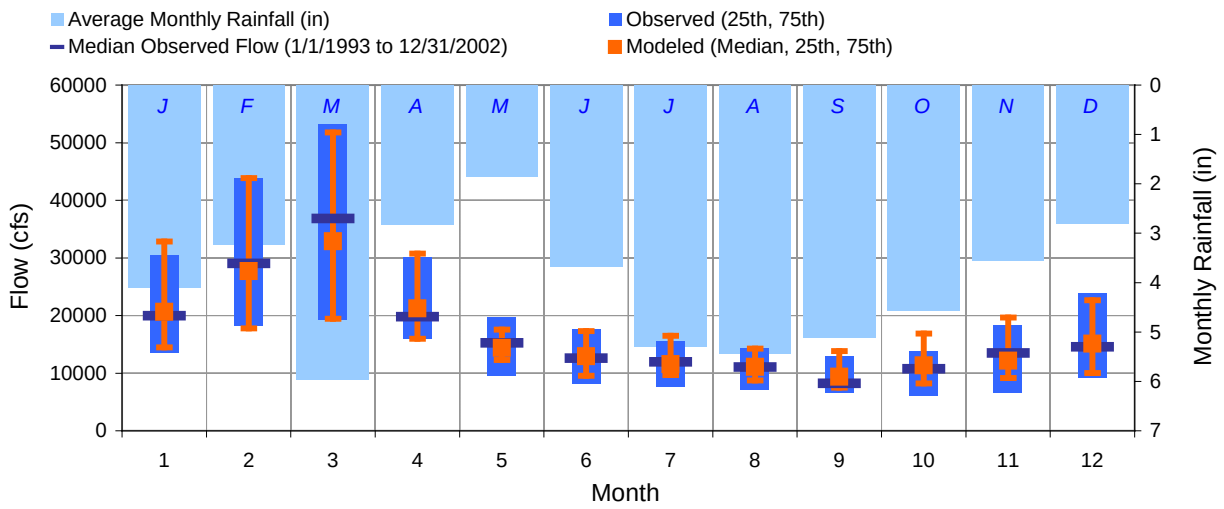

Figure 25. Seasonal medians and ranges: Model DSN 9001 vs. USGS 02358000 Apalachicola River At Chattahoochee, FL– calibration period (HSPF).

Table 11. Seasonal summary: Model DSN 9001 vs. USGS 02358000 Apalachicola River At Chattahoochee, FL– calibration period (HSPF).

MONTH	OBSERVED FLOW (CFS)				MODELED FLOW (CFS)			
	MEAN	MEDIAN	25TH	75TH	MEAN	MEDIAN	25TH	75TH
Jan	24730.16	19950.00	13500.00	30475.00	26069.98	20647.35	14491.39	32838.93
Feb	34453.44	29050.00	18275.00	43900.00	35291.43	27706.10	17766.08	43841.35
Mar	41056.97	36850.00	19300.00	53300.00	43511.83	32896.58	19444.48	51756.70
Apr	25249.20	19800.00	16000.00	30250.00	26617.77	21242.91	15995.22	30764.85
May	15972.58	15250.00	9570.00	19675.00	16032.37	14369.52	12295.58	17570.34
Jun	12939.23	12600.00	8237.50	17600.00	14124.72	12931.98	9530.52	17294.53
Jul	18873.90	11950.00	7665.00	15575.00	20000.73	11560.84	9687.78	16487.60
Aug	12411.87	11050.00	7102.50	14300.00	13379.10	11102.23	8740.66	14248.45
Sep	10850.80	8235.00	6530.00	12900.00	12790.03	9367.20	7476.25	13854.01
Oct	12458.10	10750.00	6112.50	13900.00	15607.91	11368.60	8238.77	16874.80
Nov	13896.10	13500.00	6557.50	18250.00	16250.34	12148.80	9171.31	19639.35
Dec	19332.77	14550.00	9150.00	23800.00	20267.76	15105.64	10019.73	22663.99

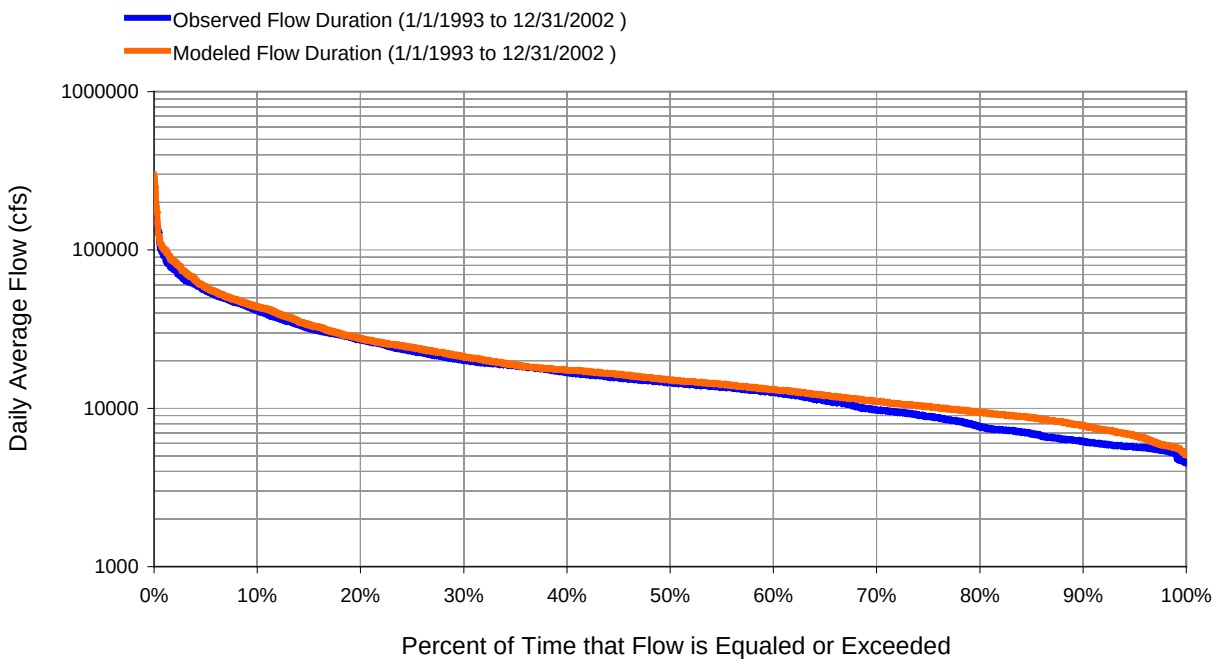

Figure 26. Flow exceedence: Model DSN 9001 vs. USGS 02358000 Apalachicola River At Chattahoochee, FL– calibration period (HSPF).

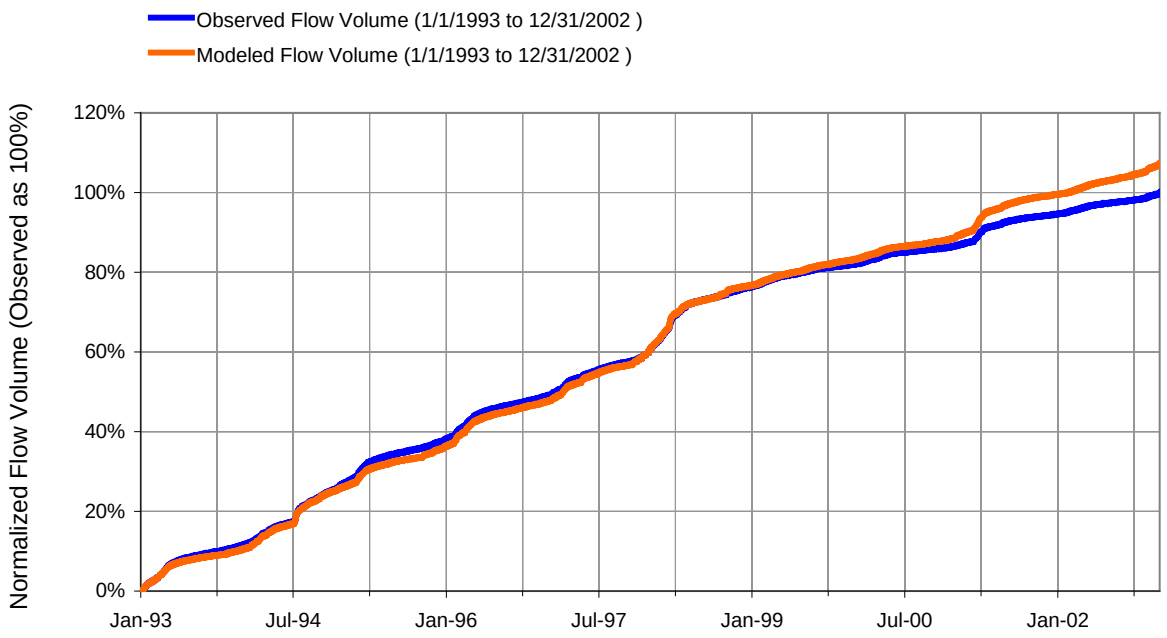

Figure 27. Flow accumulation: Model DSN 9001 vs. USGS 02358000 Apalachicola River At Chattahoochee, FL– calibration period (HSPF).

Table 12. Summary statistics: Model DSN 9001 vs. USGS 02358000 Apalachicola River At Chattahoochee, FL– calibration period (HSPF).

HSPF Simulated Flow		Observed Flow Gage	
REACH OUTFLOW FROM DSN 9001 10-Year Analysis Period: 1/1/1993 - 12/31/2002 Flow volumes are (inches/year) for upstream drainage area		USGS 02358000 APALACHICOLA RIVER AT CHATTAHOOCHEE FLA Hydrologic Unit Code: 3130011 Latitude: 30.7010251 Longitude: -84.8590871 Drainage Area (sq-mi): 17200	
Total Simulated In-stream Flow:	**17.06**	Total Observed In-stream Flow:	**15.89**
Total of simulated highest 10% flows:	**5.55**	Total of Observed highest 10% flows:	**5.11**
Total of Simulated lowest 50% flows:	**4.09**	Total of Observed Lowest 50% flows:	**3.65**
Simulated Summer Flow Volume (months 7-9):	**3.07**	Observed Summer Flow Volume (7-9):	**2.80**
Simulated Fall Flow Volume (months 10-12):	**3.46**	Observed Fall Flow Volume (10-12):	**3.03**
Simulated Winter Flow Volume (months 1-3):	**6.82**	Observed Winter Flow Volume (1-3):	**6.51**
Simulated Spring Flow Volume (months 4-6):	**3.72**	Observed Spring Flow Volume (4-6):	**3.55**
Total Simulated Storm Volume:	**4.27**	Total Observed Storm Volume:	**3.71**
Simulated Summer Storm Volume (7-9):	**0.72**	Observed Summer Storm Volume (7-9):	**0.64**
Errors (Simulated-Observed)	*Error Statistics*	*Recommended Criteria*	
Error in total volume:	7.35	10	
Error in 50% lowest flows:	**12.13**	**10**	
Error in 10% highest flows:	8.50	15	
Seasonal volume error - Summer:	9.50	30	
Seasonal volume error - Fall:	14.07	30	
Seasonal volume error - Winter:	4.69	30	
Seasonal volume error - Spring:	4.78	30	
Error in storm volumes:	15.09	20	
Error in summer storm volumes:	12.02	50	
Nash-Sutcliffe Coefficient of Efficiency, E:	0.769	Model accuracy increases	
Baseline adjusted coefficient (Garrick), E':	0.575	as E or E' approaches 1.0	

The calibration and validation statistical measurements, at all USGS gages used in the ACF basin for the 20 Watershed project, are shown in Tables 13 and 14 respectively.

Table 13. Summary statistics (percent error) for all stations – calibration period 1993-2002 (HSPF)

Station	02349605	02331600	02336300	02353500	02336000	02339500	02343801	02353000	02358000
Error in total volume:	5.50	0.14	17.16	3.93	24.16	15.40	16.79	8.33	7.35
Error in 50% lowest flows:	-1.49	3.09	2.56	17.11	59.65	74.07	49.13	4.70	12.13
Error in 10% highest flows:	6.32	4.62	6.29	9.69	-7.60	-0.36	8.63	14.97	8.50
Seasonal volume error - Summer:	10.14	2.28	1.30	1.33	8.20	9.33	11.54	16.06	9.50
Seasonal volume error - Fall:	5.17	6.04	19.26	-8.97	42.13	19.50	26.84	7.59	14.07
Seasonal volume error - Winter:	4.48	4.19	27.56	9.57	16.81	9.17	10.78	7.54	4.69
Seasonal volume error - Spring:	4.21	-10.90	13.02	9.42	35.91	27.67	24.10	4.65	4.78
Error in storm volumes:	1.25	-0.25	8.76	6.61	-56.00	-70.75	-37.96	4.85	15.09
Error in summer storm volumes:	-2.14	-28.59	3.05	-34.98	-62.85	-87.05	-60.30	12.41	12.02
Nash-Sutcliffe Coefficient of Efficiency, E:	0.707	0.640	0.536	0.339	0.539	0.591	0.717	0.607	0.769
Baseline adjusted coefficient (Garrick), E':	0.568	0.552	0.414	0.414	0.222	0.312	0.415	0.617	0.575

Table 14. Summary statistics (percent error) for all stations – validation period 1983-1992 (HSPF)

Station	02349605	02331600	02336300	02353500	02336000	02339500	02343801	02353000	02358000
Error in total volume:	5.79	-8.32	13.73	1.19	12.01	10.86	13.28	6.91	2.21
Error in 50% lowest flows:	-3.16	-4.98	4.87	-1.92	47.20	80.89	37.90	-1.14	-9.05
Error in 10% highest flows:	3.69	-6.88	3.05	6.48	-14.34	-5.02	7.57	11.27	8.49
Seasonal volume error - Summer:	17.40	-9.94	5.82	23.48	-2.55	6.67	13.98	17.92	3.55
Seasonal volume error - Fall:	1.92	-4.13	19.78	-14.67	8.67	-1.60	8.04	7.94	1.33
Seasonal volume error - Winter:	3.33	-2.73	19.85	-3.02	22.43	16.08	14.33	4.62	4.57
Seasonal volume error - Spring:	6.93	-17.08	7.49	7.15	19.52	21.34	15.92	3.64	-1.81
Error in storm volumes:	-2.74	-22.55	6.12	-0.18	-61.77	-74.01	-56.18	-10.57	20.87
Error in summer storm volumes:	9.14	-50.35	7.78	-22.89	-71.06	-87.14	-77.18	-23.32	-5.49
Nash-Sutcliffe Coefficient of Efficiency, E:	0.651	0.696	0.553	0.385	0.479	0.566	0.698	0.682	0.707
Baseline adjusted coefficient (Garrick), E':	0.551	0.574	0.431	0.452	0.225	0.266	0.365	0.609	0.588

An additional check was done on the reservoirs of the Chattahoochee River mainstem. Observed and modeled reservoir elevations were compared by using a histogram approach. This check ensured that the storage contained within a reservoir was accounted for even though the flow calibration downstream of the reservoir didn't simulate well. These comparisons were performed for the time period from January 1993 to December 2002. All lake elevation simulations closely compared to the observed elevations except for Lake Lanier (Figures 28 through 31).

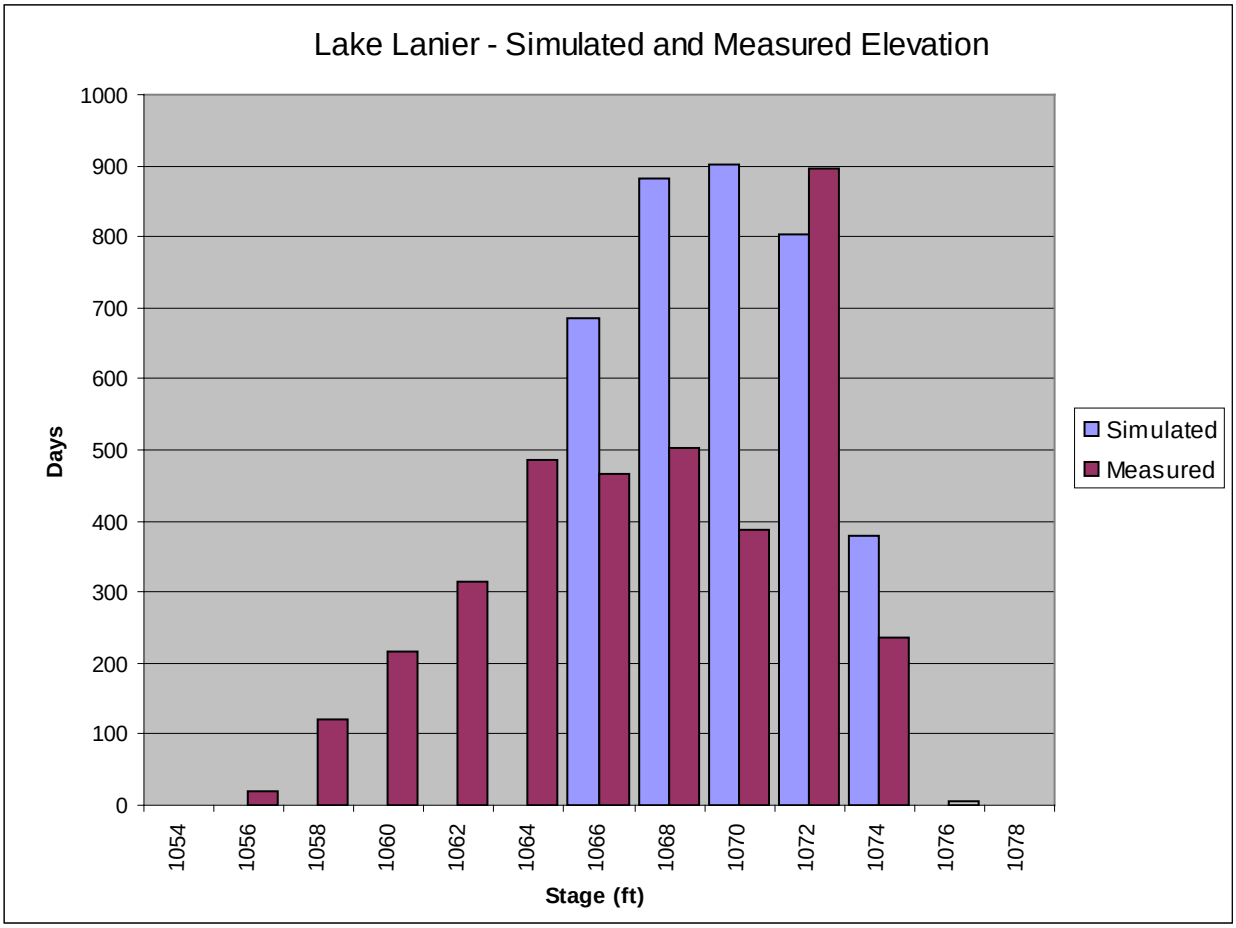

Figure 28. Histogram of simulated and measured elevation for Lake Lanier from 1/1/1993 to 12/31/2002.

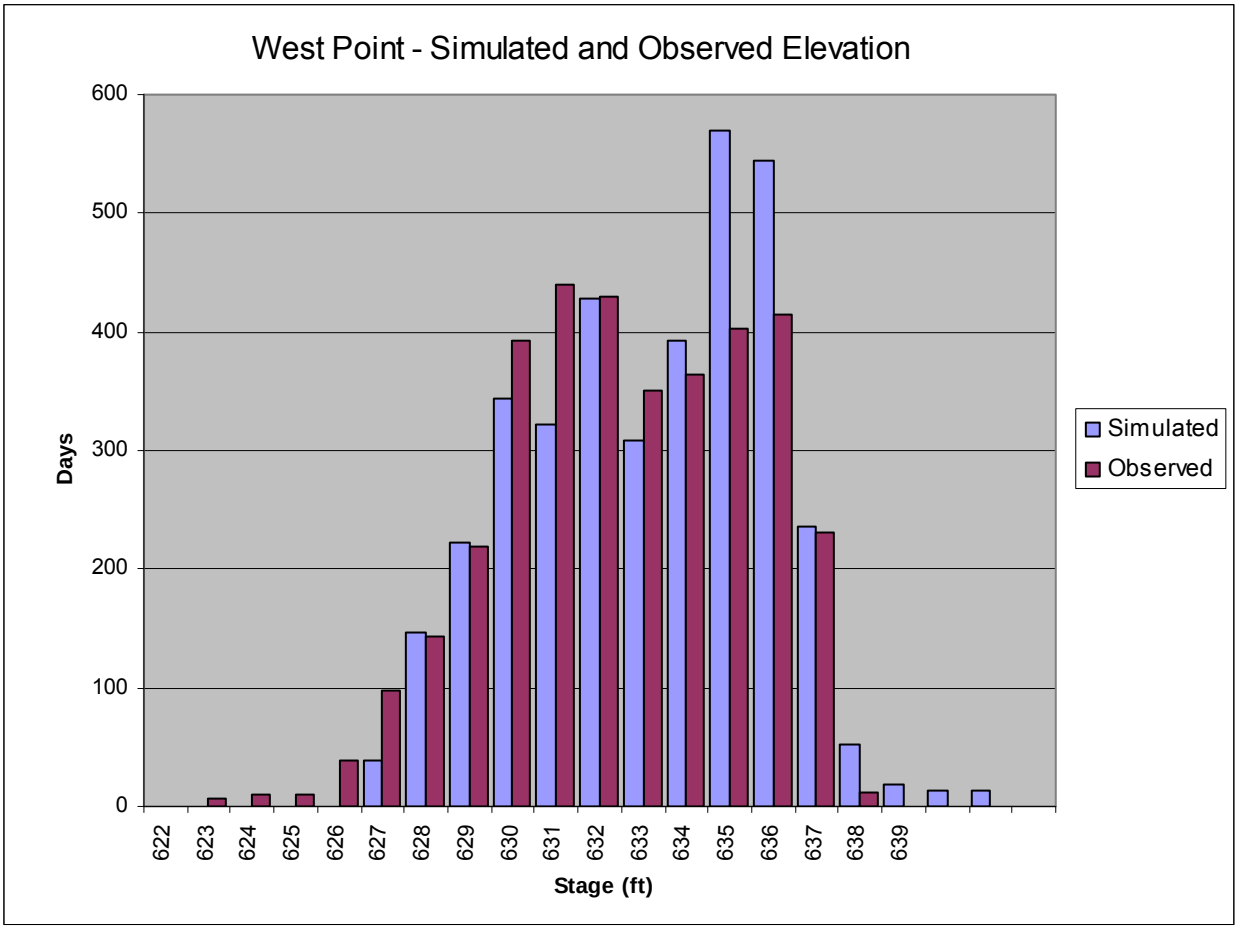

Figure 29. Histogram of simulated and measured elevation for West Point Lake from 1/1/1993 to 12/31/2002.

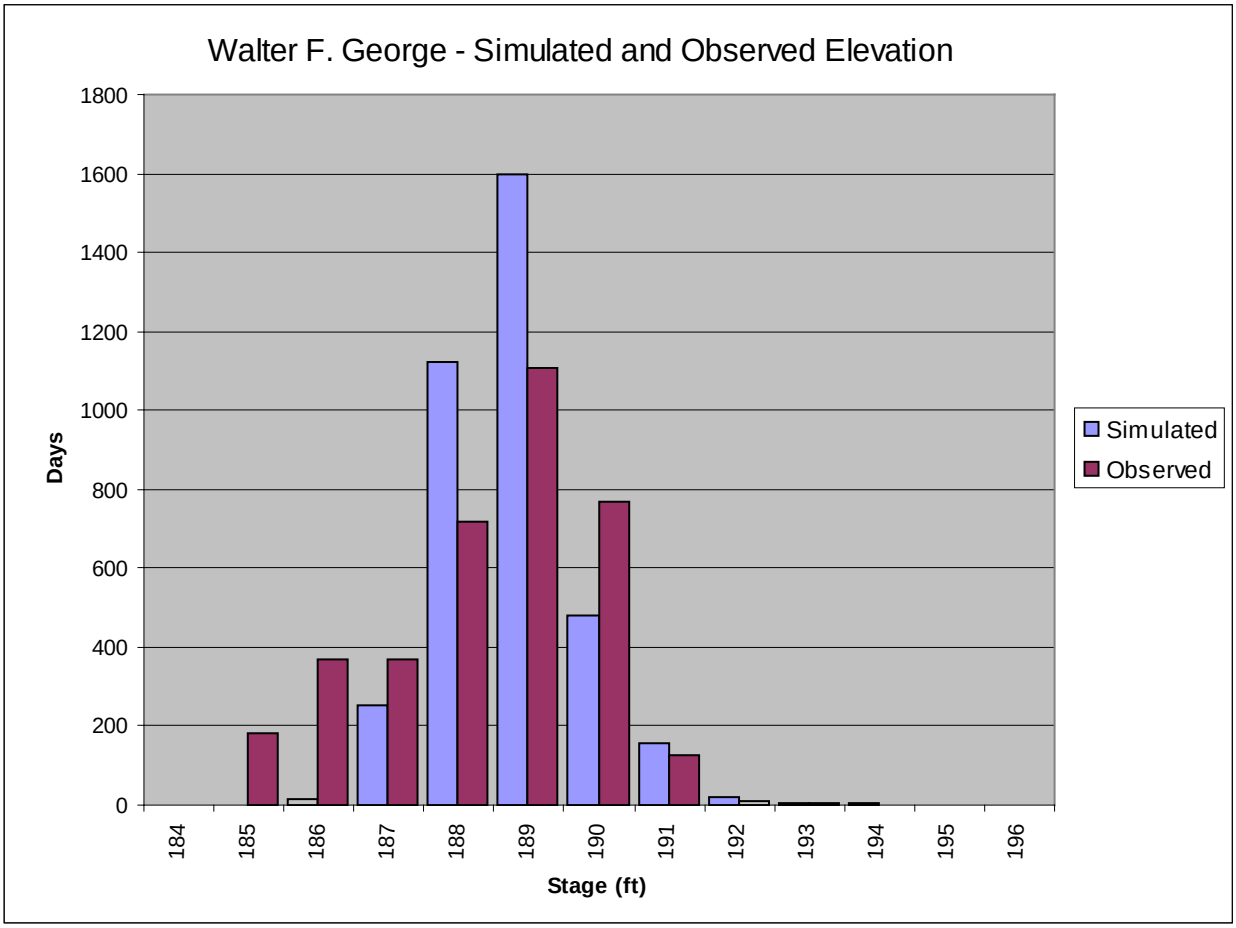

Figure 30. Histogram of simulated and measured elevation for Lake Walter F. George from 1/1/1993 to 12/31/2002.

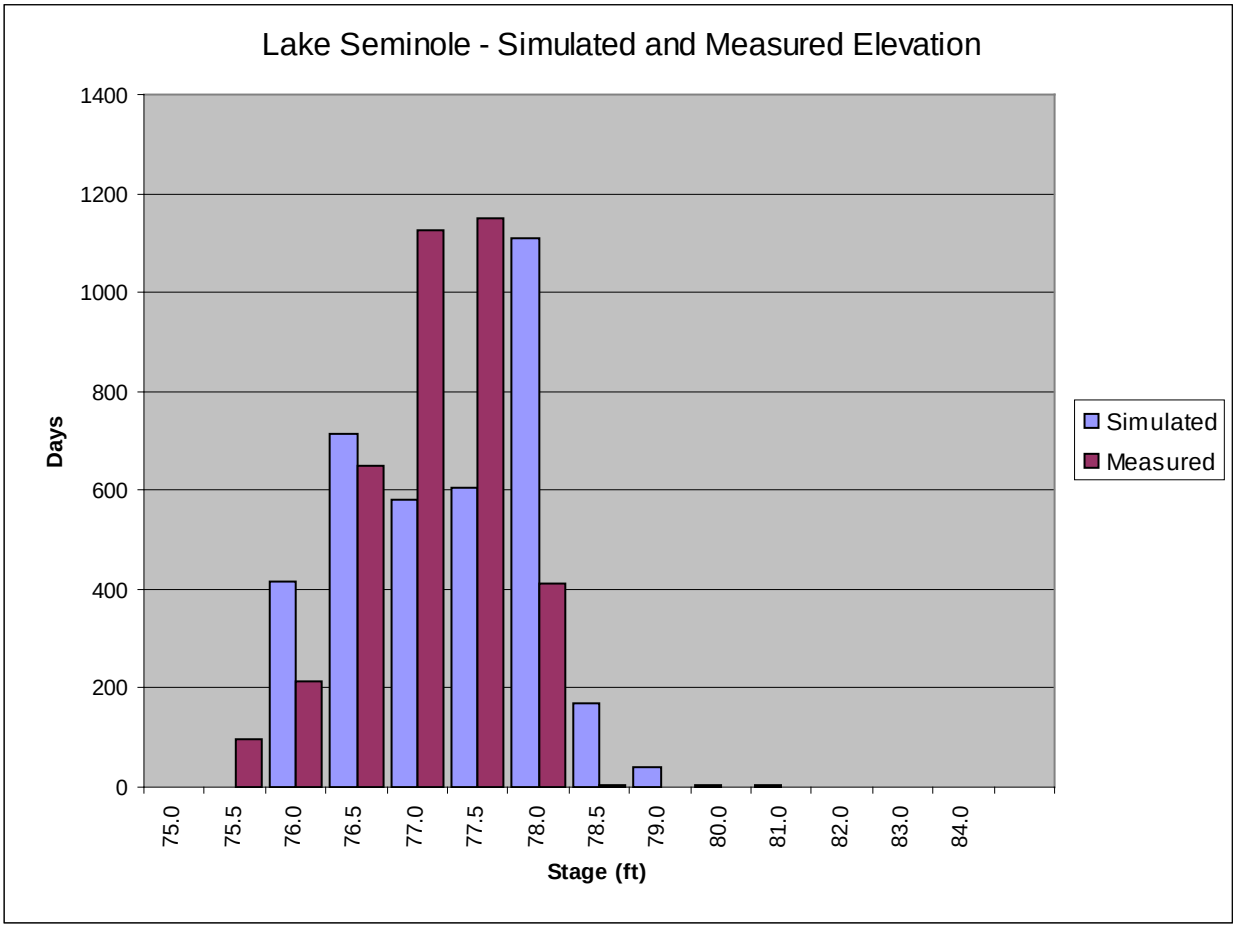

Figure 31. Histogram of simulated and measured elevation for Lake Seminole from 1/1/1993 to 12/31/2002.

Water Quality Calibration and Validation

The 20 Watershed models are designed to provide water quality simulation for total suspended solids (TSS), total nitrogen, and total phosphorus. TSS is simulated with the standard HSPF approach (USEPA 2006). In contrast to TSS, total nitrogen and total phosphorus are simulated in this application in a simplistic fashion, as HSPF general quality constituents (GQUALs) subject to an exponential decay rate during transport.

The water quality calibration focuses on the replication of monthly loads, as specified in the project QAPP. Given the approach to water quality simulation in the 20 Watershed model, a close match to individual concentration observations cannot be expected. Comparison to monthly loads presents challenges, as monthly loads are not observed. Instead, monthly loads must be estimated from scattered concentration grab samples and continuous flow records. As a result, the monthly load calibration is inevitably based on the comparison of two uncertain numbers. Nonetheless, calibration is able to achieve a reasonable agreement. Further, the load comparisons were supported by detailed examinations of the relationships of flows to loads and concentrations and the distribution of concentration prediction errors versus flow, time, and season, as well as standard time series plots.

For application on a nationwide basis, the 20 Watershed protocols assume that TSS and total phosphorus loads will likely exhibit a strong positive correlation to flow (and associated erosive processes), while total nitrogen loads, which often have a dominant groundwater component, will not. Accordingly, TSS and total phosphorus

loads were estimated from observations using a flow-stratified log-log regression approach, while total nitrogen loads were estimated using a flow-stratified averaging estimator, consistent with the findings of Preston et al. (1989).

Similarly to hydrology, initial calibration and validation of water quality was done on the Upper Flint River, comparing model results to data from USGS 02349605. The initial calibration used calendar years 1999-2002 for calibration and calendar years 1991-1998 for validation as there were no data available prior to 1992 for this gage. As stated above, initial water quality parameters were obtained from an LSPC model for a TMDL done for the Lake Allatoona watershed in North Georgia. The Lake Allatoona watershed LSPC model was parameterized with values from literature, information collected in the field, and from previous modeling work done in the state of Georgia. With the exception of shrub lands, both the TMDL model and 20 Watershed model had similar land uses. Shrub lands had parameters assigned from forest lands since these two land uses should behave similarly to each other.

Time series of simulated and estimated TSS loads at the Upper Flint gage for both periods are shown in Figure 32 and statistics for the two periods are provided separately in Table 15. Results of the TSS calibration are generally acceptable. Visually, the model is roughly simulating the trends contained in the observed data but the loading estimates are on the high side. The statistics performed on the comparison between the simulated results and observed data also indicate that TSS loading is slightly high. The key statistic in the table (consistent with the QAPP) is the relative percent error, which shows the error in the prediction of monthly load normalized to the estimated load. The table also shows the relative average absolute error, which is the average of the relative magnitude of errors in individual monthly load predictions. This number is inflated by outlier months in which the simulated and estimated loads differ by large amounts (which may be as easily due to uncertainty in the estimated load due to limited data) and the third statistic, the relative median absolute error, is likely more relevant and shows acceptable agreement.

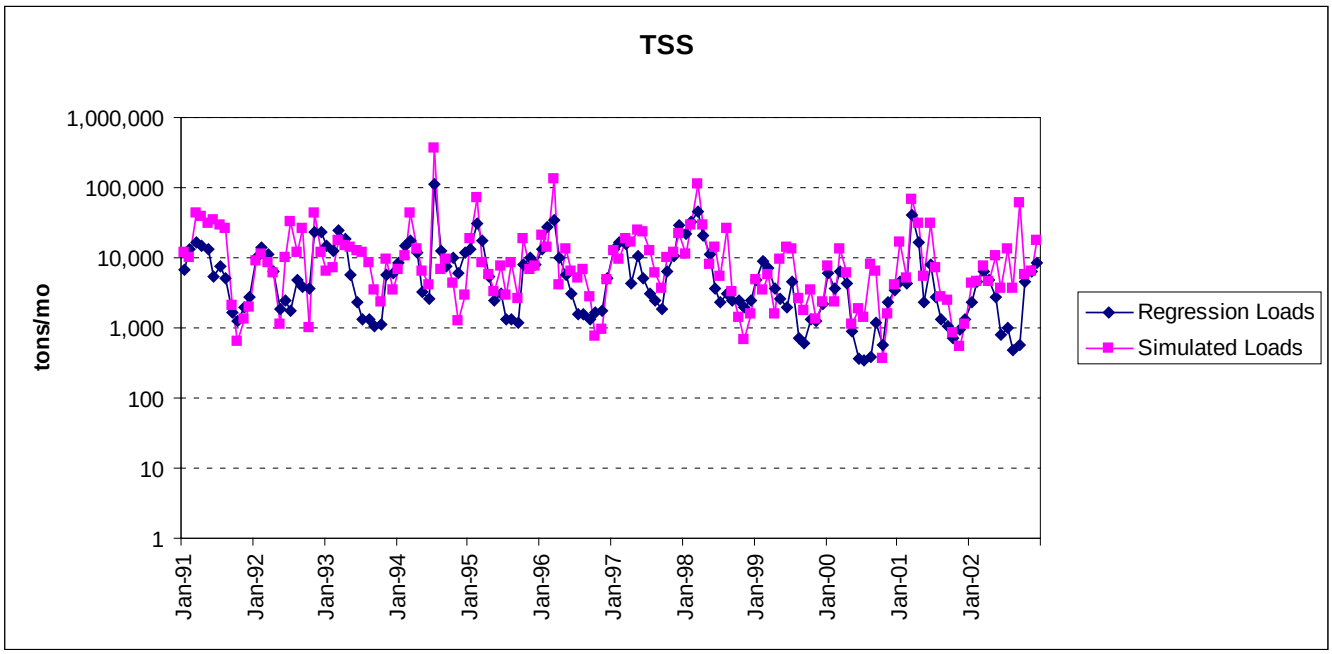

Figure 32. Fit for monthly load of TSS USGS 02349605 Flint River at Ga 26, near Montezuma, GA (HSPF).

Table 15. Model fit statistics (observed minus predicted) for monthly TSS loads using stratified regression

Statistic	Calibration period (1999-2002)	Validation period (1991-1998)
Relative Percent Error	-117%	-78%
Relative Average Absolute Error	129%	110%
Relative Median Absolute Error	38.1%	44.5%

A variety of other diagnostics were also pursued to ensure agreement between the model and observations. These are available in full in the calibration spreadsheets, but a few examples are provided below. First, load-flow power plots were compared for individual days (Figures 33 and 34). These confirm that the relationship between flow and load is consistent across the entire range of observed flows, for both the calibration and validation periods.

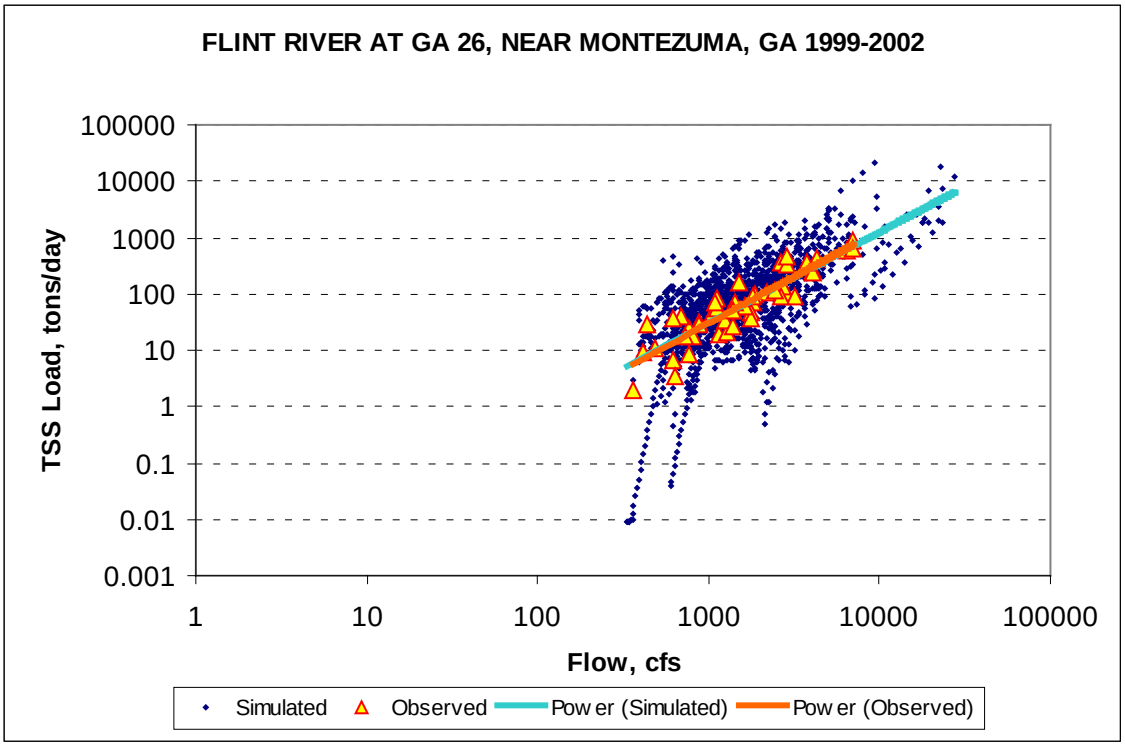

Figure 33. Power plot for observed and simulated TSS at USGS 02349605 Flint River at Ga 26, near Montezuma, GA – calibration period (HSPF).

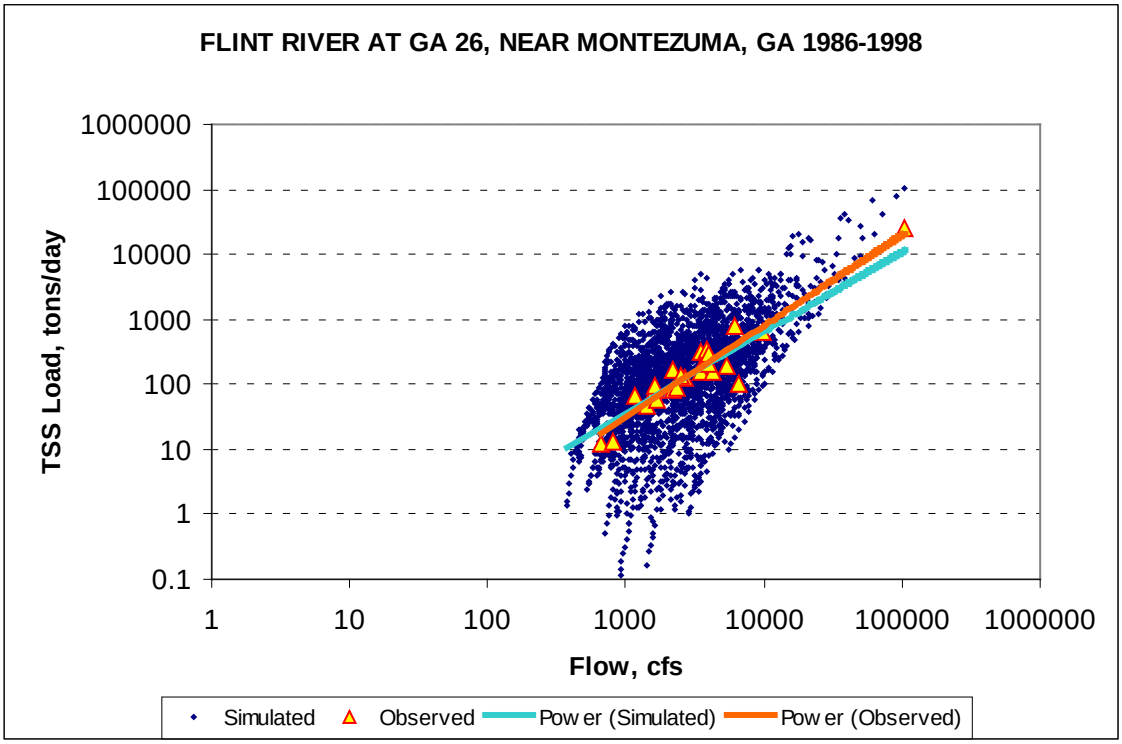

Figure 34. Power plot for observed and simulated TSS at USGS 02349605 Flint River at Ga 26, near Montezuma, GA – validation period (HSPF).

Standard time series plots (Figure 35) show that observed and simulated concentrations achieve good agreement, although individual observations may deviate. Plots of concentration error versus flow and versus month (not shown) were used to guard against hydrologic and temporal bias. Finally, statistics on concentration (Table 16) show that acceptable median errors are achieved for the calibration period.

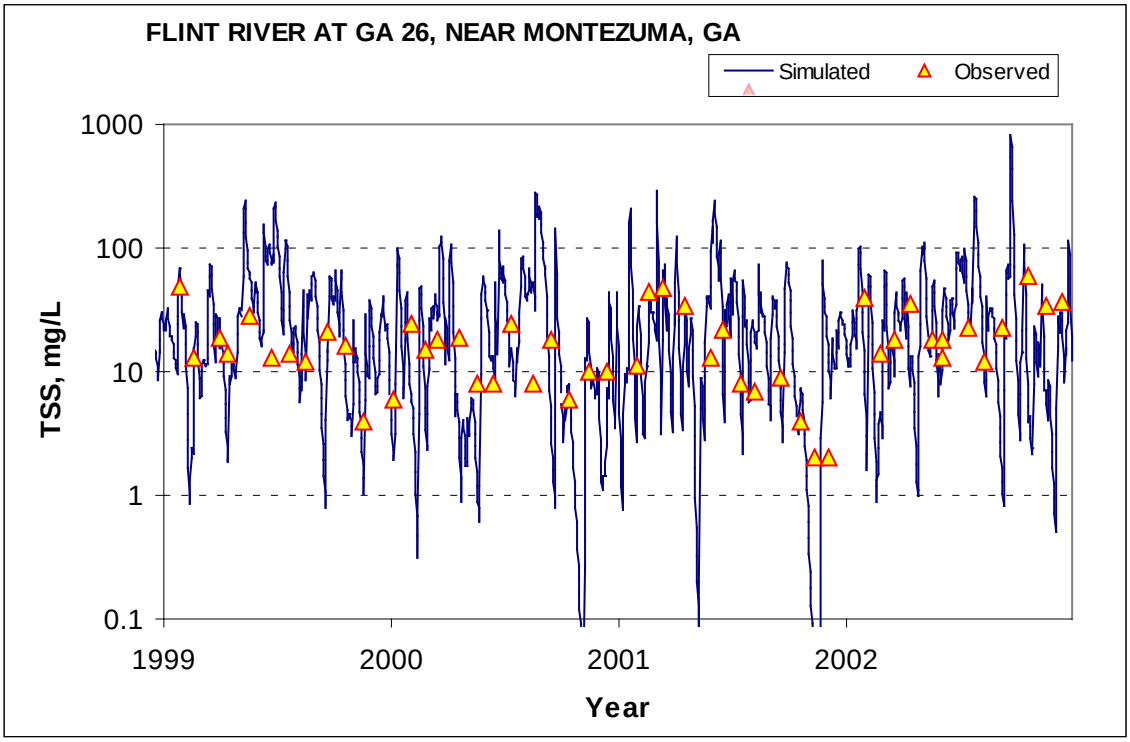

Figure 35. Time series plot of TSS concentration at USGS 02349605 Flint River at Ga 26, near Montezuma, GA – calibration period (HSPF).

Table 16. Relative errors (observed minus predicted), TSS concentration at USGS 02349605 Flint River at Ga 26, near Montezuma, GA (HSPF).

Statistic	Calibration period (1999-2002)	Validation period (1991-1998)
Count	49	24
Concentration Average Error	3.30%	-97.85%
Concentration Median Error	19.78%	-33.27%

The general quality constituent parameters in the Lake Allatoona TMDL model for total phosphorus were essentially directly transferred to the 20 Watershed model. As stated earlier, shrub land was parameterized similarly to forested lands. The model simulates total phosphorus from the uplands as having both sediment-associated and buildup-washoff components. The sediment-associated component of the surface load reflects mineral phosphorus, while the buildup-washoff component addresses organic phosphorus.

Initial parameter assignments for phosphorus for the Upper Flint calibration focus area performed well. Minor adjustments were made to the interflow and groundwater component. The same percent adjustment was made to all land uses in order to keep the land use associated loading rates, developed in the TMDL model, intact. All streams in the calibration focus area were supplied with the same first order decay rate. This decay rate was obtained from the TMDL model and is consistent with other modeling work conducted throughout the state of Georgia. Adjustment was not made to this parameter while calibration was performed on the calibration focus area.

Monthly loading series for total phosphorus are shown in Figure 36 and load statistics are summarized in Table 17. In general, the observed and simulated total phosphorus loads attain an acceptable match for both the calibration and validation periods. There are a few locations where the simulation is not trending and the

simulated loads are higher than the observed loads. These errors are most likely attributed to the error in the TSS simulation during the same time period.

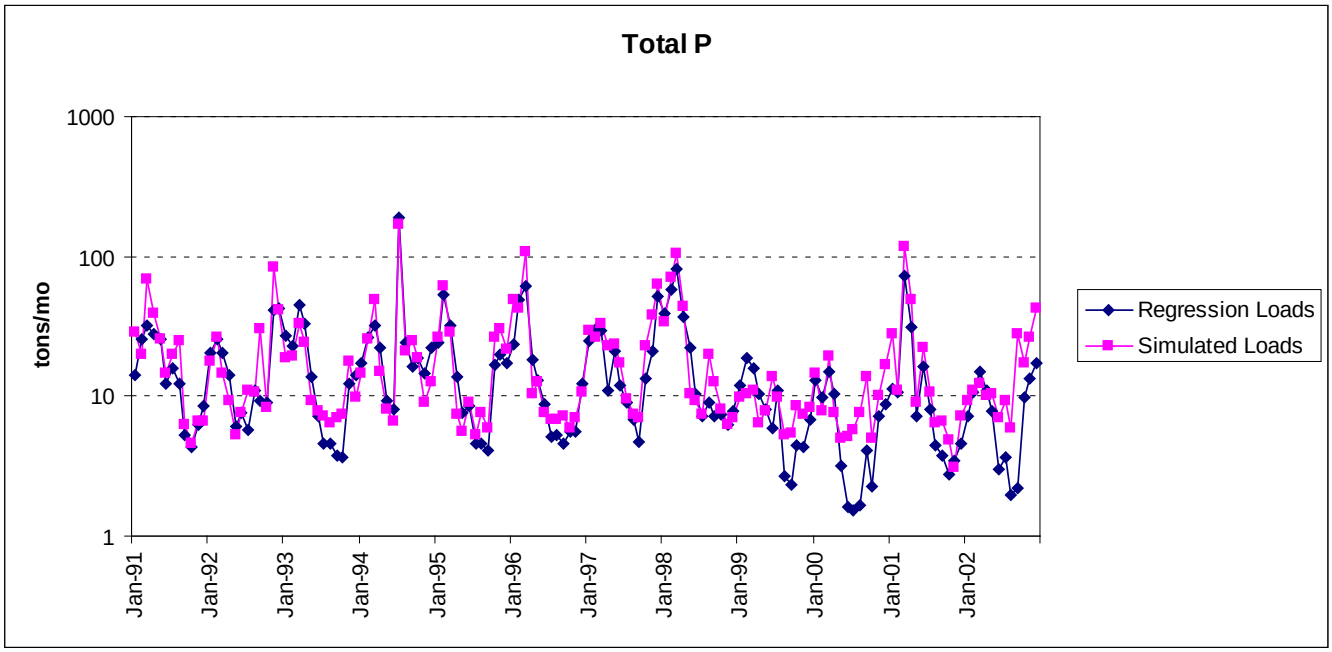

Figure 36. Fit for monthly load of total phosphorus at USGS 02349605 Flint River at Ga 26, near Montezuma, GA (HSPF).

Table 17. Model fit statistics (observed minus predicted) for monthly total phosphorus loads using stratified regression

Statistic	Calibration period (1999-2002)	Validation period (1986-1998)
Relative Percent Error	-59%	-23%
Average Absolute Error	69%	35%
Median Absolute Error	35.3%	18.5%

As with TSS, additional diagnostics for total phosphorus included flow-load power plots (Figures 37 and 38), time series plots (Figure 39) and analysis of concentration errors (Table 18). All show acceptable agreement.

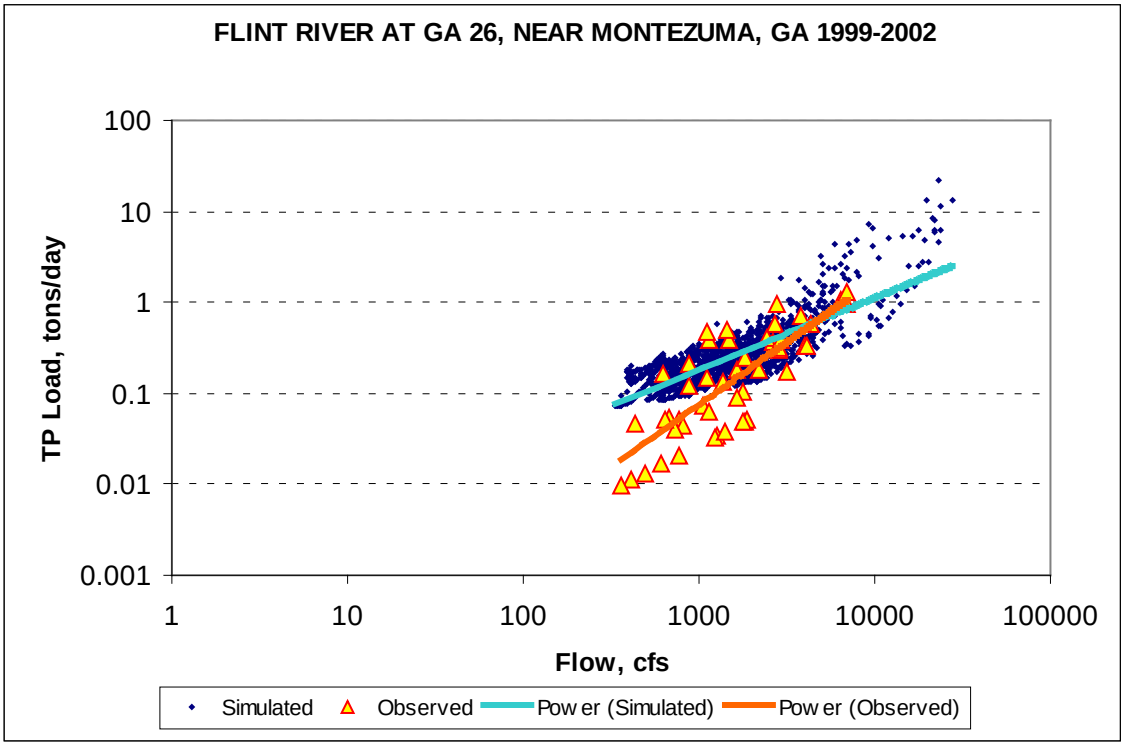

Figure 37. Power plot for observed and simulated total phosphorus at USGS 02349605 Flint River at Ga 26, near Montezuma, GA – calibration period (HSPF).

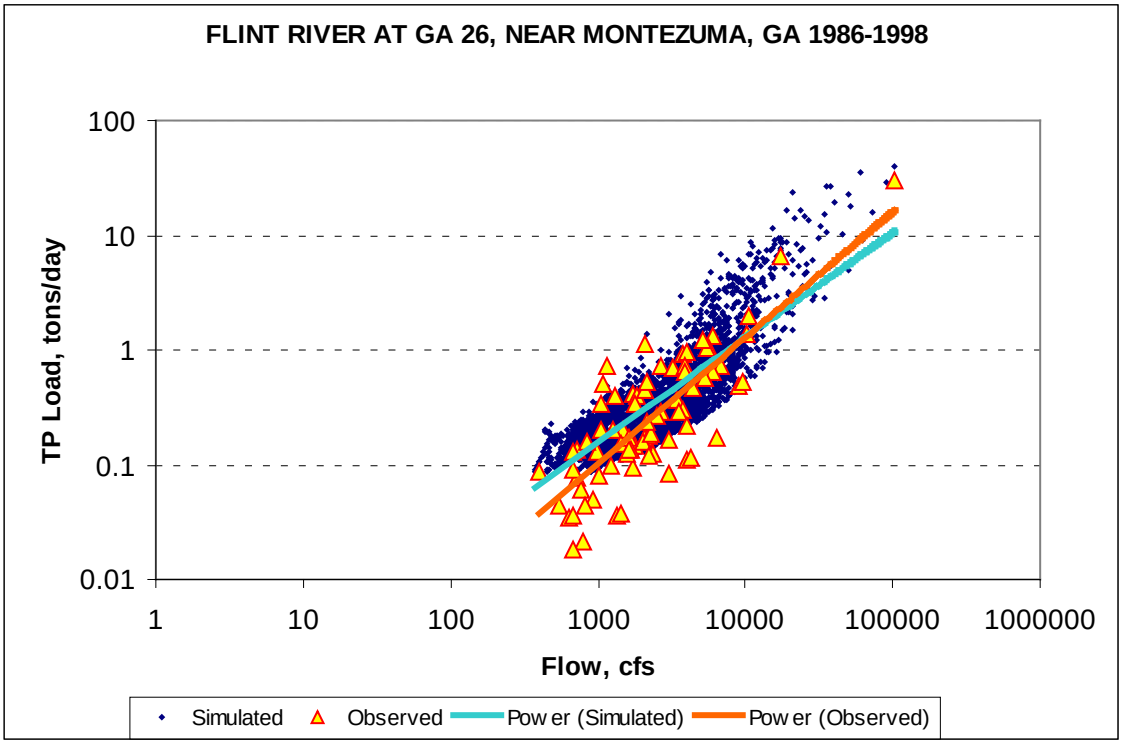

Figure 38. Power plot for observed and simulated total phosphorus at USGS 02349605 Flint River at Ga 26, near Montezuma, GA – validation period (HSPF).

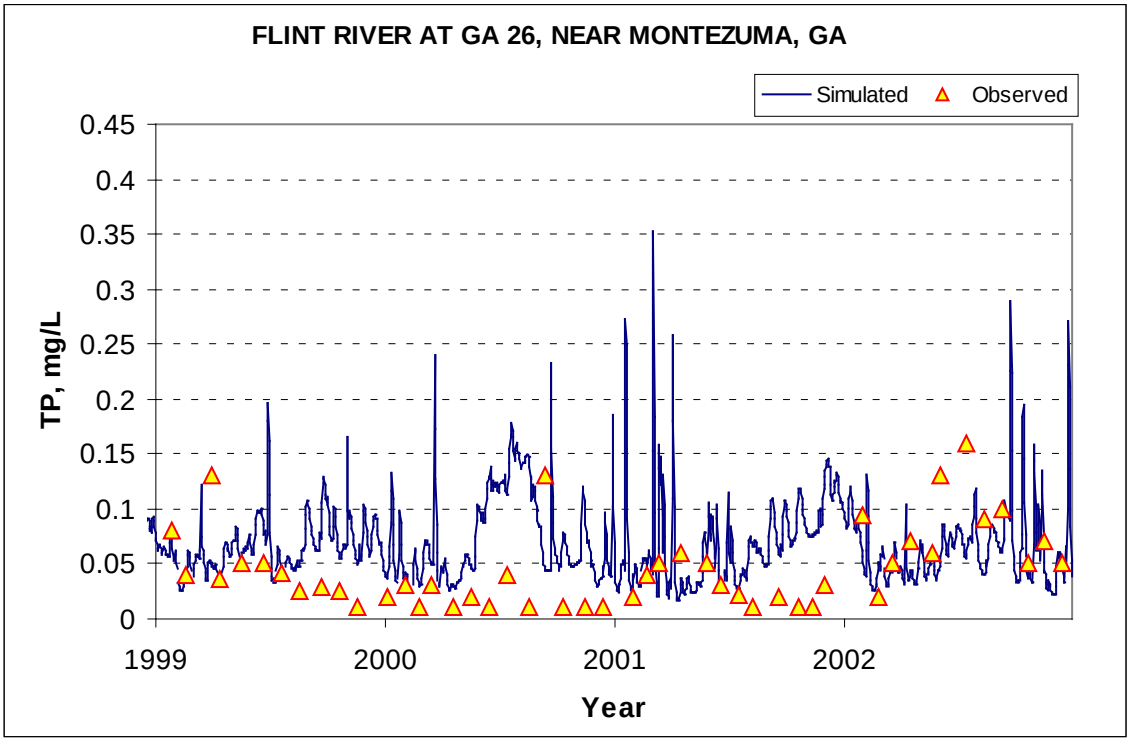

Figure 39. Time series plot of total phosphorus concentration at USGS 02349605 Flint River at Ga 26, near Montezuma, GA – calibration period (HSPF).

Table 18. Relative errors (observed minus predicted), total phosphorus concentration at USGS 02349605 Flint River at Ga 26, near Montezuma, GA (HSPF)

Statistic	Calibration period (1999-2002)	Validation period (1986-1998)
Count	48	80
Concentration Average Error	-31.2%	-2.2%
Concentration Median Error	-26.5%	-12.5%

As discussed above in the Calibration Data and Locations section of this report, the number of measured total nitrogen observations was very limited for the ACF. The approach used to estimate the observed total nitrogen should give reasonable values for total nitrogen since two of the three components making up total nitrogen were measured. Similarly to total phosphorus, total nitrogen parameters in the Lake Allatoona TMDL model were easily transferred to the 20 Watershed model. Also, similarly to total phosphorus, initial interflow and groundwater total nitrogen concentrations were adjusted for all land uses together in order to keep the land use associated loading rates, developed in the TMDL model, intact.

Results for total nitrogen are summarized in Figures 40 through 43 and Tables 19 and 20, following the same format as total phosphorus. The results are acceptable, and generally better than those for total phosphorus. This is because nitrogen is not sediment-associated, therefore, problems with sediment are not reflected in the calibration for total nitrogen.

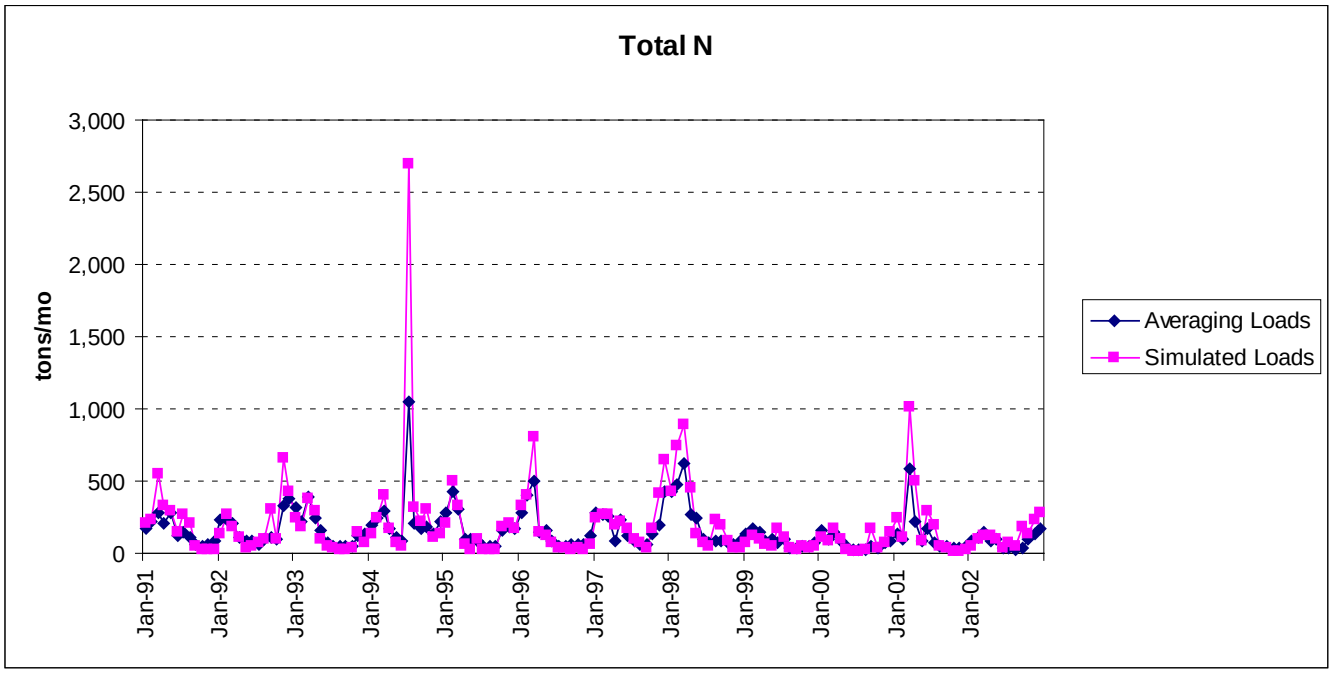

Figure 40. Fit for monthly load of total nitrogen at USGS 02349605 Flint River at Ga 26, near Montezuma, GA (HSPF).

Table 19. Model fit statistics (observed minus predicted) for monthly total nitrogen loads using averaging estimator (HSPF)

Statistic	Calibration period (1999-2002)	Validation period (1986-1998)
Relative Percent Error	-30%	-22%
Average Absolute Error	54%	42%
Median Absolute Error	26.1%	18.2

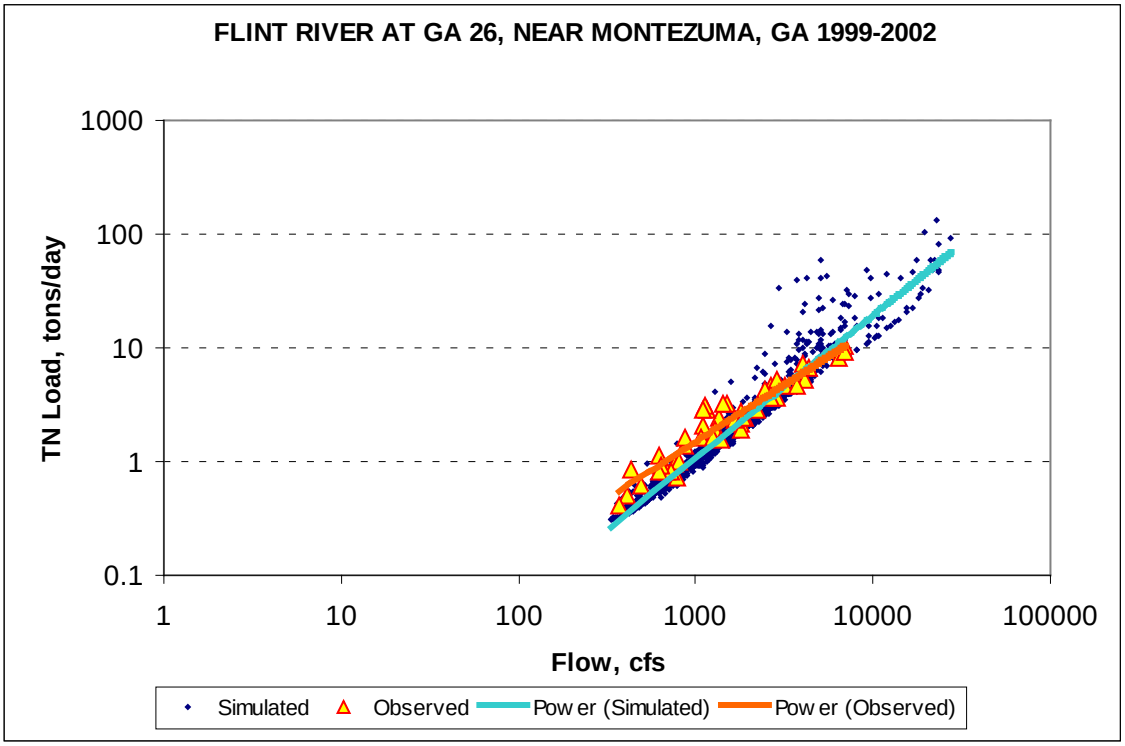

Figure 41. Power plot for observed and simulated total nitrogen at USGS 02349605 Flint River at Ga 26, near Montezuma, GA – calibration period (HSPF).

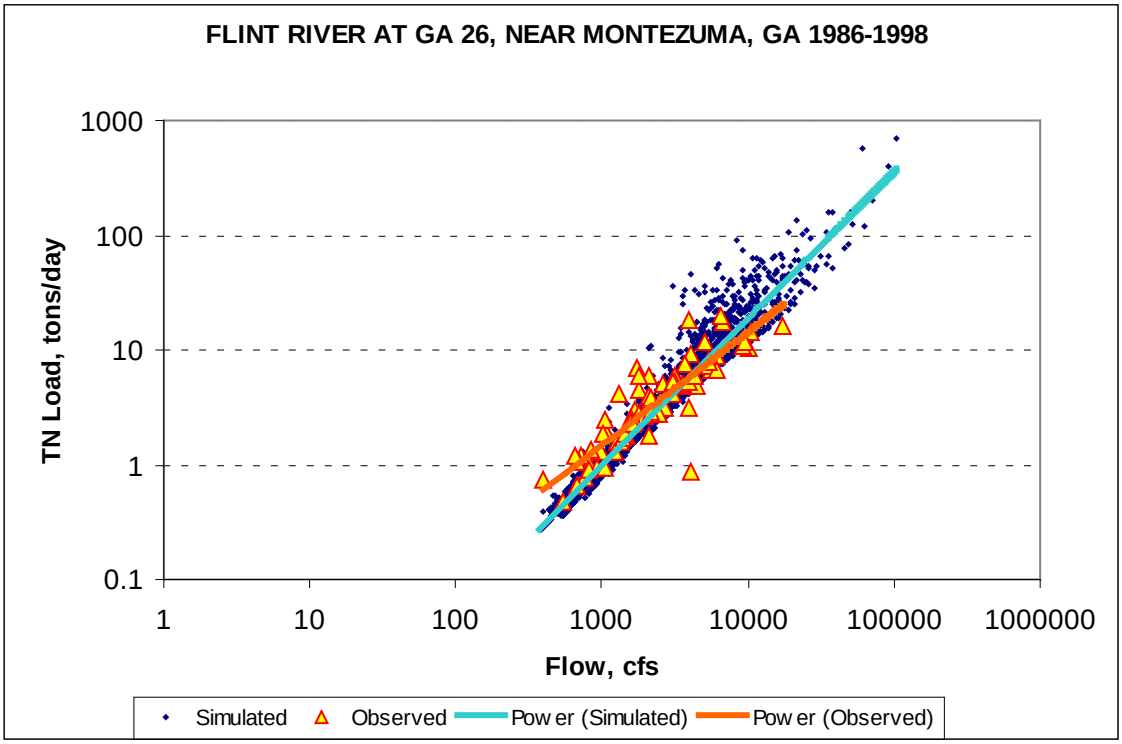

Figure 42. Power plot for observed and simulated total nitrogen at USGS 02349605 Flint River at Ga 26, near Montezuma, GA – validation period (HSPF).

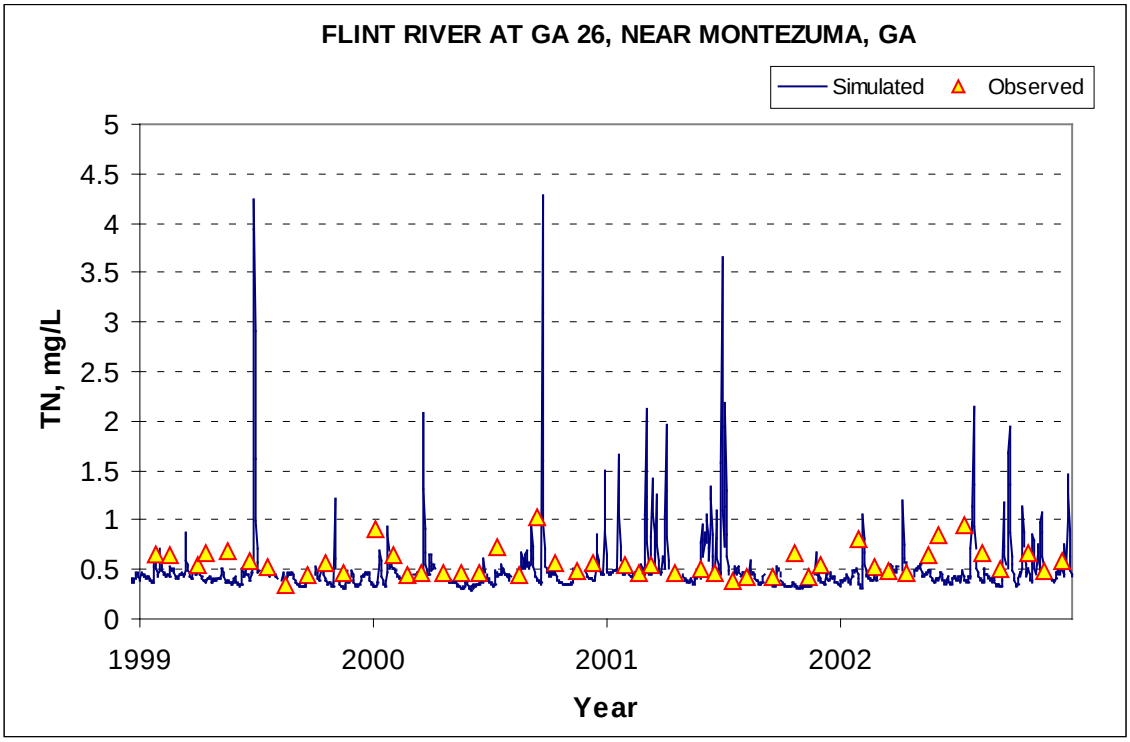

Figure 43. Time series plot of total nitrogen concentration at USGS 02349605 Flint River at Ga 26, near Montezuma, GA – calibration period (HSPF).

Table 20. Relative errors (observed minus predicted), total nitrogen concentration at USGS 02349605 Flint River at Ga 26, near Montezuma, GA (HSPF)

Count	48	76
Concentration Average Error	25.5%	27.2%
Concentration Median Error	19.3%	14.7%

Water Quality Results for Larger Watershed

Similar to hydrology, the Upper Flint water quality parameterization was not directly transferrable to other areas of the watershed. The Upper Flint parameters were utilized as starting parameters at the other calibration locations. Once those locations reasonably agreed with the observed data, they were transferred to other parts of the watershed, as with the hydrology calibration. The decay rates assigned to the streams in the calibration focus area were also assigned to all streams in the ACF basin.

Upon initial water quality parameterization mapping, the water quality simulation below the reservoirs was checked. At this point the simulation suggested that each of the reservoirs consumed all of the nitrogen and phosphorus entering the reservoir and the water leaving the reservoir was free of all total nitrogen and total phosphorus. This was taken to mean that due to longer residence time within reservoir reaches, the first order decay rate applied to the reservoirs was too high. Total nitrogen and total phosphorus first order decay rates were lowered until the simulation below each of the reservoirs better matched the observed water quality. This resulted

in decay rates that were an order of magnitude lower than those applied to the other stream reaches. HSPF assumes that the water within a reach is both vertically and horizontally mixed; therefore it does not take into account nutrient transformations and cycling occurring within a reservoir. The lowered decay rate was utilized as a parameter to capture nutrient dynamics within the reservoirs, therefore they decay rate was the only parameter adjusted in order to get a reasonable representation of water quality below the reservoirs.

Summary statistics for the water quality calibration and validation at all stations in the watershed are provided in Tables 21 and 22. The results of the water quality calibration and validation are much better at some gages than others. The gages that are simulating poorly are probably doing so because of a lack of data to reasonably construct observed monthly loadings. Another source of error that can balloon error statistics is poor hydrology simulation at some of the monitoring locations. These two errors coupled together can severely impact the error statistics presented.

Table 21. Summary statistics for water quality (observed minus predicted) for all stations – calibration period 1999-2002 (HSPF)

Station	02349605	02331600	02336300	02353500	02336000	02339500	02343801	02353000
Relative Percent Error TSS Load	-117%	-4%	74%	-438%	-215%	-141%	34%	-63%
TSS Concentration Median Percent Error	19.78%	16.73%	10.16%	-38.90%	1.72%	-120.07%	28.57%	-64.66%
Relative Percent Error TP Load	-59%	-1%	24%	-205%	-77%	-272%	-202%	-82%
TP Concentration Median Percent Error	-26.5%	12.8%	-13.8%	-224.5%	-40.1%	-759.0%	-1107.9%	-89.2%
Relative Percent Error TN Load	-30%	-25%	-38%	-38%	-35%	2%	3%	32%
TN Concentration Median Percent Error	19.3%	4.2%	16.8%	46.7%	35.8%	46.4%	54.8%	53.1%

Table 22. Summary statistics for water quality (observed minus predicted) for all stations – validation period 1986-1998 (HSPF)

Station	02349605	02331600	02336300	02353500	02336000	02339500	02343801	02353000
Relative Percent Error TSS Load	-78%	90%	89%	-570%	18%	-7%	84%	-77%
TSS Concentration Median Percent Error	-33.3%	7.2%	3.5%	-103.8%	6.7%	-36.9%	8.0%	-1.0%
Relative Percent Error TP Load	-23%	53%	47%	-94%	-16%	-64%	54%	-22%
TP Concentration Median Percent Error	-12.5%	43.6%	5.9%	-17.0%	-9.1%	-85.2%	-499.6%	-26.1%
Relative Percent Error TN Load	-22%	-8%	-21%	-20%	10%	25%	7%	16%
TN Concentration Median Percent Error	14.7%	1.3%	20.7%	32.7%	20.0%	-28.2%	31.2%	-39.9%

SWAT Modeling

Changes Made to Base Data Provided

As mentioned in the above section for the HSPF model, no changes were made to the meteorological or land use base data for the SWAT model. However, an error in the connectivity of reaches was found in the predefined reach file, which was rectified. The impoundments of Lake Blackshear and Lake Seminole have large tributaries contributing to them. The pre-defined reach file had reaches of the upstream tributaries draining into the next downstream reach rather than into the reach within the subwatershed containing the lakes. This made the contributing drainage areas for these lakes incorrect. The connectivity was modified so that the tributaries pour into the reaches within the subwatersheds containing the lakes. Incorrect connectivity of reaches would pose a problem because of the incorrect drainage area contributing flow to the impoundments. In the SWAT model, reservoirs are modeled to be simulated at the outlet of the subwatershed in which they are located and receive flow from all the upstream drainage area.

Assumptions

Reservoirs

Jim Woodruff Dam, Muckafoonee Creek Dam, West Point, and Buford (Table 6) reservoirs were represented in the ACF basin 20 Watershed SWAT model. Pertinent reservoir information including surface area and storage at principal (normal) and emergency spillway levels for the reservoirs modeled were obtained from the National Inventory of Dams (NID) database (USACE 1982). The SWAT model provides four options to simulate reservoir outflow: 1) measured daily outflow, 2) measured monthly outflow, 3) average annual release rate for uncontrolled reservoir, and 4) controlled outflow with target release. Keeping the goals of the 20 Watershed climate change impact evaluation application, it was assumed that the best representation of the reservoirs was to simulate them without supplying time series of outflow records. Therefore, a target release approach was used in the GCRP-SWAT model. The average release rate was estimated using the outflow data available at the (USACE 2010). The number of days to reach target storage was assumed to be 90 days for all lakes except Lake Worth, which was assumed to be 10 days.

Irrigation

Croplands occupy about eight percent of the total watershed area. It was found that irrigation occurred on about 5.5 percent of the total watershed area with 4.18 percent being irrigated by groundwater and 1.35 percent being irrigated by surface water (Hook 2009). To simulate irrigation in the SWAT model, the auto-irrigation feature was used in the management set-up on those HRUs that represented cotton and peanut crops.

Hydrology Calibration

The SWAT model setup for the ACF basin was set up fresh, with no prior-existing SWAT model for the watershed. The model calibration period was set to calendar years 1993-2002.

Consistent with the HSPF modeling efforts, the specific site chosen for initial calibration was the Flint River at GA 26, near Montezuma, GA (USGS 02349605) (Table 5). Most of the calibration efforts were geared toward getting a closer match between simulated and observed flows at the outlet of the calibration focus area. Initially, the parameters set for this area were applied across the watershed and the model performance was verified at other

stations. Model performance was not the same as it was for the calibration focus area, mostly due to the dominance of different land uses in different parts of the watershed. In response to the variations in spatial characteristics of the subwatersheds, a systematic adjustment of parameters individually, by land use type has been adopted and the same adjustment is applied throughout the watershed. Observed data at other gaging stations with the dominance of a different land use type was used to adjust the corresponding parameters. For example, at the gaging station that drains predominantly urban land, the area was used to set the parameters for the urban land areas.

It is acknowledged that a hydrologic/water quality model can be precisely calibrated, given the degree of freedom, resources, time, and data. Keeping in view the interests of this project, which are to study the land use change and climate change impacts on flow and water quality, a site specific calibration was deliberately not attempted. To some extent, the limitation of this approach is that the local differences in soil, weather, management, and hydrology is not thoroughly accounted for. This approach will provide an idea of the model performance when it is not spatially-tightly calibrated and what to expect when transferring the parameters to other ungaged watersheds or to watersheds where detailed modeling is not practical due to limited resources.

Land Use / Soil / Slope Definition

A 5/10/5 percent threshold was used for land use/soil/slope in the SWAT model while defining the HRUs. The cropland HRUs were split into cotton, peanuts, and corn in proportions of 48, 30, and 22 percent, respectively. Further these classes and the urban (including current and future urban class types) classes were exempt from applying the thresholds.

The calibration focus area represents 21 subwatersheds that, together, consist of 1,342 HRUs. The parameters were adjusted within the practical range to obtain a reasonable fit between the simulated and measured flows in terms of Nash-Sutcliffe modeling efficiency and the high flow and low flow components as well as the seasonal flows. The general land use characteristics of the watershed were represented well in the calibration focus area. Two other locations: one predominantly forested (Chattahoochee River near Cornelia, GA; USGS 02331600) and the other, predominantly urban (Peachtree Creek at Atlanta, GA; USGS 02336300), were chosen to set the parameters for forest and urban areas, respectively. These parameters were then applied across the entire watershed. There is essentially one set of parameters for a land use type for the entire watershed.

During calibration, parameters were carefully adjusted such that different components of streamflow contribution were adequately simulated. For instance, the observed and simulated baseflow and surface runoff contributions to streamflow, as well as seasonal flows, matched well. Reasonable estimations of actual ET and crop yields were also given consideration.

Calibration adjustments focused on the following parameters:

- Curve numbers (varied systematically by land use)
- ESCO (soil evaporation compensation factor)
- SURLAG (surface runoff lag coefficient)
- Groundwater “revap” rates
- Baseflow factor
- GW_DELAY (groundwater delay time)
- GWQMN (threshold depth of water in the shallow aquifer required for return flow to occur)
- RevapMN (threshold depth of water in the shallow aquifer required for “revap” or percolation to the deep aquifer to occur
- CANMAX (maximum canopy storage)
- Manning’s “n” value for overland flow, main channels, and tributary channels
- Sol_AWC (available water capacity of the soil layer, mm water/mm of soil)

Initial calibrations were performed for the Flint River at GA 26, near Montezuma, GA and are summarized in Figures 44 through 50 and Tables 23 and 24. As evidenced through the time series plots and the Nash-Sutcliffe modeling efficiency, the model performed well in simulating the timing and magnitude of streamflow for various seasons.

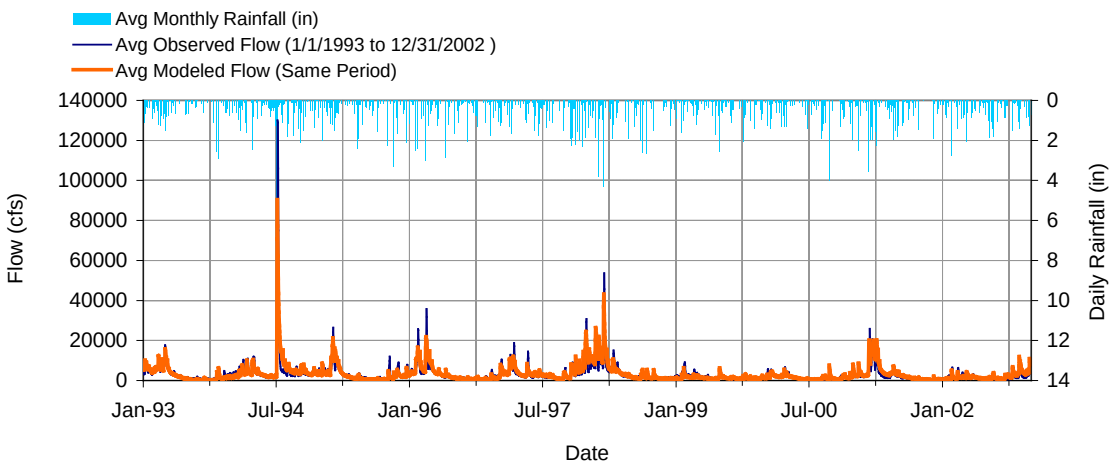

Figure 44. Mean daily flow at USGS 02349605 Flint River at Ga 26, near Montezuma, GA – calibration period (SWAT).

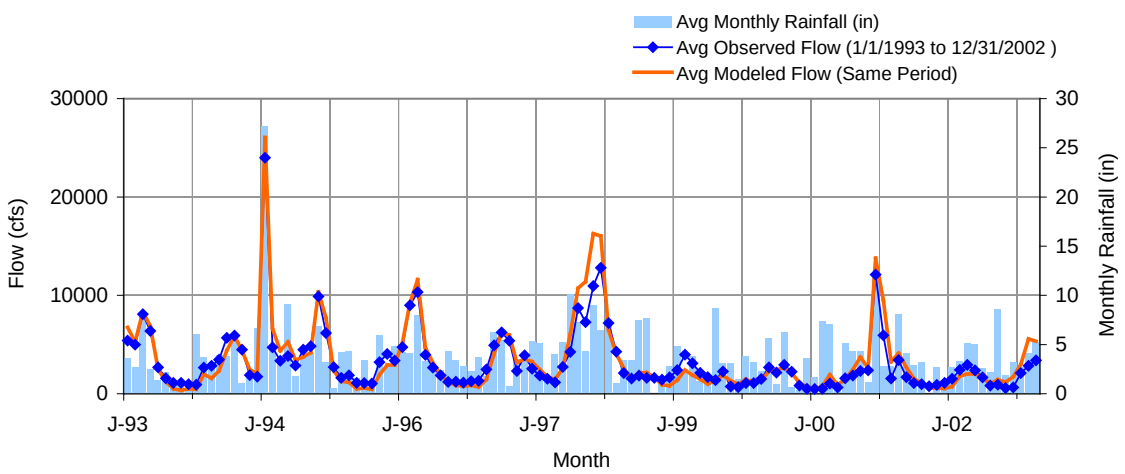

Figure 45. Mean monthly flow at USGS 02349605 Flint River at Ga 26, near Montezuma, GA – calibration period (SWAT).

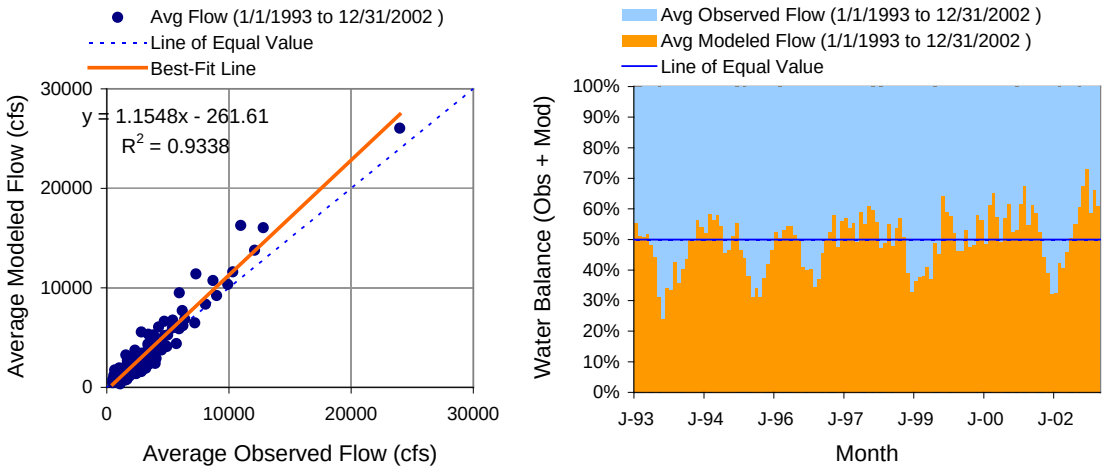

Figure 46. Monthly flow regression and temporal variation at USGS 02349605 Flint River at Ga 26, near Montezuma, GA – calibration period (SWAT).

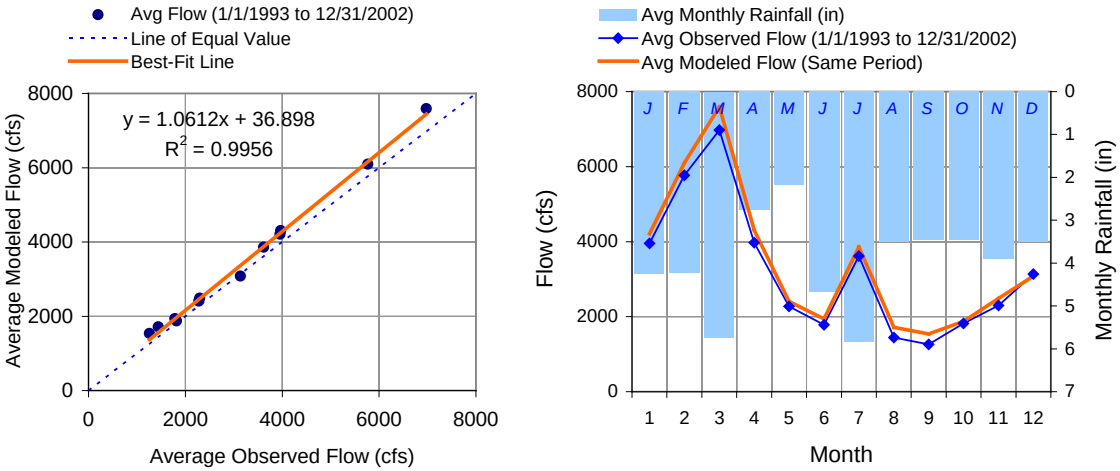

Figure 47. Seasonal regression and temporal aggregate at USGS 02349605 Flint River at Ga 26, near Montezuma, GA – calibration period (SWAT).

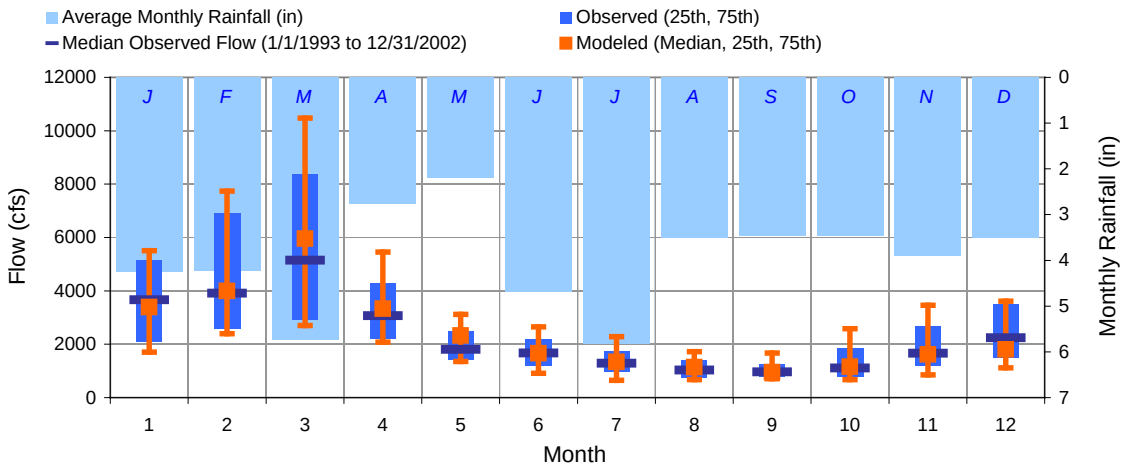

Figure 48. Seasonal medians and ranges at USGS 02349605 Flint River at Ga 26, near Montezuma, GA – calibration period (SWAT).

Table 23. Seasonal summary at USGS 02349605 Flint River at Ga 26, near Montezuma, GA – calibration period (SWAT)

MONTH	OBSERVED FLOW (CFS)				MODELED FLOW (CFS)			
	MEAN	MEDIAN	25TH	75TH	MEAN	MEDIAN	25TH	75TH
Jan	3955.13	3665.00	2110.00	5155.00	4206.77	3393.41	1700.42	5504.55
Feb	5767.27	3915.00	2572.50	6887.50	6093.10	3996.73	2395.72	7738.14
Mar	6976.42	5150.00	2932.50	8377.50	7590.84	5958.04	2700.58	10476.33
Apr	3970.93	3065.00	2210.00	4297.50	4303.82	3329.58	2078.74	5450.56
May	2277.06	1810.00	1400.00	2470.00	2405.19	2322.73	1358.75	3121.85
Jun	1783.49	1670.00	1180.00	2170.00	1937.85	1659.04	909.57	2654.73
Jul	3617.54	1290.00	977.25	1765.00	3856.12	1342.07	644.18	2287.50
Aug	1440.71	1035.00	752.00	1420.00	1715.12	1139.52	673.31	1722.66
Sep	1260.28	964.00	770.50	1252.50	1538.55	957.90	710.14	1670.33
Oct	1816.83	1105.00	775.75	1855.00	1874.05	1162.76	673.08	2586.26
Nov	2297.06	1660.00	1220.00	2685.00	2484.96	1619.56	854.25	3456.35
Dec	3137.85	2240.00	1490.00	3497.50	3082.68	1810.72	1116.26	3611.32

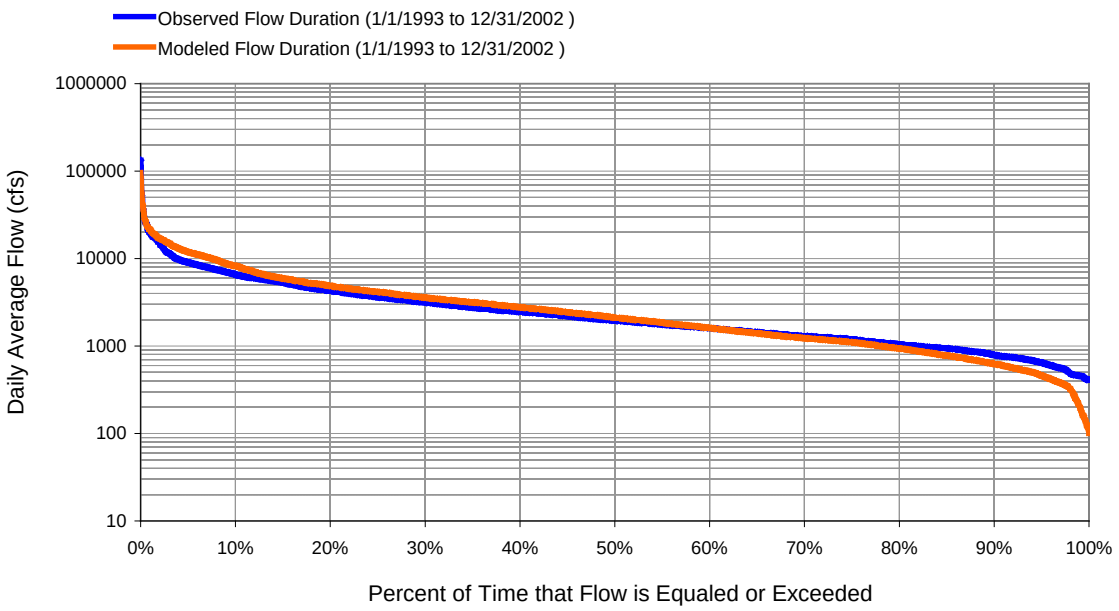

Figure 49. Flow exceedence at USGS 02349605 Flint River at Ga 26, near Montezuma, GA – calibration period (SWAT).

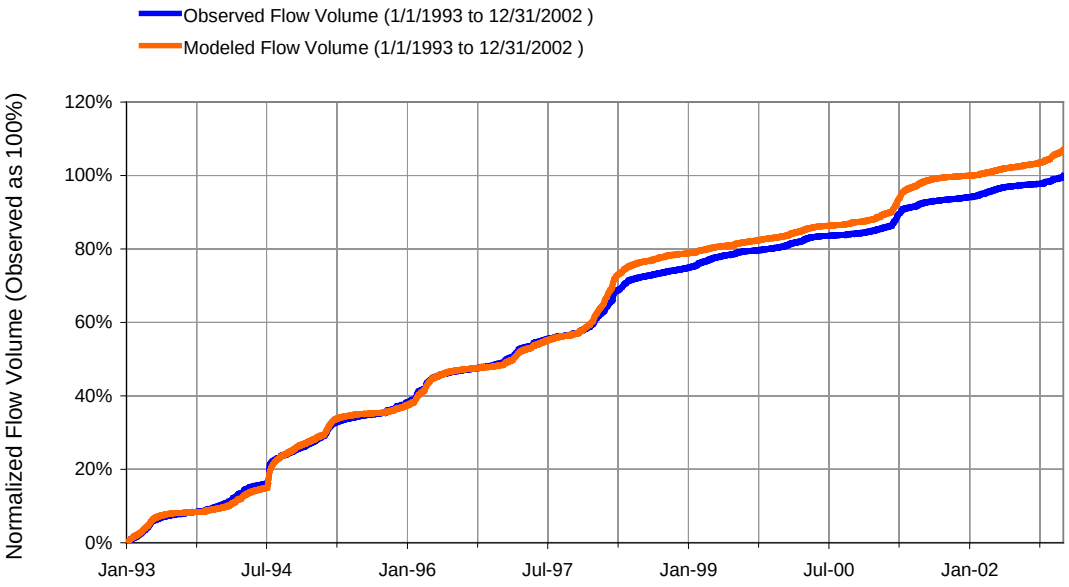

Figure 50. Flow accumulation at USGS 02349605 Flint River at Ga 26, near Montezuma, GA – calibration period (SWAT).

Table 24. Summary statistics at USGS 02349605 Flint River at Ga 26, near Montezuma, GA – calibration period (SWAT)

SWAT Simulated Flow		Observed Flow Gage		
REACH OUTFLOW FROM OUTLET 38 10-Year Analysis Period: 1/1/1993 - 12/31/2002 Flow volumes are (inches/year) for upstream drainage area		USGS 02349605 FLINT RIVER AT GA 26, NEAR MONTEZUMA, GA Hydrologic Unit Code: 3130006 Latitude: 32.29305556 Longitude: -84.0436111 Drainage Area (sq-mi): 2920		
Total Simulated In-stream Flow:	**15.88**	Total Observed In-stream Flow:		**14.80**
Total of simulated highest 10% flows:	**6.39**	Total of Observed highest 10% flows:		**5.74**
Total of Simulated lowest 50% flows:	**2.49**	Total of Observed Lowest 50% flows:		**2.75**
Simulated Summer Flow Volume (months 7-9):	**2.79**	Observed Summer Flow Volume (7-9):		**2.48**
Simulated Fall Flow Volume (months 10-12):	**2.91**	Observed Fall Flow Volume (10-12):		**2.83**
Simulated Winter Flow Volume (months 1-3):	**6.85**	Observed Winter Flow Volume (1-3):		**6.39**
Simulated Spring Flow Volume (months 4-6):	**3.33**	Observed Spring Flow Volume (4-6):		**3.10**
Total Simulated Storm Volume:	**4.22**	Total Observed Storm Volume:		**4.80**
Simulated Summer Storm Volume (7-9):	**0.90**	Observed Summer Storm Volume (7-9):		**1.02**
Errors (Simulated-Observed)	*Error Statistics*	*Recommended Criteria*	*Run (n-1)*	*Run (n-2)*
Error in total volume:	7.28	10	5.50	
Error in 50% lowest flows:	-9.39	10	-1.49	
Error in 10% highest flows:	11.34	15	6.32	
Seasonal volume error - Summer:	12.46	30	10.14	
Seasonal volume error - Fall:	2.56	30	5.17	
Seasonal volume error - Winter:	7.19	30	4.48	
Seasonal volume error - Spring:	7.64	30	4.21	
Error in storm volumes:	-12.03	20	1.25	
Error in summer storm volumes:	-12.28	50	-2.14	
Nash-Sutcliffe Coefficient of Efficiency, E:	0.624	Model accuracy increases	0.707	
Baseline adjusted coefficient (Garrick), E':	0.442	as E or E' approaches 1.0	0.568	

Hydrology Validation

Consistent with HSPF modeling efforts, validation for the Upper Flint calibration focus area was performed at the same location but for calendar years 1983-1992. Results are presented in Figures 51 through 57 and Tables 25 and 26. Although, the Nash-Sutcliffe modeling efficiency is not as good as it was for the calibration period, the model performance was adequate for the validation period. None of the metrics fall out of the range set for the 20 Watershed study.

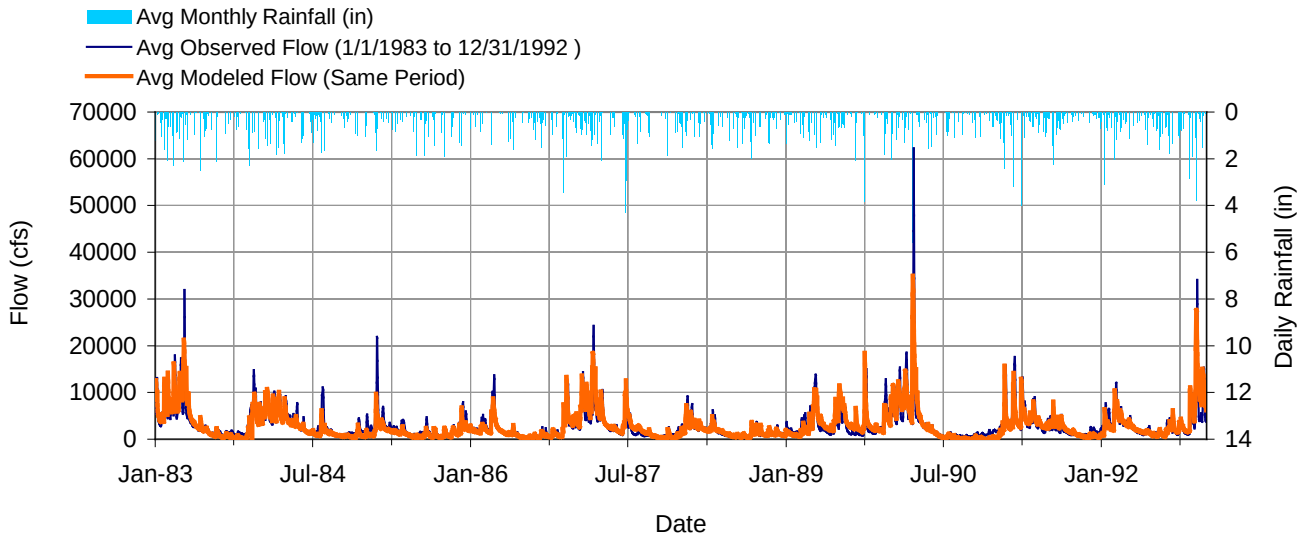

Figure 51. Mean daily flow at USGS 02349605 Flint River at Ga 26, near Montezuma, GA – validation period (SWAT).

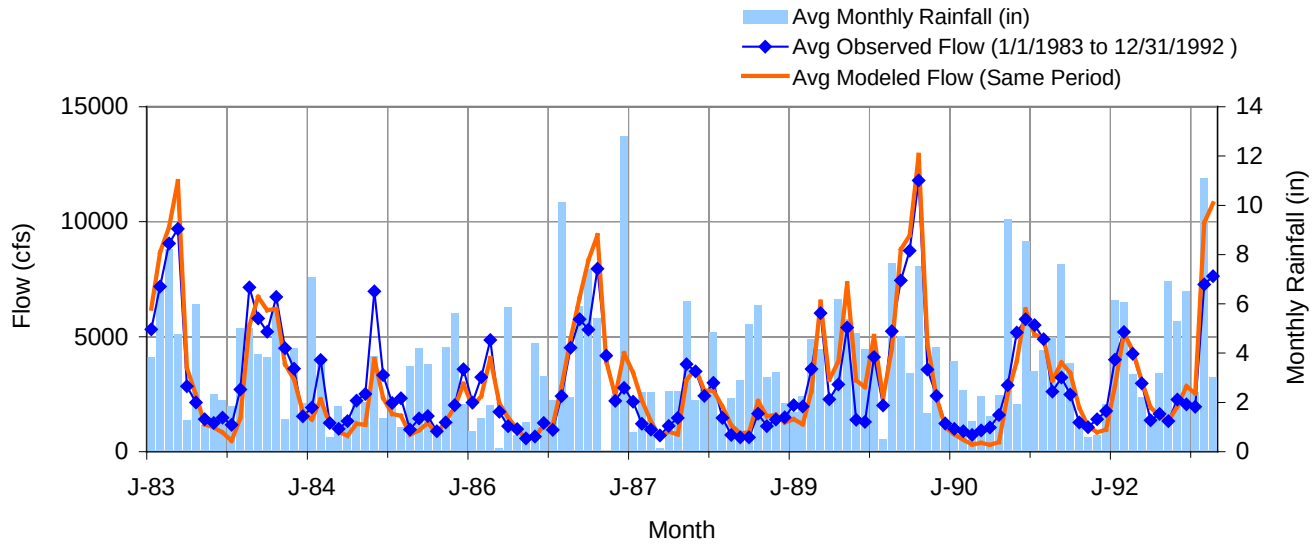

Figure 52. Mean monthly flow at USGS 02349605 Flint River at Ga 26, near Montezuma, GA – validation period (SWAT).

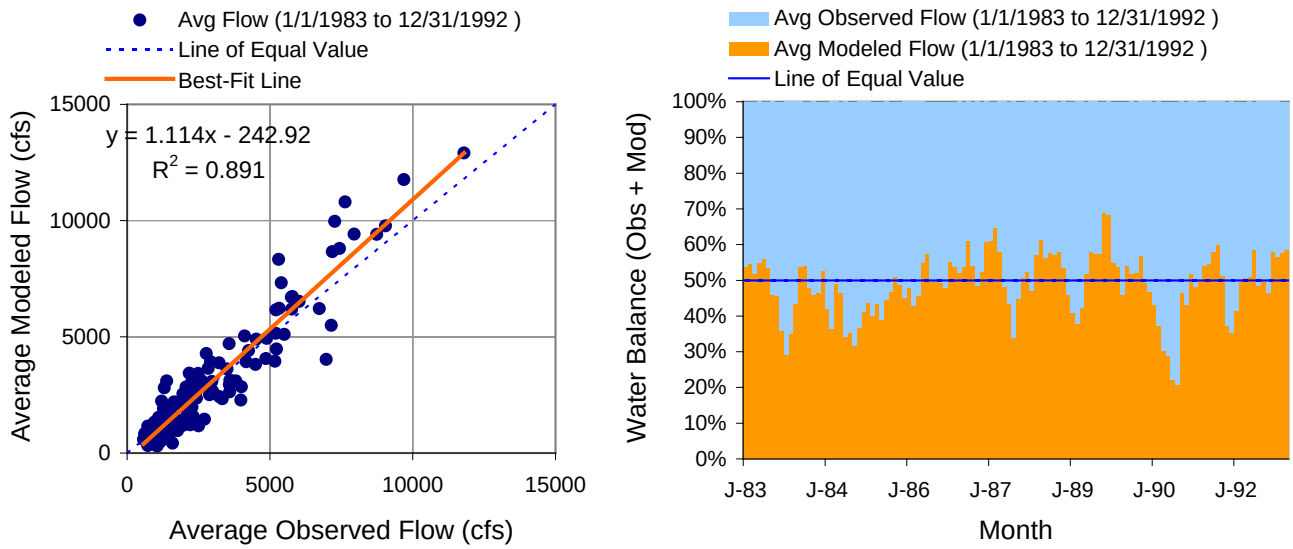

Figure 53. Monthly flow regression and temporal variation at USGS 02349605 Flint River at Ga 26, near Montezuma, GA – validation period (SWAT).

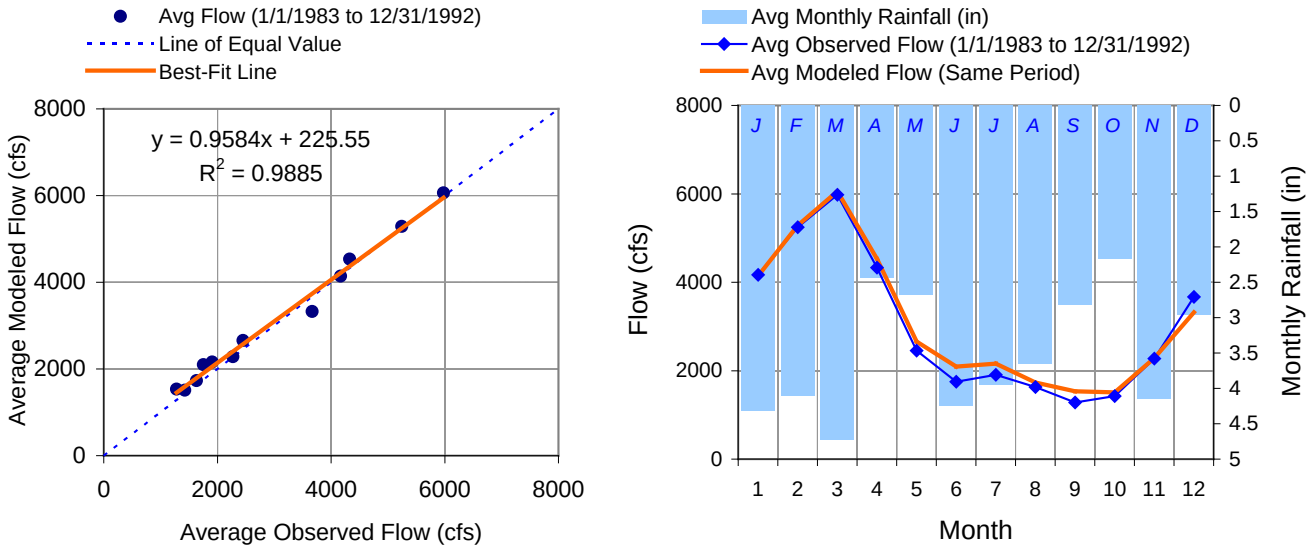

Figure 54. Seasonal regression and temporal aggregate at USGS 02349605 Flint River at Ga 26, near Montezuma, GA – validation period (SWAT).

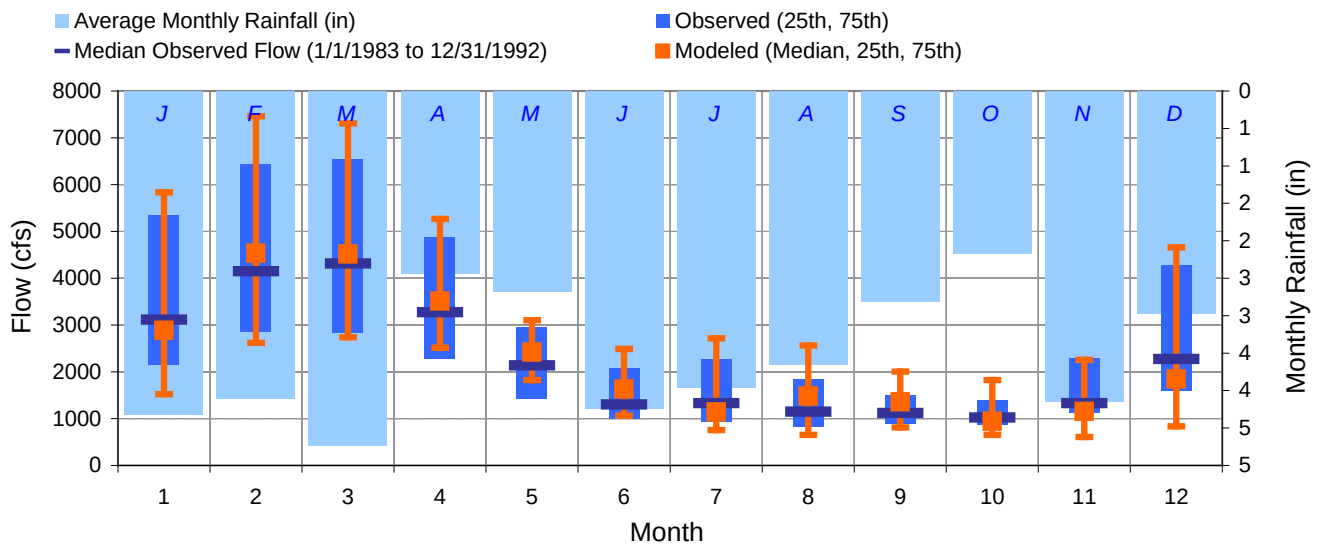

Figure 55. Seasonal medians and ranges at USGS 02349605 Flint River at Ga 26, near Montezuma, GA – validation period (SWAT).

Table 25. Seasonal summary at USGS 02349605 Flint River at Ga 26, near Montezuma, GA – validation period (SWAT)

MONTH	OBSERVED FLOW (CFS)				MODELED FLOW (CFS)			
	MEAN	MEDIAN	25TH	75TH	MEAN	MEDIAN	25TH	75TH
Jan	4168.00	3115.00	2152.50	5350.00	4143.78	2886.66	1525.30	5836.80
Feb	5242.97	4150.00	2850.00	6430.00	5285.84	4532.61	2618.46	7460.70
Mar	5976.65	4310.00	2830.00	6542.50	6060.01	4515.09	2739.77	7304.52
Apr	4328.17	3275.00	2277.50	4880.00	4531.12	3509.51	2517.97	5265.76
May	2451.47	2135.00	1420.00	2937.50	2658.75	2418.76	1824.58	3102.27
Jun	1753.24	1300.00	986.75	2072.50	2095.76	1629.70	1060.96	2490.67
Jul	1908.70	1330.00	927.50	2257.50	2160.97	1141.19	757.51	2715.43
Aug	1632.54	1150.00	816.50	1830.00	1732.26	1482.31	655.52	2563.83
Sep	1283.93	1120.00	881.75	1500.00	1534.60	1359.25	812.62	2005.97
Oct	1425.06	1020.00	869.50	1390.00	1509.13	945.55	654.00	1823.54
Nov	2275.14	1330.00	1120.00	2277.50	2284.09	1154.11	608.47	2252.94
Dec	3667.95	2275.00	1602.50	4277.50	3322.66	1848.91	833.94	4660.44

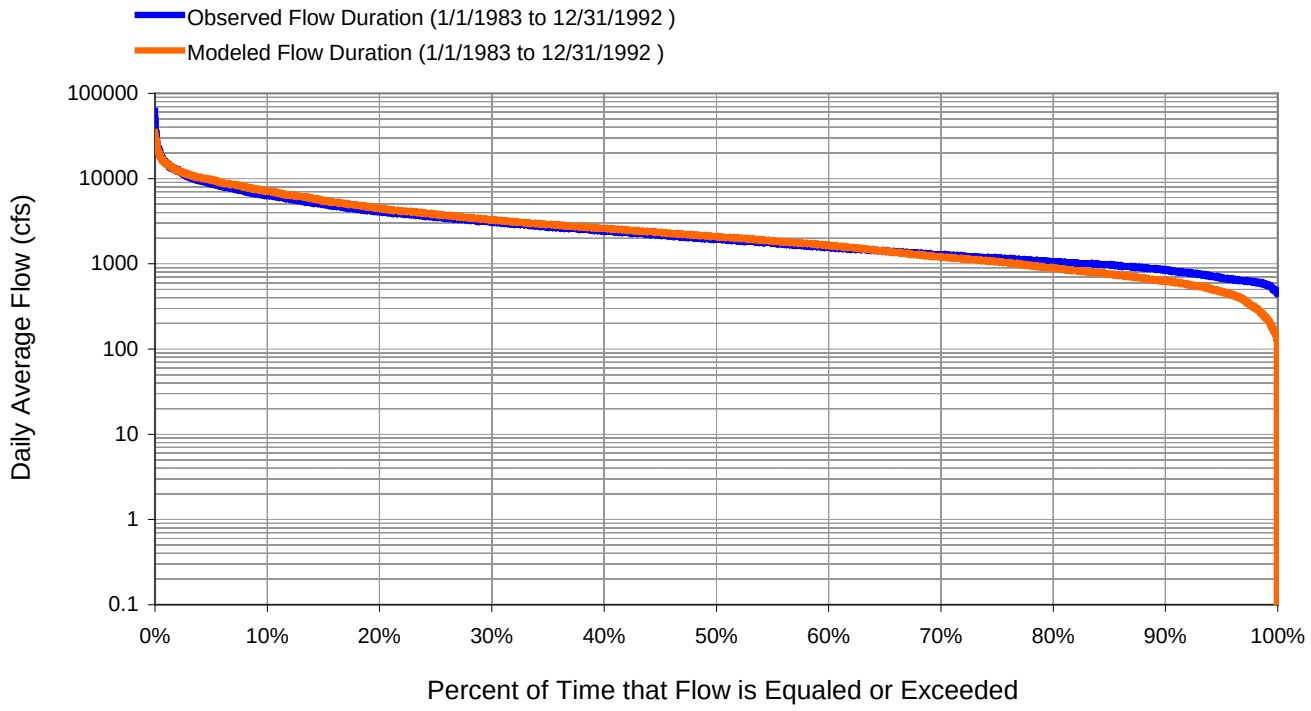

Figure 56. Flow exceedence at USGS 02349605 Flint River at Ga 26, near Montezuma, GA – validation period (SWAT).

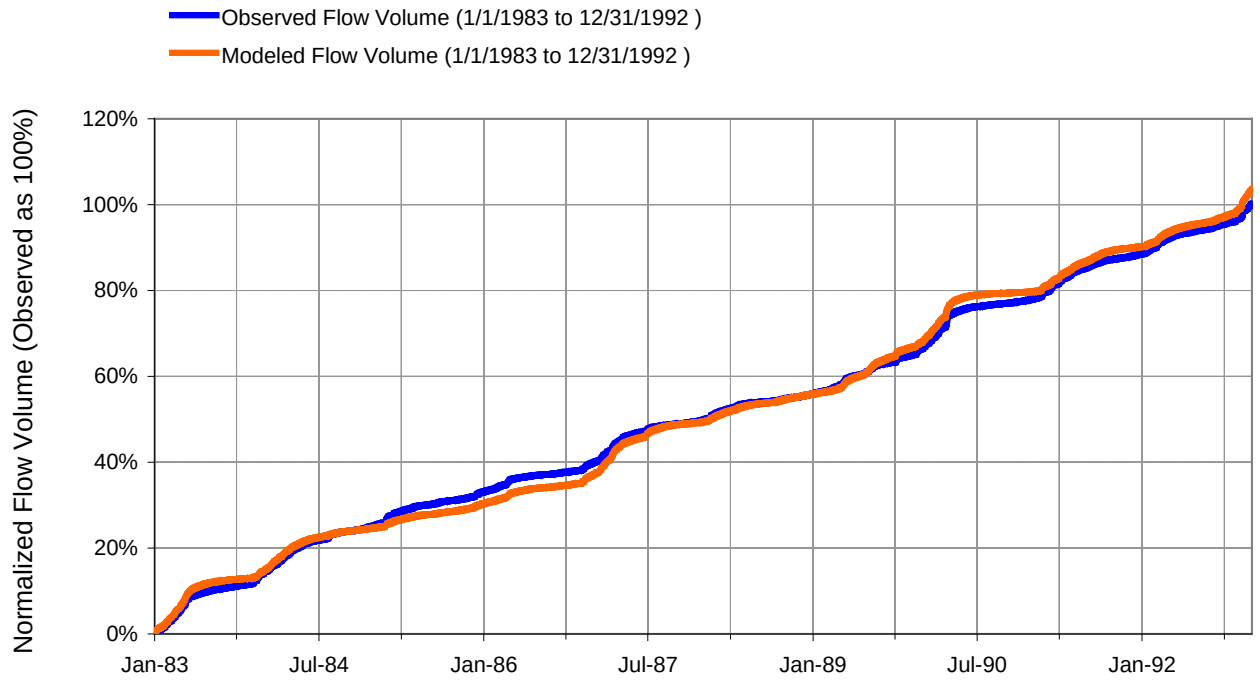

Figure 57. Flow accumulation at USGS 02349605 Flint River at Ga 26, near Montezuma, GA – validation period (SWAT).

Table 26. Summary statistics at USGS 02349605 Flint River at Ga 26, near Montezuma, GA – validation period (SWAT)

SWAT Simulated Flow		Observed Flow Gage	
REACH OUTFLOW FROM OUTLET 37 10-Year Analysis Period: 1/1/1983 - 12/31/1992 Flow volumes are (inches/year) for upstream drainage area		USGS 02349605 FLINT RIVER AT GA 26, NEAR MONTEZUMA, GA Hydrologic Unit Code: 3130006 Latitude: 32.29305556 Longitude: -84.0436111 Drainage Area (sq-mi): 2920	
Total Simulated In-stream Flow:	**14.42**	Total Observed In-stream Flow:	**13.95**
Total of simulated highest 10% flows:	**5.01**	Total of Observed highest 10% flows:	**4.87**
Total of Simulated lowest 50% flows:	**2.57**	Total of Observed Lowest 50% flows:	**2.78**
Simulated Summer Flow Volume (months 7-9):	**2.12**	Observed Summer Flow Volume (7-9):	**1.89**
Simulated Fall Flow Volume (months 10-12):	**2.78**	Observed Fall Flow Volume (10-12):	**2.88**
Simulated Winter Flow Volume (months 1-3):	**5.93**	Observed Winter Flow Volume (1-3):	**5.89**
Simulated Spring Flow Volume (months 4-6):	**3.58**	Observed Spring Flow Volume (4-6):	**3.29**
Total Simulated Storm Volume:	**3.67**	Total Observed Storm Volume:	**4.42**
Simulated Summer Storm Volume (7-9):	**0.46**	Observed Summer Storm Volume (7-9):	**0.51**
Errors (Simulated-Observed)	*Error Statistics*	*Recommended Criteria*	
Error in total volume:	3.33	10	
Error in 50% lowest flows:	-7.57	10	
Error in 10% highest flows:	2.89	15	
Seasonal volume error - Summer:	12.43	30	
Seasonal volume error - Fall:	-3.46	30	
Seasonal volume error - Winter:	0.66	30	
Seasonal volume error - Spring:	8.82	30	
Error in storm volumes:	-16.93	20	
Error in summer storm volumes:	-10.04	50	
Nash-Sutcliffe Coefficient of Efficiency, E:	0.559	Model accuracy increases	
Baseline adjusted coefficient (Garrick), E':	0.444	as E or E' approaches 1.0	

Hydrology Results for Larger Watershed

Calibration and validation results at all gages are summarized in Tables 29 and 30. As discussed above, a detailed spatial calibration was not conducted for the GCRP-SWAT model of the ACF basin. The parameterization is identical across the entire watershed, although, measured flow and water quality data at other stations (other than the calibration focus area) where land use dominance occurred were used to set the corresponding parameters. A better model fit could perhaps be achieved if the model was more tightly calibrated but this was not attempted deliberately keeping in view the intended bigger scope of the project.

In general, the model performance was good, as noticed from the Nash-Sutcliffe modeling efficiency statistics, except for forest and urban dominated subwatersheds. The model over-predicted flow in winter months and under-predicted flow in spring months. Also, the Ichawaynochaway Creek subwatershed (station 02353500) simulation statistics are relatively lower than those at the other stations. The model over-predicted high flows and under-predicted low flows. The simulated peak flows correlated well with the observed high rainfall events; however, watershed response, as noticed from the measured streamflows, didn't result in such high flows.

All the reservoir parameters were set such that inflow equals outflow and this approach worked well for all reservoirs except Lake Lanier. Similar to the HSPF results, after the confluence of Chattahoochee and Flint rivers and downstream of Lake Seminole, the simulation and the model fit greatly improved as shown in Figures 58 through 64 and Tables 27 and 28.

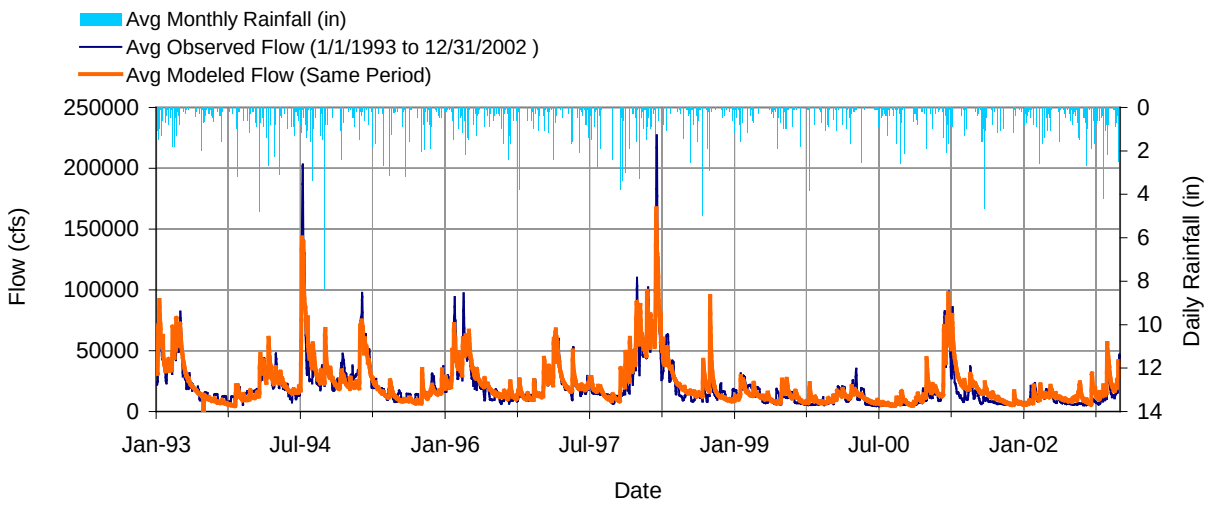

Figure 58. Mean daily flow at USGS 02358000 Apalachicola River at Chattahoochee, FL– calibration period (SWAT)

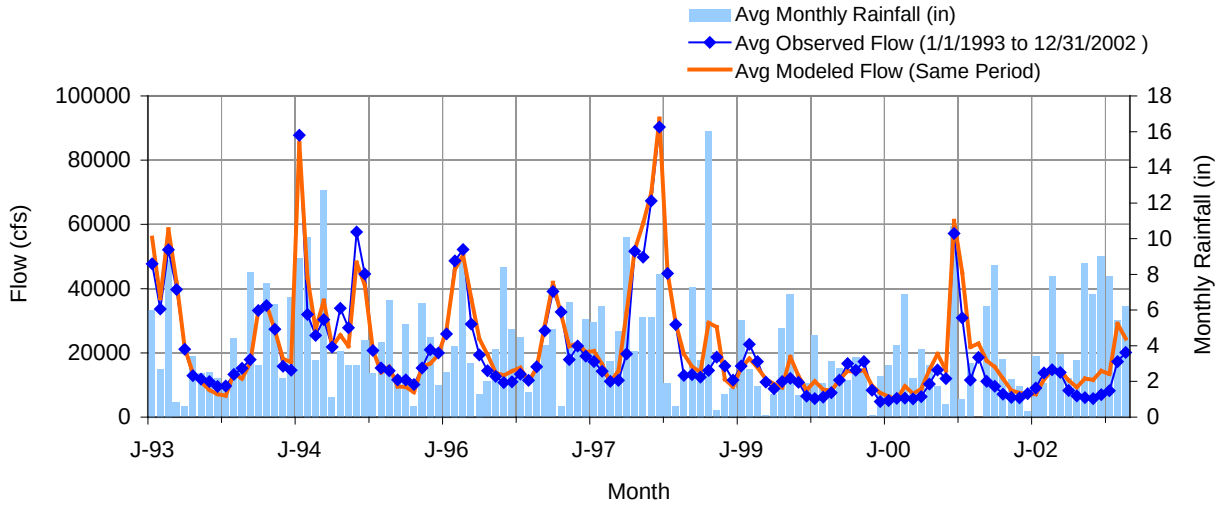

Figure 59. Mean monthly flow at USGS 02358000 Apalachicola River at Chattahoochee, FL– calibration period (SWAT)

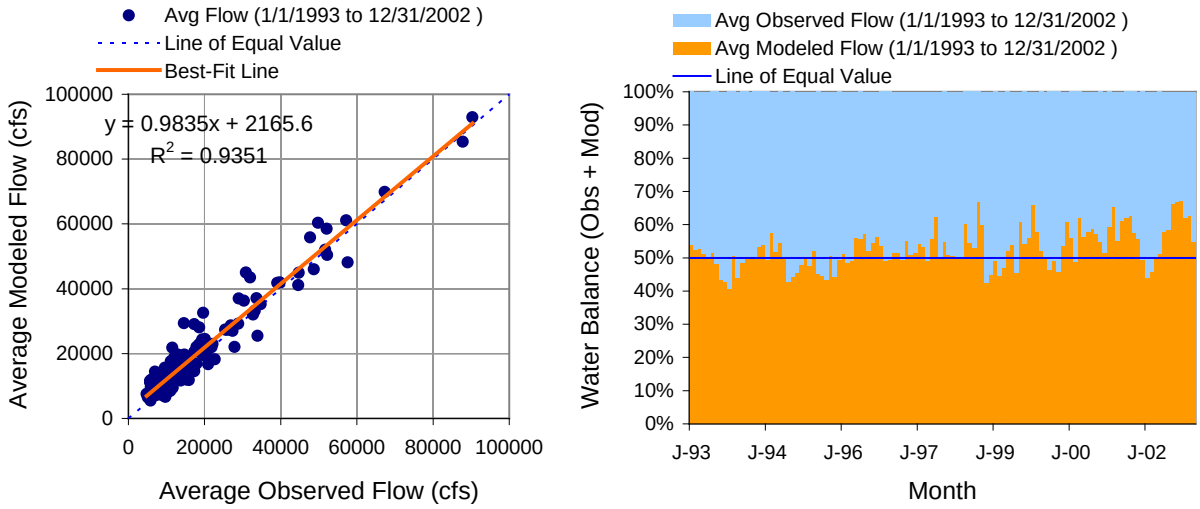

Figure 60. Monthly flow regression and temporal variation at USGS 02358000 Apalachicola River at Chattahoochee, FL– calibration period (SWAT)

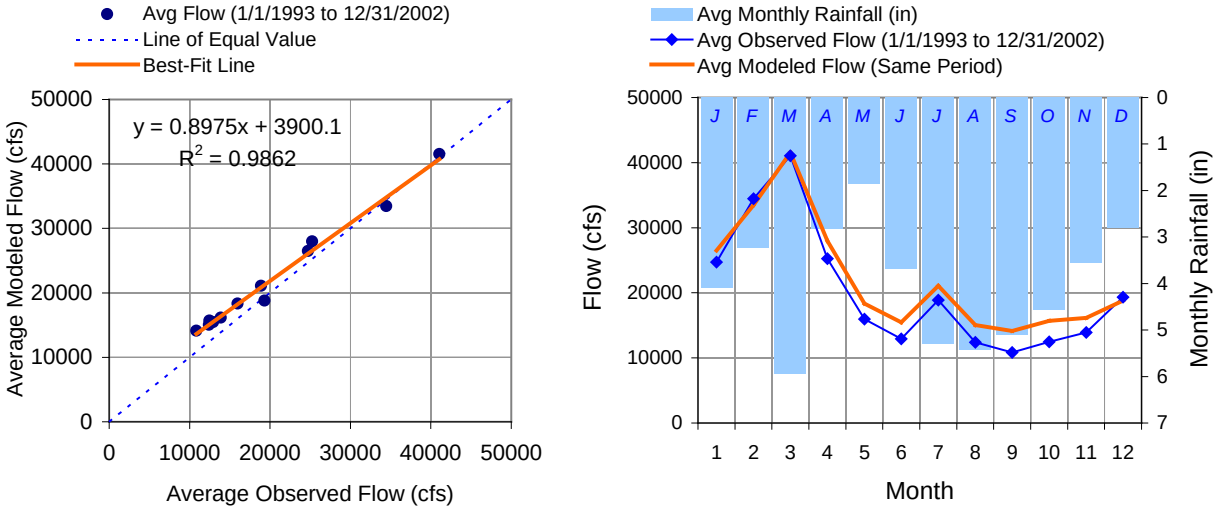

Figure 61. Seasonal regression and temporal aggregate at USGS 02358000 Apalachicola River at Chattahoochee, FL– calibration period (SWAT)

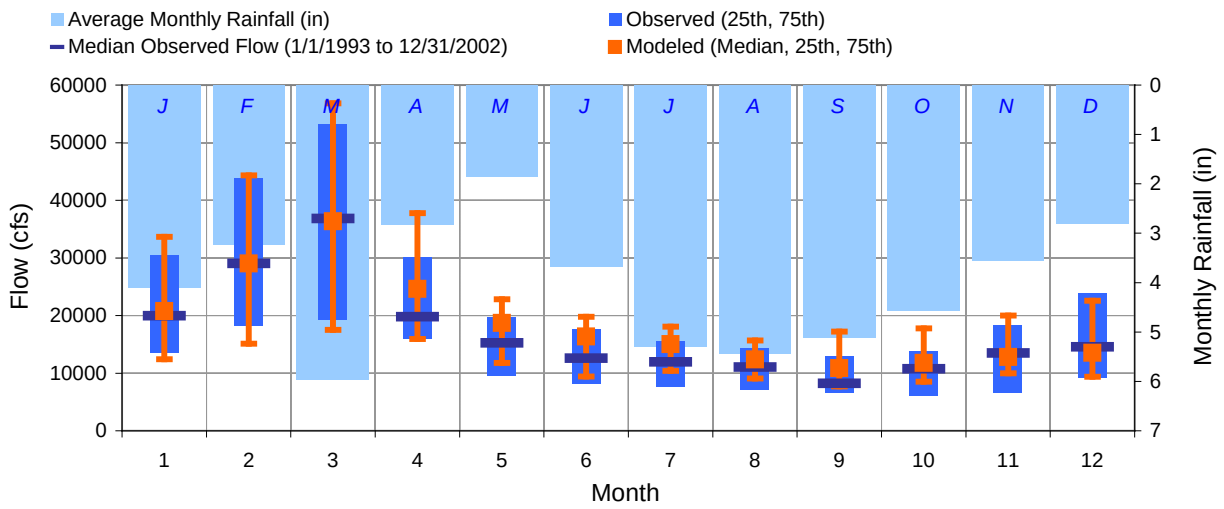

Figure 62. Seasonal medians and ranges at USGS 02358000 Apalachicola River at Chattahoochee, FL– calibration period (SWAT)

Table 27. Seasonal summary at USGS 02358000 Apalachicola River at Chattahoochee, FL– calibration period (SWAT)

MONTH	OBSERVED FLOW (CFS)				MODELED FLOW (CFS)			
	MEAN	MEDIAN	25TH	75TH	MEAN	MEDIAN	25TH	75TH
Jan	24730.16	19950.00	13500.00	30475.00	26487.83	20770.32	12429.88	33656.64
Feb	34453.44	29050.00	18275.00	43900.00	33462.26	29041.02	15105.85	44319.91
Mar	41056.97	36850.00	19300.00	53300.00	41547.96	36338.79	17536.38	56838.96
Apr	25249.20	19800.00	16000.00	30250.00	27986.54	24610.79	15952.52	37760.21
May	15972.58	15250.00	9570.00	19675.00	18337.31	18704.41	11760.67	22816.81
Jun	12939.23	12600.00	8237.50	17600.00	15481.95	16359.52	9413.12	19775.33
Jul	18873.90	11950.00	7665.00	15575.00	21090.83	15028.16	10404.58	18080.23
Aug	12411.87	11050.00	7102.50	14300.00	15037.00	12370.73	9075.87	15658.52
Sep	10850.80	8235.00	6530.00	12900.00	14122.01	10885.75	7701.25	17196.48
Oct	12458.10	10750.00	6112.50	13900.00	15677.74	11788.04	8509.07	17775.64
Nov	13896.10	13500.00	6557.50	18250.00	16163.41	12783.91	9989.64	20016.35
Dec	19332.77	14550.00	9150.00	23800.00	18812.57	13546.71	9380.46	22589.03

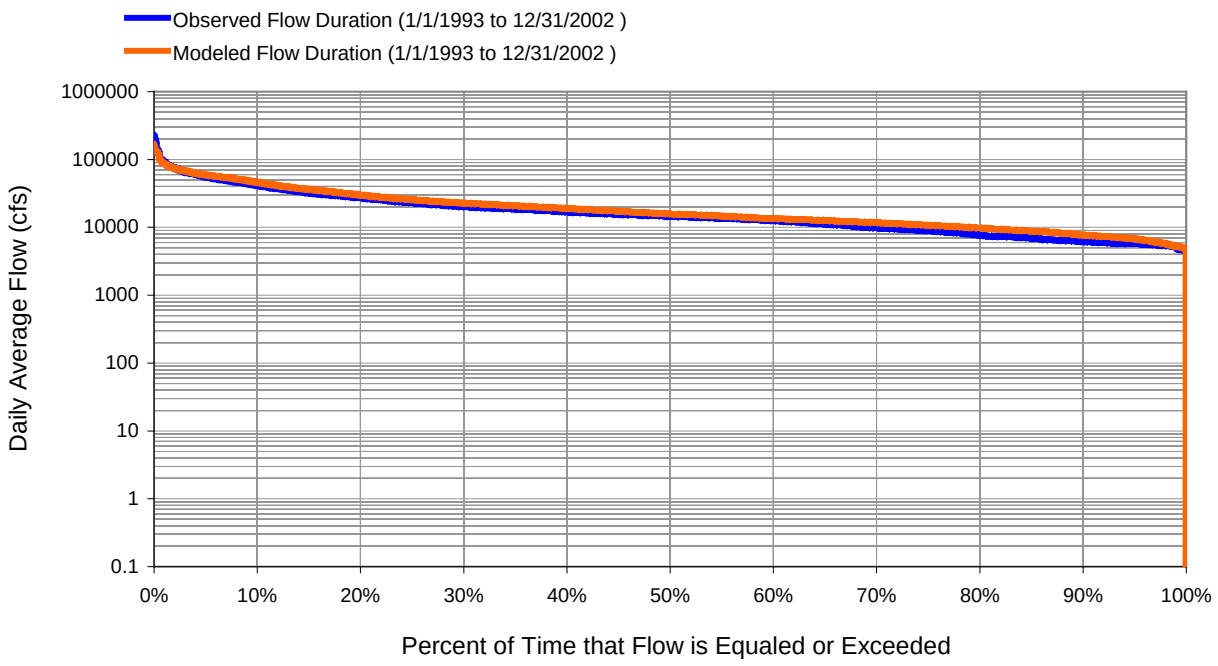

Figure 63. Flow exceedence at USGS 02358000 Apalachicola River at Chattahoochee, FL– calibration period (SWAT)

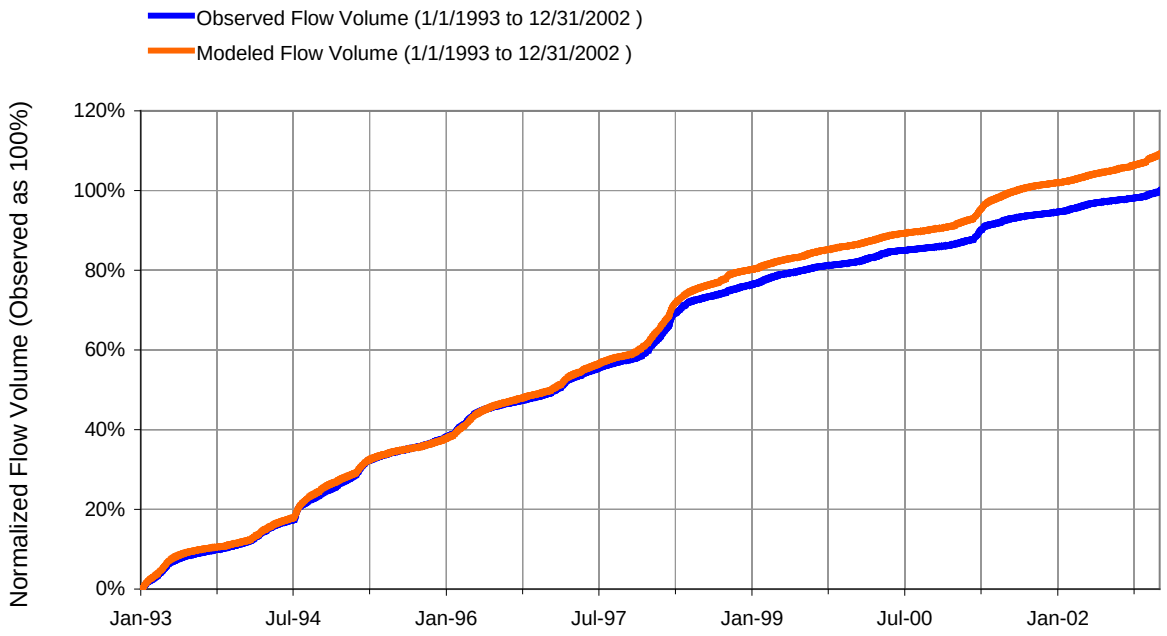

Figure 64. Flow accumulation at USGS 02358000 Apalachicola River at Chattahoochee, FL– calibration period (SWAT)

Table 28. Summary statistics at USGS 02358000 Apalachicola River at Chattahoochee, FL– calibration period (SWAT)

SWAT Simulated Flow		Observed Flow Gage	
REACH OUTFLOW FROM OUTLET 13 10-Year Analysis Period: 1/1/1993 - 12/31/2002 Flow volumes are (inches/year) for upstream drainage area		USGS 02358000 APALACHICOLA RIVER AT CHATTAHOOCHEE FLA Hydrologic Unit Code: 3130011 Latitude: 30.7010251 Longitude: -84.8590871 Drainage Area (sq-mi): 17200	
Total Simulated In-stream Flow:	**17.35**	Total Observed In-stream Flow:	**15.89**
Total of simulated highest 10% flows:	**5.19**	Total of Observed highest 10% flows:	**5.11**
Total of Simulated lowest 50% flows:	**4.21**	Total of Observed Lowest 50% flows:	**3.65**
Simulated Summer Flow Volume (months 7-9):	**3.34**	Observed Summer Flow Volume (7-9):	**2.80**
Simulated Fall Flow Volume (months 10-12):	**3.36**	Observed Fall Flow Volume (10-12):	**3.03**
Simulated Winter Flow Volume (months 1-3):	**6.60**	Observed Winter Flow Volume (1-3):	**6.51**
Simulated Spring Flow Volume (months 4-6):	**4.05**	Observed Spring Flow Volume (4-6):	**3.55**
Total Simulated Storm Volume:	**3.13**	Total Observed Storm Volume:	**3.71**
Simulated Summer Storm Volume (7-9):	**0.62**	Observed Summer Storm Volume (7-9):	**0.64**
Errors (Simulated-Observed)	*Error Statistics*	*Recommended Criteria*	
Error in total volume:	9.16	10	
Error in 50% lowest flows:	**15.49**	**10**	
Error in 10% highest flows:	1.57	15	
Seasonal volume error - Summer:	19.16	30	
Seasonal volume error - Fall:	10.82	30	
Seasonal volume error - Winter:	1.39	30	
Seasonal volume error - Spring:	14.12	30	
Error in storm volumes:	-15.66	20	
Error in summer storm volumes:	-3.56	50	
Nash-Sutcliffe Coefficient of Efficiency, E:	0.793	Model accuracy increases	
Baseline adjusted coefficient (Garrick), E':	0.543	as E or E' approaches 1.0	

Table 29. Summary statistics (percent error) for all stations – calibration period 1993-2002 (SWAT)

Station	02349605	02331600	02336300	02336000	02353500	02339500	02343801	02353000	02358000
Error in total volume:	7.28	1.74	-10.17	17.52	5.89	6.26	16.53	10.45	9.16
Error in 50% lowest flows:	-9.39	-44.46	-22.69	34.07	-20.35	33.88	62.17	-2.48	15.49
Error in 10% highest flows:	11.34	28.59	-27.08	-10.28	37.75	-7.29	-10.00	16.02	1.57
Seasonal volume error - Summer:	12.46	9.11	26.93	-4.30	0.78	-8.34	28.70	17.53	19.16
Seasonal volume error - Fall:	2.56	22.61	-15.44	25.99	-2.69	0.51	19.75	1.02	10.82
Seasonal volume error - Winter:	7.19	16.05	10.95	13.79	25.04	5.34	-2.93	9.50	1.39
Seasonal volume error - Spring:	7.64	-27.05	-24.11	37.03	-21.27	25.48	41.14	15.31	14.12
Error in storm volumes:	-12.03	71.60	-38.66	-69.57	25.40	-75.17	-52.52	-48.51	-15.66
Error in summer storm volumes:	-12.28	107.67	-49.29	-77.02	-10.26	-82.70	-58.88	-42.31	-3.56
Nash-Sutcliffe Coefficient of Efficiency, E:	0.624	0.358	0.334	0.489	0.335	0.542	0.642	0.697	0.793
Baseline adjusted coefficient (Garrick), E':	0.442	0.127	0.312	0.238	0.261	0.306	0.338	0.483	0.543

Table 30. Summary statistics (percent error) for all stations – validation period 1983-1992 (SWAT)

Station	02349605	02331600	02336300	02336000	02353500	02339500	02343801	02353000	02358000
Error in total volume:	3.33	-4.33	-12.32	5.62	1.03	0.92	11.47	6.48	2.17
Error in 50% lowest flows:	-7.57	-49.69	-23.46	18.44	-38.73	36.21	50.10	-7.51	-7.83
Error in 10% highest flows:	2.89	26.93	-29.96	-16.50	35.73	-12.47	-10.38	5.33	-2.31
Seasonal volume error - Summer:	12.43	-13.83	-18.32	-15.29	14.60	-11.16	25.32	21.21	9.39
Seasonal volume error - Fall:	-3.46	9.43	-12.56	-3.92	-15.20	-15.65	1.66	-0.29	-3.96
Seasonal volume error - Winter:	0.66	11.99	-3.15	23.35	9.61	12.01	1.04	3.04	1.04
Seasonal volume error - Spring:	8.82	-27.97	-18.51	18.15	-11.43	15.39	27.43	8.68	3.84
Error in storm volumes:	-16.93	56.71	-40.06	-73.11	26.32	-77.02	-65.86	-52.34	-8.64
Error in summer storm volumes:	-10.04	66.81	-43.98	-81.91	14.15	-83.37	-76.19	-52.71	-6.41
Nash-Sutcliffe Coefficient of Efficiency, E:	0.559	0.347	0.420	0.369	0.222	0.481	0.599	0.685	0.770
Baseline adjusted coefficient (Garrick), E':	0.444	0.102	0.342	0.175	0.271	0.235	0.316	0.493	0.580

Water Quality Calibration and Validation

Initial calibration and validation of water quality was done on the Flint River near Montezuma (USGS02349605), using calendar years 1999-2002 for calibration and calendar years 1991-1998 for validation. As with hydrology, calibration was performed on the later period as this better reflects the land use included in the model. The start of the validation period is constrained by data availability.

Calibration adjustments for sediment focused on the following parameters:

- PRF (Peak rate adjustment factor for sediment routing in the main channel)
- SPCON and SPEXP (Linear and Exponent parameters for estimating maximum amount of sediment that can be reentrained during channel sediment routing)
- RSDCO (Residue decomposition coefficient)
- USLE-P (USLE equation support practice factor

Simulated and estimated sediment loads at the Montezuma station for both periods are shown in Figures 65 through 68 and statistics for the two periods are provided separately in Tables 31 and 32. The key statistic in

Table 31 is the relative percent error, which shows the error in the prediction of monthly load normalized to the estimated load. Table 31 also shows the relative average absolute error, which is the average of the relative magnitude of errors in individual monthly load predictions. This number is inflated by outlier months in which the simulated and estimated loads differ by large amounts (that may be as easily due to uncertainty in the estimated load due to limited data as to problems with the model) and the third statistic, the relative median absolute error, is likely more relevant and shows good agreement.

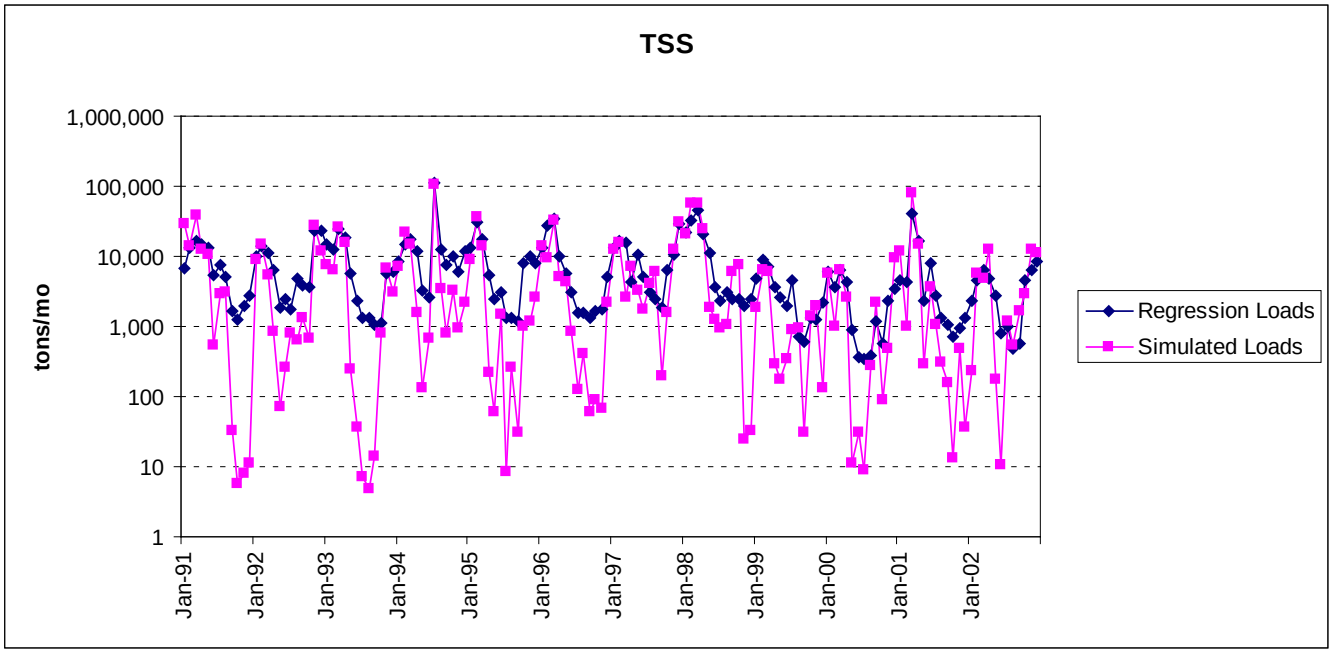

Figure 65. Fit for monthly load of TSS at USGS 02349605 Flint River at Ga 26, near Montezuma, GA – calibration period (SWAT).

Table 31. Model fit statistics (observed minus predicted) for monthly TSS loads using stratified regression at USGS 02349605 Flint River at Ga 26, near Montezuma, GA (SWAT)

Statistic	Calibration period (1999-2002)	Validation period (1991-1998)
Relative Percent Error	-9%	17%
Relative Average Absolute Error	66%	42%
Relative Median Absolute Error	39.1%	25.8%

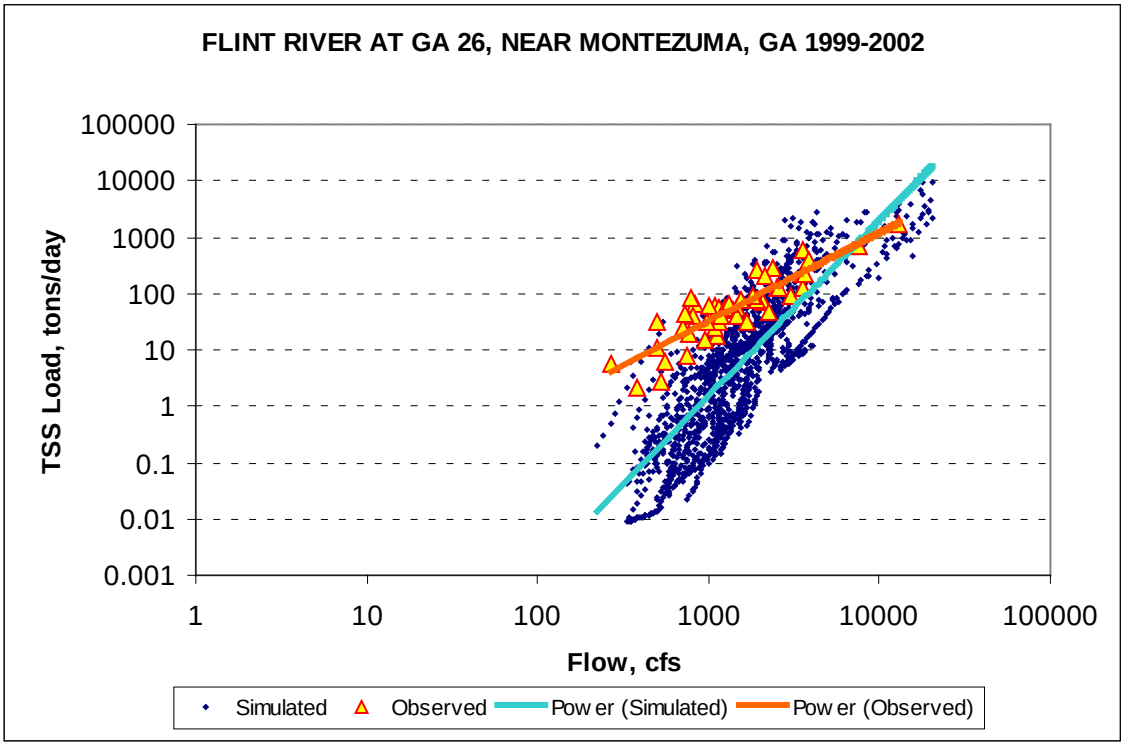

Figure 66. Power plot for observed and simulated TSS at USGS 02349605 Flint River at Ga 26, near Montezuma, GA – calibration period (SWAT).

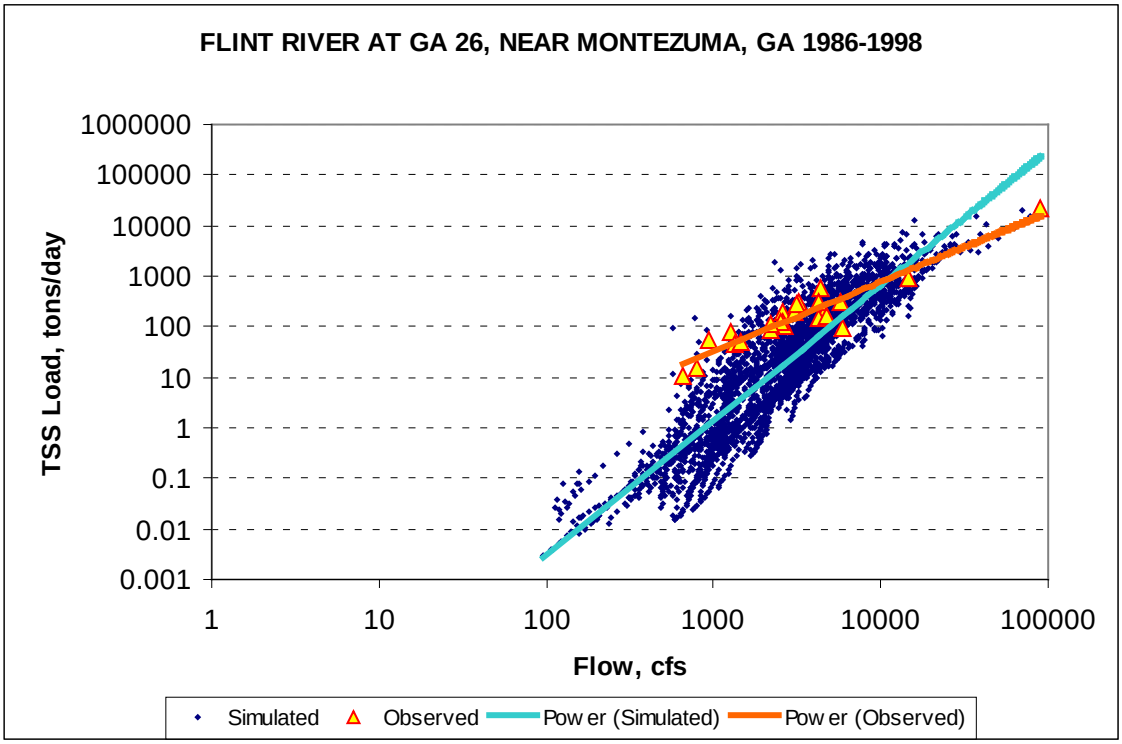

Figure 67. Power plot for observed and simulated TSS at USGS 02349605 Flint River at Ga 26, near Montezuma, GA – validation period (SWAT).

A low baseflow recession factor used in the calibrated model setup allowed streamflow to reach very low values, which in turn simulated numerous days with extremely low sediment values as seen in Figure 68.

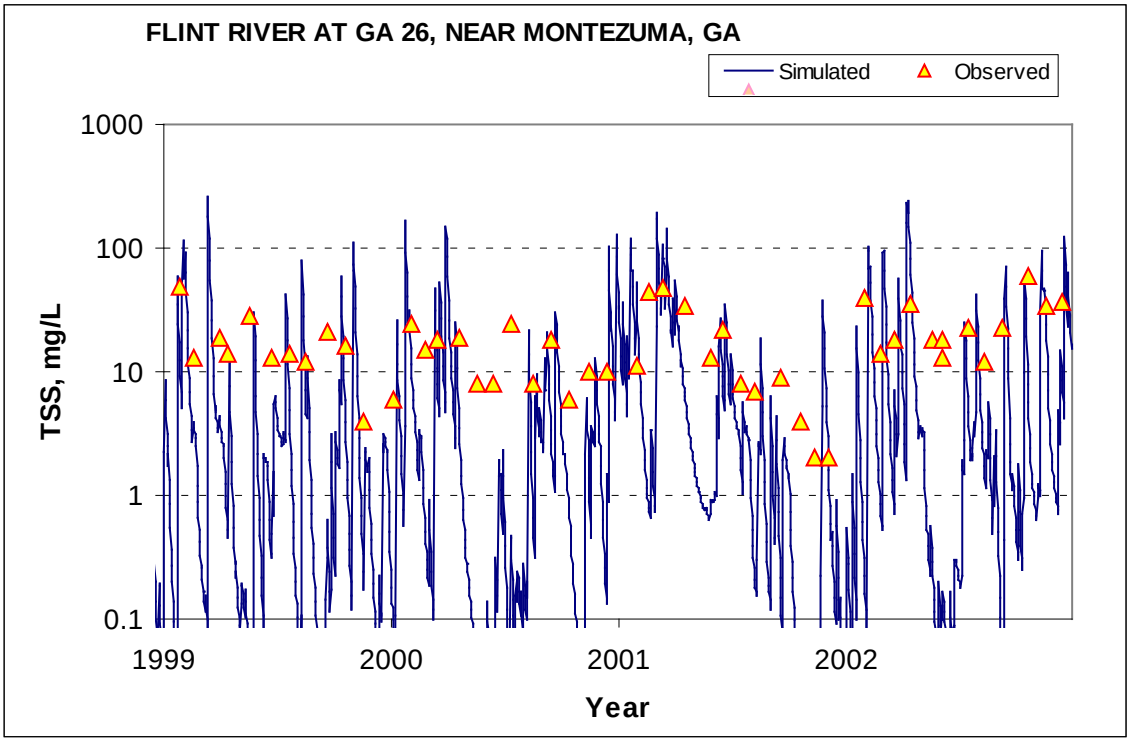

Figure 68. Time series plot of TSS concentration at USGS 02349605 Flint River at Ga 26, near Montezuma, GA (SWAT).

Table 32. Relative errors (observed minus predicted), TSS concentration at USGS 02349605 Flint River at Ga 26, near Montezuma, GA (SWAT)

Statistic	Calibration period (1999-2002)	Validation period (1991-1998)
Count	49	24
Concentration Average Error	63.01%	60.61%
Concentration Median Error	64.14%	52.79%

Calibration adjustments for total phosphorus and total nitrogen focused on the following parameters:

- PPERCO (phosphorus percolation coefficient)
- NPERCO (nitrogen percolation coefficient)
- PHOSKD (phosphorus soil partitioning coefficient)
- HLIFE_NGW (half life of nitrate in the shallow aquifer)
- SOL_CBN1 (organic carbon in the first soil layer)
- QUAL2E parameters such as algal, organic nitrogen, and organic phosphorus settling rate in the reach, benthic source arte for dissolved phosphorus and NH4-N in the reach, fraction of algal biomass that is nitrogen and phosphorus, Michaelis-Menton half-saturation constant for nitrogen and phosphorus

In general, the match between observed and measured total phosphorus and total nitrogen was acceptable. Total phosphorus and total nitrogen calibration results are presented in Figures 69 through 76 and Tables 33 through 36.

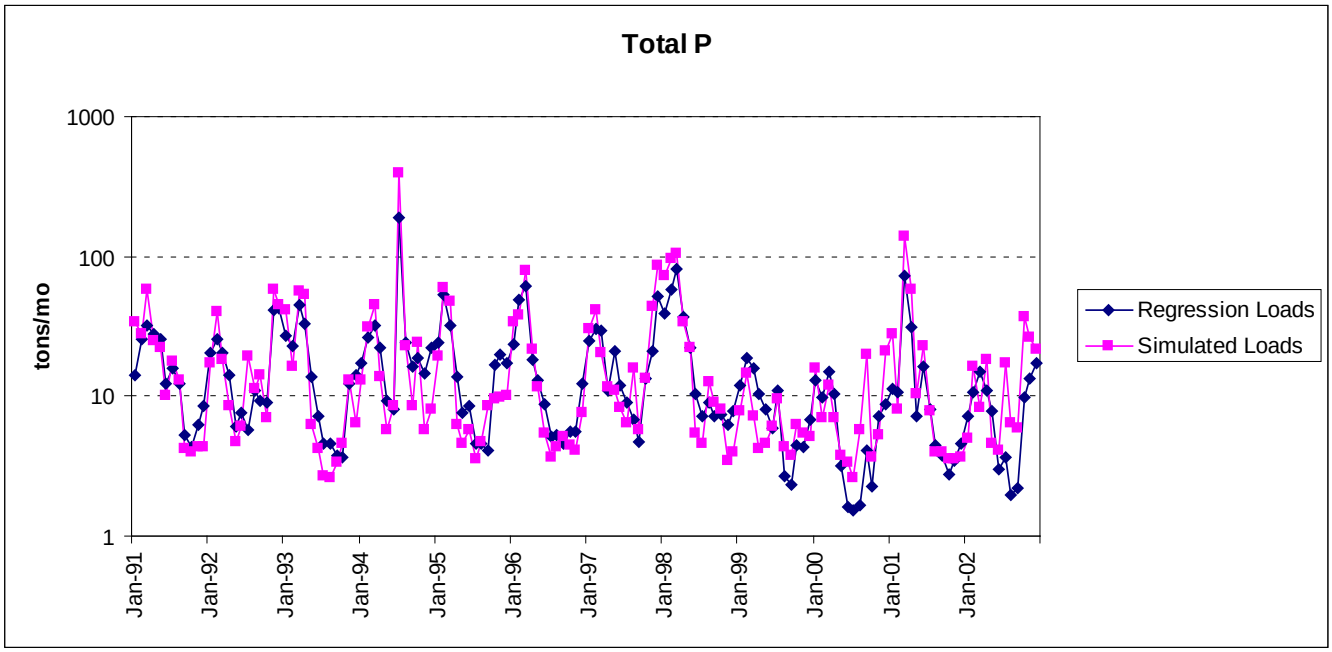

Figure 69. Fit for monthly load of total phosphorus at USGS 02349605 Flint River at Ga 26, near Montezuma, GA (SWAT).

Table 33. Model fit statistics (observed minus predicted) for monthly total phosphorus loads using stratified regression at USGS 02349605 Flint River at Ga 26, near Montezuma, GA (SWAT)

Statistic	Calibration period (1999-2002)	Validation period (1991-1998)
Relative Percent Error	-50%	-30%
Average Absolute Error	72%	49%
Median Absolute Error	31.8%	18.9%

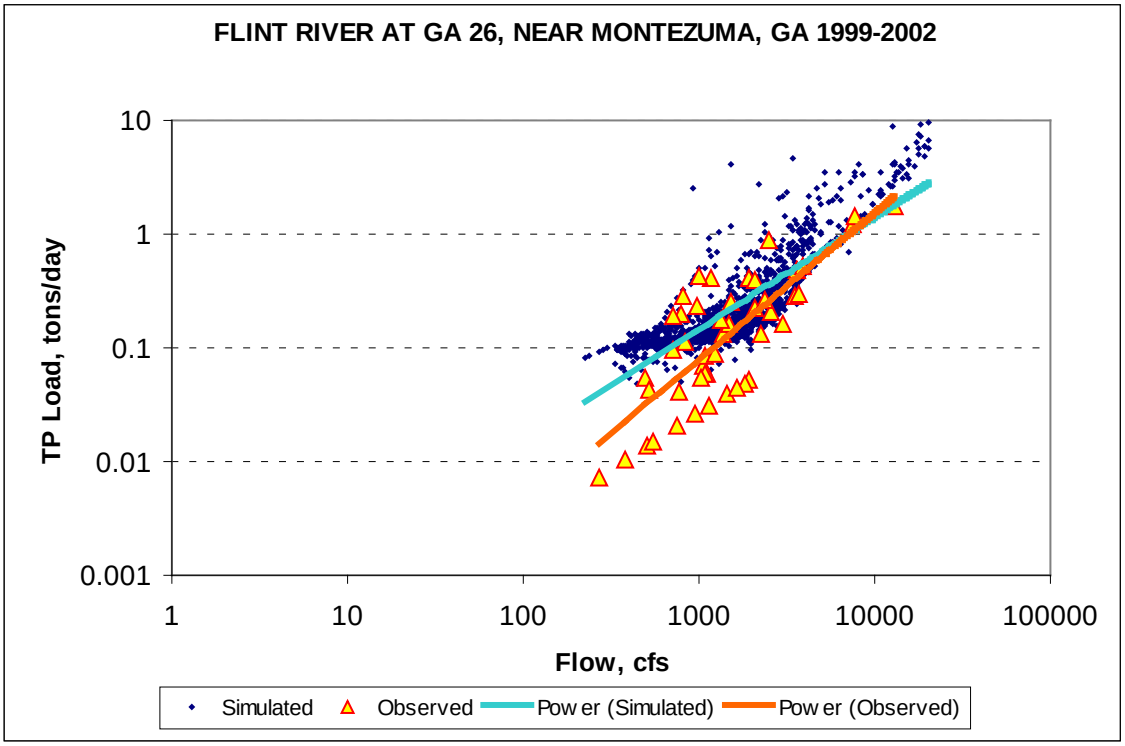

Figure 70. Power plot for observed and simulated total phosphorus at USGS 02349605 Flint River at Ga 26, near Montezuma, GA – calibration period (SWAT).

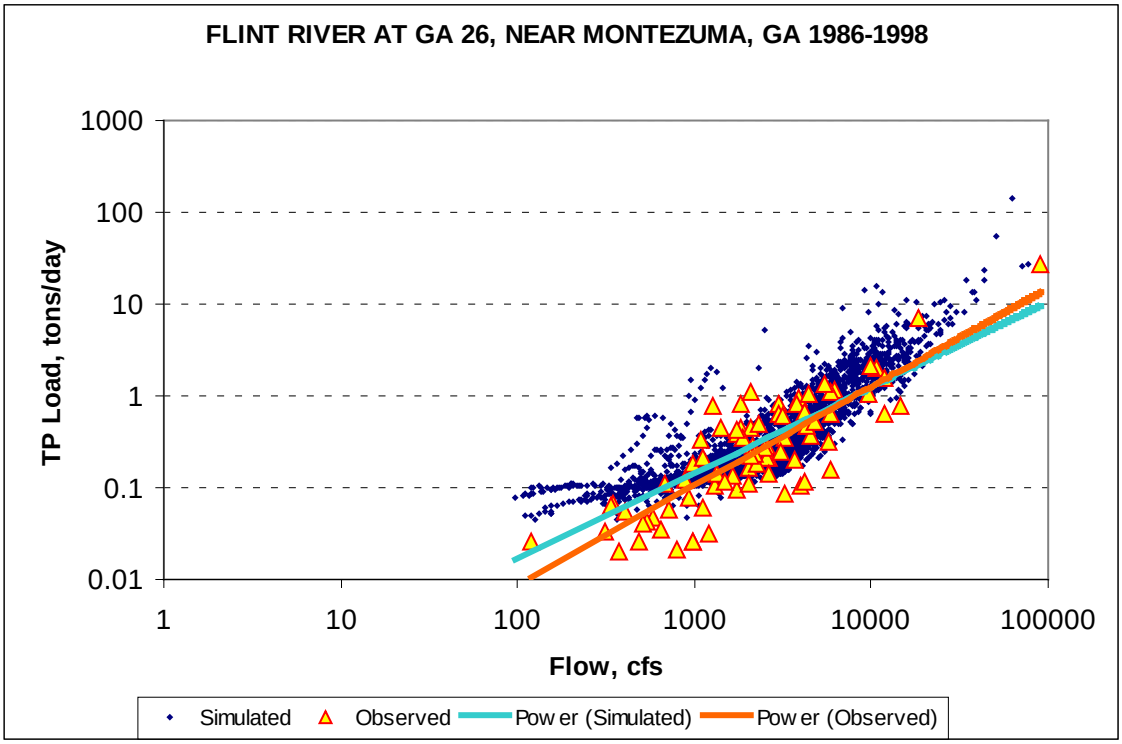

Figure 71. Power plot for observed and simulated total phosphorus at USGS 02349605 Flint River at Ga 26, near Montezuma, GA – validation period (SWAT).

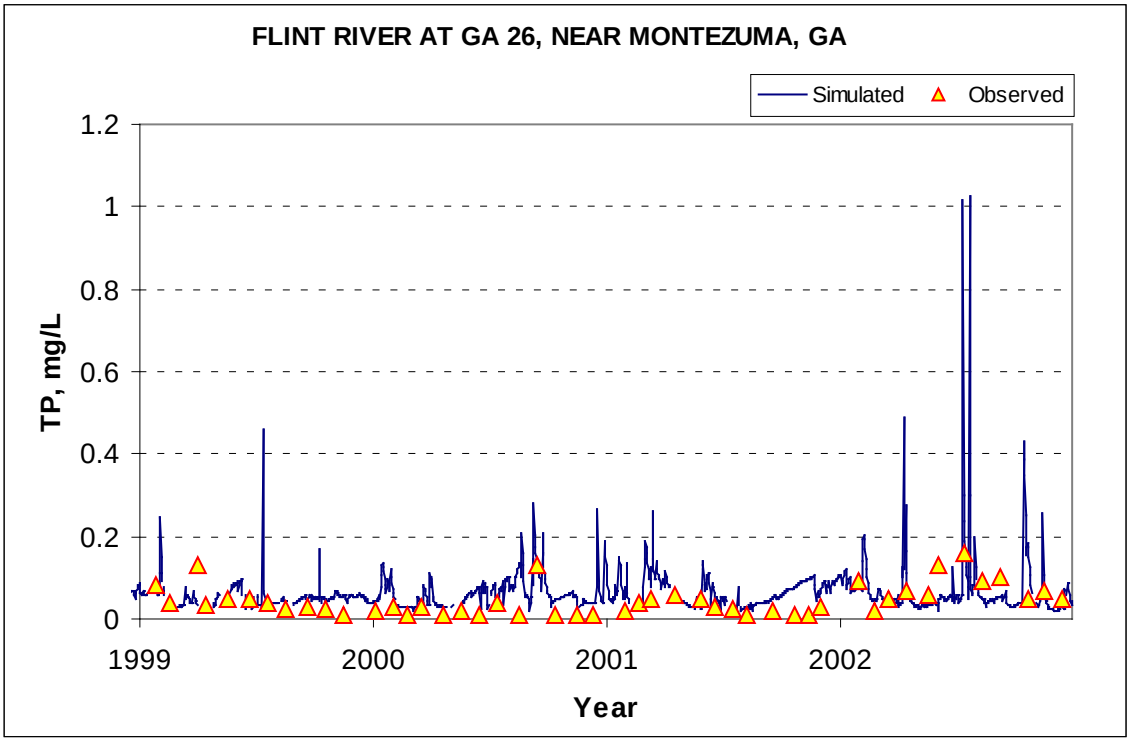

Figure 72. Time series plot of total phosphorus concentration at USGS 02349605 Flint River at Ga 26, near Montezuma, GA (SWAT).

Table 34. Relative errors (observed minus predicted), total phosphorus concentration, USGS 02349605 Flint River at Ga 26, near Montezuma, GA (SWAT)

Statistic	Calibration period (1999-2002)	Validation period (1991-1998)
Count	48	80
Concentration Average Error	-32.67%	-8.3%
Concentration Median Error	-41.28%	-11.99%

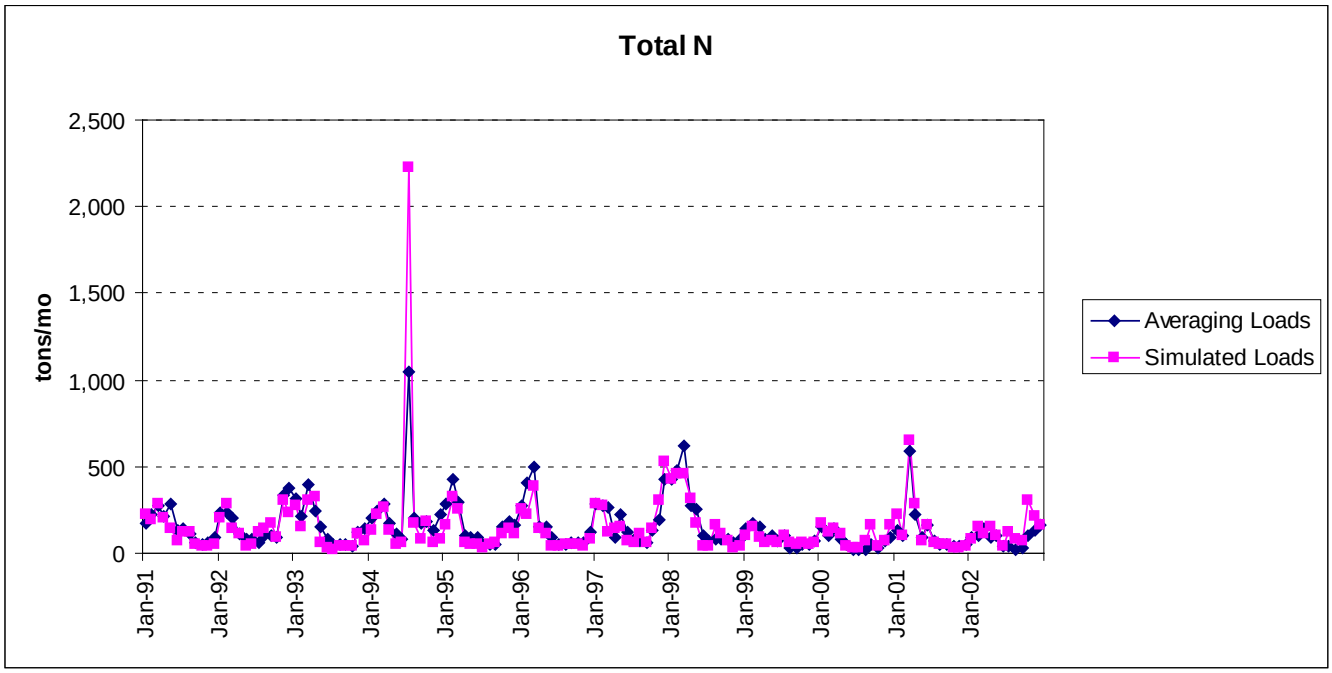

Figure 73. Fit for monthly load of total nitrogen at USGS 02349605 Flint River at Ga 26, near Montezuma, GA (SWAT).

Table 35. Model fit statistics (observed minus predicted) for monthly total nitrogen loads using averaging estimator at USGS 02349605 Flint River at Ga 26, near Montezuma, GA (SWAT)

Statistic	Calibration period (1999-2002)	Validation period (1991-1998)
Relative Percent Error	-18%	9%
Average Absolute Error	31%	30%
Median Absolute Error	15.7%	19.9%

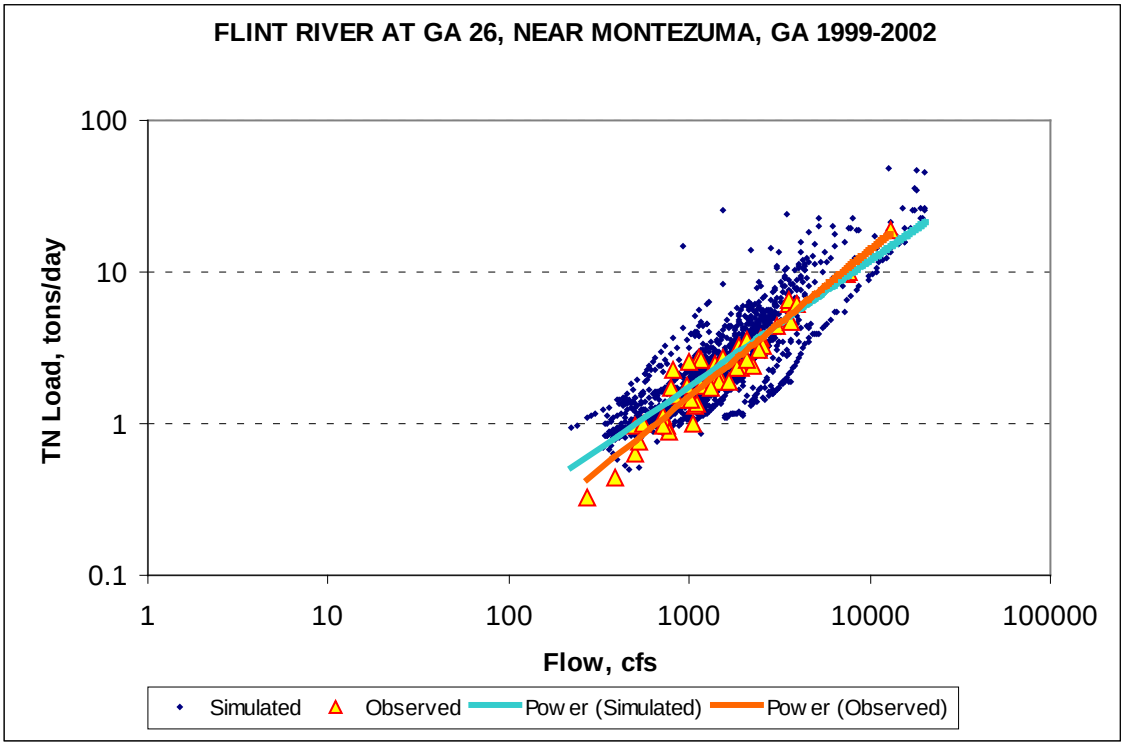

Figure 74. Power plot for observed and simulated total nitrogen at USGS 02349605 Flint River at Ga 26, near Montezuma, GA – calibration period (SWAT).

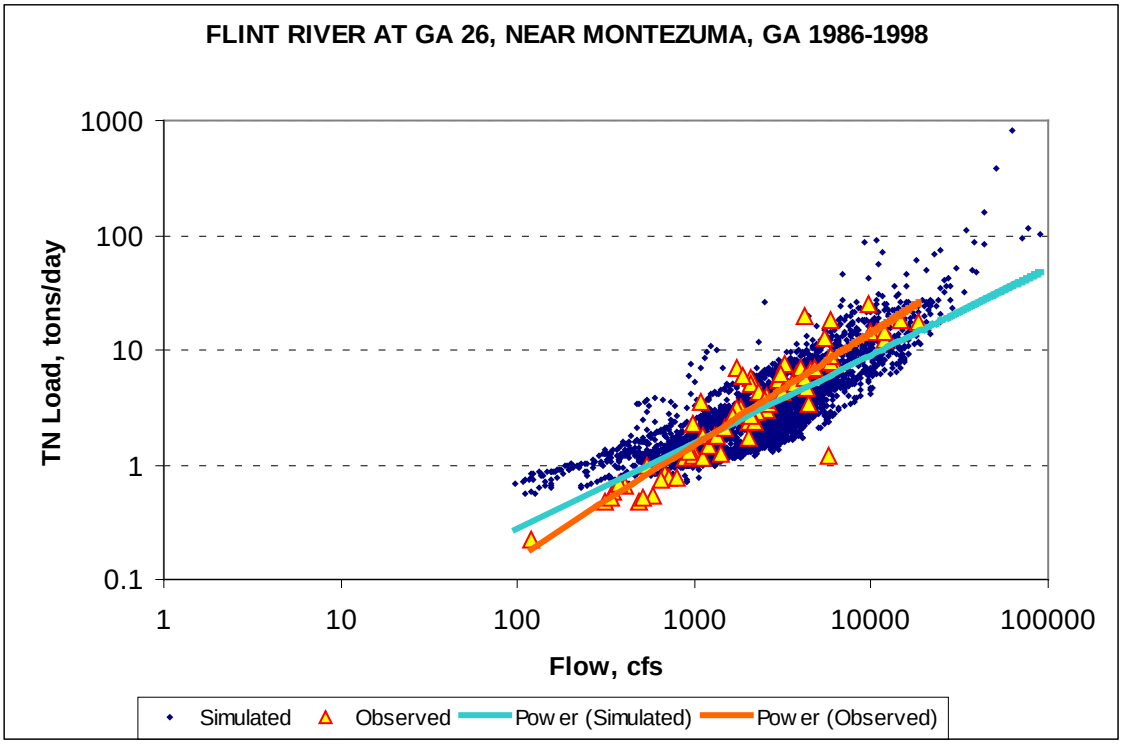

Figure 75. Power plot for observed and simulated total nitrogen at USGS 02349605 Flint River at Ga 26, near Montezuma, GA – validation period (SWAT).

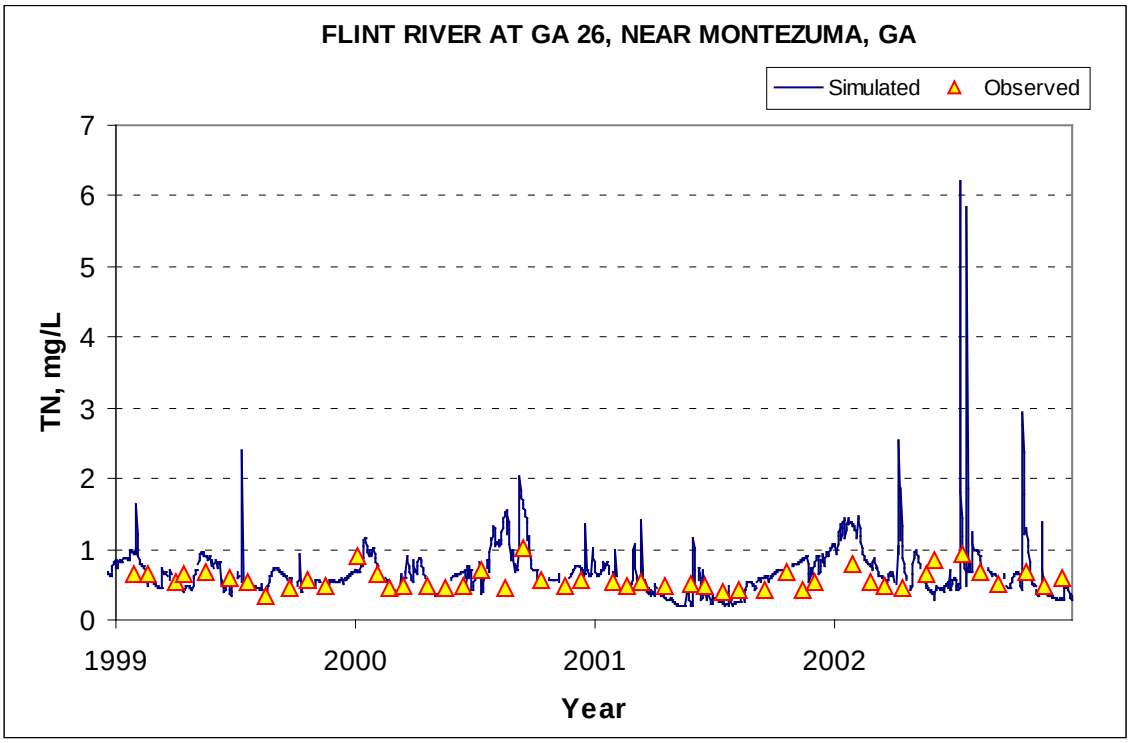

Figure 76. Time series plot of total nitrogen concentration at USGS 02349605 Flint River at Ga 26, near Montezuma, GA (SWAT).

Table 36. Relative errors (observed minus predicted), total nitrogen concentration, USGS 02349605 Flint River at Ga 26, near Montezuma, GA (SWAT)

Statistic	Calibration period (1999-2002)	Validation period (1991-1998)
Count	48	76
Concentration Average Error	-14.52%	2.26%
Concentration Median Error	-10.44%	8.07%

Water Quality Results for Larger Watershed

As with hydrology, the Flint River watershed parameters for water quality were directly transferred to other portions of the watershed. In general, simulated sediment was low and simulated total phosphorus and total nitrogen was high at most of the stations. Ortho phosphorus and mineral nitrogen made up most of the total phosphorus and total nitrogen as organic components corresponded to the sediment fraction. Summary statistics for the water quality calibration and validation at other stations in the watershed are provided in Tables 37 and 38, respectively.

Table 37. Summary statistics (observed minus predicted) for water quality for all stations – calibration period 1999-2002 (SWAT)

Station	02349605	02331600	02336300	02336000	02353500	02339500	02343801	02353000
Relative Percent Error TSS Load	-9	37	91	-3	33	71	83	66
TSS Concentration Median Percent Error	64.1	-26.0	-20.4	3.2	41.9	16.9	32.6	33.7
Relative Percent Error TP Load	-50	25	40	-29	-305	-317	-85	-45
TP Concentration Median Percent Error	-41.3	0.0	-21.6	-56.4	-124.5	-1136.7	-814.9	-24.8
Relative Percent Error TN Load	-18	13	-59	-117	0	-606	-310	26
TN Concentration Median Percent Error	-10.4	54.3	15.8	-46.1	63.9	-461.8	-335.7	25.8

Table 38. Summary statistics (observed minus predicted) for water quality for all stations – validation period 1986-1998 (SWAT)

Station	02349605	02331600	02336300	02336000	02353500	02339500	02343801	02353000
Relative Percent Error TSS Load	17	91	93	33	42	87	95	65
TSS Concentration Median Percent Error	53.8	0.9	1.7	14.4	89.9	54.9	31.1	33.8
Relative Percent Error TP Load	-30	62	18	14	-177	-59	72	-10
TP Concentration Median Percent Error	-12.0	46.6	11.2	2.8	-15.1	-134.0	-291.1	-12.1
Relative Percent Error TN Load	9	44	-75	-52	14	-280	-144	37
TN Concentration Median Percent Error	8.1	59.7	37.4	-50.3	70.6	-467.1	-229.4	20.2

References

Alabama River Alliance. 2007. Water Wars Background: http://www.alabamarivers.org/current_work/water-wars (Accessed January 2, 2010)

Cherry, R.N. 1961. Chemical Quality of Water of Georgia Stream. 1957-58, U.S. Geological Survey Bulletin No. 69.

Couch, C.A. 1993. Environmanetal Seetting of the Apalachicola-Chattahoochee_Flint River Basin. *Proceedings of the 1993 Georgia Water Resources Conference.* April 20-21, 1993 at the University of Georgia.

Hook, J.E., 2009. Agricultural Irrigation Water Demand (1 June 2009): http://www.nespal.org/SIRP/waterinfo/State/common/AgWaterDemand.htm

Preston, S.D., V.J. Bierman, Jr., and S.E. Silliman. 1989. An evaluation of methods for the estimation of tributary mass loads. *Water Resources Research.* 25(6): 1379-1389.

USACE (Unites States Army Corps of Engineers). 2010. Apahalachicola-Chattahoochee-Flint River (1/23/2009): http://water.sam.usace.army.mil/acfframe.htm (Accessed August 10, 2010).

U. S. Army Corps of Engineers (USACE). 1982. National inventory of dams data base in card format, available from National Technical Information Service, Springfield, VA 22162, #ADA 118670

USEPA (United States Environmental Protection Agency). 2008. Using the BASINS Meteorological Database (Version 2006). BASINS Technical Note 10. Office of Water, U.S. Environmental Protection Agency. Washington, DC.

USEPA (United States Environmental Protection Agency). 2007. Creating Hydraulic Function Tables (FTABLES) for Reservoirs in BASINS. BASINS Technical Note 1. Office of Water, U.S. Environmental Protection Agency. Washington, DC.

USEPA (United States Environmental Protection Agency). 2006. Sediment Parameter and Calibration Guidance for HSPF. BASINS Technical Note 8. Office of Water, U.S. Environmental Protection Agency. Washington, DC.

USEPA (United States Environmental Protection Agency). 2000. Estimating Hydrology and Hydraulic Parameters for HSPF. BASINS Technical Note 6. EPA-823-R00-012. Office of Water, U.S. Environmental Protection Agency. Washington, DC.

USGS (United States Geological Survey). 2008. Description of the ACF River Basin Study Area (July 17, 2008): http://ga.water.usgs.gov/nawqa/basinall.html, Jan. 2, 2010