

CHAPTER 3: WATERSHED HYDROLOGY
APPENDIX 3.L: 07-OCKLAWAHA RIVER BASIN CALIBRATION

7BCD LAKE APOPKA WATERSHED

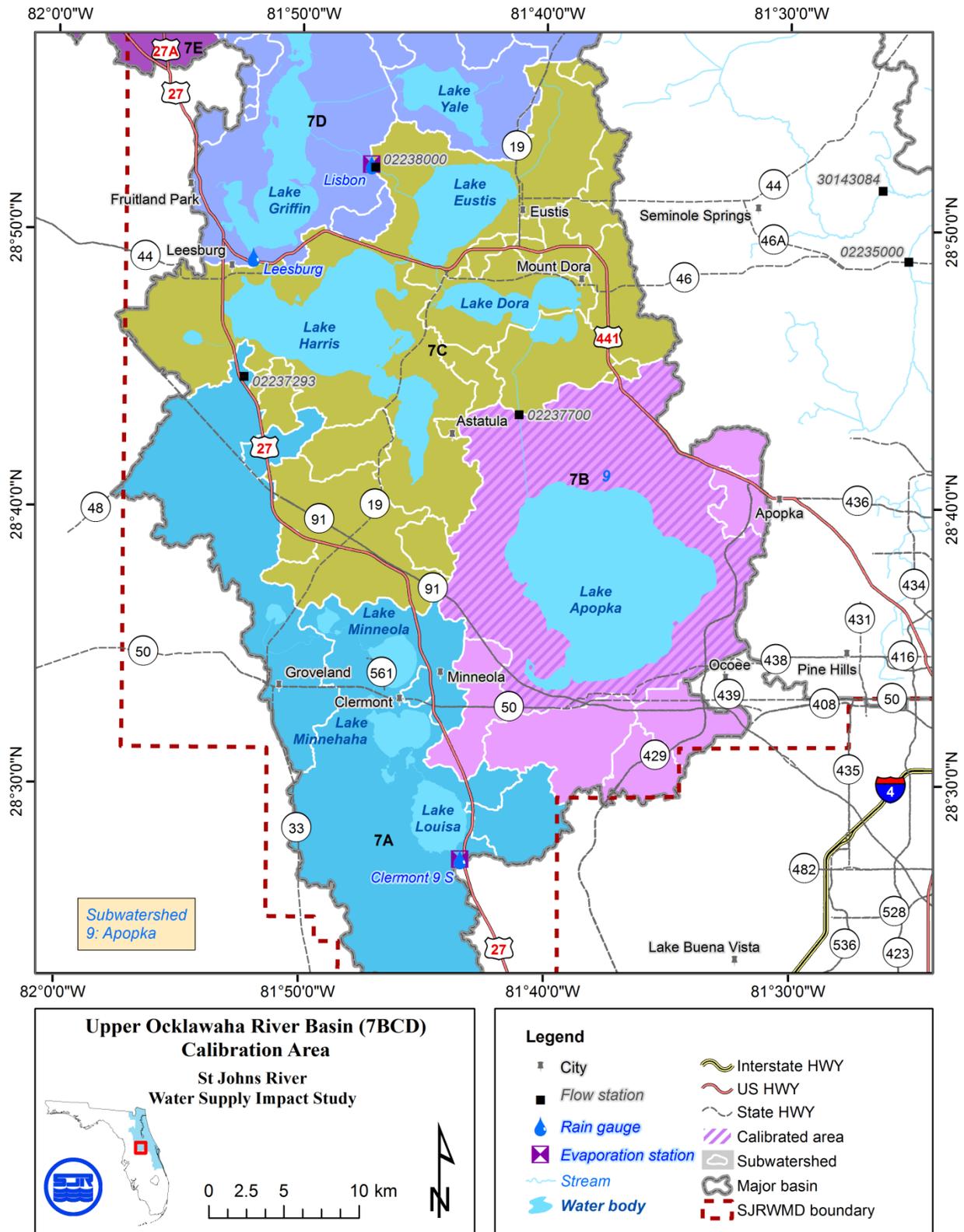


Figure 3.L.1: 7BCD Lake Apopka Watershed calibration areas

7BCD LAKE APOPKA WATERSHED. APOPKA SUBWATERSHEDS

Lake Apopka, the fourth largest lake in Florida, is a headwater lake for the Ocklawaha (Harris) Chain of Lakes. The area of the Lake Apopka drainage basin, including the surface of the lake, is approximately 120,000 acres. The water surface of Lake Apopka is approximately 30,800 acres at a lake surface elevation of 66.5 feet (NGVD). Average depth at this surface elevation is 5.4 feet. The only surface water outflow from Lake Apopka is the Apopka-Beauclair Canal, which flows north into Lake Beauclair. This canal is not a free-flowing channel, and since 1956 its flow is regulated by manipulation of gates in spillway at the Apopka Lock and Dam. Hence, the calibration was based on the lake stage instead of the flow rate. PEST computer program was used to calibrate the parameter sets in the UORB HSPF model against the observed lake elevation recorded at the USGS gage station 02237700 located at left bank 80 ft upstream from the lake Apopka lock and dam, 500 ft upstream from bridge on County Road 48, and 3.0 mi east of Astatula.

It is well known that Lake Apopka recharges the Upper Floridian Aquifer. In our UORB HSPF model, the rate of groundwater recharge from the lake was estimated as a function of the head difference between the lake surface elevation and the groundwater aquifer piezometric surface as in the Darcy's Equation:

$$Q = K \frac{\Delta H}{\Delta L} A \quad (1)$$

Where Q is the rate of groundwater recharge, ft^3/s ; K is hydraulic conductivity, ft/s ; A is the cross-sectional area of the porous medium through which water seeps from the lake to the groundwater aquifer, ft^2 ; ΔL is the distance between the lake bottom and the groundwater aquifer, ft ; and ΔH is the hydraulic gradient represented by the difference between the piezometric surface of the groundwater and the lake elevation. Since parameters A and ΔL should remain constant and it is difficult to quantify them individually, we lumped K , A , and ΔL into K' , where

$$K' = K \frac{A}{\Delta L}$$

Hence, the Equation (1) is simplified as:

$$Q = K' \Delta H \quad (2)$$

PEST was also used to estimate K' in the Equation (2). From the observed Lake Apopka stage and the well stage located at Plymouth Tower from 1/1/1995 to 12/31/2006, we calculated that the average head difference (ΔH) between the lake and well stage was 12.4 feet. Based on the field measurements by Jay Polinkas (SJRWMD staff) et al, the average recharge rate of the entire lake is 15.4 cfs with a STD of 18.4 cfs (see Model Setup section). Taking one STD, so the recharge rate should vary between 15.4 ± 18.4 cfs, i.e., between 0 to 33.8 cfs. So the quasi K (K') should range from 0 to 2.73 cfs/ft ($K' = 33.8 \text{ cfs} / 12.4 \text{ ft}$). Let K' varying from 0 to 2.73, and

running PEST on the UORB HSPF model to minimize the objective function, PEST chose 2.67966880 as the best parameter value for K' .

According to the Thiessen polygons of the rainfall gages, Lake Apopka sub-basin should use the rainfall data of the gage located at Crescent, Florida. However, we believe the total rainfalls in years of 2002 and 2003 were overestimated at Crescent rainfall gage. Compared with Onerain rainfall and nearby Lisbon rain gage, the Crescent gage in Year 2002 and 2002 were 40% to 60% higher. Hence, we adopted the rainfall data at Lisbon gage for Lake Apopka subbasin instead of Crescent gage.

The parameter sets within UORB HSPF model that were calibrated using PEST (Parameter Estimation) were DEEPFR, IRC, BASETP, LZSN, INFILT, AGWRC, UZSN, INTFW, LZETP, AGWETP, and KVARY following the general guideline and parameter ranges of the WSIS project. The calibration period ran from January 1, 1995 to December 31, 2006. The calibration result was presented in Tables G1 and G2, and Figures G3 through G6. The Nash-Sutcliffe coefficient (the model's goodness-of-the-fit) is 0.85 (Table G1), and modeled maximum, mean and minimum Lake Apopka water levels were 68.37, 66.17, and 62.85 ft in comparison with the observed 68.16, 66.14, and 62.59 ft, respectively. These statistics between the modeled and observed results demonstrated the UORB model was a well-calibrated model, which could be visually observed from the hydrographs from Figures G3 through G6. More importantly, the calibrated UORB model reflected the big drought from 2000 to 2002 (Figures G3 and G4), which was not possible from the previous modeling attempts.

Table 3.L.1: Calibration Model Performance

Nash-Sutcliffe (Monthly Mean Water Level)	Percent Error of the Mean
0.85	0.05

Table 3.L.2: Descriptive Calibration Statistics

Statistic (Daily Water Level (ft))	Observed (USGS:02237700)	Simulated
Average	66.14	66.17
Median	66.63	66.46
Variance	1.56	1.26
Standard Deviation	1.25	1.12
Skew	-1.10	-0.82
Kurtosis	0.10	0.10
Minimum	62.59	62.85
Maximum	68.16	68.37
Range	5.57	5.52

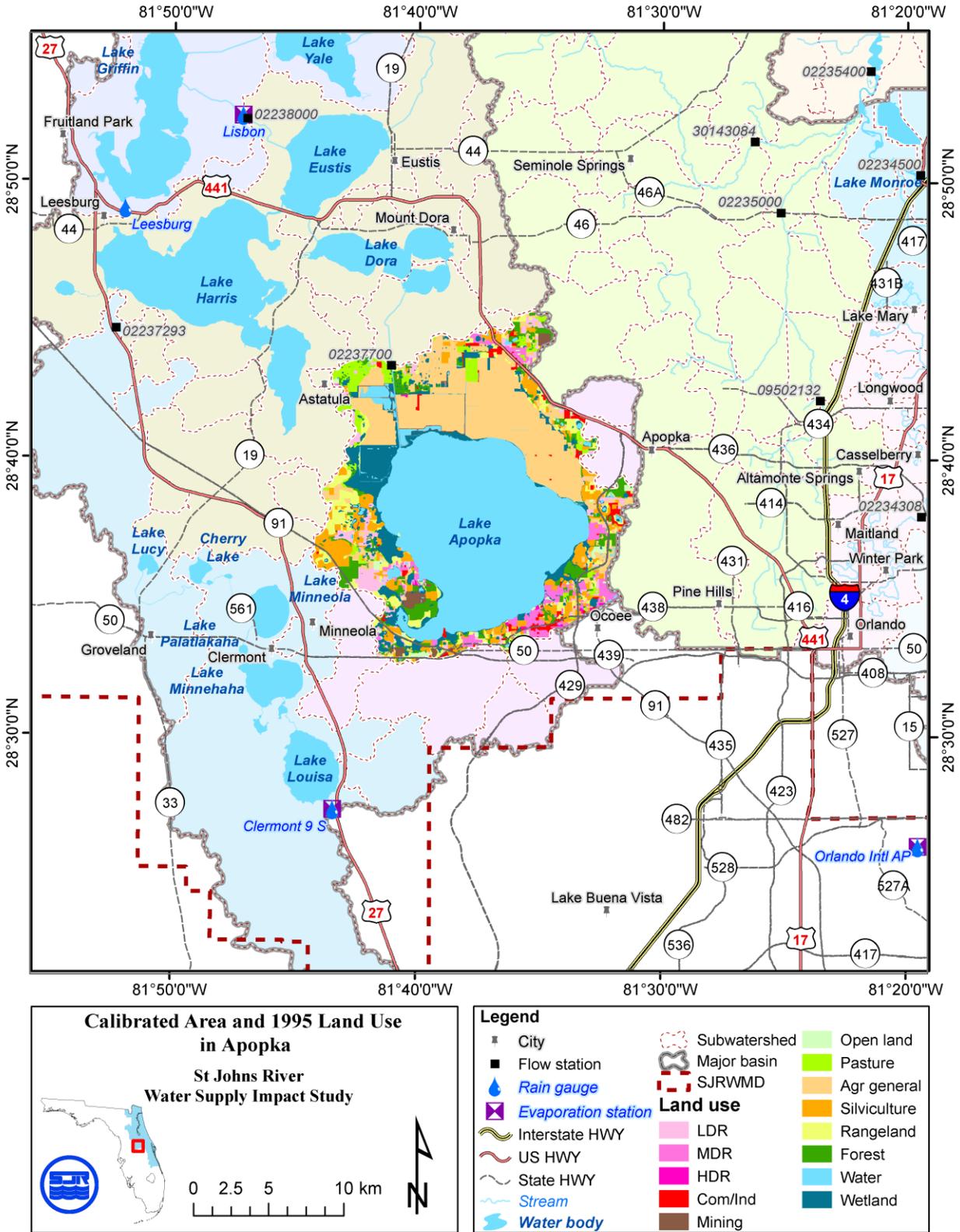


Figure 3.L.2: Apopka land use map

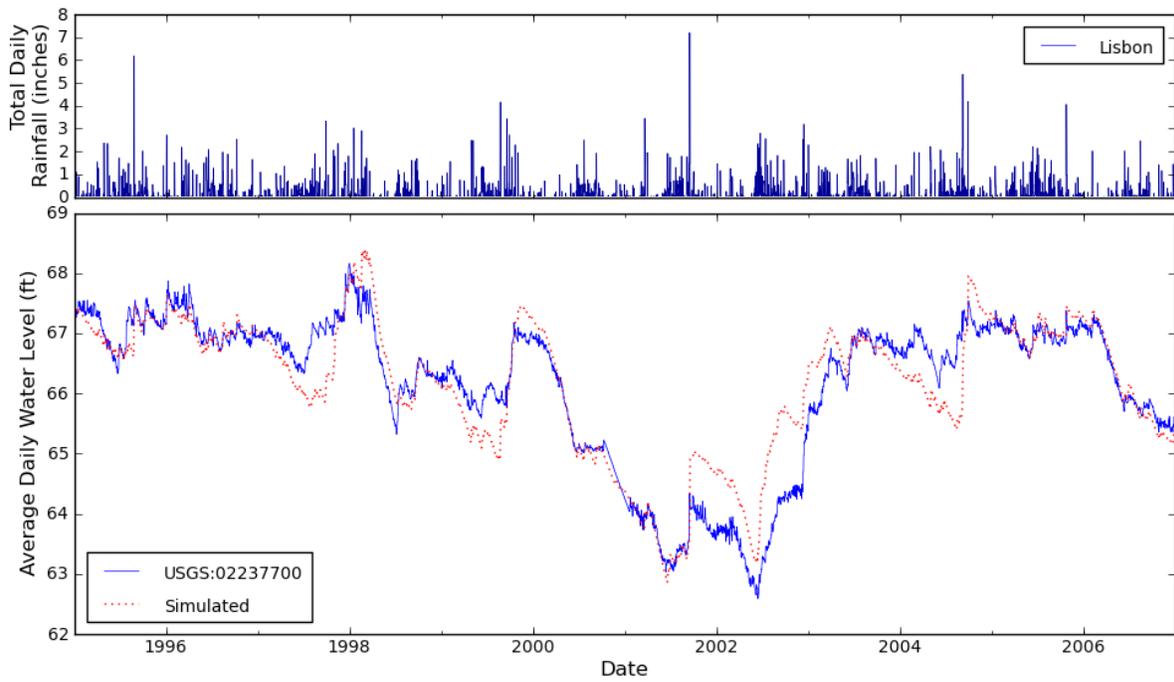


Figure 3.L.3: Apopka daily hydrograph

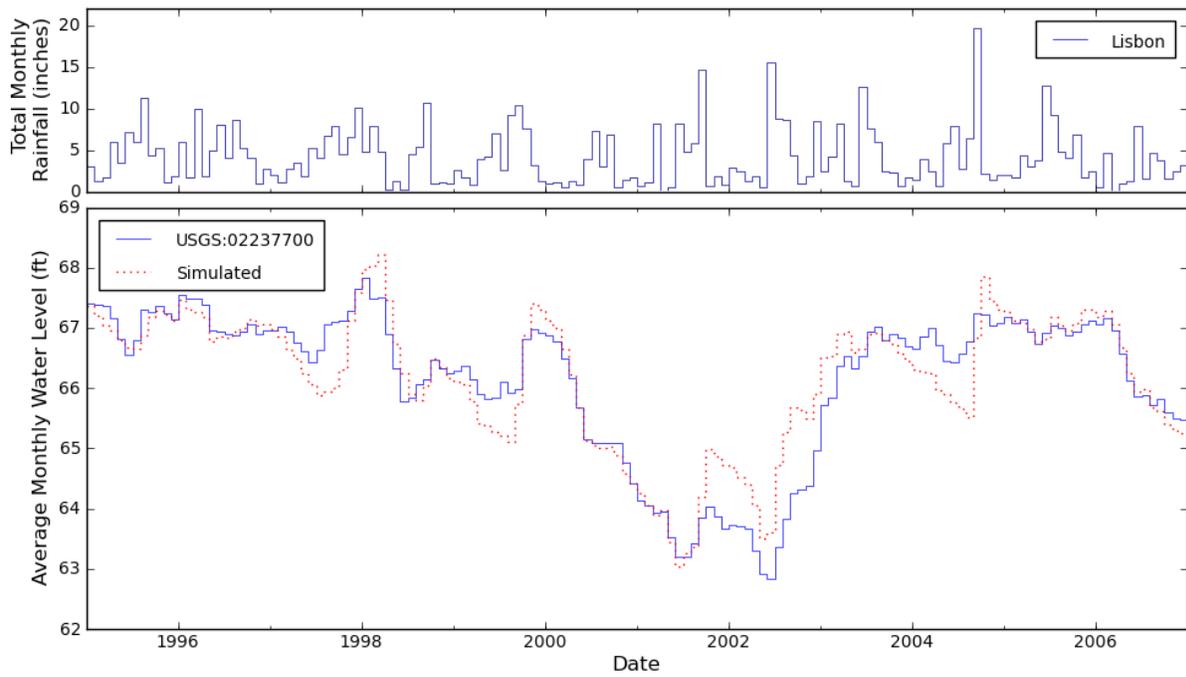


Figure 3.L.4: Apopka monthly hydrograph

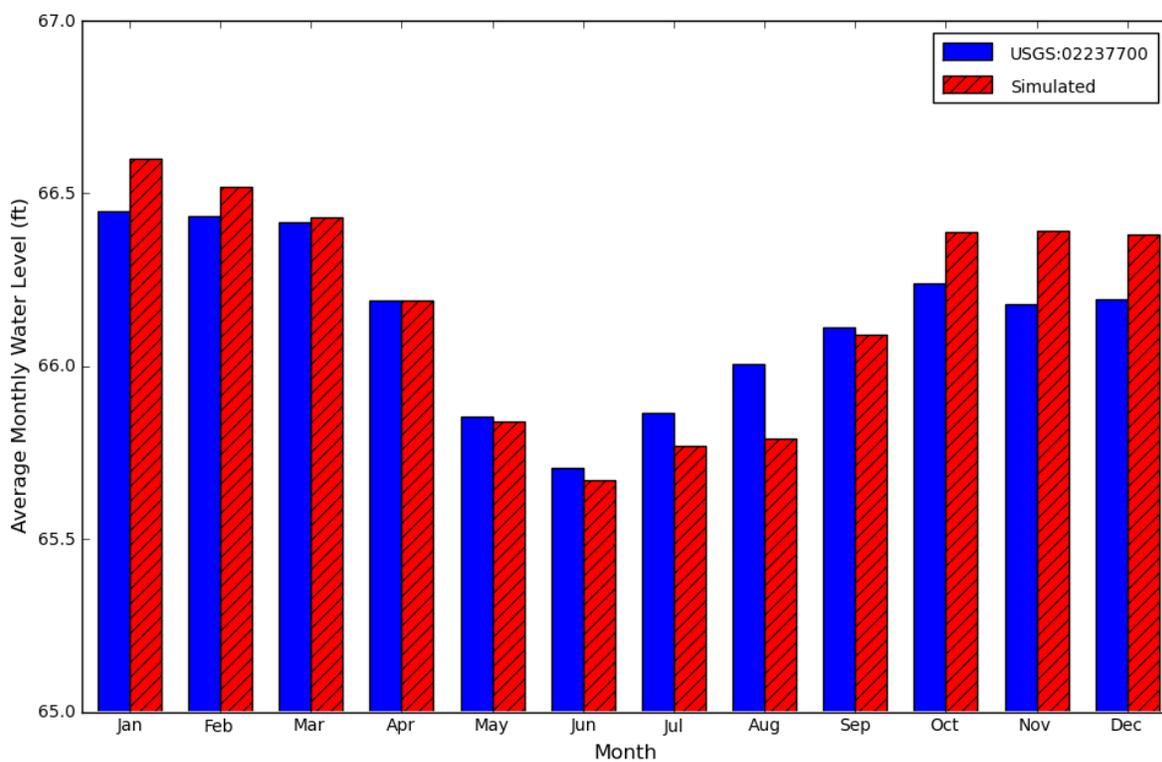


Figure 3.L.5: Apopka average monthly flow

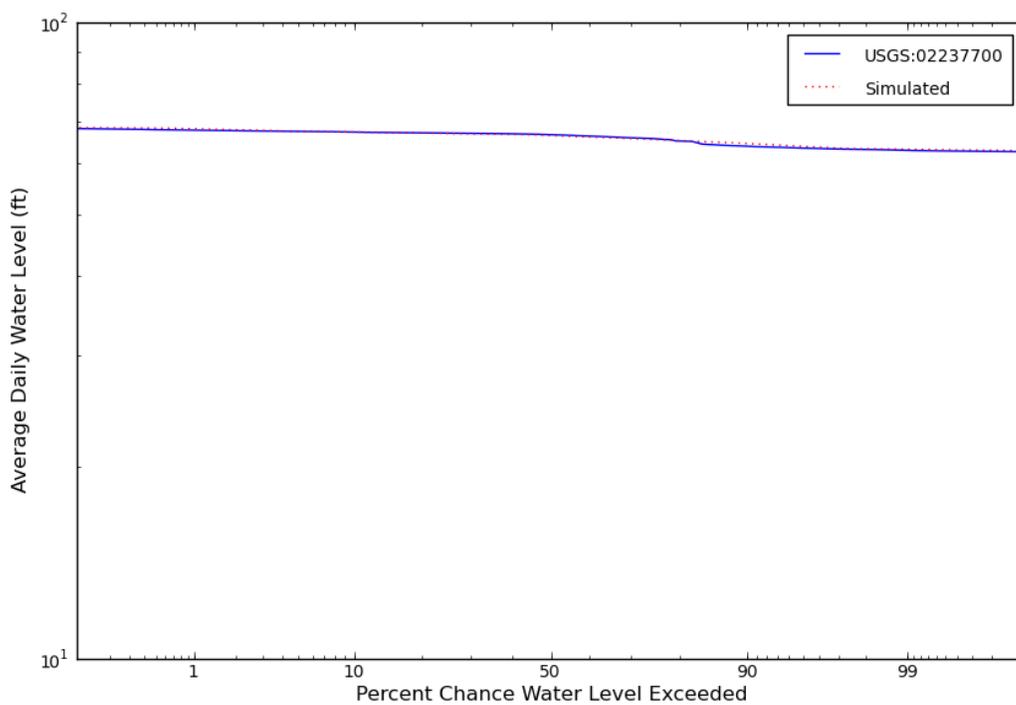


Figure 3.L.6: Apopka exceedance probability curve

7EF OCKLAWAHA WATERSHED

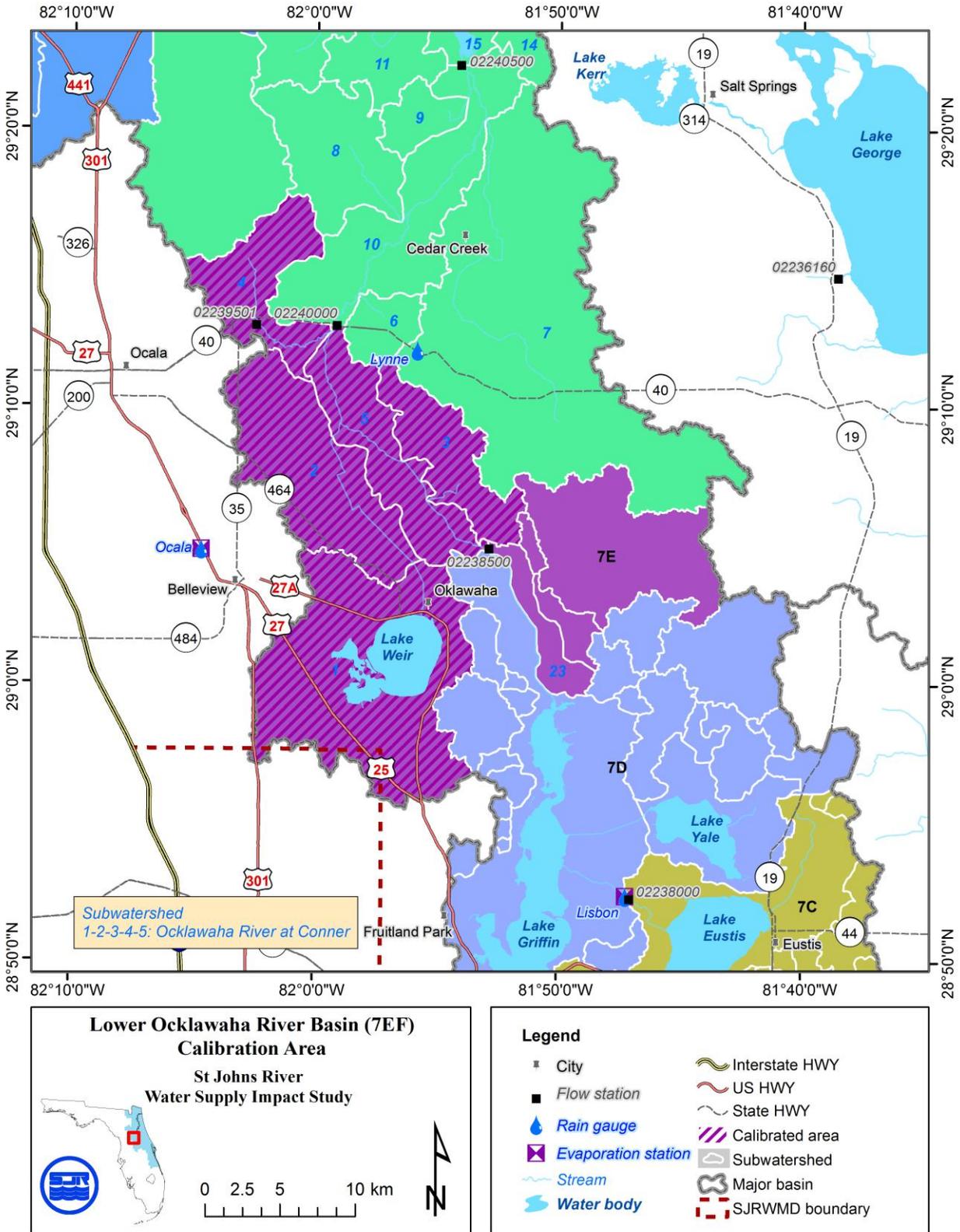


Figure 3.L.7: 7EF Ocklawaha Watershed calibration areas

7EF OCKLAWAHA WATERSHED. OCKLAWAHA RIVER AT CONNER SUBWATERSHEDS

The Lower Ocklawaha River Basin (LORB) is located at the downstream portion of the Ocklawaha River. The Upper Ocklawaha River Basin (UORB) discharges to LORB at Moss Bluff Lock and Dam. The Orange Creek, a tributary of Ocklawaha River, discharges to Lower Ocklawaha River near Orange Springs. The Lower Ocklawaha River discharges to St Johns River near Welaka, Florida, 9 miles downstream of Lake George. LORB model was calibrated at USGS gage station 02240000 near Conner. The gage station is located on the right bridge fender 75 ft upstream from bridge on State Highway 40, 0.2 mi downstream from Silver River, 1.5 mi southwest of Conner, 8 mi east of Ocala, and 51.0 mi upstream from mouth. The basin drainage area to this point is 1,196 square miles. Although there are two more USGS gage stations at Eureka and Rodman Dam, however both of these flow measurements can be influenced by the impoundment at Rodman Reservoir. The river flow at Conner is not impacted by the upper boundary of the Rodman Reservoir. Hence, LORB HSPF model was calibrated with the flow measured at USGS gage station 02240000. The parameters estimated at Conner were applied to other subbasins within LORB. This methodology is reasonable, as the LORB basin is relatively small and uniform. The LORB model was calibrated from January 1, 1995 to the end of 2006. Due to the difficulties of modeling of the spring flow at Silver Springs, the observed flows at USGS gage station 02239501 was directly input into LORB model. For calibration purpose, the observed flows at Moss Bluff Lock and Dam (USGS gage 02238500), and Orange Creek (USGS gage 02243000) were directly input into LORB HSPF model.

The parameters within LORB HSPF model that were calibrated using PEST (Parameter Estimation) were DEEPPFR, IRC, BASETP, LZSN, INFILT, AGWRC, UZSN, INTFW, LZETP, and AGWETP following the general guideline and parameter ranges of the WSIS project. The calibration results at Conner were presented at Tables G-3 and G-4, and at Figures G-9 through G-12. The Nash-Sutcliffe coefficient of monthly mean flows, a model goodness-of-fit statistics, was 0.98 with a -0.01% error of the mean (Table G-3). The simulated average daily flow was 612.59 MGD with a standard deviation of 351.02 MGD in comparison with the observed average of 612.65 MGD with a standard deviation of 353.64 MGD. The minimum, median and maximum daily flows at Conner were 242.99, 515.68, and 2268.20 MGD for modeled results, and 256.59, 501.54, and 2223.33 MGD for observed results during the calibration period (1/1/1995 to 12/31/2006). Graphical comparisons between modeled and observed daily flows were presented in the Figures G-9 through G-12 for daily or monthly hydrographs, flow duration curve, etc. In addition, the statistics were checked for flows at other gauges that were not calibrated. All the Nash-Sutcliffe coefficients were at least greater than 0.5. Based on these, it is reasonable to assume that the LORB HSPF model was very well calibrated from 1/1/1995 to 12/31/2006. The calibrated parameters were used in the other subbasins within LORB.

Table 3.L.3: Calibration Model Performance

Nash-Sutcliffe (Monthly Mean Flow)	Percent Error of the Mean
0.98	-0.01

Table 3.L.4: Descriptive Calibration Statistics

Statistic (Daily Flow (mgd))	Observed (USGS:02240000)	Simulated
Average	612.65	612.59
Median	501.54	515.68
Variance	125063.64	123216.98
Standard Deviation	353.64	351.02
Skew	1.97	2.00
Kurtosis	3.57	4.04
Minimum	256.59	242.99
Maximum	2223.33	2268.20
Range	1966.74	2025.21

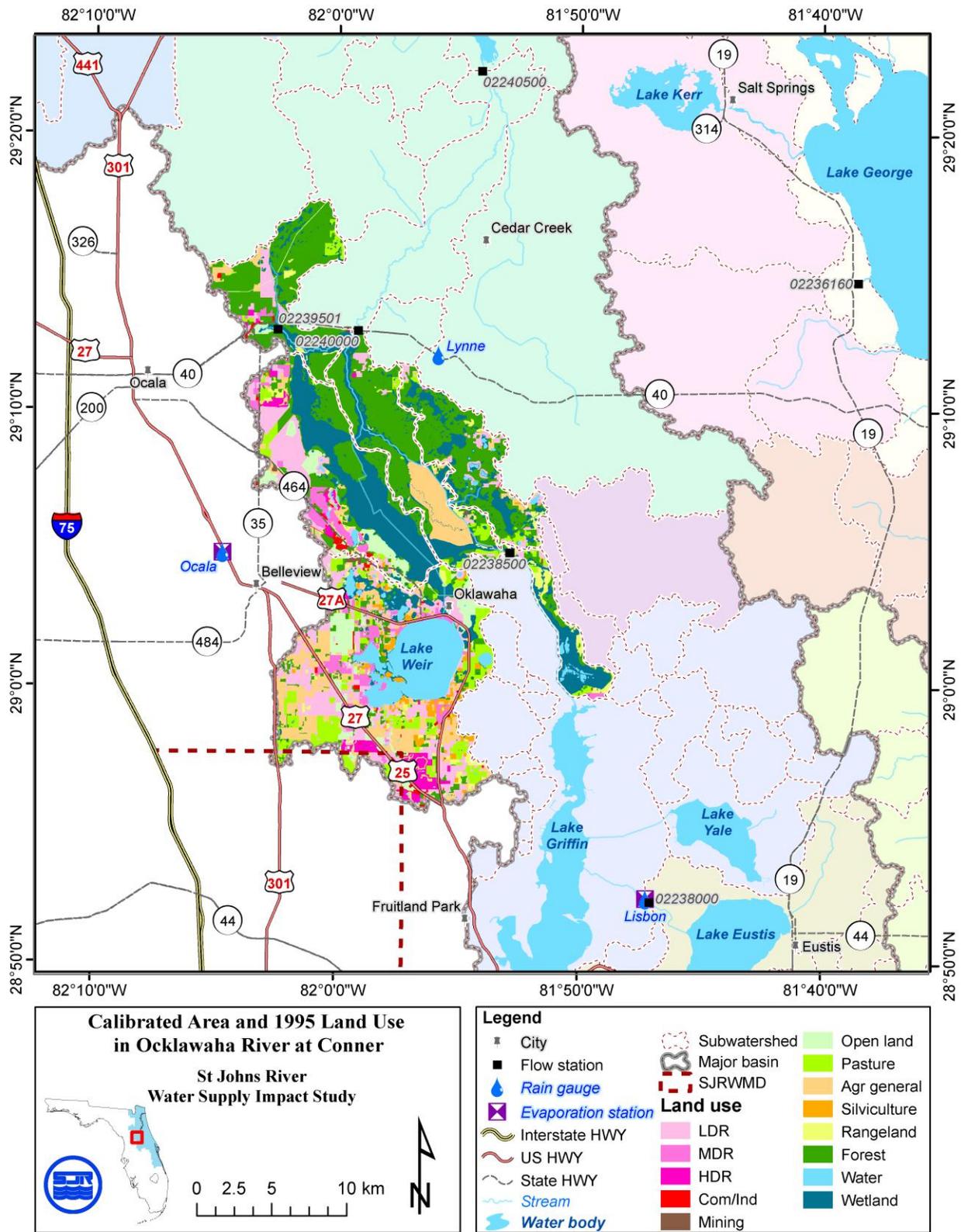


Figure 3.L.8: Ocklawaha River at Conner land use map

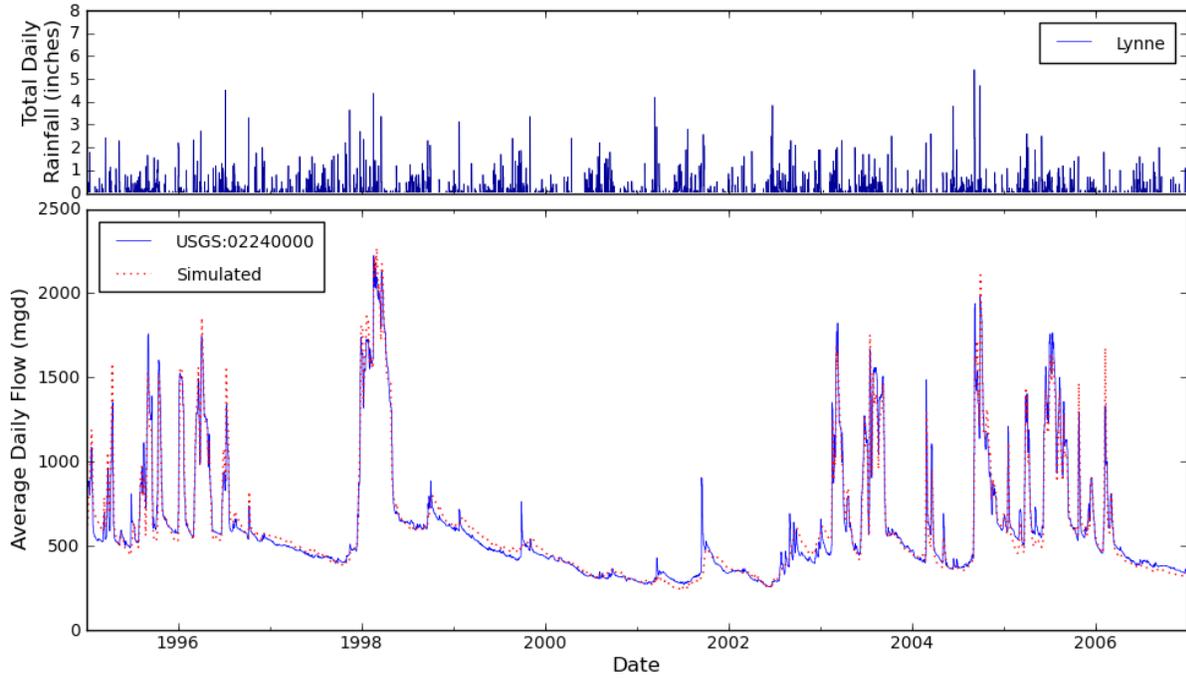


Figure 3.L.9: Ocklawaha River at Conner daily hydrograph

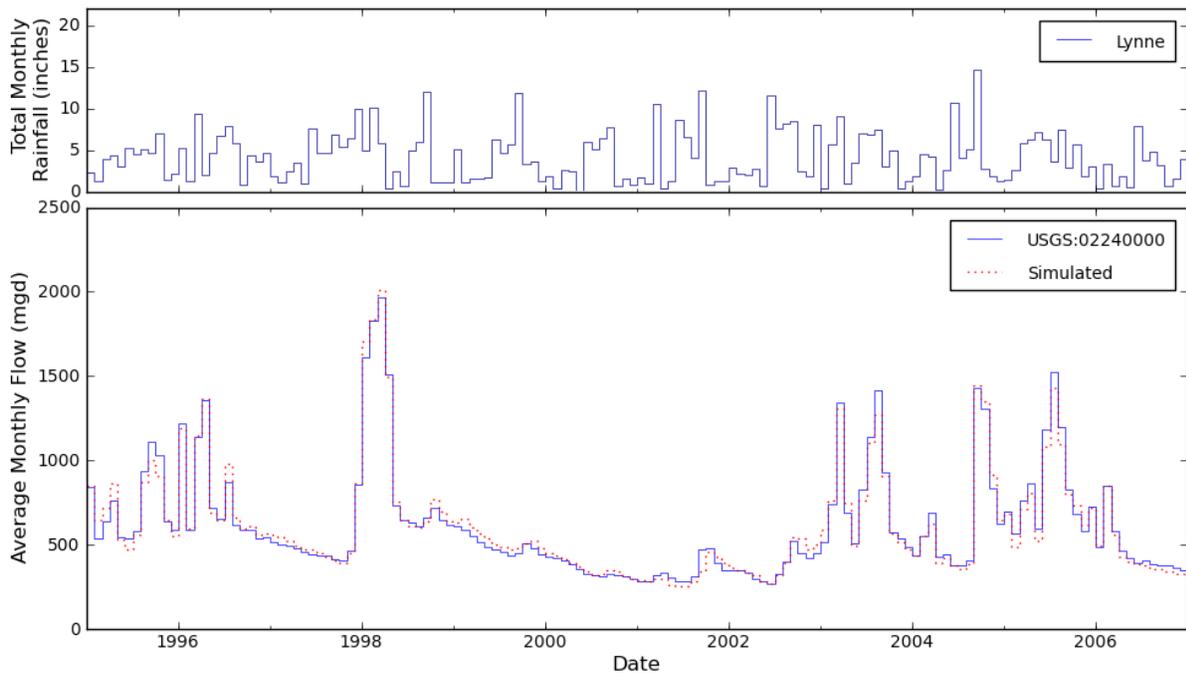


Figure 3.L.10: Ocklawaha River at Conner monthly hydrograph

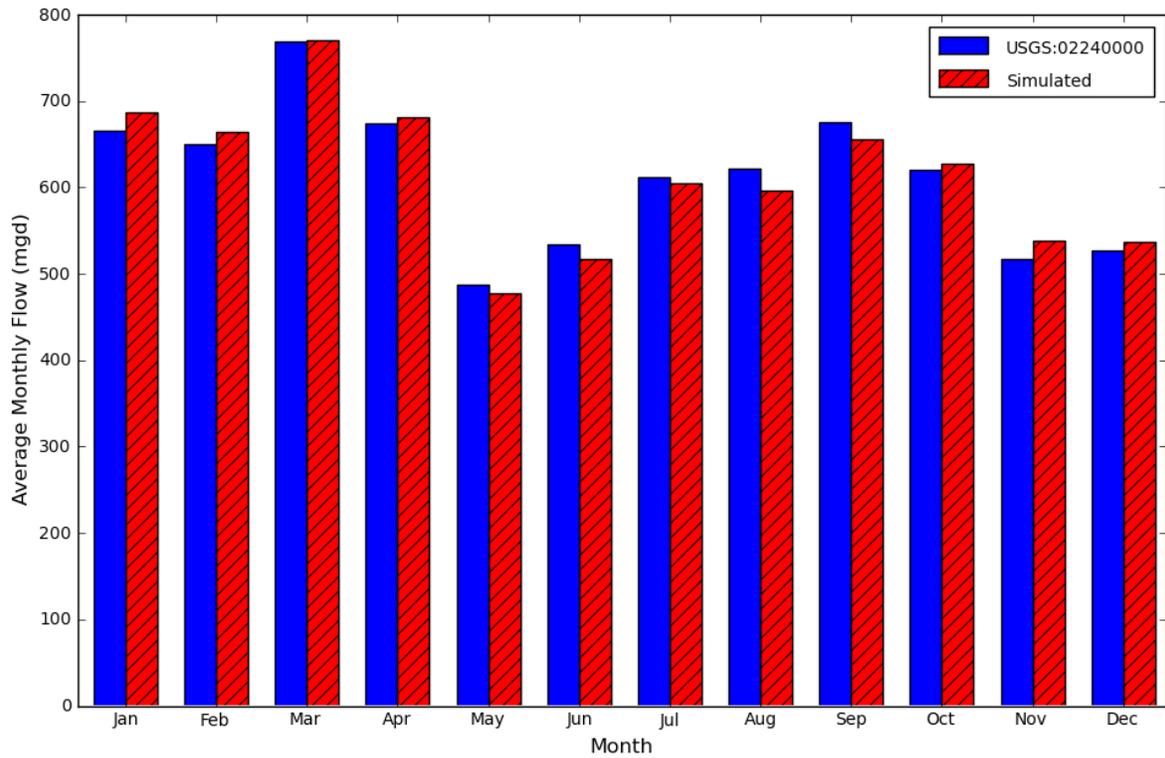


Figure 3.L.11: Ocklawaha River at Conner average monthly flow

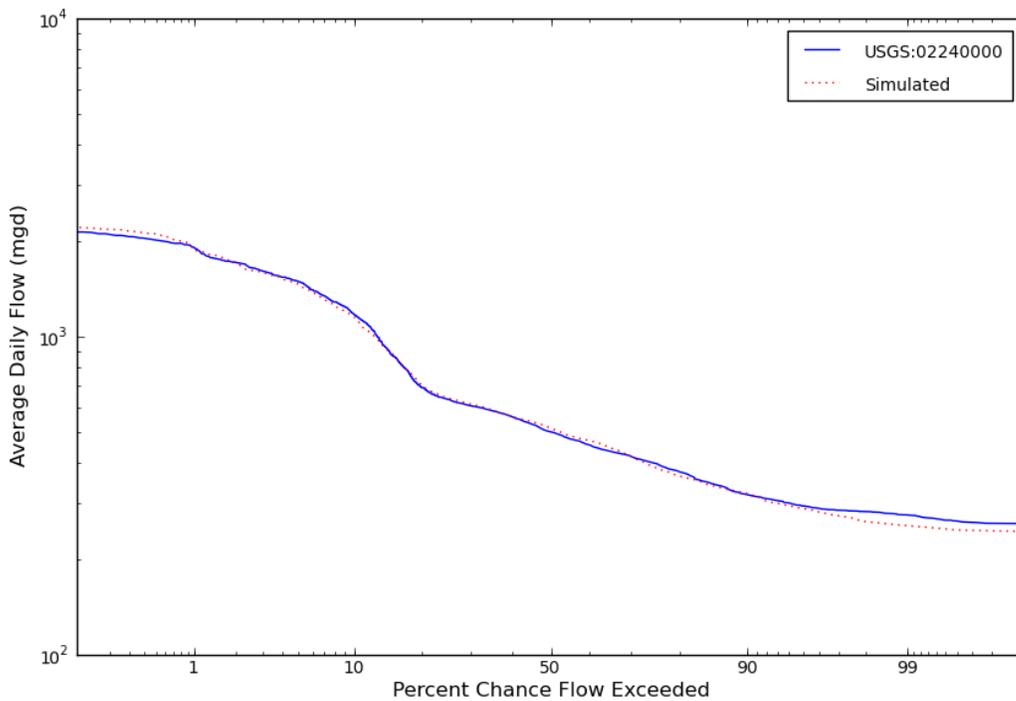


Figure 3.L.12: Ocklawaha River at Conner exceedance probability curve

7G UPPER ORANGE CREEK WATERSHED

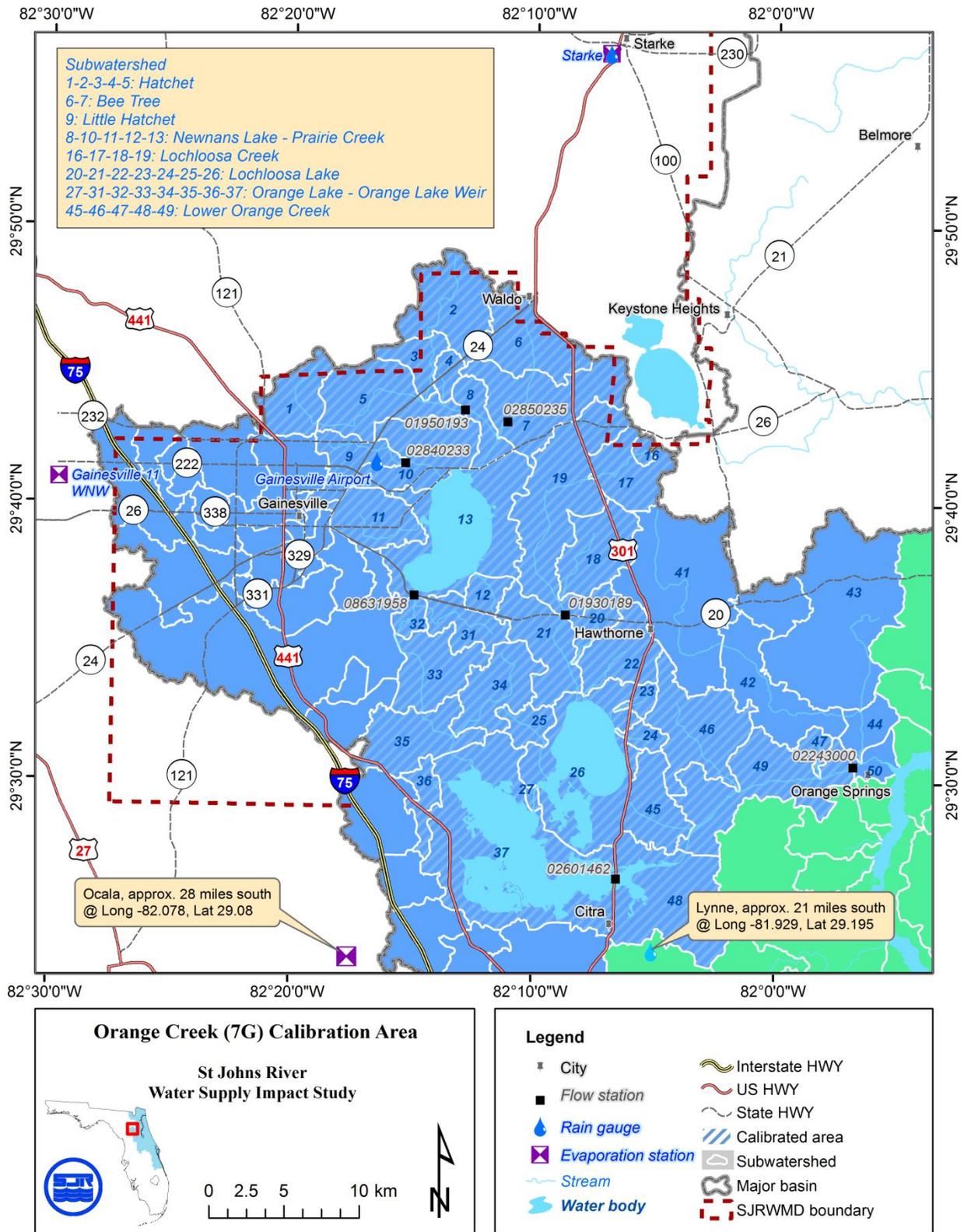


Figure 3.L.13: 7G Upper Orange Creek Watershed calibration areas

7G UPPER ORANGE CREEK WATERSHED. HATCHET CREEK SUBWATERSHEDS

The Hatchet Creek subwatershed has a drainage area of 35.5 square miles and is divided into 5 subbasins. Subbasins 1 and 2 include large expansive shallow wetland areas, which are nearly dry during severe droughts but cover large areas during wet periods. Wetland area was 32 percent of the total surface basin area for subbasin 1 and 35 percent of total surface area for subbasin 2. Subbasin 3 is a basin between the storage area of subbasin 2 and Hatchet Creek. Subbasin 4 is a small tributary basin to the east of subbasin 3. Subbasin 5 is Hatchet Creek. This subbasin has a well-defined channel surrounded by a riverine floodplain. Wetland surface area was 21 percent of the total surface basin area for subbasin 5. Most of these wetlands are within the riverine floodplain.

The model used Gainesville Airport rainfall station for all subbasins in the Hatchet Creek Watershed. The Gainesville evaporation station is located 11 miles West Northwest of Gainesville. Therefore, the theissen polygons indicated that the divide between the Starke and Gainesville evaporation was in the middle of the Hatchet Creek subwatershed. Subbasins 1 and 5 used the Gainesville evaporation and subbasins 2,3, and 4 used the Starke evaporation. The Hatchet Creek gage (01950193) is located 3.7 mile upstream from its mouth into Newnans Lake. The gage currently is maintained by the SJRWMD although data prior to October 1998 the gage was maintained by the USGS. The Gage was established by USGS on June 29, 1995. Therefore, the calibration period for the HSPF Model was from July 1995 through December 2006.

The groundwater interaction special action explained in a previous section of this report was used for Hatchet Creek. This special actions was used because of a small sink observed upstream of the gage. The estimate of the stage difference between the surface water and groundwater needed for this special action was determined by subtracting the SJRWMD observed stage at the Sparr Well (06691640), located south of Orange Lake, from the modeled stage at the Hatchet Creek gage.

Parameter Estimation Program (PEST) was applied for HSPF model parameters calibration to the 10 parameters according to the WSI project general model parameters guideline and ranges. The observed annual mean discharge for Hatchet Creek was 13.62 mgd. The simulated discharge over the calibration was 13.62 mgd. The model goodness-of-fit statistics resulted in a Nash-Sutcliffe coefficient of 0.80. During the process of hydrologic calibration, the daily flow-frequency duration curves and the correlation of simulated and observed daily flows are evaluated. Furthermore, the comparison of simulated and observed flows is performed for monthly values. The plots for these comparisons are provided in the following subsection. Based on the results of hydrologic calibration, it is concluded that the HSPF model reasonably represents the hydrologic processes of the subwatershed.

Though this is a reasonable calibration several issues can be observed with this model that seem to be systematic through many of the models which supply input into the Orange Lake Model.

The most significant of these issues is the underestimation of discharge in 2005. This issue occurs in all the models, which support the Orange Lake Model. A possible cause for this

underestimation of discharge is rainfall is at the Gainesville Airport underestimates the rainfall, which generally fell in the area for 2005.

This model significantly underestimated volume of runoff after both the 1998 and 2004 storm events. Observations indicated that many of the forest roads needed repair after the 2004. The upstream marsh storage areas could be drained further than they would be normally. This could cause more discharge following the storm events of 1998 and 2004 than during the normal condition being modeled. This is one possible reason for the under simulation of discharges after the storm events. A comparison of rainfall to runoff between December 10, 1997 and April 10, 1998 indicated that runoff at the Hatchet Creek gage was 98.2 percent of the rainfall at the Gainesville Airport. This also may indicate that a groundwater ridging effect may be part of these very high runoff volumes after the large storms.

For the Hatchet Creek model several responses to rainfall occur in the model during the 1999 thru 2002 drought event while these discharges did not occur for the observed data. This pattern is observed for all subwatersheds models that have significant wetland area in the Orange Lake Basin. The inclusion of Surface F-Tables has significantly improved this response although the pattern is still exists in the model.

Discharge to the groundwater is potentially very high for the Hatchet Creek subbasins. The St. Johns River Water Management District's groundwater recharge basin map, have much of the basin in areas with over 16 inches of recharge to the groundwater. However, with most of the soils being C and D soils the HSPF model was never able to simulate groundwater recharge at these levels. This estimate of groundwater recharge was considered reasonable since discharges were zero for 27 percent of the time along with water lost still being under the potential recharge map for this area.

Table 3.L.5: Calibration Model Performance

Nash-Sutcliffe (Monthly Mean Flow)	Percent Error of the Mean
0.80	-0.05

Table 3.L.6: Descriptive Calibration Statistics

Statistic (Daily Flow (mgd))	Observed (SJRWMD:01950193)	Simulated
Average	13.62	13.61
Median	1.49	2.56
Variance	1621.38	980.95
Standard Deviation	40.27	31.32
Skew	6.89	6.61
Kurtosis	69.21	69.70
Minimum	0.00	0.00
Maximum	710.95	553.05
Range	710.95	553.05

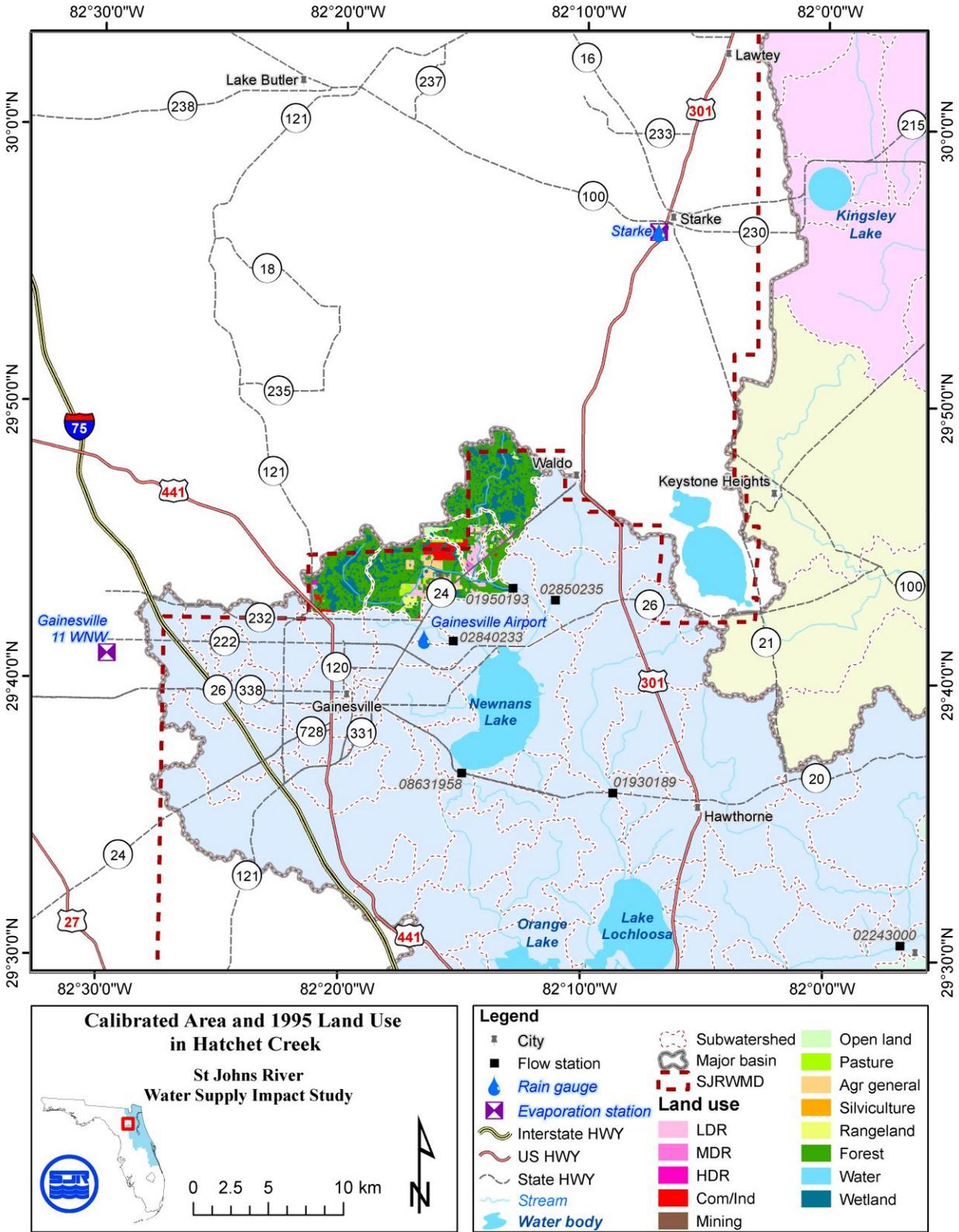


Figure 3.L.14: Hatchet Creek land use map

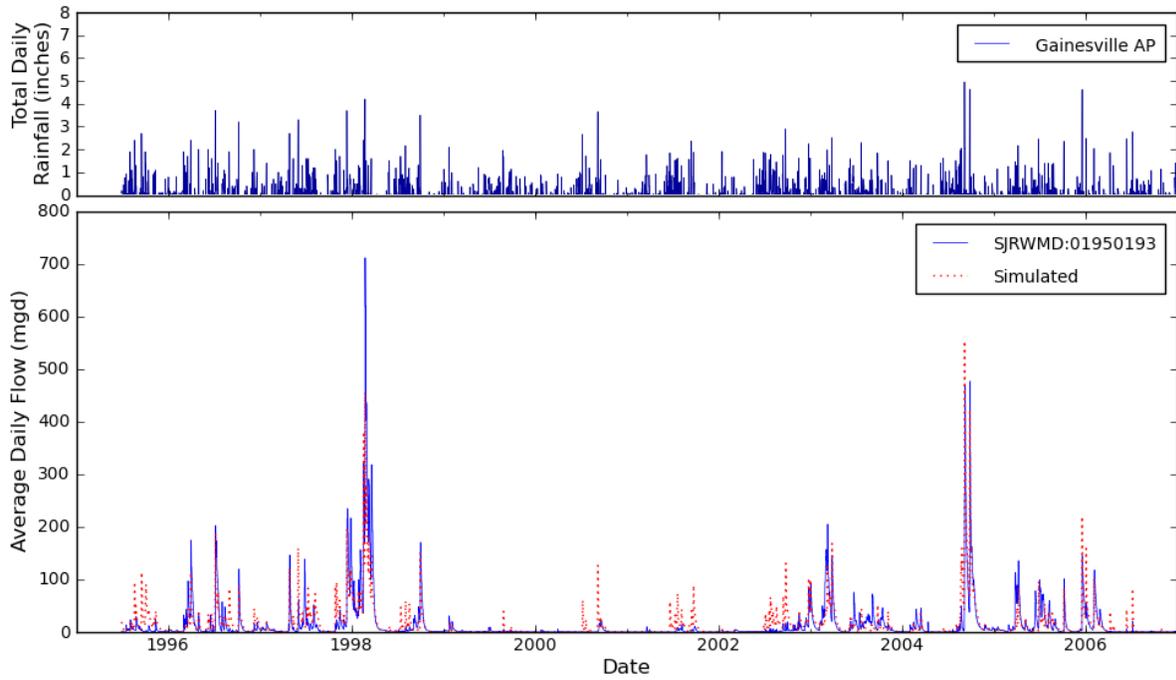


Figure 3.L.15: Hatchet Creek daily hydrograph

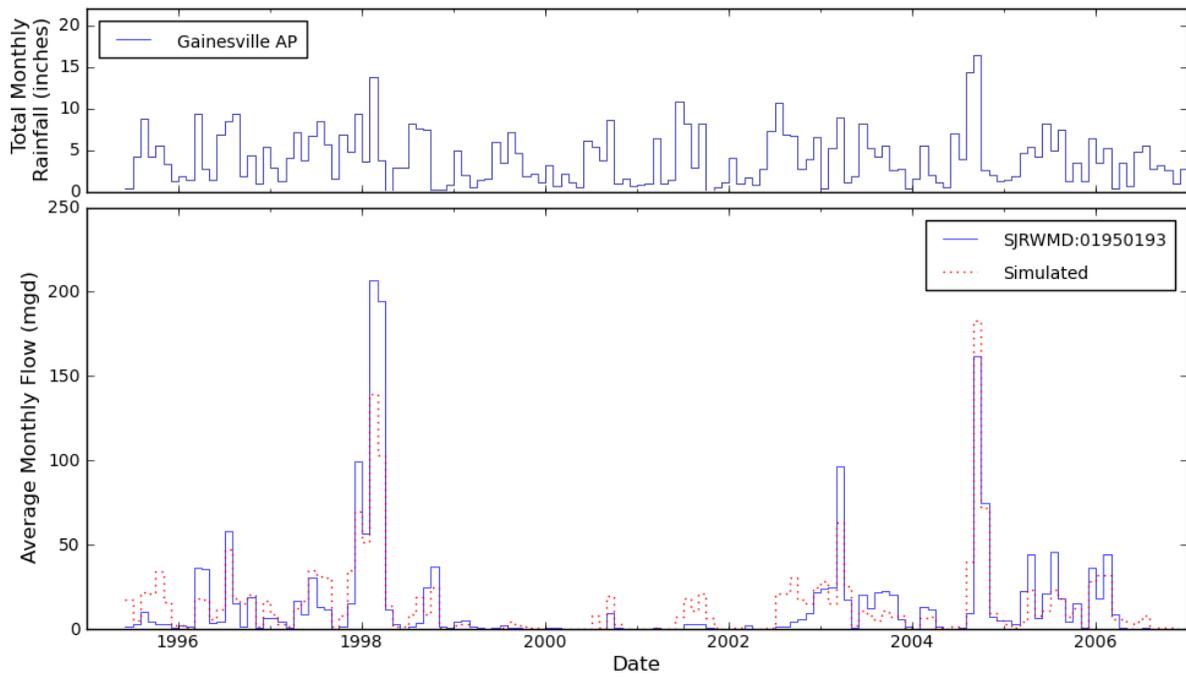


Figure 3.L.16: Hatchet Creek monthly hydrograph

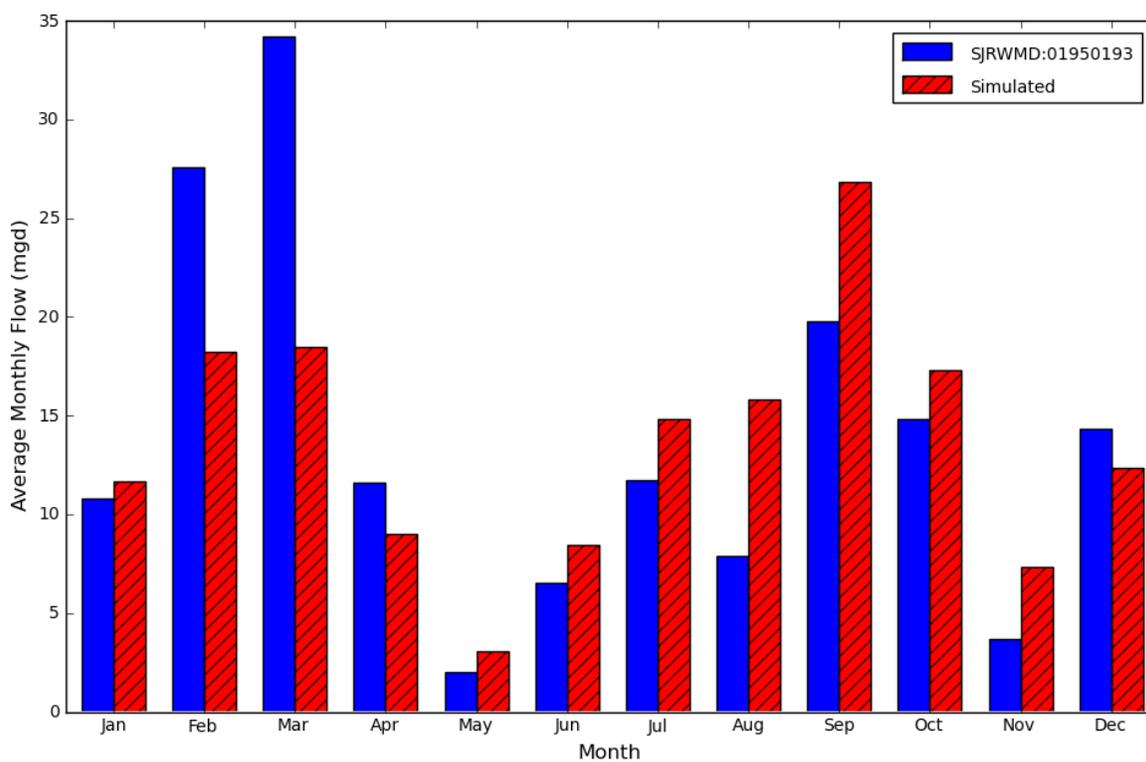


Figure 3.L.17: Hatchet Creek average monthly flow

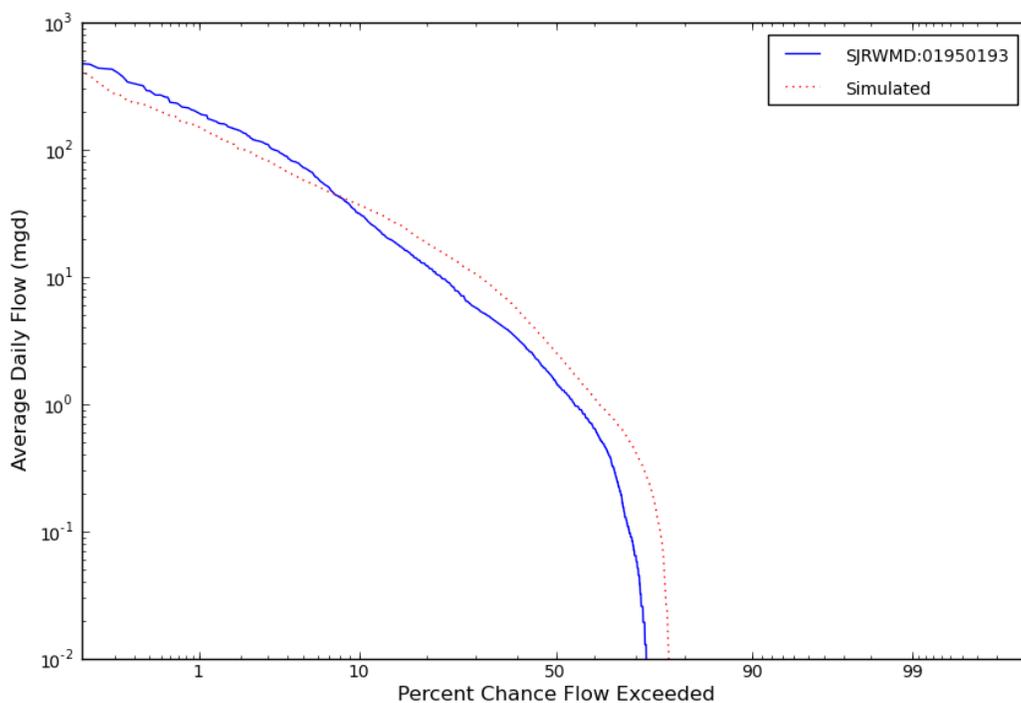


Figure 3.L.18: Hatchet Creek exceedance probability curve

7G UPPER ORANGE CREEK WATERSHED. BEE TREE CREEK SUBWATERSHEDS

The Bee Tree Creek subwatershed has a drainage area of 24.9 square miles and is divided into 2 subbasins. Subbasin-6 is the headwater basin. This subbasin receives an inflow from Lake Alto (Santa Fe River Basin) during high flow periods through a culvert under SR-301. A HEC-RAS model was set up using map cross-sections for upstream and downstream of the culvert. A rating curve for Lake Alto stage and discharge through this culvert was developed with the HEC-RAS model. Lake Alto stage was obtained from Suwannee River Water Management District. These stages and the rating developed by HEC-RAS was used to develop and estimated discharge into the Bee Tree Basin through this culvert. Drainage from the upland areas of this subbasin drain into a central wetland area. Wetlands area is 16 percent of the total area of this subbasin. Subbasin-7 is the downstream portion of the Bee Tree Creek. Bee Tree Creek is a small poorly defined creek draining through a wetland area into Hatchet Creek. Wetlands area is 16 percent of the total area of this subbasin.

The model used Gainesville Airport rainfall station and the Starke evaporation for both subbasins of Bee Tree Creek. The gage on Bee Tree Creek (02850235) is located 0.95 miles upstream of the confluence of Bee Tree Creek and Hatchet Creek. The gage was established by the SJRWMD in October 1999. Therefore, the calibration period for the HSPF Model was from October 1999 through December 2006.

Parameter Estimation Program (PEST) was applied for HSPF model parameters calibration to the 10 parameters according to the WSIS project general model parameters guideline and ranges. The observed annual mean discharge for Bee Tree Creek was 6.2 mgd. The simulated discharge over the calibration was 6.1 mgd. The model goodness-of-fit statistics resulted in a Nash-Sutcliffe coefficient of 0.86. During the process of hydrologic calibration, the daily flow-frequency duration curves and the correlation of simulated and observed daily flows are evaluated. Furthermore, the comparison of simulated and observed flows is performed for monthly values. The plots for these comparisons are provided in the following subsection. Based on the results of hydrologic calibration, it is concluded that the HSPF model reasonably represents the hydrologic processes of the subwatershed.

The model has two similar issues as the Hatchet Creek Model. The small storm events during the major drought and the significant underestimate of discharge in 2005. The model also significantly underestimates the observed peak discharge. This observed peak (1230 mgd) seems higher than a basin of this size would support and is much higher than the measured peak discharge (154 mgd) used to develop the rating curve for this location. Therefore, the observed peak is a poor estimate of actual discharge for this storm event.

Table 3.L.7: Calibration Model Performance

Nash-Sutcliffe (Monthly Mean Flow)	Percent Error of the Mean
0.86	-1.68

Table 3.L.8: Descriptive Calibration Statistics

Statistic (Daily Flow (mgd))	Observed (SJRWMD:02850235)	Simulated
Average	6.22	6.12
Median	0.00	0.52
Variance	1495.41	754.20
Standard Deviation	38.67	27.46
Skew	20.71	17.13
Kurtosis	535.99	384.13
Minimum	0.00	0.00
Maximum	1229.79	786.59
Range	1229.79	786.59

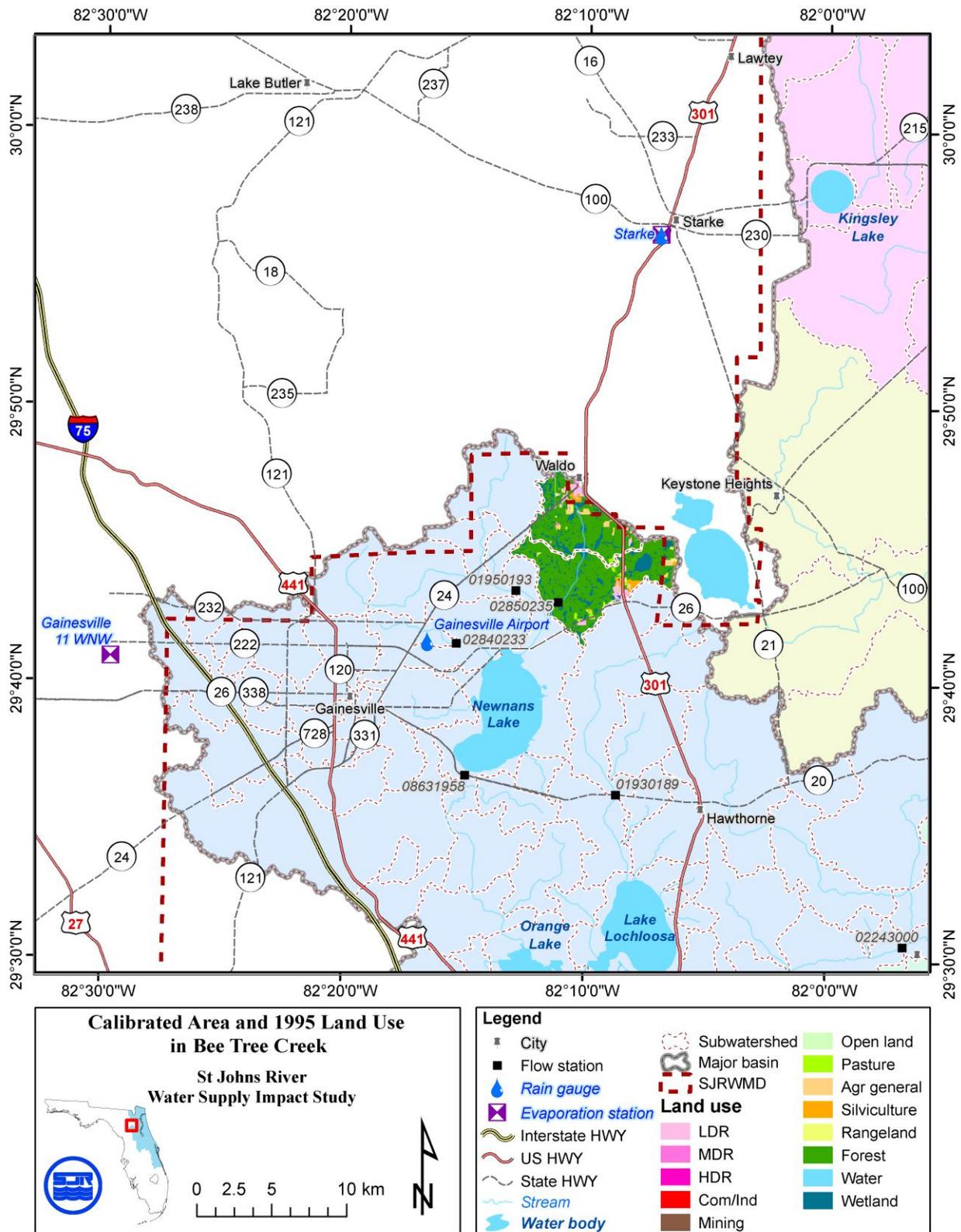


Figure 3.L.19: Bee Tree Creek land use map

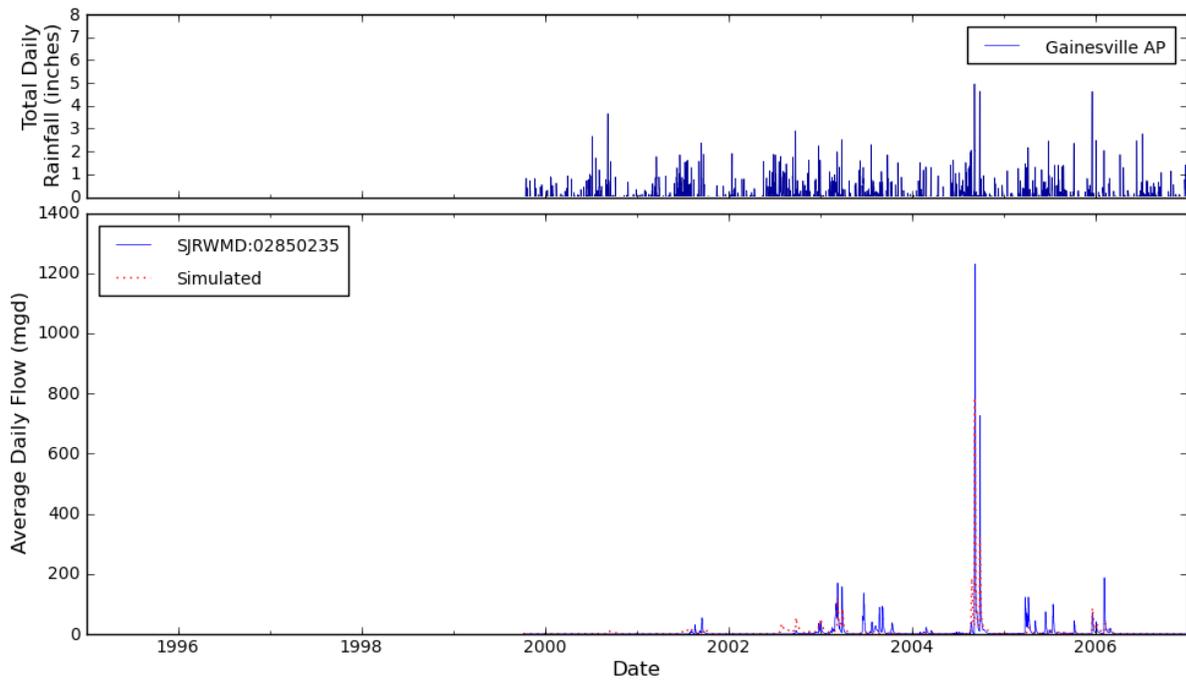


Figure 3.L.20: Bee Tree Creek daily hydrograph

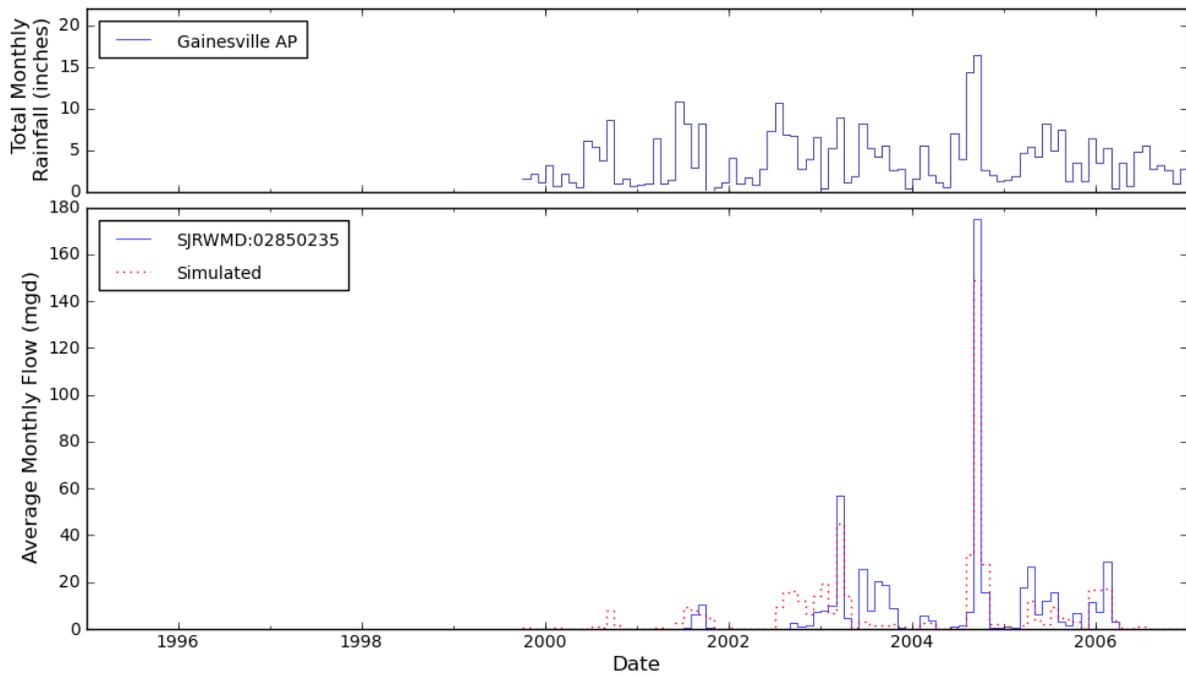


Figure 3.L.21: Bee Tree Creek monthly hydrograph

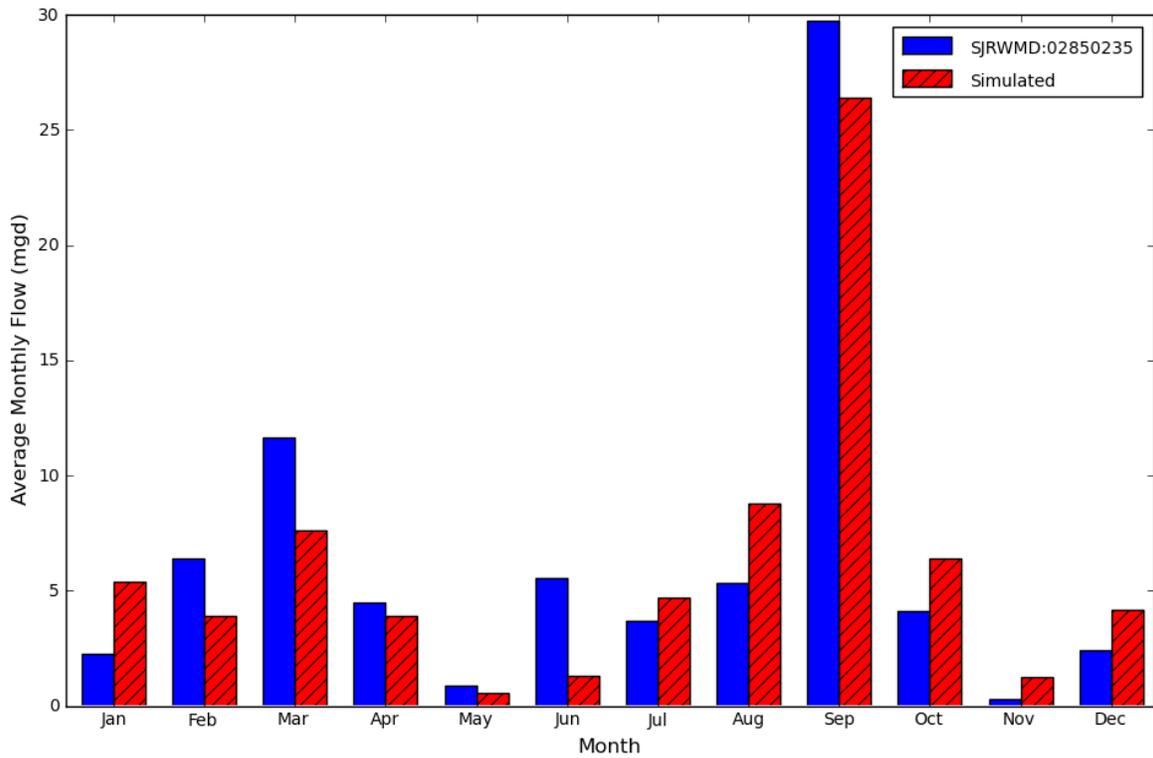


Figure 3.L.22: Bee Tree Creek average monthly flow

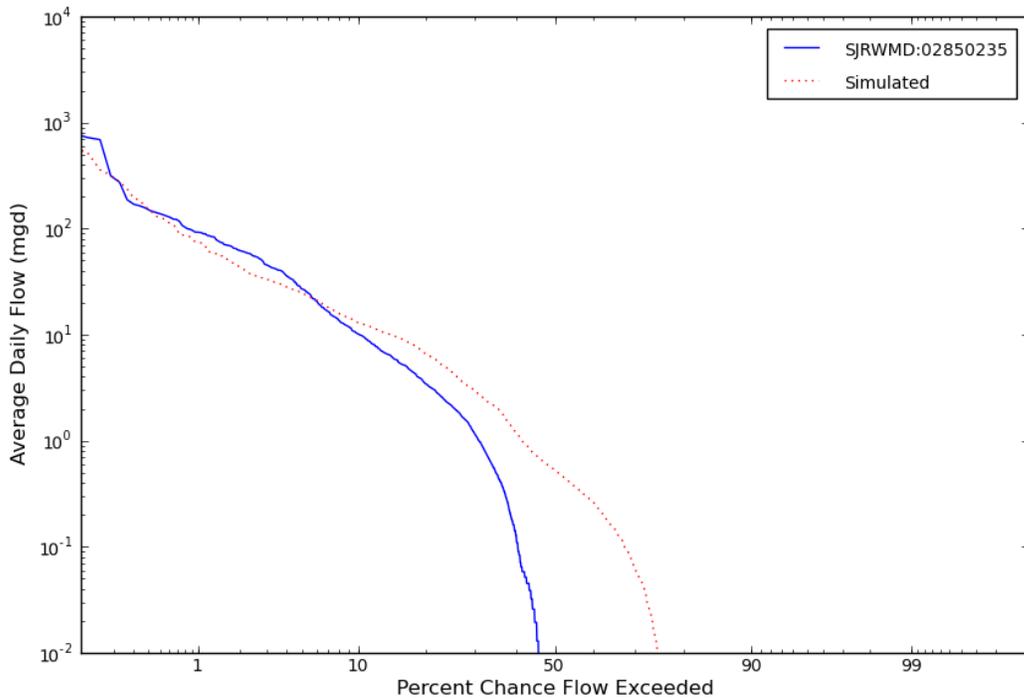


Figure 3.L.23: Bee Tree Creek exceedance probability curve

7G UPPER ORANGE CREEK WATERSHED. LITTLE HATCHET CREEK SUBWATERSHEDS

The Little Hatchet Creek subwatershed has a drainage area of 5.6 square miles and consists of only subbasin 9. This subbasin is significantly different from the other calibrated basins in the Upper Orange Creek Watershed. This basin is primarily A and B soils and has significant urban area. The hydrograph for subbasin 9 has significantly more base flow than observed for other gages in the Upper Orange Creek Watershed. This base flow probably occurs because the channel through the airport section of this creek is a deep cut canal thus exposing this creek to much more subsurface flow than the shallow channels in the rest of the watershed. These changes in soil type and channel characteristics cause the parameters for this basin to be significantly different than most of the parameters in the other Upper Orange Creek subbasins.

The model used Gainesville Airport rainfall station and the Gainesville evaporation for Little Hatchet Creek. The gage on Little Hatchet Creek (02840233) is located just east of the Gainesville Airport. The gage was established by the SJRWMD in October 1998. However, data collected by USGS at a gage west of the airport (02240806) at SR-24 was used to extend data back to May 25, 1995. This was considered close enough to the current drainage area to be able to help the calibration of this gage. Therefore, the calibration period for the HSPF Model was from June 1995 through December 2006.

Parameter Estimation Program (PEST) was applied for HSPF model parameters calibration to the 10 parameters according to the WSIS project general model parameters guideline and ranges. The observed annual mean discharge for Hatchet Creek was 2.64 mgd. The simulated discharge over the calibration was 2.64 mgd. The model goodness-of-fit statistics resulted in a Nash-Sutcliffe coefficient of 0.78. During the process of hydrologic calibration, the daily flow-frequency duration curves and the correlation of simulated and observed daily flows are evaluated. Furthermore, the comparison of simulated and observed flows is performed for monthly values. The plots for these comparisons are provided in the following subsection. Based on the results of hydrologic calibration, it is concluded that the HSPF model reasonably represents the hydrologic processes of the subwatershed.

This basin has very different characteristics than the other basins contributing to the Orange Lake Model. This is an urban basin with primarily sandy soils with few large swamps or waterbodies and a deep narrow channel through the airport. These characteristics lead to a stream with comparatively large base flows and many small peaks of short duration. Despite this basin having the rain gauge within the boundary of this basin this basin still has a large underestimation of flow in 2005.

Table 3.L.9: Calibration Model Performance

Nash-Sutcliffe (Monthly Mean Flow)	Percent Error of the Mean
0.78	-0.01

Table 3.L.10: Descriptive Calibration Statistics

Statistic (Daily Flow (mgd))	Observed (SJRWMD:02840233)	Simulated
Average	2.64	2.64
Median	1.10	1.12
Variance	25.32	28.04
Standard Deviation	5.03	5.30
Skew	6.42	7.20
Kurtosis	63.30	80.02
Minimum	0.00	0.00
Maximum	82.73	88.93
Range	82.73	88.93

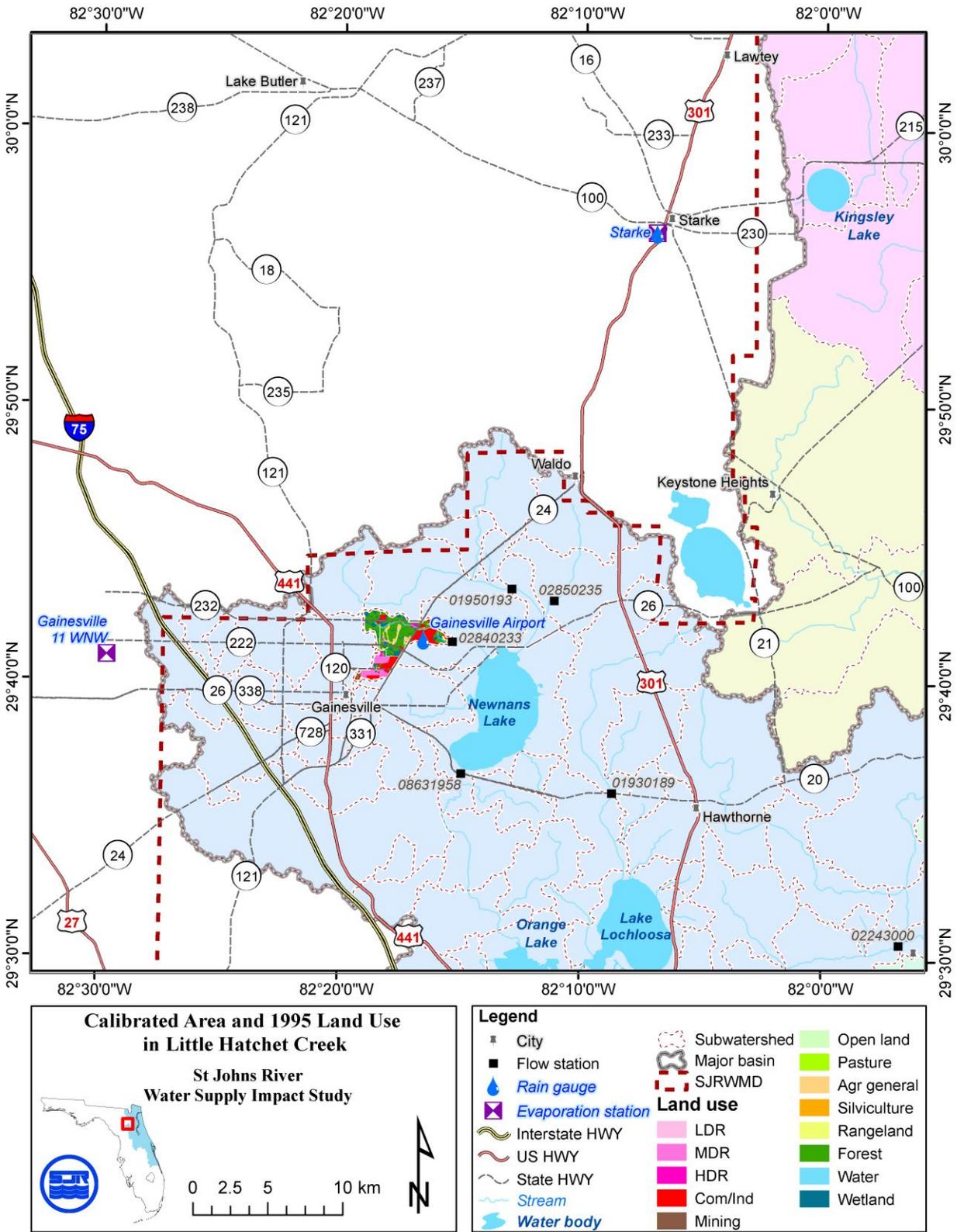


Figure 3.L.24: Little Hatchet Creek land use map

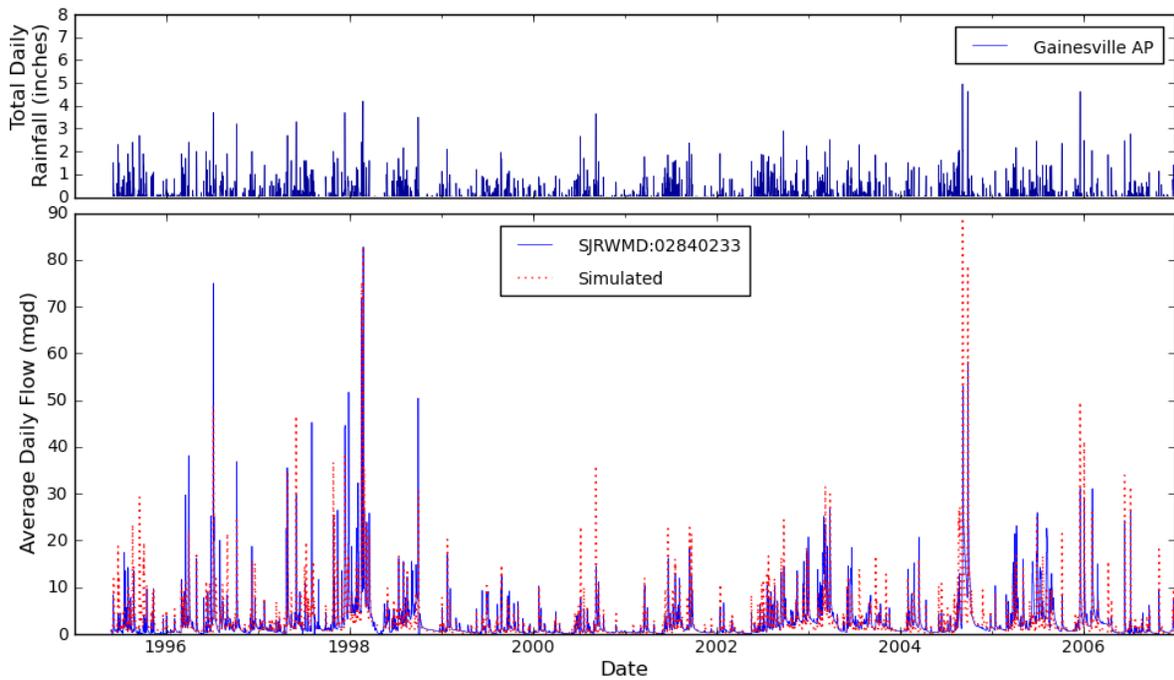


Figure 3.L.25: Little Hatchet Creek daily hydrograph

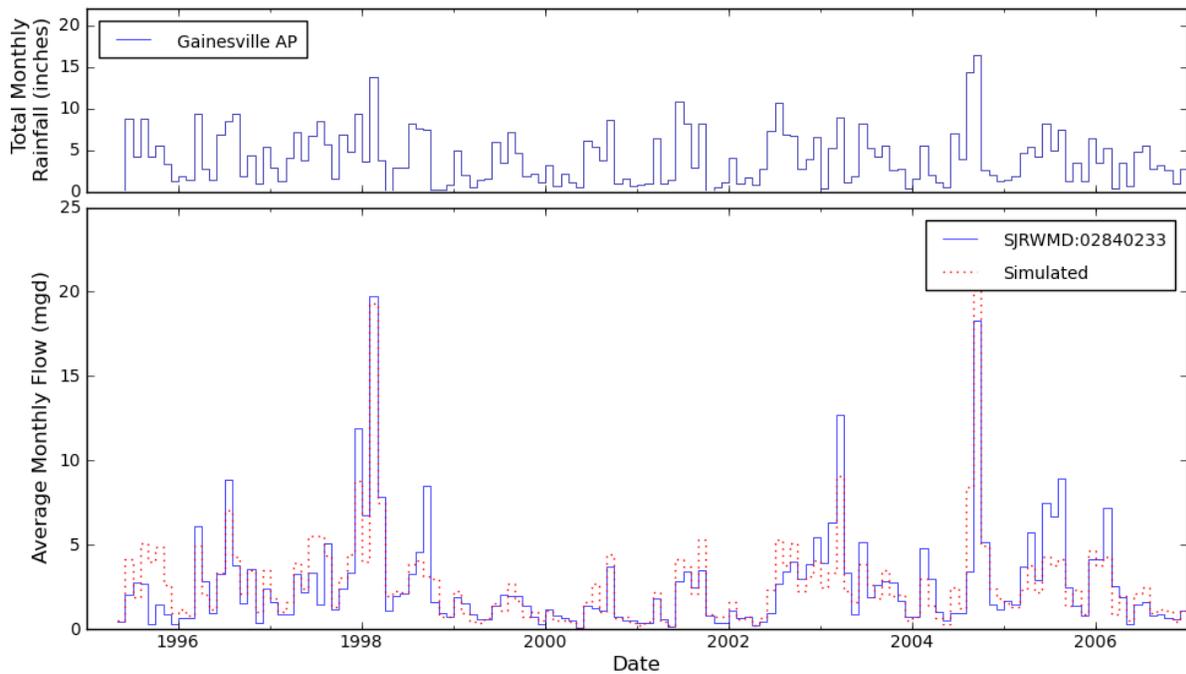


Figure 3.L.26: Little Hatchet Creek monthly hydrograph

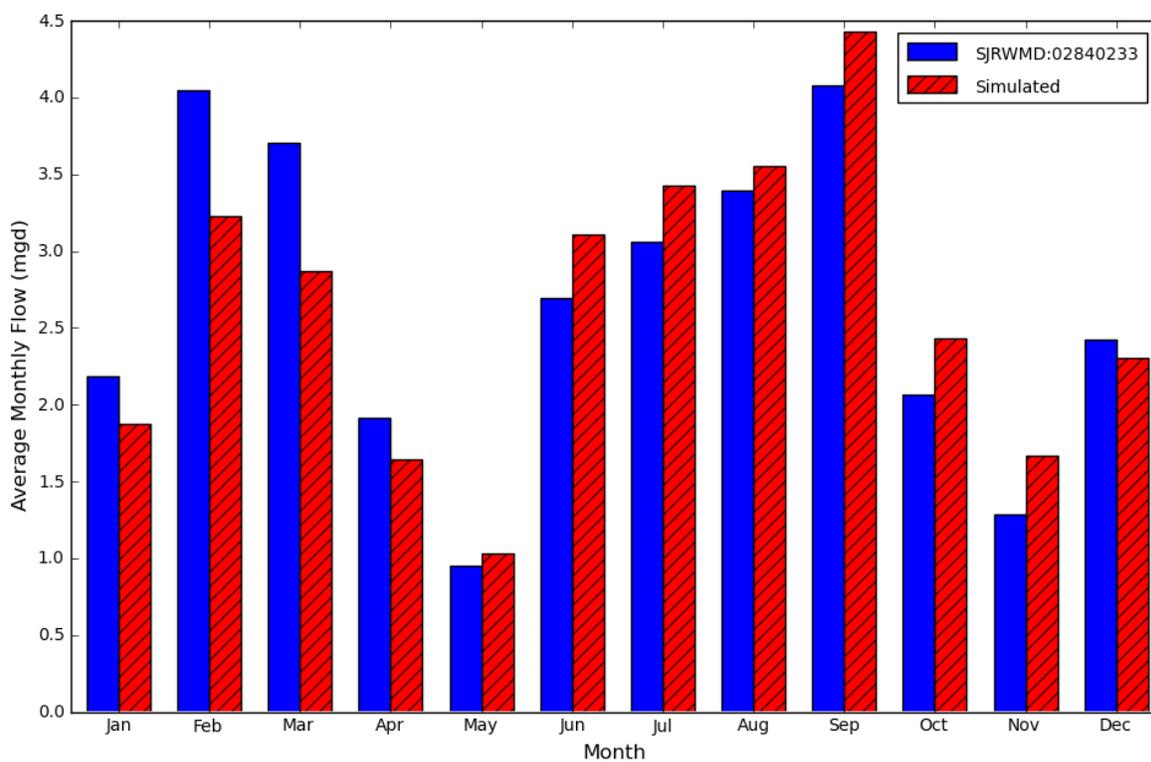


Figure 3.L.27: Little Hatchet Creek average monthly flow

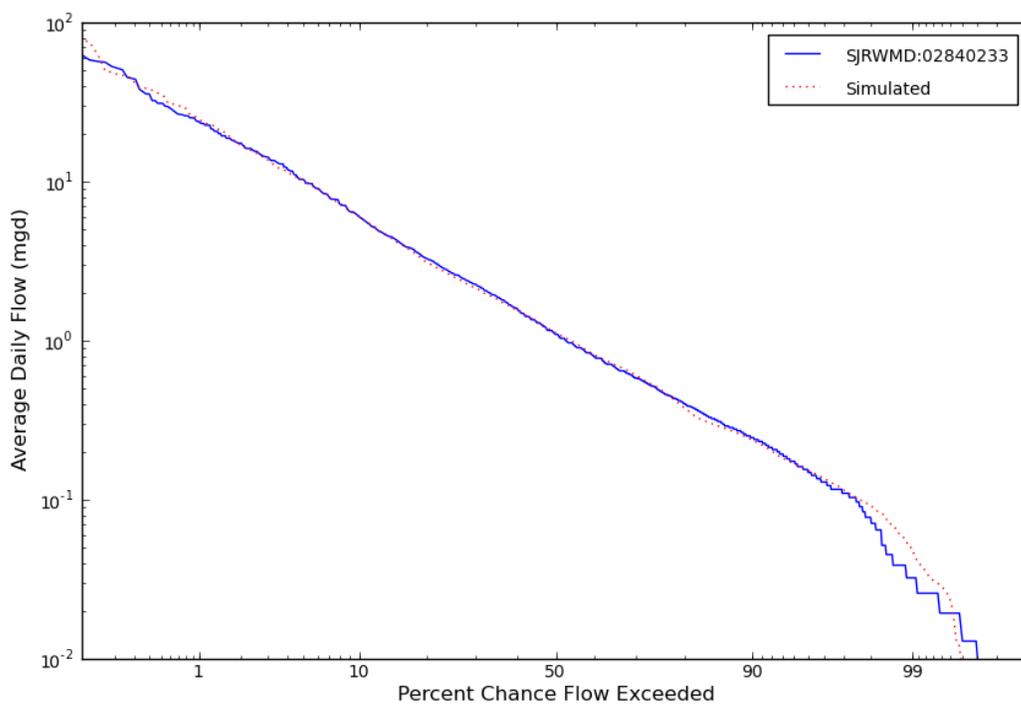


Figure 3.L.28: Little Hatchet Creek exceedance probability curve

7G UPPER ORANGE CREEK WATERSHED. NEWNANS LAKE SUBWATERSHEDS

The Newnans Lake subwatershed has a drainage area of 114.8 square miles and is a combination of the Hatchet Creek, Bee Tree Creek, Little Hatchet Creek, and an additional 5 subbasins surrounding Newnans Lake. Subbasin 11 (Forest Creek) which has a drainage area of 7.7 square miles is an urban basin with primarily A and B soils. This subbasin was considered similar to the Little Hatchet Creek (subbasin 9) so the same parameters were used for subbasin 11 that were used for Little Hatchet Creek. The remaining 41.1 square miles consisting of subbasin 8 (Downstream Hatchet Creek), subbasin 10 (Gum Root Swamp), subbasin 12 (unnamed Tributary on Southeast portion of Newnans Lake), and subbasin 13 (Newnans Lake) were all calibrated together. This subbasin was primarily calibrated to stage in order to best incorporate the amount of water being lost from the lake when Newnans Lake discharge through Prairie Creek was zero. The discharge through Prairie Creek was compared to the modeled discharge from Lake Newnans to make sure reasonable results were obtained.

The model used Gainesville Airport rainfall station and the Gainesville evaporation for the four subbasins being calibrated with Newnans Lake stage data. The current SJRWMD gage on Newnans Lake (04831007) on the southwest side of Newnans Lake. The SJRWMD has collected data at this site since January 2, 1996. Prior to this date data was collected by USGS for Newnans Lake (02240900). This data was used to extend the calibration period for the HSPF Model from January 1995 through December 2006.

The Newnans Lake model needed to be calibrated by stage data collected on Newnans Lake due to the extra information this data gave us through the severe drought of 1999-2002. Stages during this time were continuously below the invert elevation to Prairie Creek, thus discharges were zero throughout this period. When calibrating Newnans Lake using the observed stage weights for the 1998 and 2004 storm elevations and elevations above the control elevation of Newnans Lake, in the duration analysis, were tripled in comparison to the weights for other elevations for Newnans Lake. This put more emphasis on higher elevations and resulted in a better comparison with the observed discharge data at Prairie Creek.

Two special actions were needed for the Newnans Lake subwatershed in addition to the special actions used by all of the WSIS project models. A Special action for a variable discharge-rating curve through Prairie Creek and a special action for the groundwater outlet from Lake Newnans were included in the Newnans Lake model.

A special action was used to model two different rating curves for the Newnans Lake discharge through Prairie Creek. From 1995 through 2002, the rating curve developed by USGS was used. From 2003 through 2006, a rating curve developed by the SJRWMD was used. The timing of this change not only coincides with SJRWMD taking over the monitoring of this station from USGS but also when the outlet of Newnans Lake was change due to construction for SR-20 at this location.

The groundwater interaction special action explained in a previous section of this report was used for Newnans Lake. Newnans Lake is shown as both a recharge area and discharge area on the St. Johns River Water Management District's groundwater recharge maps. However, when

looking at the way Newnans Lake responded during the 1999-2002 drought the only way to account for this response is if Newnans Lake is a net recharge area to the ground water. The estimate of the stage difference between the surface water and groundwater needed for this special action was determined by subtracting the SJRWMD observed stage at the Sparr Well (06691640), located south of Orange Lake, from the modeled stage at Newnans Lake.

Parameter Estimation Program (PEST) was applied for HSPF model parameters calibration to the 10 parameters according to the WSIS project general model parameters guideline and ranges. The observed annual mean elevation for Newnans Lake was 65.13 ft NGVD29. The simulated elevation over the calibration was 65.10 ft NGVD29. The model goodness-of-fit statistics resulted in a Nash-Sutcliffe coefficient of 0.86. During the process of hydrologic calibration, the daily elevation-frequency duration curves and the correlation of simulated and observed daily elevations are evaluated. Furthermore, the comparison of simulated and observed elevations is performed for monthly values. The plots for these comparisons are provided in the following subsection. Based on the results of hydrologic calibration, it is concluded that the HSPF model reasonably represents the hydrologic processes of the subwatershed.

Although no parameters were calibrated using discharge data at Prairie Creek (08631958), the modeled discharge was compared to observed discharge at Prairie Creek to confirm that the model had a reasonable calibration. The tables and plots for this comparison are provided in the following subsection.

The issue, which causes much of the difference between observed and simulated data is the continued underestimation of elevation and discharge during 2005.

Table 3.L.11: Calibration Model Performance

Nash-Sutcliffe (Monthly Mean Water Level)	Percent Error of the Mean
0.86	-0.05

Table 3.L.12: Descriptive Calibration Statistics

Statistic (Daily Water Level (ft))	Observed (SJRWMD:04831007)	Simulated
Average	65.13	65.10
Median	65.18	65.38
Variance	3.75	2.92
Standard Deviation	1.94	1.71
Skew	0.15	-0.04
Kurtosis	-0.32	0.16
Minimum	60.86	61.02
Maximum	71.16	70.63
Range	10.30	9.61

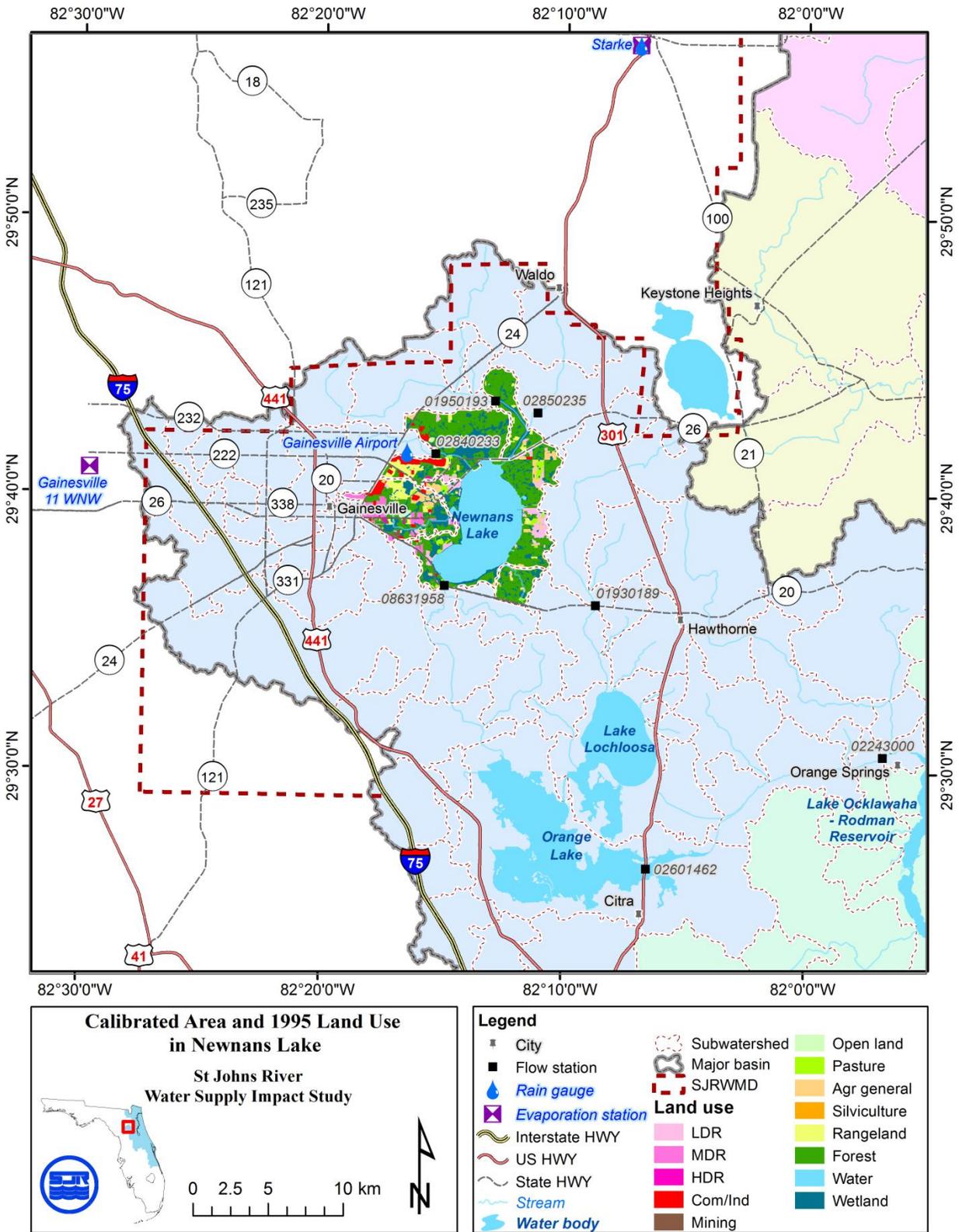


Figure 3.L.29: Newnans Lake land use map

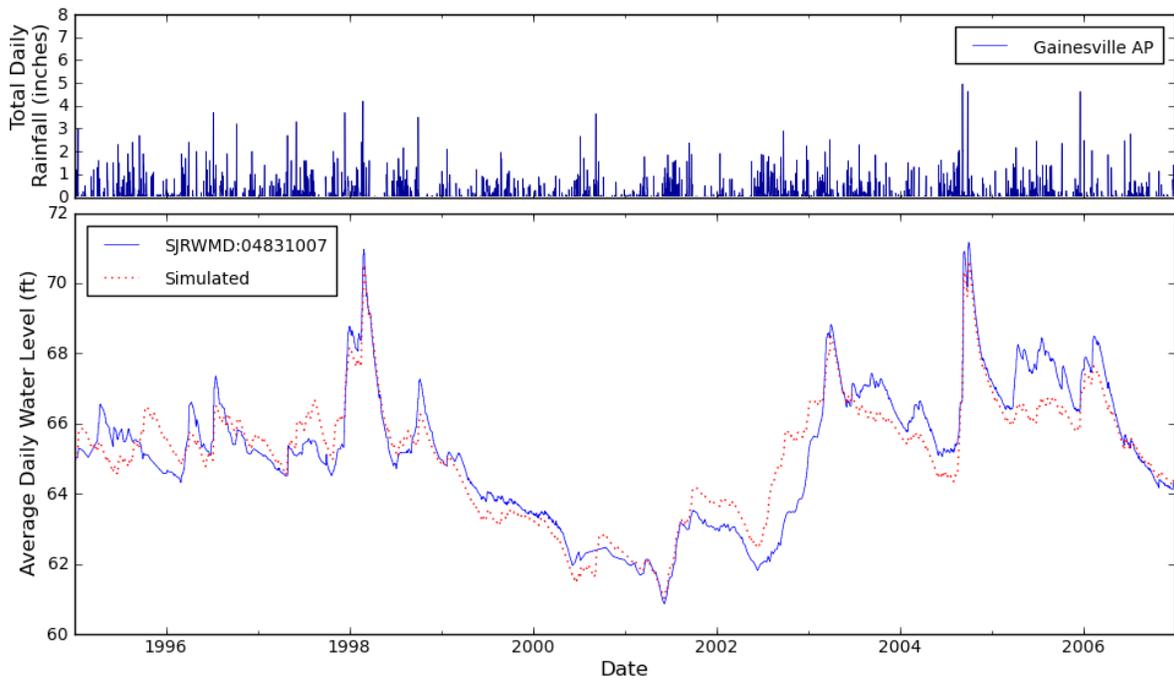


Figure 3.L.30: Newnans Lake daily hydrograph

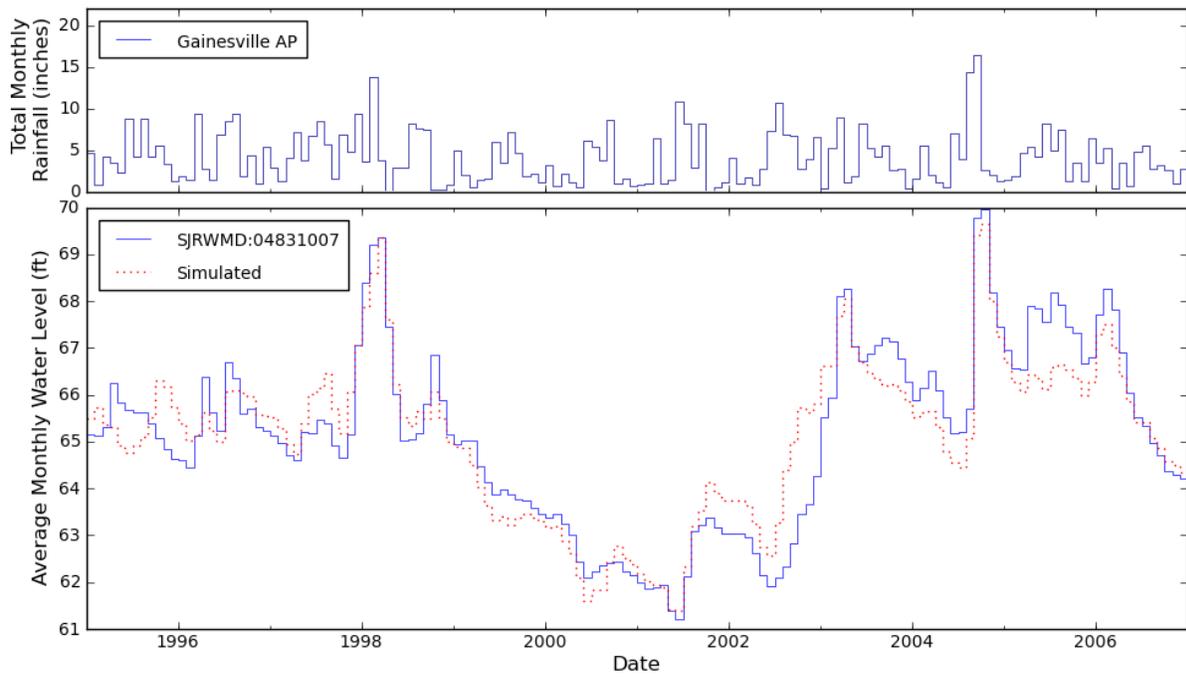


Figure 3.L.31: Newnans Lake monthly hydrograph

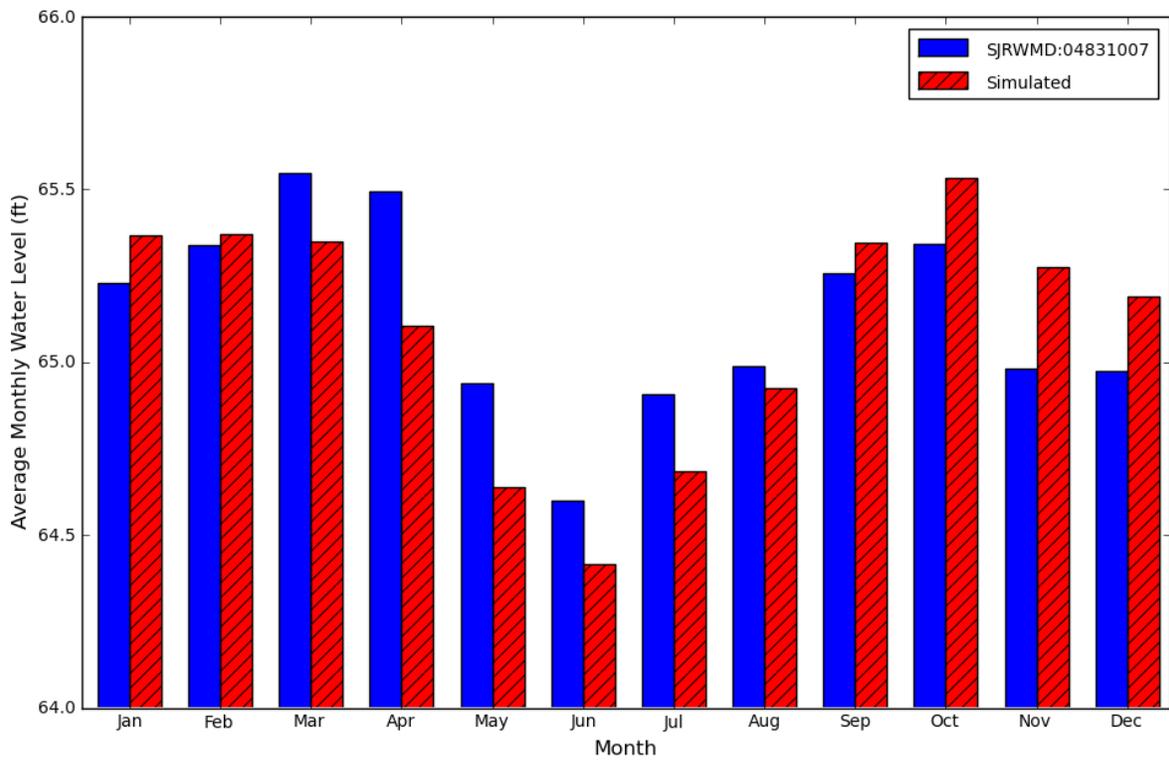


Figure 3.L.32: Newnans Lake average monthly flow

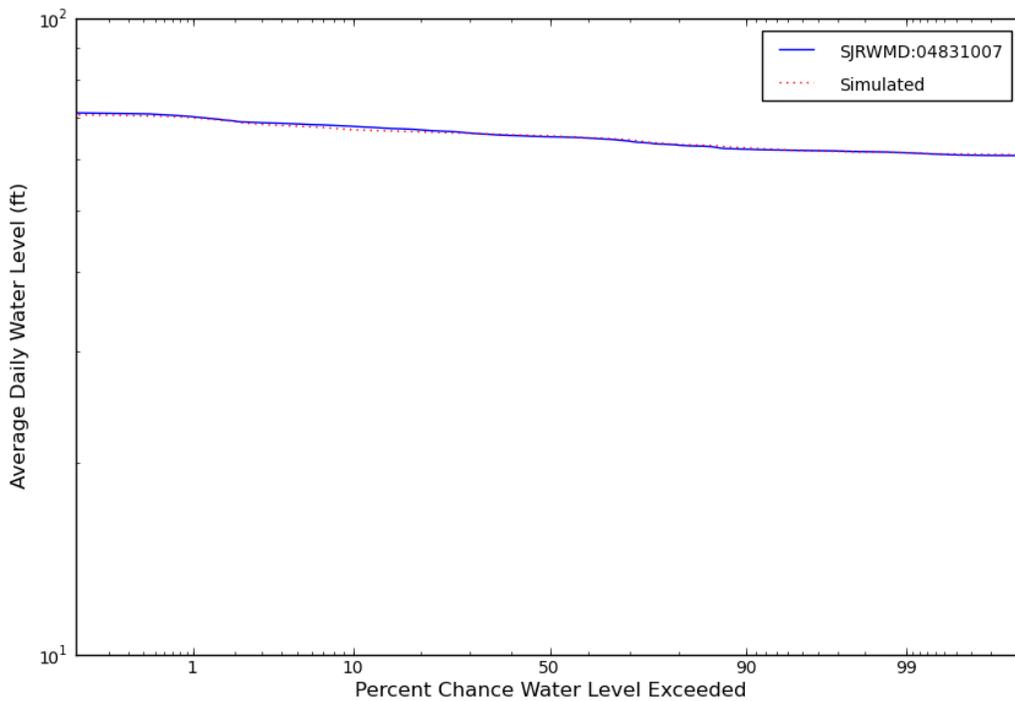


Figure 3.L.33: Newnans Lake exceedance probability curve

7G UPPER ORANGE CREEK WATERSHED. PRAIRIE CREEK SUBWATERSHEDS

Prairie Creek is the discharge gage for the Newnans Lake Basin. This section of the appendix presents the statistics for comparing modeled and observed discharges. However, these statistics were not used in the direct calibration of Newnans Lake as described in the previous section of this report.

Table 3.L.13: Calibration Model Performance

Nash-Sutcliffe (Monthly Mean Flow)	Percent Error of the Mean
0.90	-6.17

Table 3.L.14: Descriptive Calibration Statistics

Statistic (Daily Flow (mgd))	Observed (SJRWMD:08631958)	Simulated
Average	34.36	32.24
Median	20.68	20.71
Variance	3655.10	3374.97
Standard Deviation	60.46	58.09
Skew	4.60	5.63
Kurtosis	27.24	42.89
Minimum	0.00	0.00
Maximum	624.34	710.85
Range	624.34	710.85

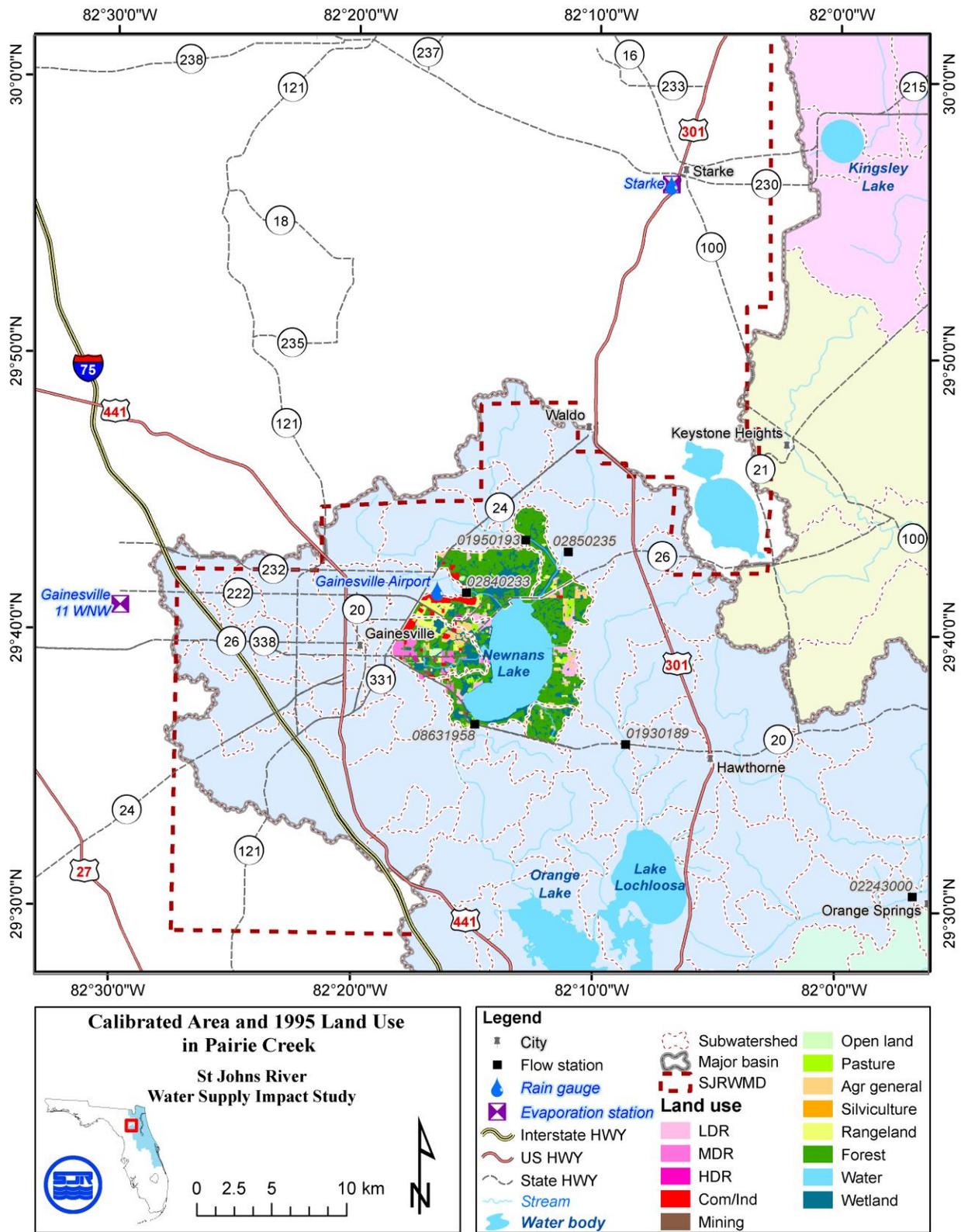


Figure 3.L.34: Prairie Creek land use map

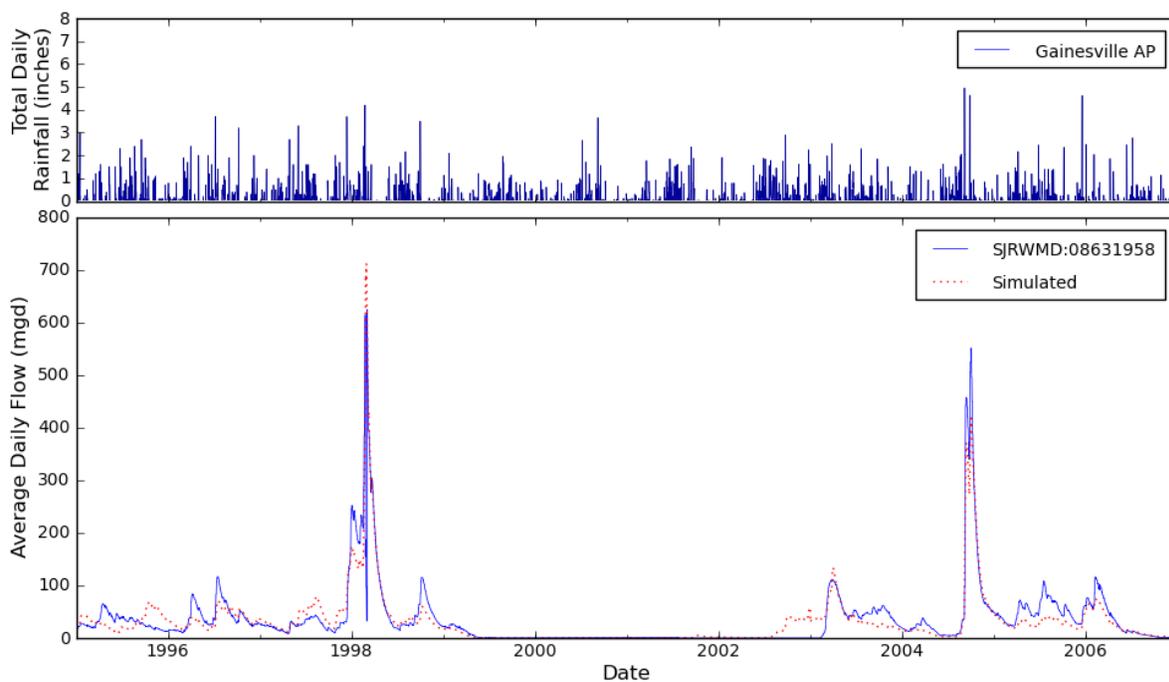


Figure 3.L.35: Prairie Creek daily hydrograph

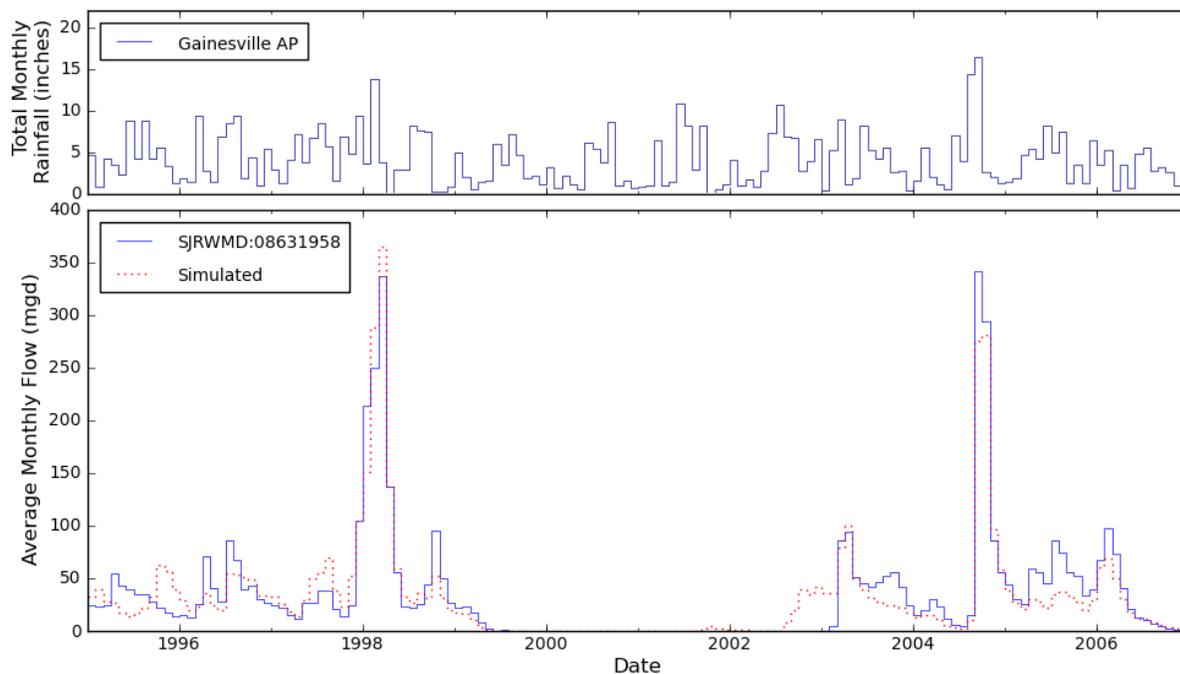


Figure 3.L.36: Prairie Creek monthly hydrograph

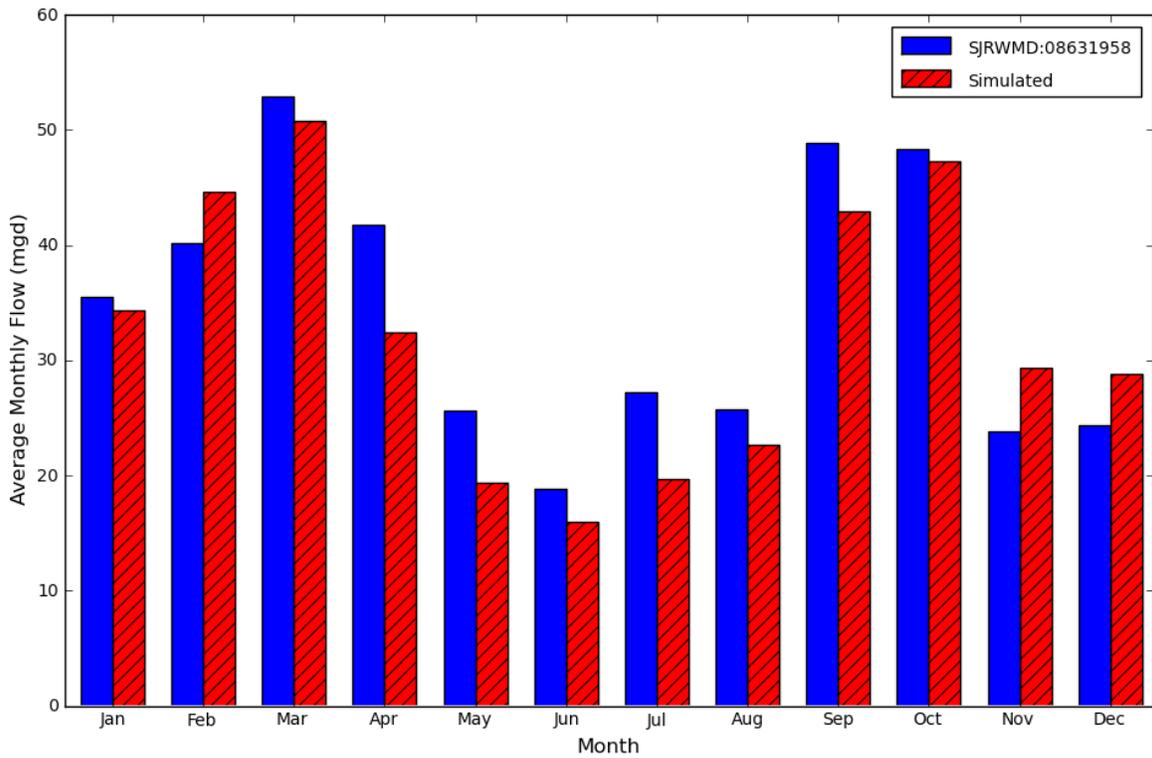


Figure 3.L.37: Prairie Creek average monthly flow

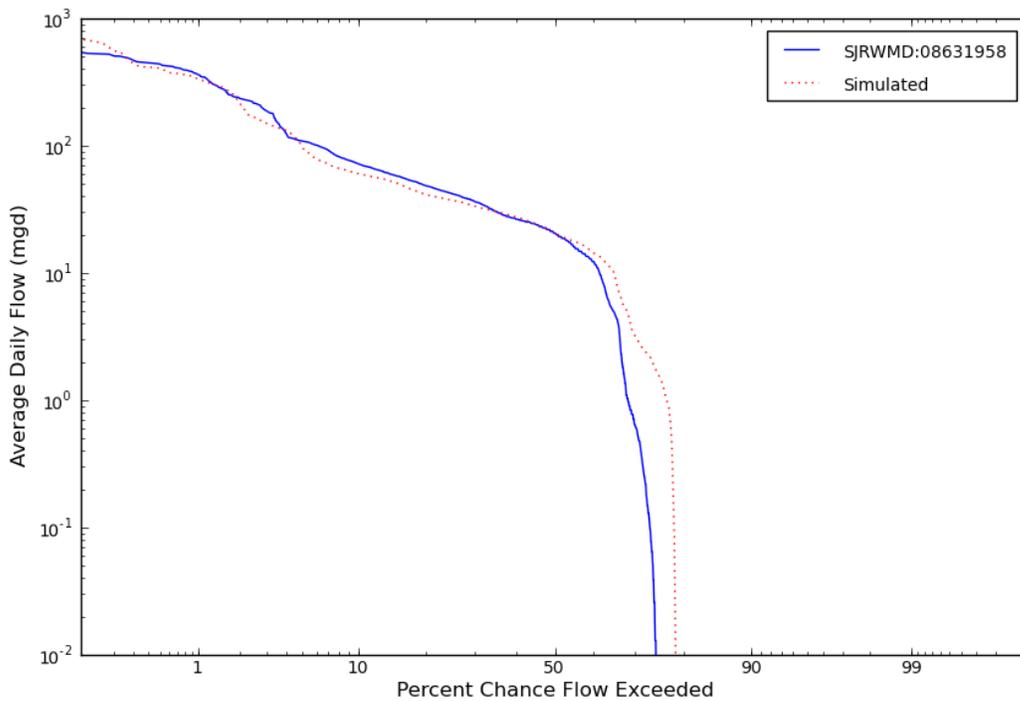


Figure 3.L.38: Prairie Creek exceedance probability curve

7G UPPER ORANGE CREEK WATERSHED. LOCHLOOSA CREEK SUBWATERSHEDS

The Lochloosa Creek subwatershed has a drainage area of 37.2 square miles and is divided into 4 subbasins. Subbasin 16 (Lake Elizabeth) is a small lake basin, subbasin 16 flows into subbasin 17 (Morans Prairie). Subbasin 17 and subbasin 18 (Unnamed Slough) both drain into subbasin 19 (Lochloosa Creek above SR-20). Lochloosa Creek similar to Hatchet Creek has a well defined channel surrounded by a large riverine swamp. The wetland area of Lochloosa Creek is 18 percent of the total area of this subbasin.

The model used Gainesville Airport rainfall station and the Starke evaporation for all four subbasins of Lochloosa Creek. The gage on Lochloosa Creek (01930189) is located downstream of the SR-20 bridge. The gage has been maintained by the SJRWMD since October 1998. From June 14, 1995 when the station was established through September 1998 USGS maintained data at this station. Therefore, the calibration period for the HSPF Model was from June 1995 through December 2006.

Similar issues existed with the rating curve for Lochloosa Creek at SR-20 that occurred for Prairie Creek at SR-20. The agency that collected this data changed from USGS to the SJRWMD at approximately the same time construction for the widening of SR-20 occurred. However, at this location we were not calibrating to stage so the model result was not nearly as sensitive to the rating curve so the USGS rating curve was used in the model for the entire period.

Parameter Estimation Program (PEST) was applied for HSPF model parameters calibration to the 10 parameters according to the WSIS project general model parameters guideline and ranges. The observed annual mean discharge for Lochloosa Creek was 8.64 mgd. The simulated discharge over the calibration was 8.59 mgd. The model goodness-of-fit statistics resulted in a Nash-Sutcliffe coefficient of 0.86. During the process of hydrologic calibration, the daily flow-frequency duration curves and the correlation of simulated and observed daily flows are evaluated. Furthermore, the comparison of simulated and observed flows is performed for monthly values. The plots for these comparisons are provided in the following subsection. Based on the results of hydrologic calibration, it is concluded that the HSPF model reasonably represents the hydrologic processes of the subwatershed.

The one issue in this basin is the continued underestimation of discharge in 2005. This issue is even greater in this basin than in the Newnans Lake basins with total modeled discharge being over 50% less than then the observed discharge for 2005. If much of this issue is caused by the rainfall dataset used this can be explained because the rain station used is farther from the Gainesville Airport than the basins contributing to Newnans Lake

Table 3.L.15: Calibration Model Performance

Nash-Sutcliffe (Monthly Mean Flow)	Percent Error of the Mean
0.86	-0.65

Table 3.L.16: Descriptive Calibration Statistics

Statistic (Daily Flow (mgd))	Observed (SJRWMD:01930189)	Simulated
Average	8.64	8.59
Median	0.59	1.86
Variance	907.13	729.15
Standard Deviation	30.12	27.00
Skew	11.04	9.33
Kurtosis	183.57	115.60
Minimum	0.00	0.00
Maximum	728.40	500.85
Range	728.40	500.85

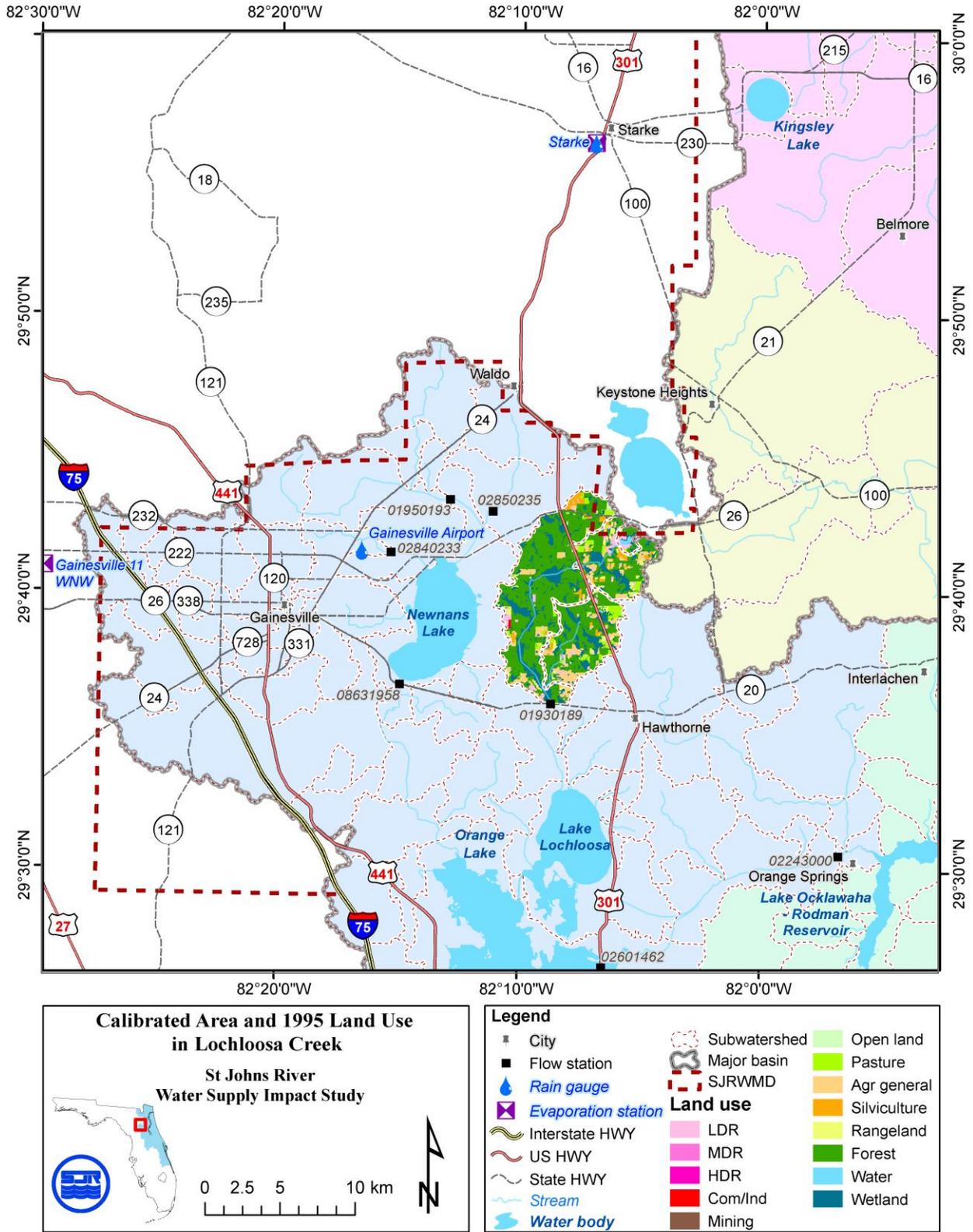


Figure 3.L.39: Lochloosa Creek land use map

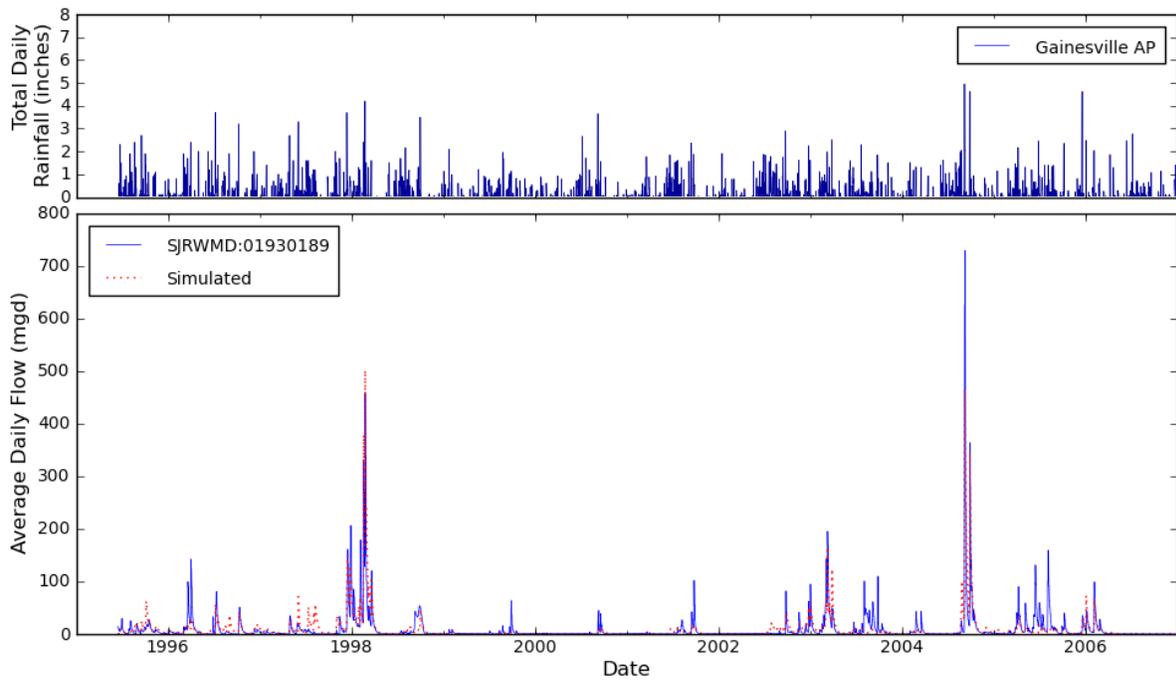


Figure 3.L.40: Lochloosa Creek daily hydrograph

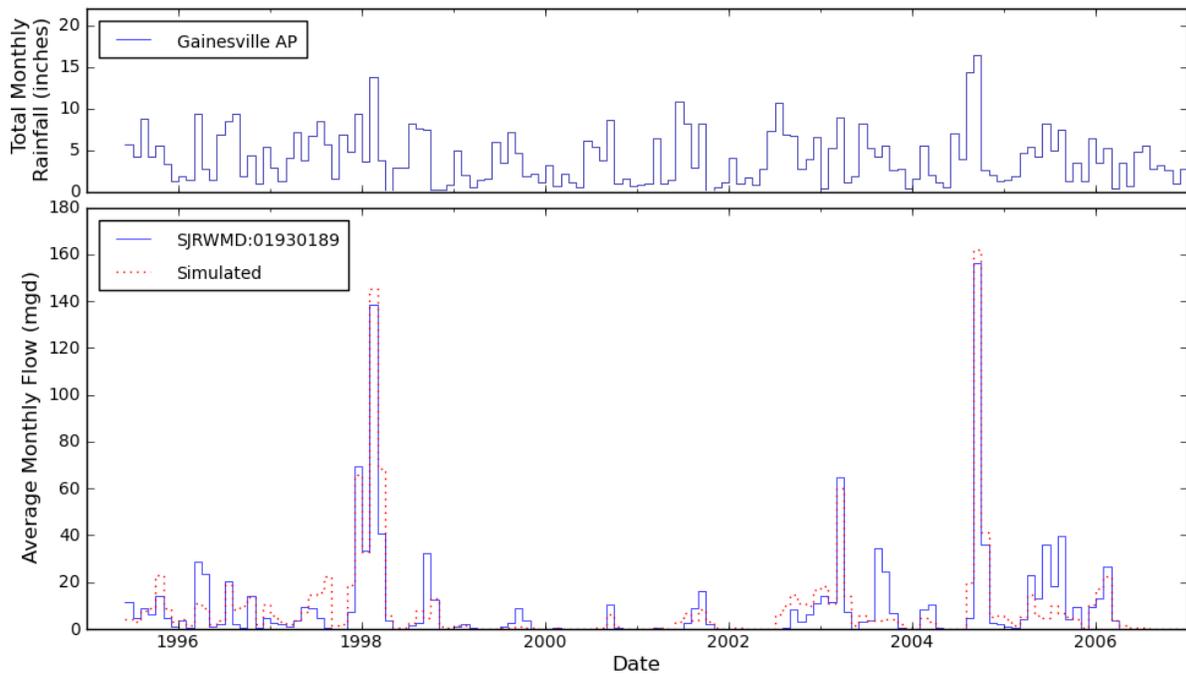


Figure 3.L.41: Lochloosa Creek monthly hydrograph

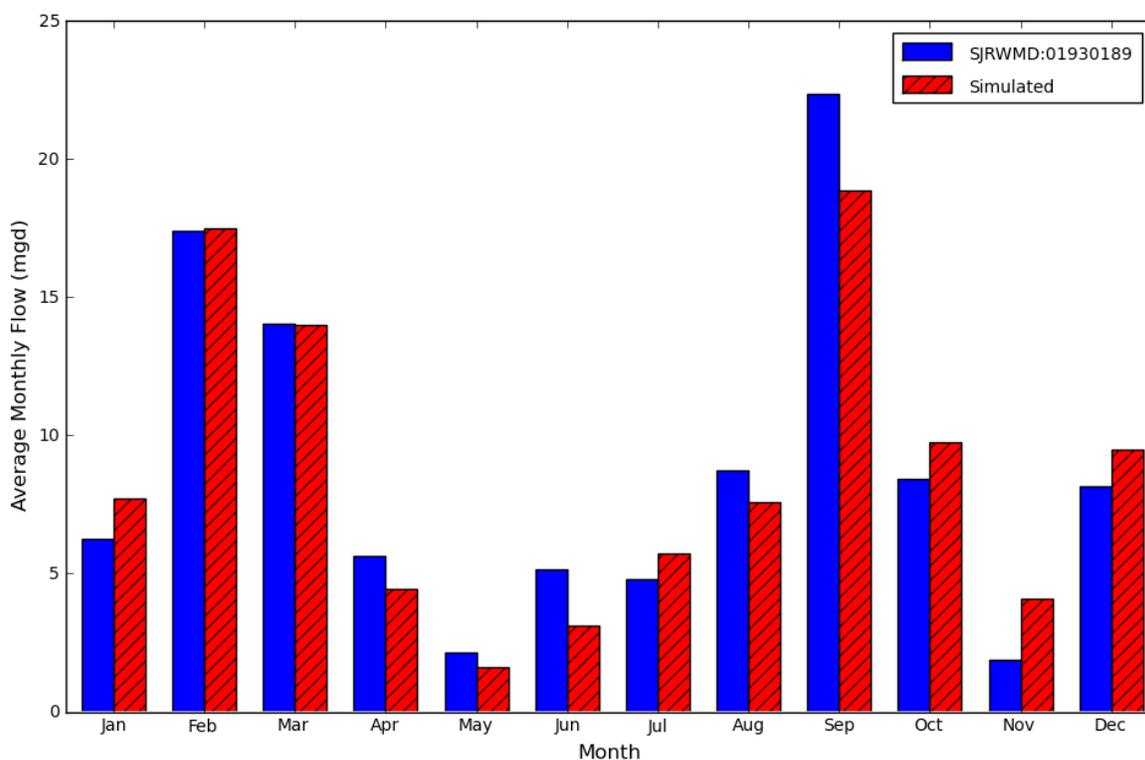


Figure 3.L.42: Lochloosa Creek average monthly flow

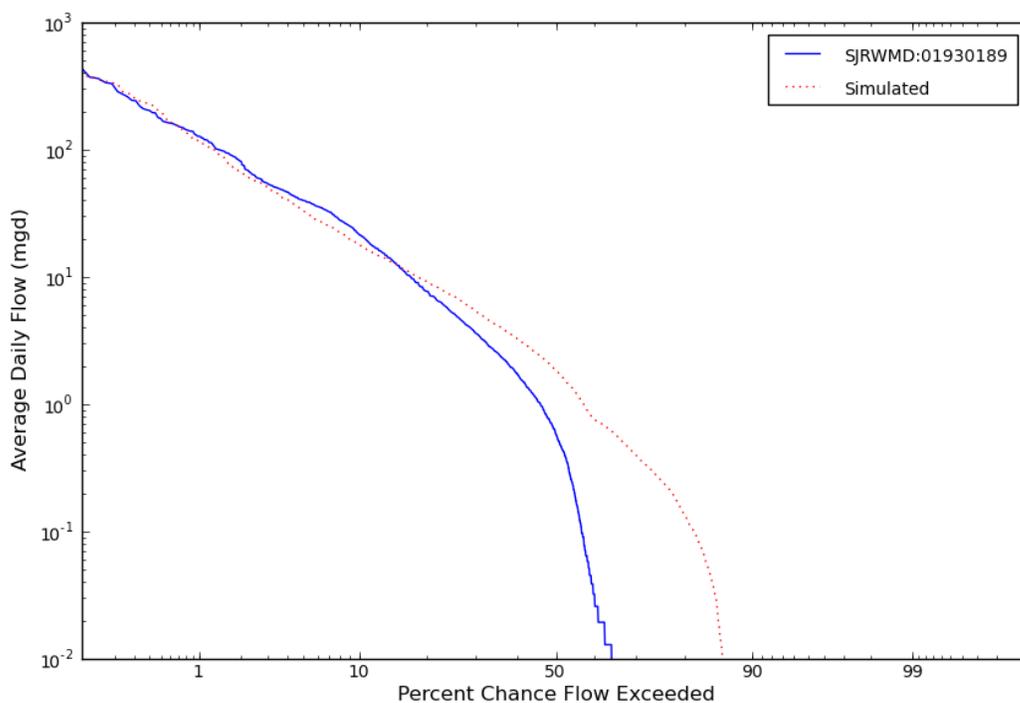


Figure 3.L.43: Lochloosa Creek exceedance probability curve

7G UPPER ORANGE CREEK WATERSHED. ORANGE LAKE SUBWATERSHEDS

Orange Lake watershed has a total drainage area of 291.8 square miles. This includes Newnans Lake (114.8 square miles) and Lochloosa Lake (97.9 square miles). The discharge from Newnans lake was input directly from the Newnans Lake model discussed in a previous section of this report.

Orange Lake and Lochloosa Lake was calibrated together using lake stages from both lakes in the objective function. Both Lochloosa Lake and Orange Lake have extensive shallow marshes surrounding both lakes with similar landuse and soil types for the basins, which drain into the lakes. These lakes also have similar elevations, thus discharge between the two lakes thru Cross Creek is controlled by the water levels of both lakes. Therefore, Orange and Lochloosa lakes were calibrated together.

Parameters for Lochloosa Creek (subbasins 16-19, 37.2 square miles) were copied into this model for these basins. Parameters for subbasins 20 thru 27 (Lochloosa Lake, 60.7 square miles) and 31 thru 37 (Orange Lake, 79.1 square miles) were calibrated together with a dual objective function for both Orange Lake stage and Lochloosa Lake stage.

The combined Orange Lake and Lochloosa Lake model has two outlets to the Lower Orange Lake watershed. The primary outlet discharges from Orange Lake into Orange Creek. Discharge from this outlet, is controlled by the Orange Lake Weir. The weir is located just east of SR-301. The second outlet is Lochloosa Slough, which flows to Orange Creek when Lochloosa Lake is above 57.8 feet NGVD29. The discharge for both of these outlets, was directly input into the Lower Orange Creek Model at the appropriate locations.

The model used Gainesville Airport rainfall station and the Gainesville evaporation for all subbasins being calibrated with Orange Lake and Lochloosa Lake stage data. The current SJRWMD gage on Orange Lake (02601462) is near Boardman on the West shore of Orange Lake. The SJRWMD has collected data at this site since October 11, 1995. Prior to this date data was collected by USGS for Orange Lake (02242450). The current SJRWMD gage on Lochloosa Lake (71481615) on the East shore of Lochloosa Lake. The SJRWMD has collected data at this site since October 17, 1995. Prior to this date data was collected by USGS for Orange Lake (02242400). The USGS data for Orange and Lochloosa lakes was used to extend the calibration period for the HSPF Model from January 1995 through December 2006.

Similar to Newnans Lake discussed in a previous section of this report this model needed to be calibrated to lake stage in order to simulate elevations in Lochloosa Lake and Orange Lake during periods when discharge was zero. When calibrating Orange Lake and Lochloosa Lake using the observed stage weights for the 1998 and 2004 storm elevations and elevations above the control elevation of these lakes in the duration analysis was tripled in comparison to the weights for other elevations for the lakes. This put more emphasis on higher elevations and resulted in a better comparison with the observed discharge data at Orange Lake Weir. This calibration was done by combining Lochloosa Lake stage and Orange Lake stage into combined series of objective functions.

Several additional special actions were needed for Orange and Lochloosa lakes subwatersheds in addition to the special actions used by all of the WSIS project models. A special action for a variable discharge-rating curve through reach 32 and 33 of Camps Canal and a special action for discharge to Paynes Prairies was used to calculate discharge through Camps Canal. The groundwater connections special action was used for spring flow into Lochloosa Lake and flow through the Orange Lake sink into the groundwater. A special action to calculate discharge from Lochloosa Lake to Orange Lake was to estimate the effect of backwater from Orange Lake on these discharges.

The special action described for Prairie Creek in the Newnans Lake section of this report for two different ratings curves was needed for Camps Canal (Reach 32 and 33). The changed ratings for Prairie Creek caused by the construction at SR-20 also affected the ratings for reach 32 and reach 33.

A special action for subbasin 32 was needed to split flow from Prairie Creek to discharge to both Paynes Prairie and Camps Canal. To calculate an estimate of the Paynes Prairie discharge the SJRWMD observed data for Camps Canal (08661963) was subtracted from the observed data for Prairie Creek (08631958). A regression analysis between the Paynes Prairie discharge and the Prairie Creek discharge was performed. The special actions block used the results of this analysis to determine an approximate discharge to Paynes Prairie and Camps Canal for a given discharge of Prairie Creek.

The groundwater interaction special action explained in a previous section of this report was used for Lochloosa Lake. Lochloosa Lake similar to Newnans Lake is both a recharge and discharge area to the groundwater. In addition to this, small springs are document into the lower section of Lochloosa Creek. With this information and the reaction of Lochloosa Lake during low flow periods Lochloosa Lake was determined to be a net discharge area from the ground water to the surface water. The estimate of the stage difference between the surface water and groundwater needed for this special action was determined by subtracting the SJRWMD observed stage at the Hawthorne Well (10321288), located northeast of Lochloosa Lake, from the modeled stage at Lochloosa Lake.

The groundwater interaction special action explained in a previous section of this report was used for Orange Lake. Orange Lake has a large documented sink on the southwest side of the lake. When the lake is low this sink is connected to the main body of Orange Lake by only a small channel. Therefore, two separate K values for this sink were used based on the Orange Lake elevation to estimate this groundwater recharge from Orange Lake. The estimate of the stage difference between the surface water and groundwater needed for this special action was determined by subtracting the SJRWMD observed stage at the Sparr Well (06691640), located south of Orange Lake, from the modeled stage at Orange Lake.

A special action to calculate discharge through Cross Creek was used in this model. Cross Creek discharge is controlled by both the Orange Lake and Lochloosa Lake stages. A HEC-RAS model was developed from a survey of seven cross-sections of Cross Creek. Lake Elevations when this survey was done and surveyed water surface elevations were used to calibrate this model. A range of discharges and tail water elevations (Orange Lake elevation) was input into the HEC-

RAS model to develop a series of rating curves for Lochloosa Lake. A special action in HSPF was then developed to determine which of these rating curves to use to calculate Cross Creek discharge for the elevations of Lochloosa Lake and Orange Lake at the beginning of each day.

Parameter Estimation Program (PEST) was applied for HSPF model parameters calibration to the 10 parameters according to the WSIS project general model parameters guideline and ranges. The observed annual mean elevation was 55.83 ft NGVD29 for Orange Lake and 57.11 ft NGVD29 for Lochloosa Lake. The simulated elevation was 55.87 ft NGVD29 for Orange Lake and 57.08 ft NGVD29 for Lochloosa Lake over the calibration period. The model goodness-of-fit statistics resulted in a Nash-Sutcliffe coefficient of 0.97 for Orange Lake and 0.88 for Lochloosa Lake. During the process of hydrologic calibration, the daily elevation-frequency duration curves and the correlation of simulated and observed daily elevations are evaluated. Furthermore, the comparison of simulated and observed elevations is performed for monthly values. The plots for these comparisons are provided in the following subsection. Based on the results of hydrologic calibration, it is concluded that the HSPF model reasonably represents the hydrologic processes of the subwatershed.

Although no parameters were calibrated using discharge data at the Orange Lake weir (02601462), the modeled discharge was compared to observed discharge at Orange Lake Weir to confirm that the model had a reasonable calibration. The data collected from USGS and SJRWMD has many long periods of missing record. Orange Lake elevation therefore was used to estimate discharge at this location using the rating curve for this structure. The tables and plots for this comparison of observed and modeled discharges are provided in the following subsection.

The issue, which causes much of the difference between observed and simulated data is the continued underestimation of elevation and discharge during 2005. Most of the difference between observed and modeled discharge is caused by a large underestimation of discharge during 2005. This large difference is caused by continued underestimation of discharge in the local basins and a cumulative effect of all the other errors in the contributing modeled basins. This underestimation of discharge in 2005 was observed in all calibrated basins contributing to the Orange Lake Model. Two factors may contribute to this error. Observed rainfall at Gainesville Airport may have been low compared with the rest of the basin. Rainfall at the Long term NOAA site used in this modeling was 49.98 inches while the SJRWMD rainfall site located on Orange Lake was 55.95 inches. The other contributing factor during 2005 may have been the erosion of several of the outlet structures from the upland swamps of the area during the 2004 hurricanes. This may have caused more discharge from these areas during 2005 than during the rest of the calibration period. This underestimation of discharge in 2005 occurred in all calibration runs tried in the process of calibrating this model.

Table 3.L.17: Calibration Model Performance

Nash-Sutcliffe (Monthly Mean Water Level)	Percent Error of the Mean
0.97	0.03

Table 3.L.18: Descriptive Calibration Statistics

Statistic (Daily Water Level (ft))	Observed (SJRWMD:02611465)	Simulated
Average	55.83	55.85
Median	57.16	57.59
Variance	9.38	9.05
Standard Deviation	3.06	3.01
Skew	-0.73	-0.88
Kurtosis	-0.90	-0.69
Minimum	49.57	49.12
Maximum	60.74	60.31
Range	11.17	11.19

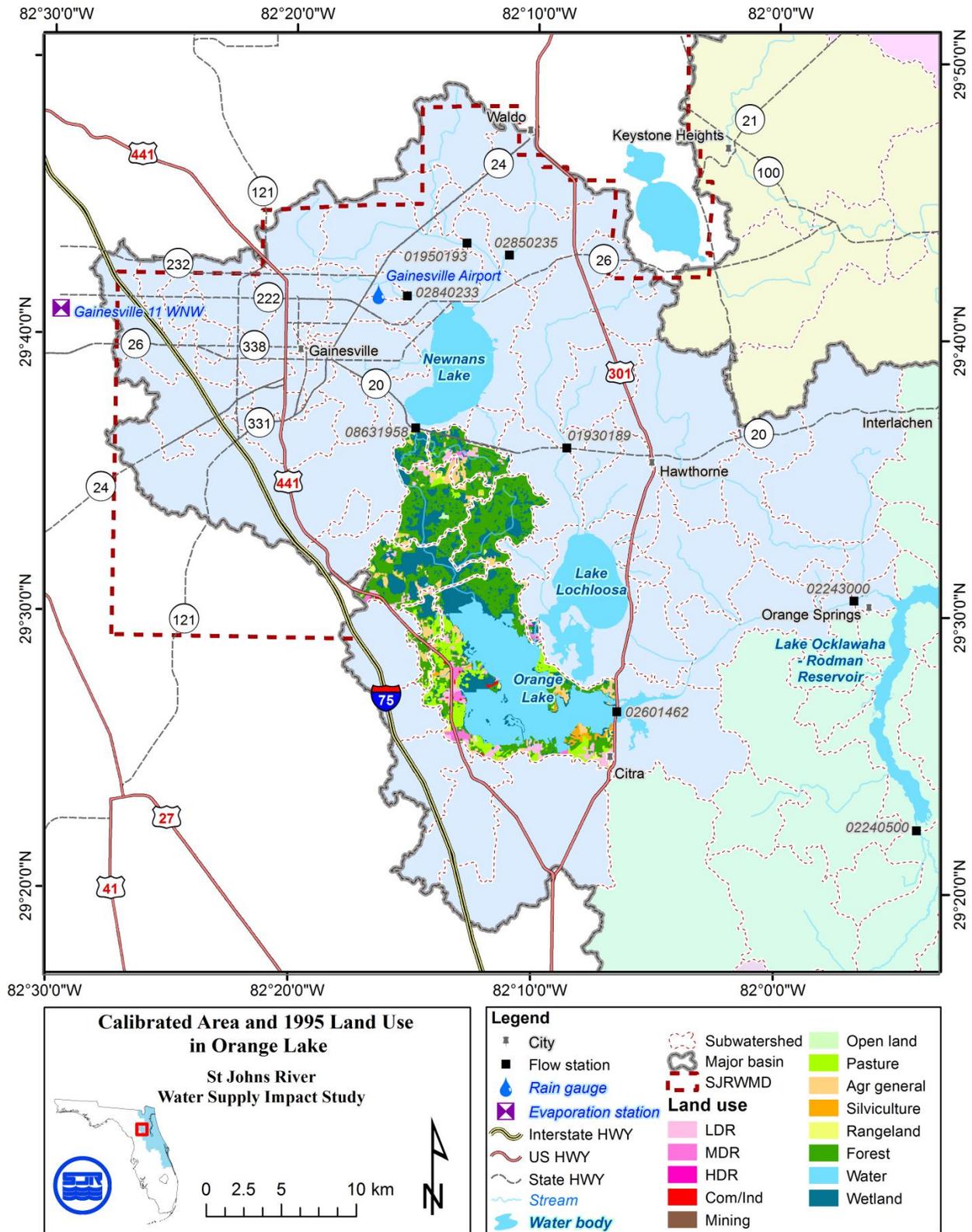


Figure 3.L.44: Orange Lake land use map

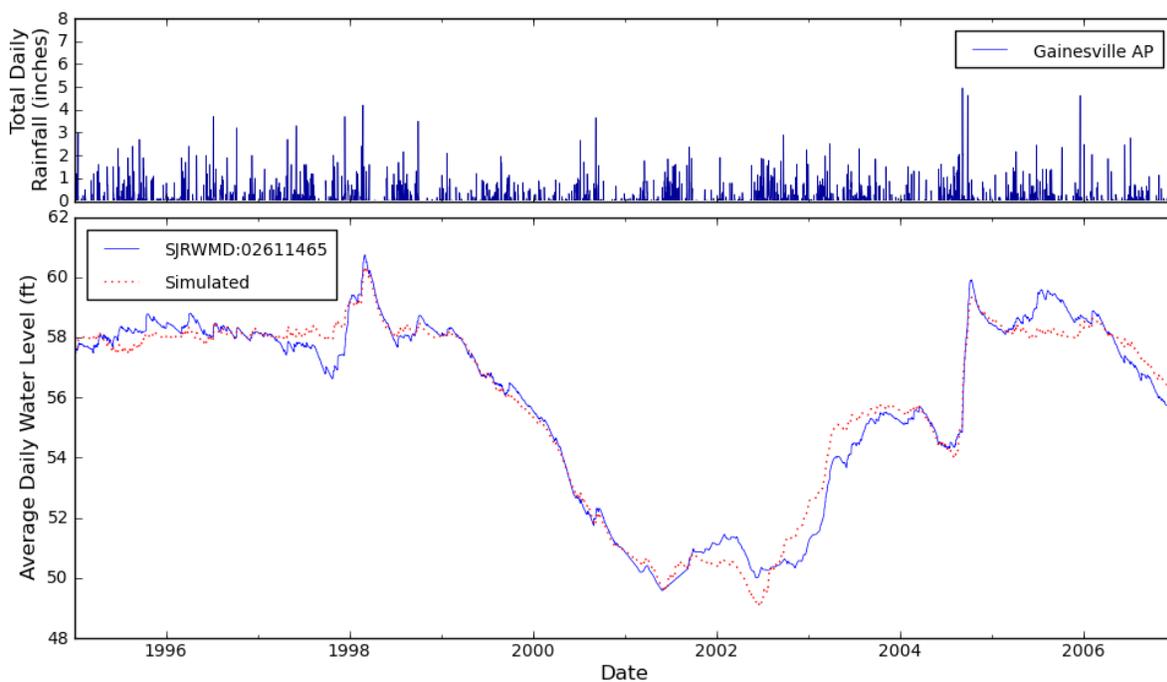


Figure 3.L.45: Orange Lake daily hydrograph

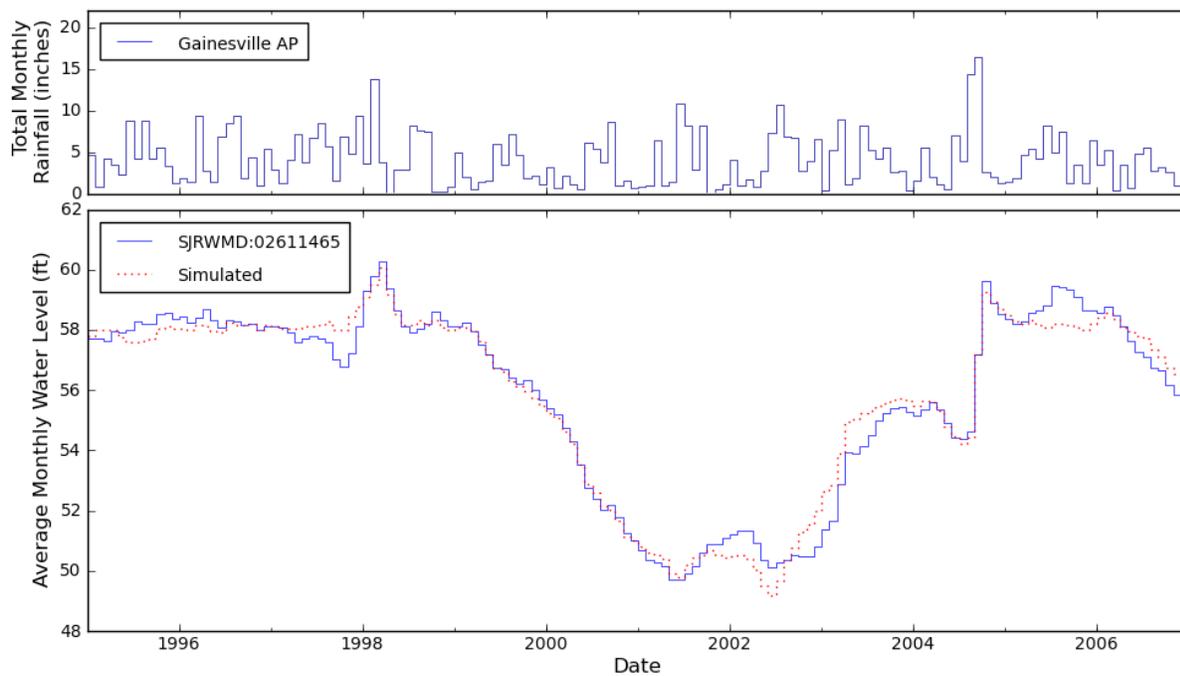


Figure 3.L.46: Orange Lake monthly hydrograph

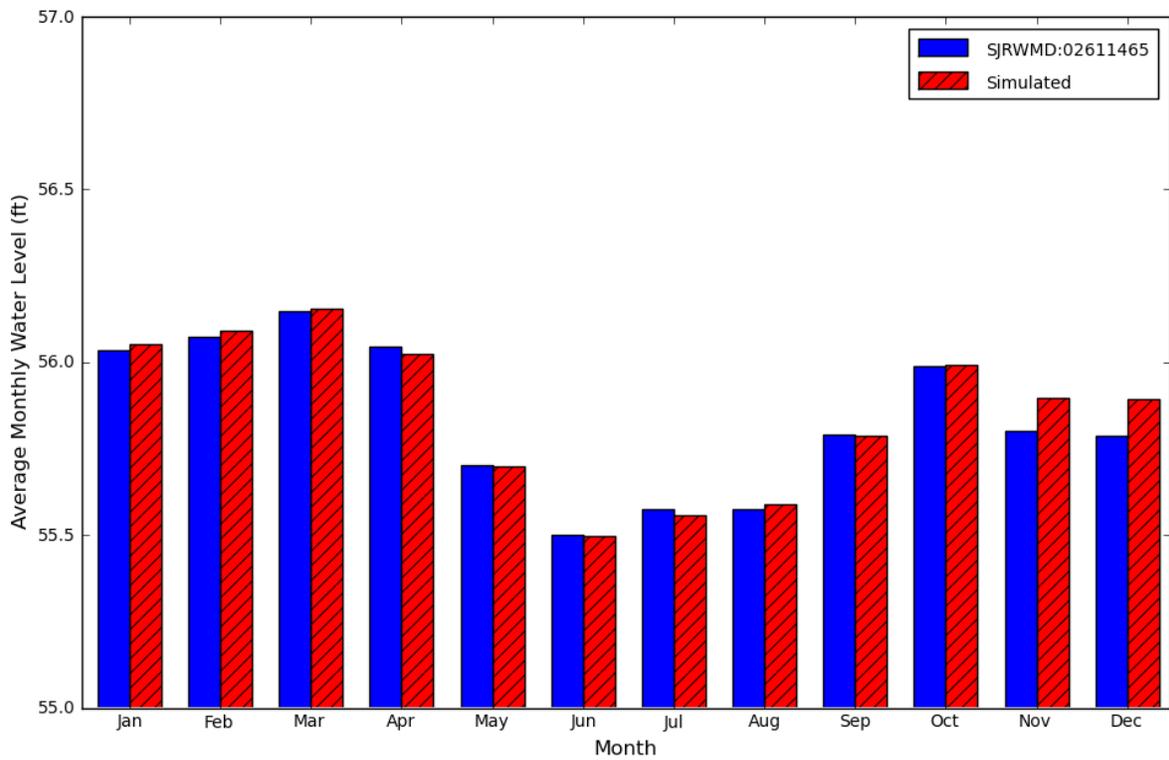


Figure 3.L.47: Orange Lake average monthly flow

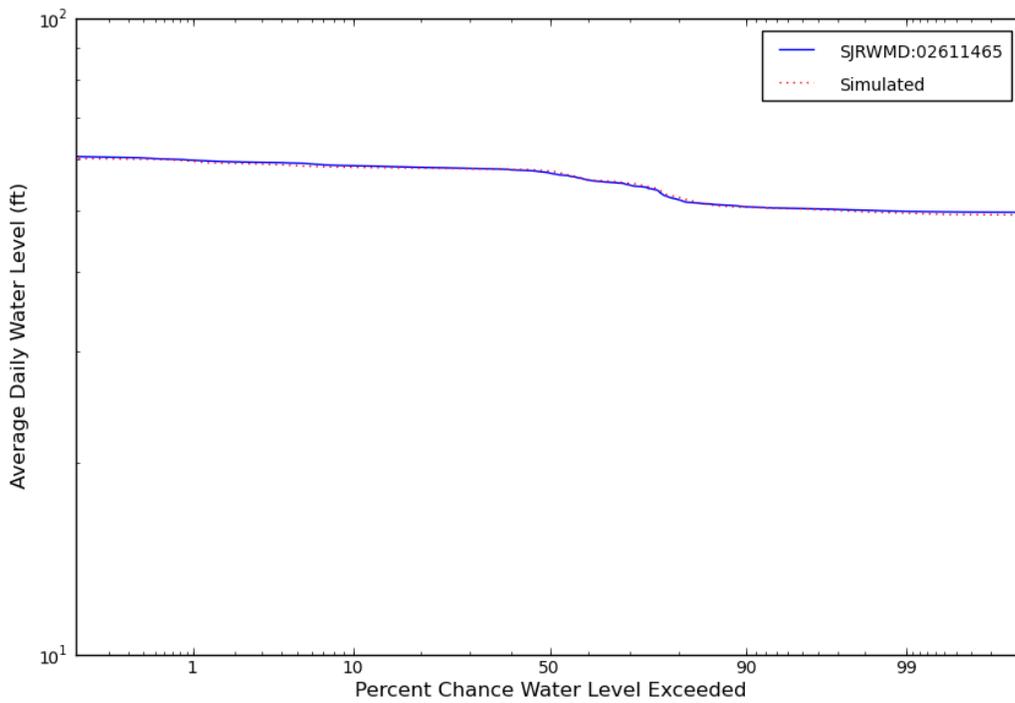


Figure 3.L.48: Orange Lake exceedance probability curve

7G UPPER ORANGE CREEK WATERSHED. LOCHLOOSA LAKE SUBWATERSHEDS

Lochloosa Lake is calibrated in conjunction with Orange Lake as described in the previous section of this appendix.

Table 3.L.19: Calibration Model Performance

Nash-Sutcliffe (Monthly Mean Water Level)	Percent Error of the Mean
0.88	-0.05

Table 3.L.20: Descriptive Calibration Statistics

Statistic (Daily Water Level (ft))	Observed (SJRWMD:71481615)	Simulated
Average	57.11	57.08
Median	57.36	57.11
Variance	2.26	1.95
Standard Deviation	1.50	1.40
Skew	-0.22	-0.20
Kurtosis	-0.84	-0.99
Minimum	53.93	54.22
Maximum	61.01	60.76
Range	7.08	6.54

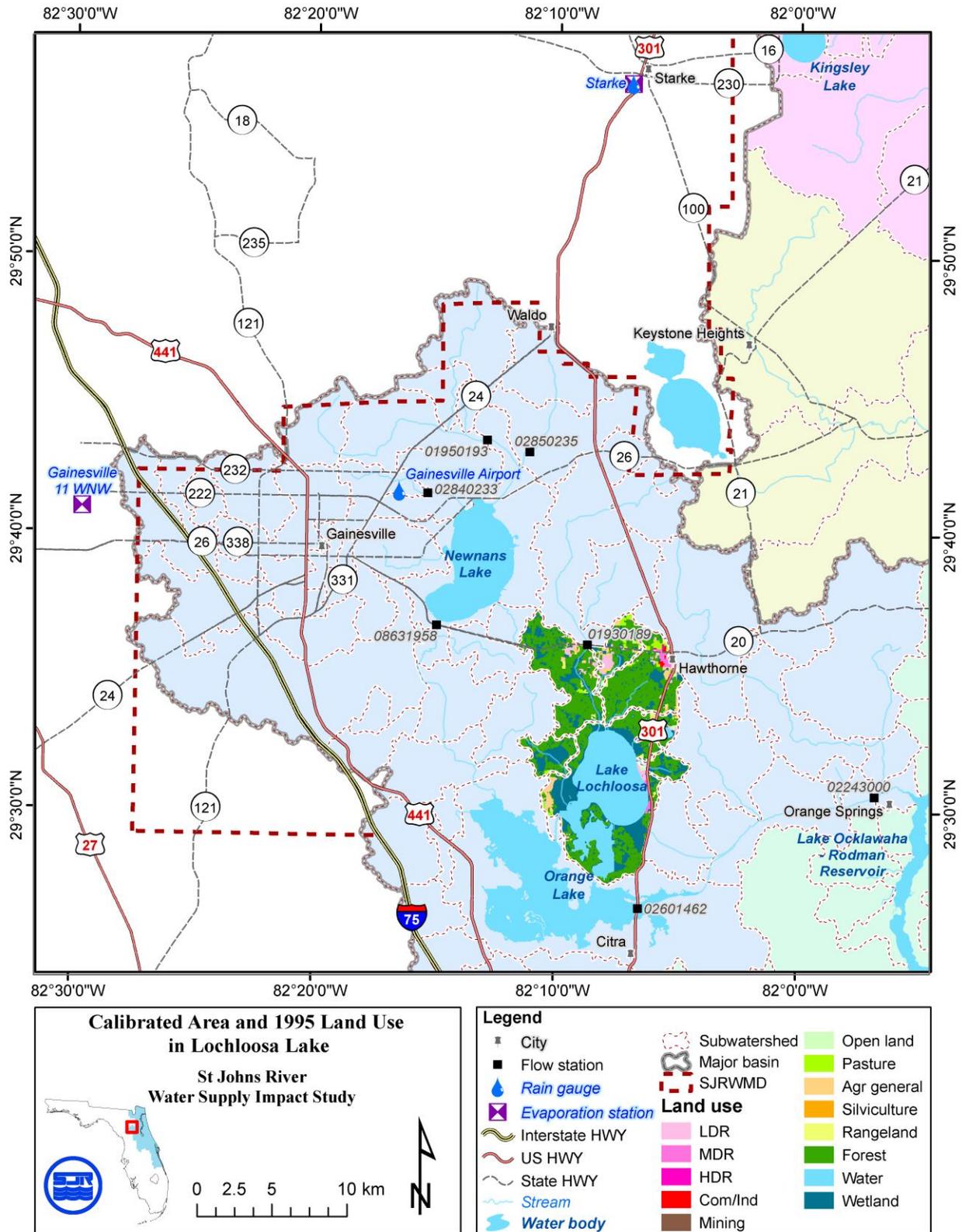


Figure 3.L.49: Lochloosa Lake land use map

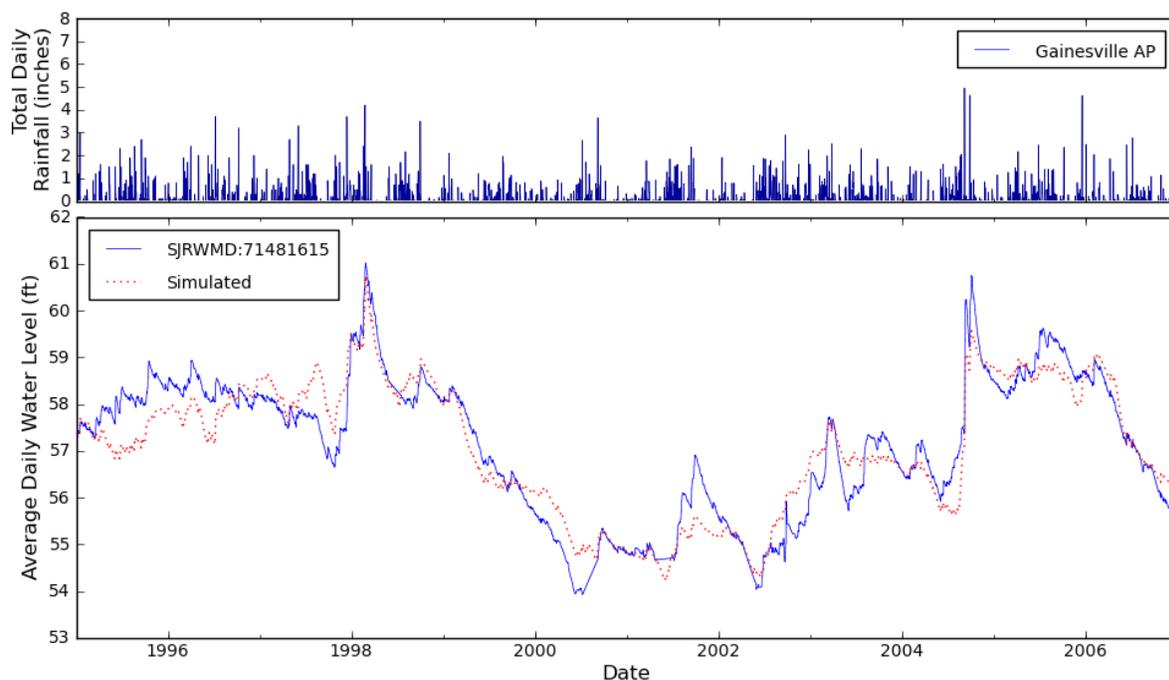


Figure 3.L.50: Lochloosa Lake daily hydrograph

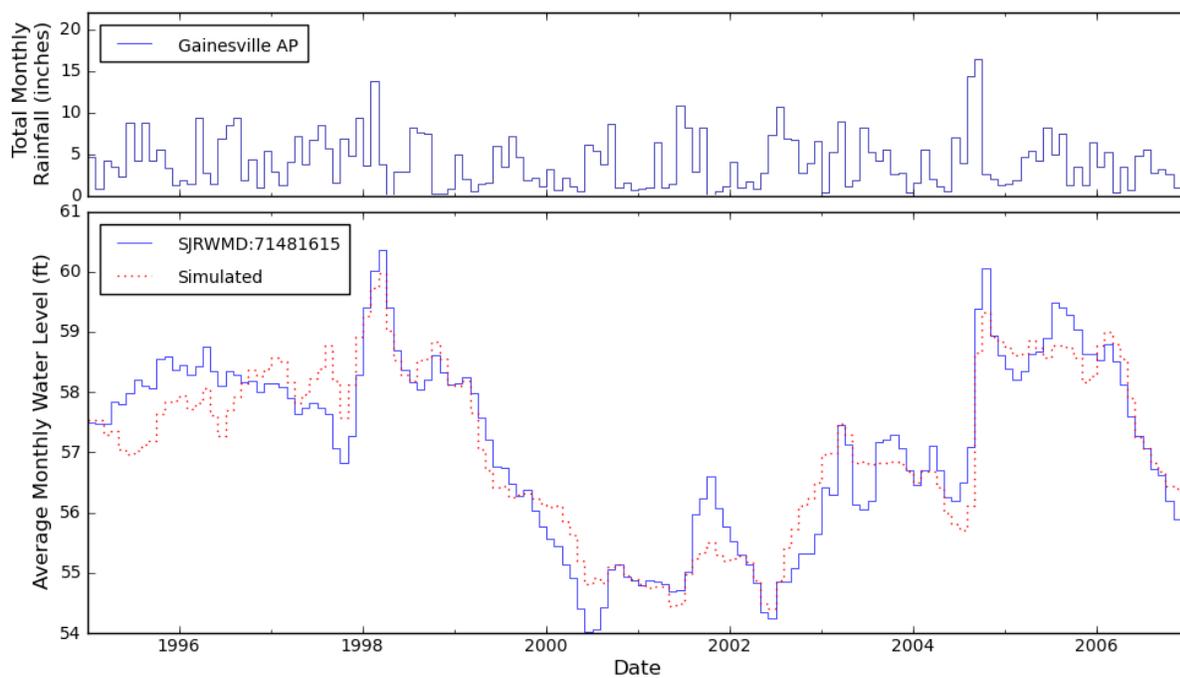


Figure 3.L.51: Lochloosa Lake monthly hydrograph

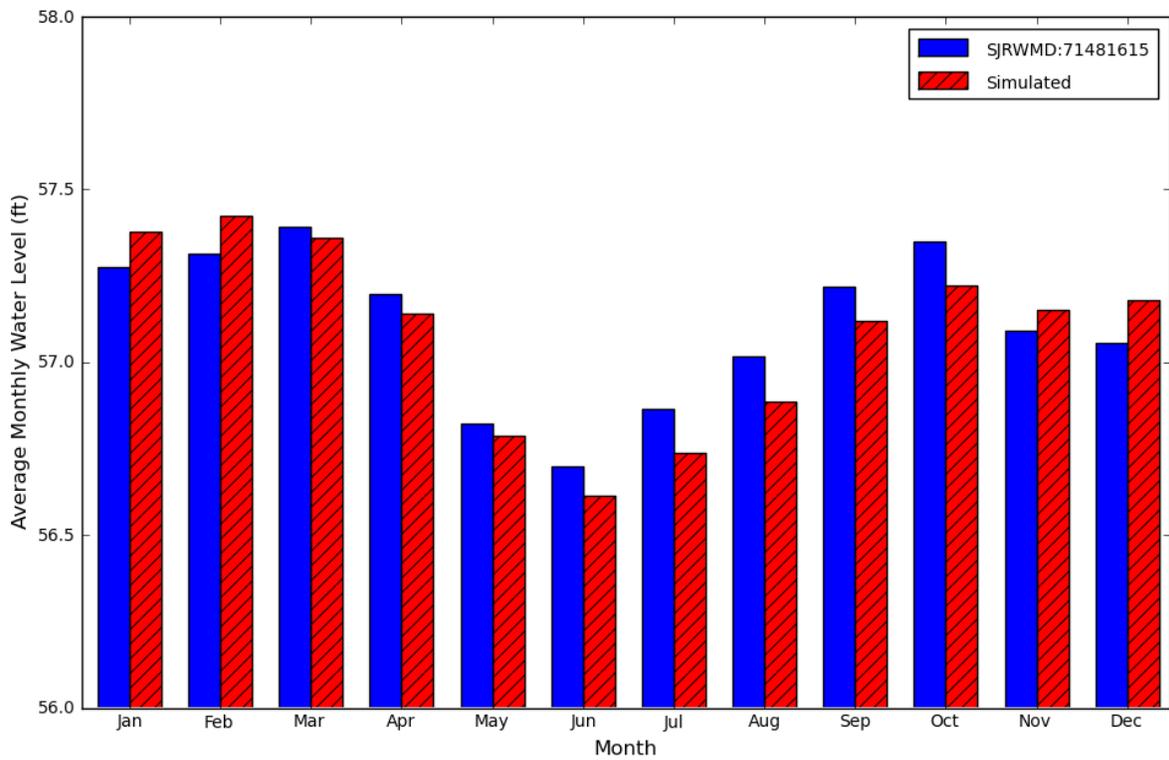


Figure 3.L.52: Lochloosa Lake average monthly flow

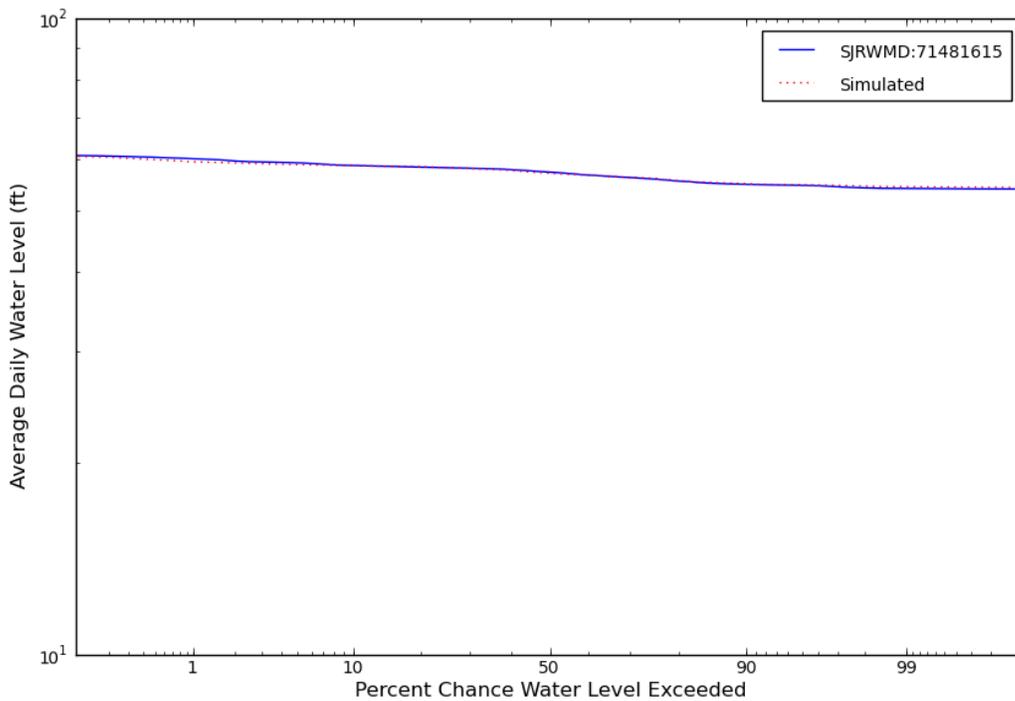


Figure 3.L.53: Lochloosa Lake exceedance probability curve

7G UPPER ORANGE CREEK WATERSHED. ORANGE LAKE WEIR SUBWATERSHEDS

Orange Lake weir is the discharge gage for the Orange Lake subwatershed. This section of the appendix presents the statistics for comparing modeled and observed discharges. However, these statistics were not used in the direct calibration of Orange Lake as described in the Orange Lake Subwatersheds section of this appendix.

Table 3.L.21: Calibration Model Performance

Nash-Sutcliffe (Monthly Mean Flow)	Percent Error of the Mean
0.90	-21.93

Table 3.L.22: Descriptive Calibration Statistics

Statistic (Daily Flow (mgd))	Observed (SJRWMD:02601462)	Simulated
Average	20.48	15.99
Median	0.00	0.75
Variance	3891.52	3561.85
Standard Deviation	62.38	59.68
Skew	5.25	6.76
Kurtosis	32.52	52.47
Minimum	0.00	0.00
Maximum	595.00	624.14
Range	595.00	624.14

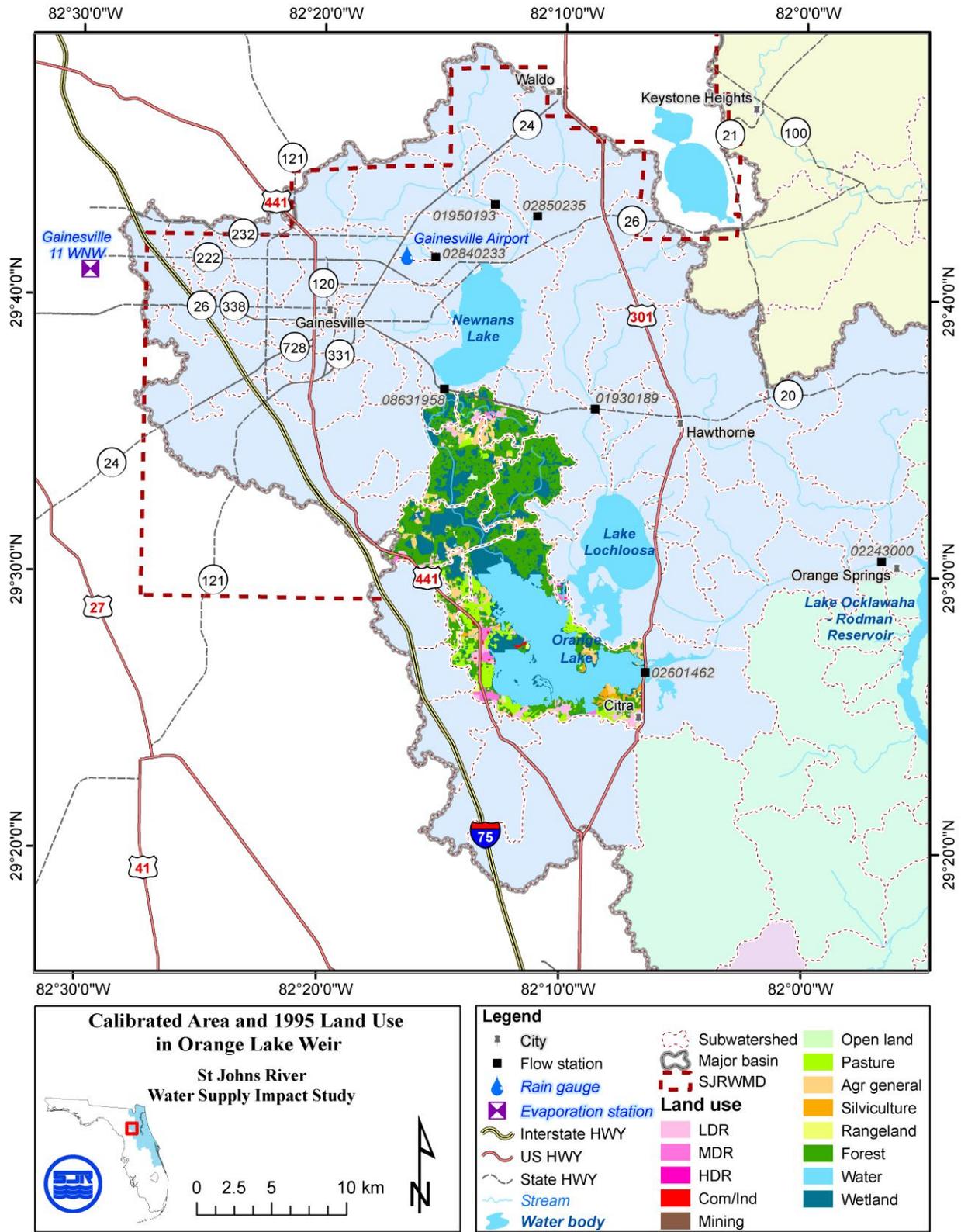


Figure 3.L.54: Orange Lake Weir land use map

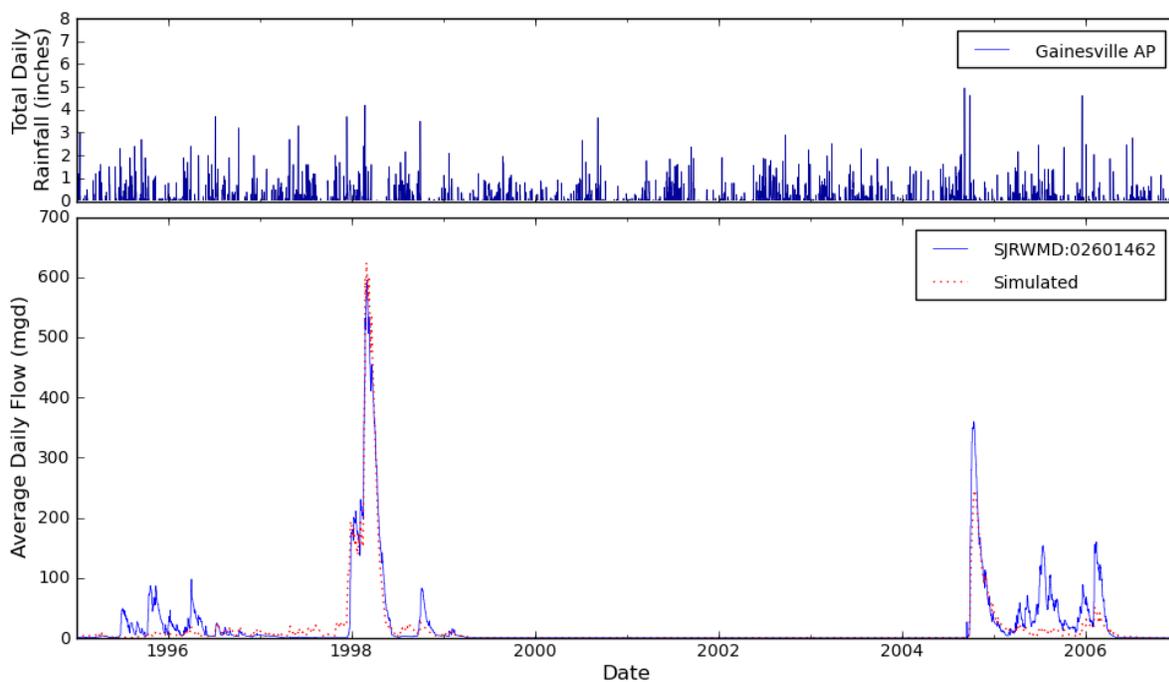


Figure 3.L.55: Orange Lake Weir daily hydrograph

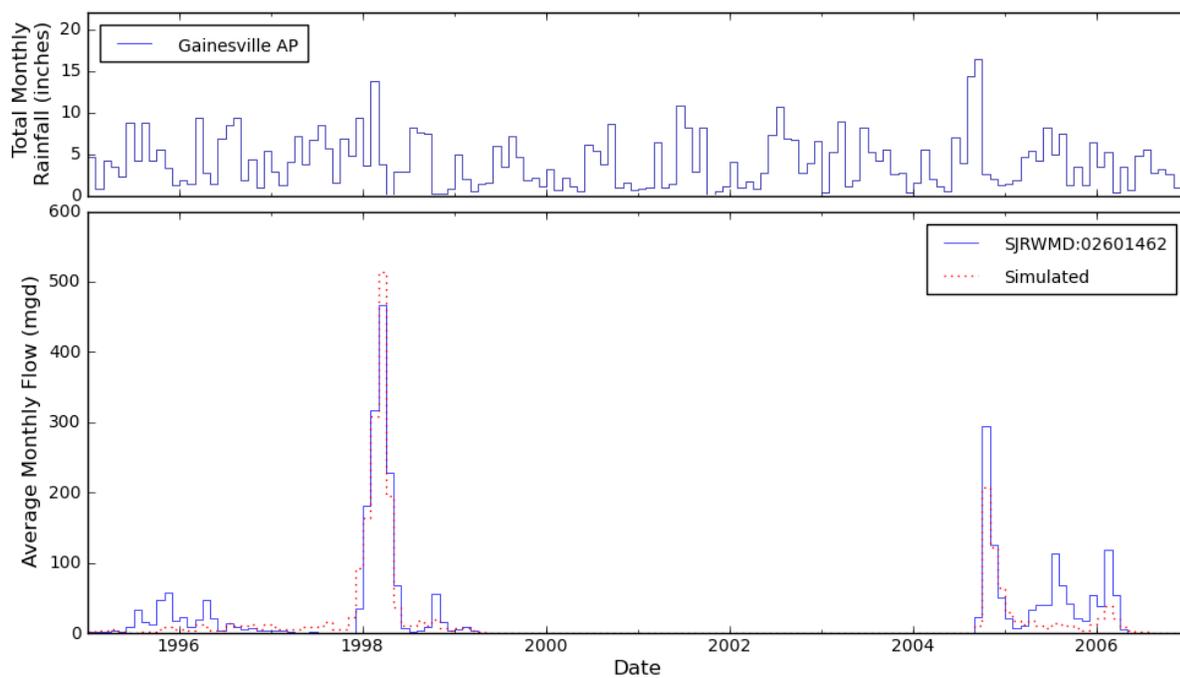


Figure 3.L.56: Orange Lake Weir monthly hydrograph

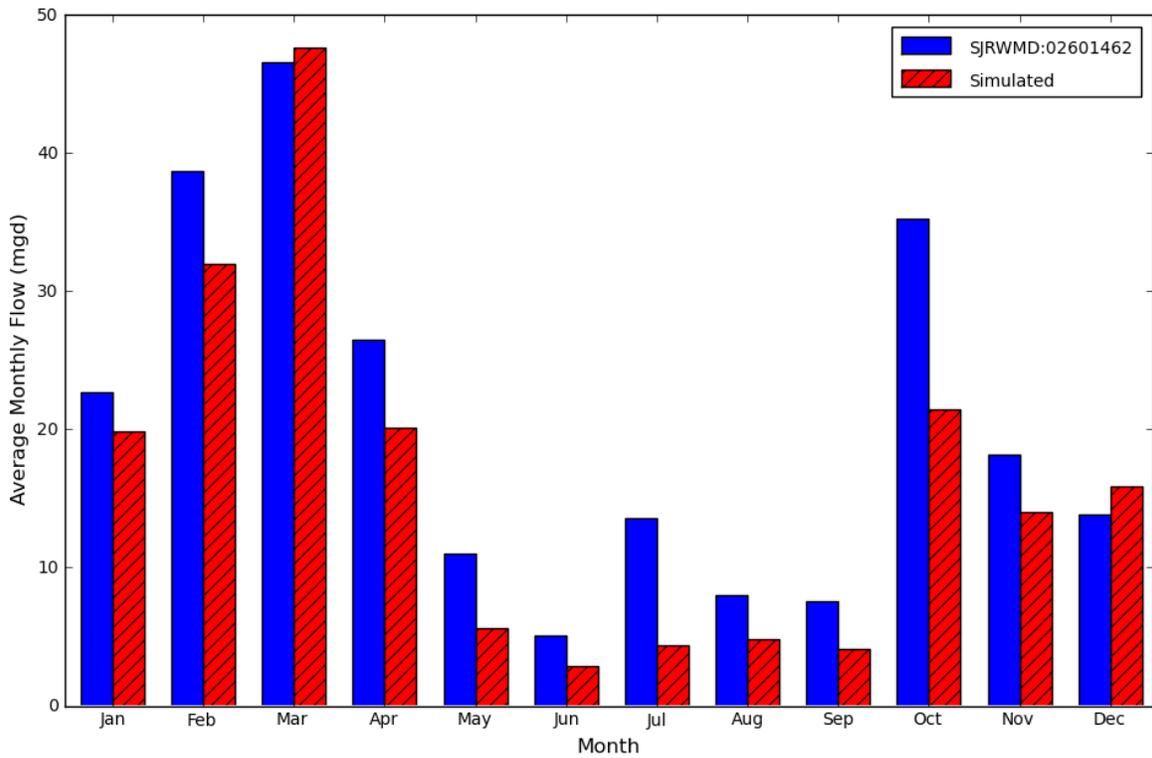


Figure 3.L.57: Orange Lake Weir average monthly flow

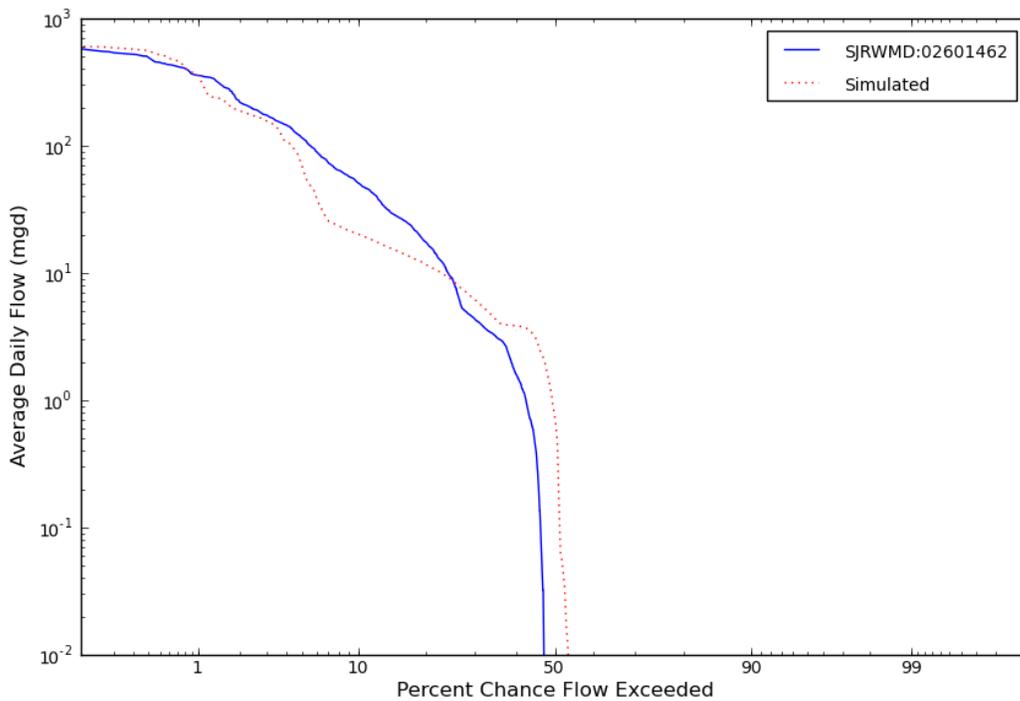


Figure 3.L.58: Orange Lake Weir exceedance probability curve

7G LOWER ORANGE CREEK WATERSHED

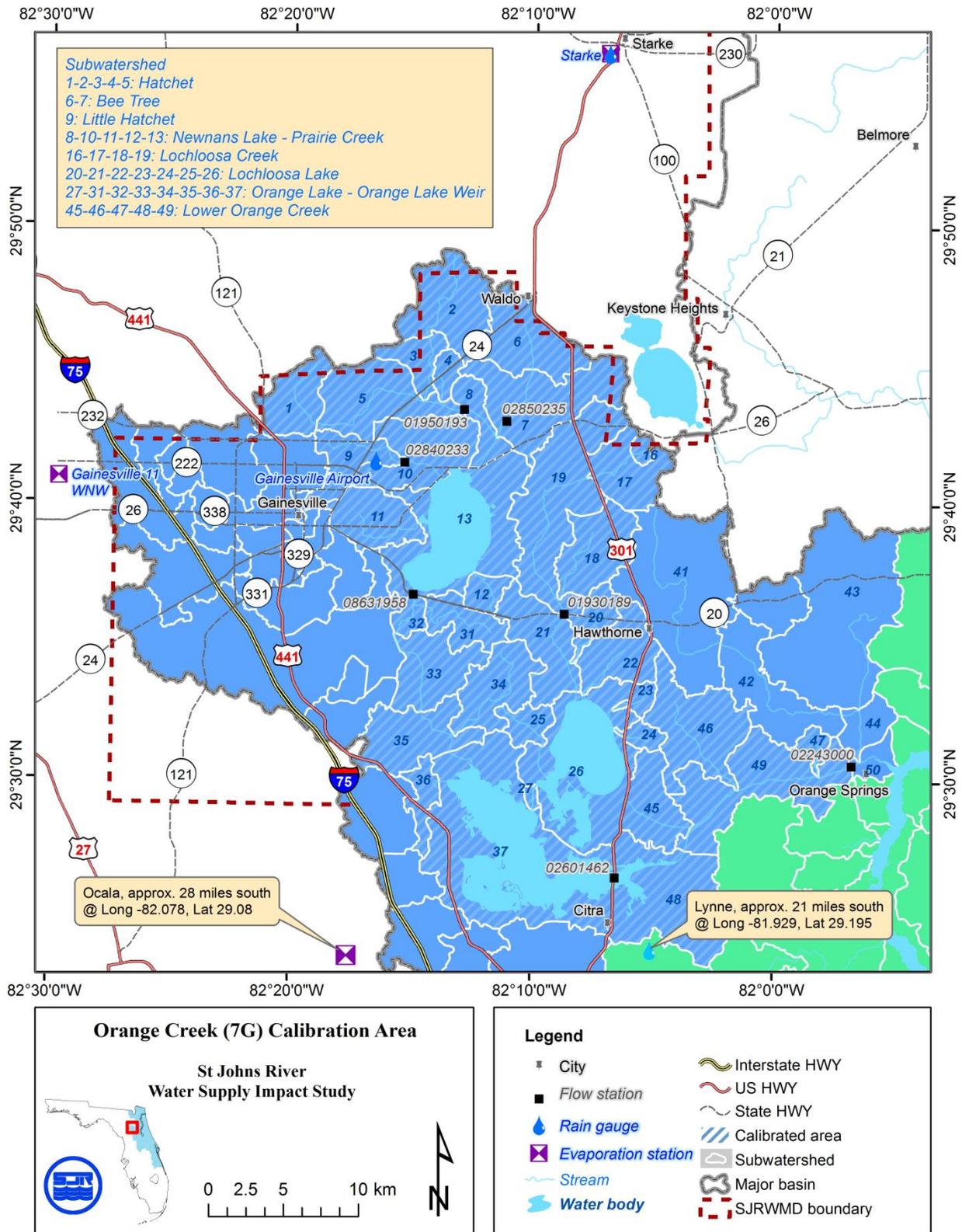


Figure 3.L.59: 7G Lower Orange Creek Watershed calibration areas

7G LOWER ORANGE CREEK WATERSHED. LOWER ORANGE CREEK SUBWATERSHEDS

Lower Orange Creek drainage area constitutes the lower portion of greater Orange Creek planning unit. The 139-square-mile (88,705-ac) area is drained by Orange Creek and receives flow input from tributaries that drain northern portions of the planning unit. Topography is generally low-gradient at western portions of the watershed with land surface slope less than 6 %. Major land uses are forest (41%) and wetlands (24%). A USGS flow gage (02243000) is located at a bridge on State Highway 21, 0.2 miles northwest of Orange Springs, and 0.45 miles upstream from Little Orange Creek. The gage records stage data at a datum of 19.81 ft above NGVD (1929). Flow records exist from 1975 to present. Rainfall measurements used for the drainage area are located in Palatka, Starke, and Lynne. Precipitation station assignment was based on proximity to a particular subwatershed. Similarly, different evapotranspiration stations at Starke, Crescent City, and Ocala were assigned based on proximity to a subwatershed in Lower Orange Creek watershed.

HSPF model developed for Lower Orange Creek drainage area was calibrated to observed stream flow using Parameter Estimation Program (PEST). Calibration period span January 1, 1995 to December 31, 2005. Based on the location of the flow gage, only subwatersheds 45, 46, 47, 48, and 49 were included in the calibration process. PEST in conjunction with HSPF was executed to obtain optimal parameters that yielded minimum error between observed and simulated stream outflows. The calibration results shows a satisfactory match between the observed and simulated daily flow hydrographs. However, the model overpredicted peak flow events, except in 2004 and 2005 when it underpredicted flows. Overprediction of peak flows may be attributed to rainfall variability across the watershed given the location of various precipitation gages. Visual comparison between observed and simulated daily stream outflows indicates that the model adequately predicted base flow and recessions after peak storm events. Inspection of daily flow-frequency duration curves show good correlation between observed and simulated outflows, except at low flow conditions, where simulated outflows were higher than their observed counterparts. The error between average daily stream outflow for the observed (46.60 mgd) and simulated (44.53 mgd) is 4%. Calibration of HSPF model for the lower Orange Creek drainage area to the observed streamflow is deemed good based daily outflow error, Nash-Sutcliffe coefficient of 0.94, and coefficient of determination of 0.95.

Table 3.L.23: Calibration Model Performance

Nash-Sutcliffe (Monthly Mean Flow)	Percent Error of the Mean
0.94	-4.45

Table 3.L.24: Descriptive Calibration Statistics

Statistic (Daily Flow (mgd))	Observed (USGS:02243000)	Simulated
Average	46.60	44.53
Median	14.22	13.96
Variance	10743.74	8555.27
Standard Deviation	103.65	92.49
Skew	4.73	4.80
Kurtosis	25.62	29.03
Minimum	0.01	0.27
Maximum	1008.25	1074.65
Range	1008.25	1074.38

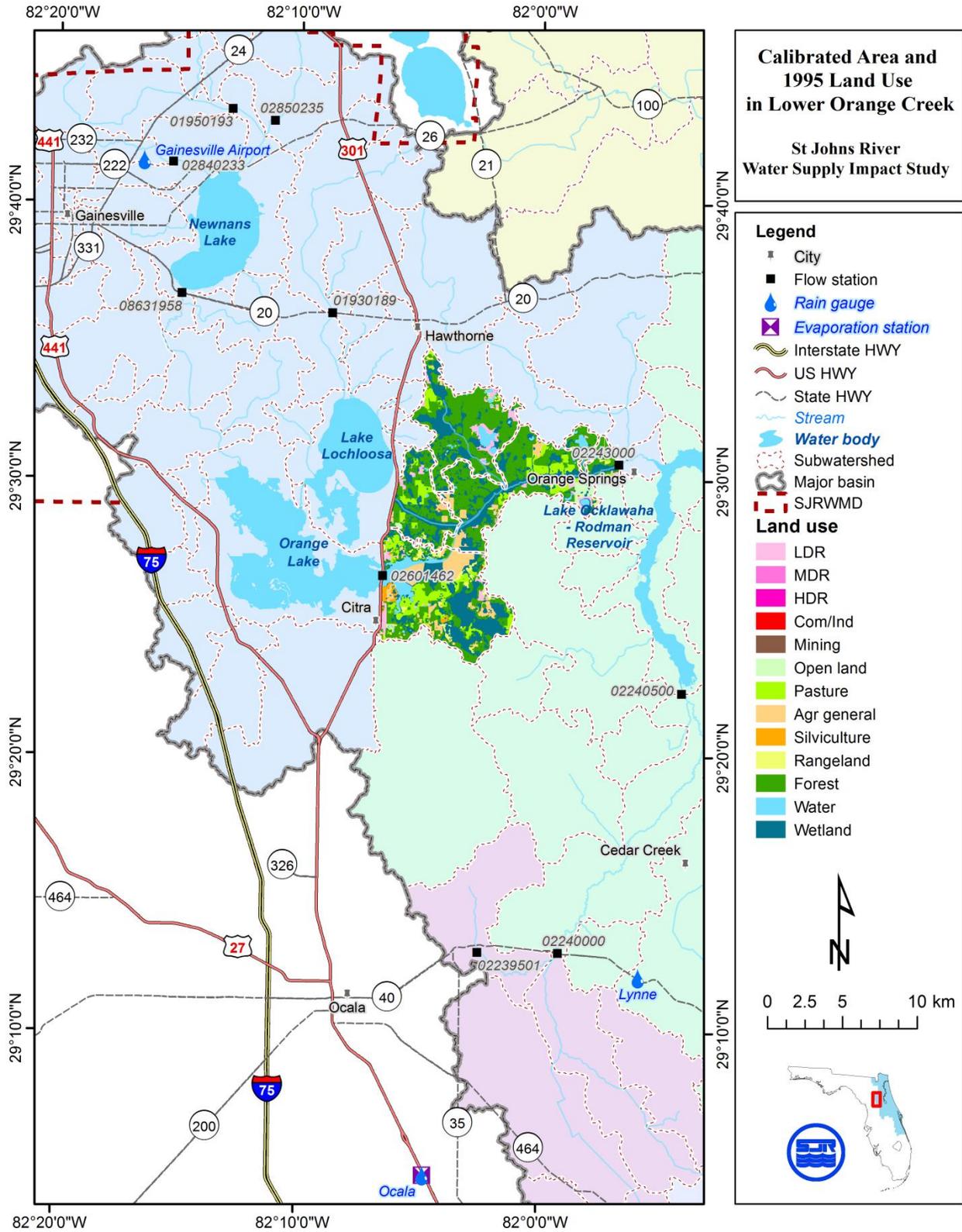


Figure 3.L.60: Lower Orange Creek land use map

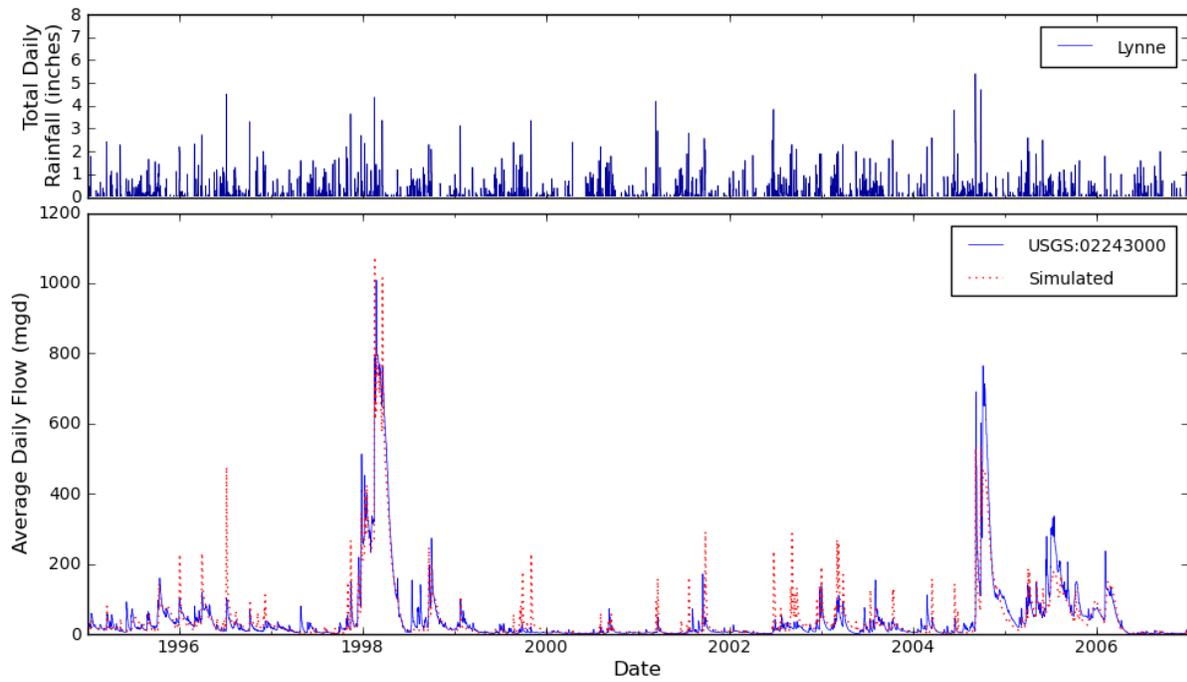


Figure 3.L.61: Lower Orange Creek daily hydrograph

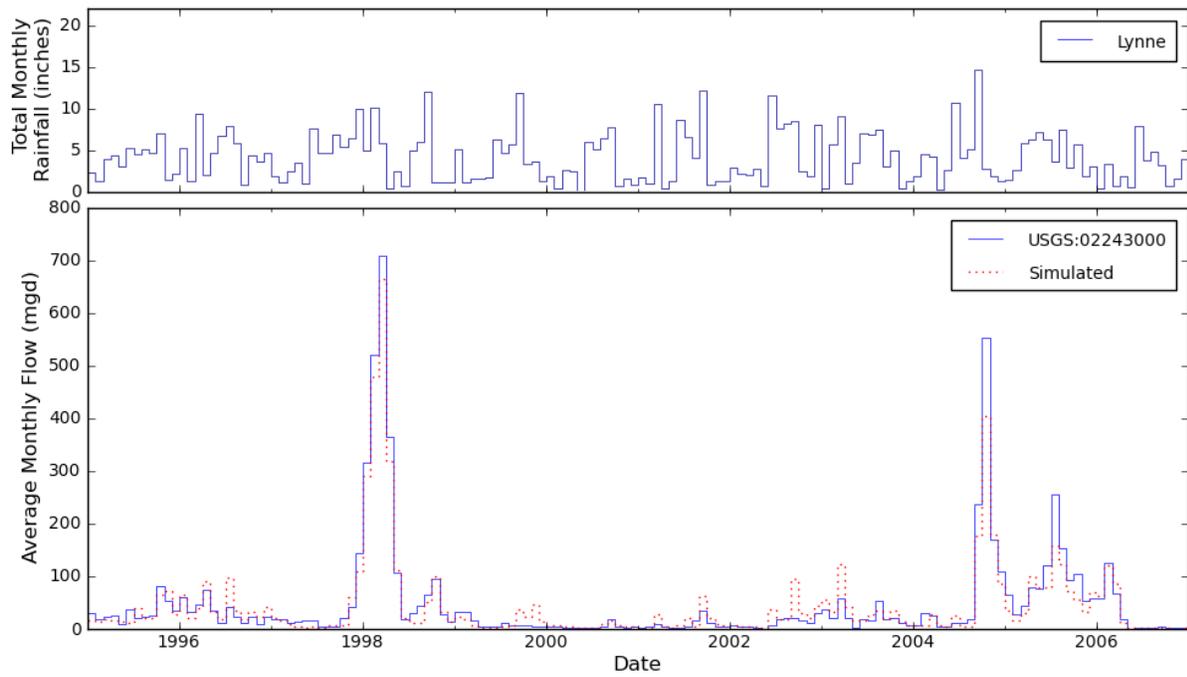


Figure 3.L.62: Lower Orange Creek monthly hydrograph

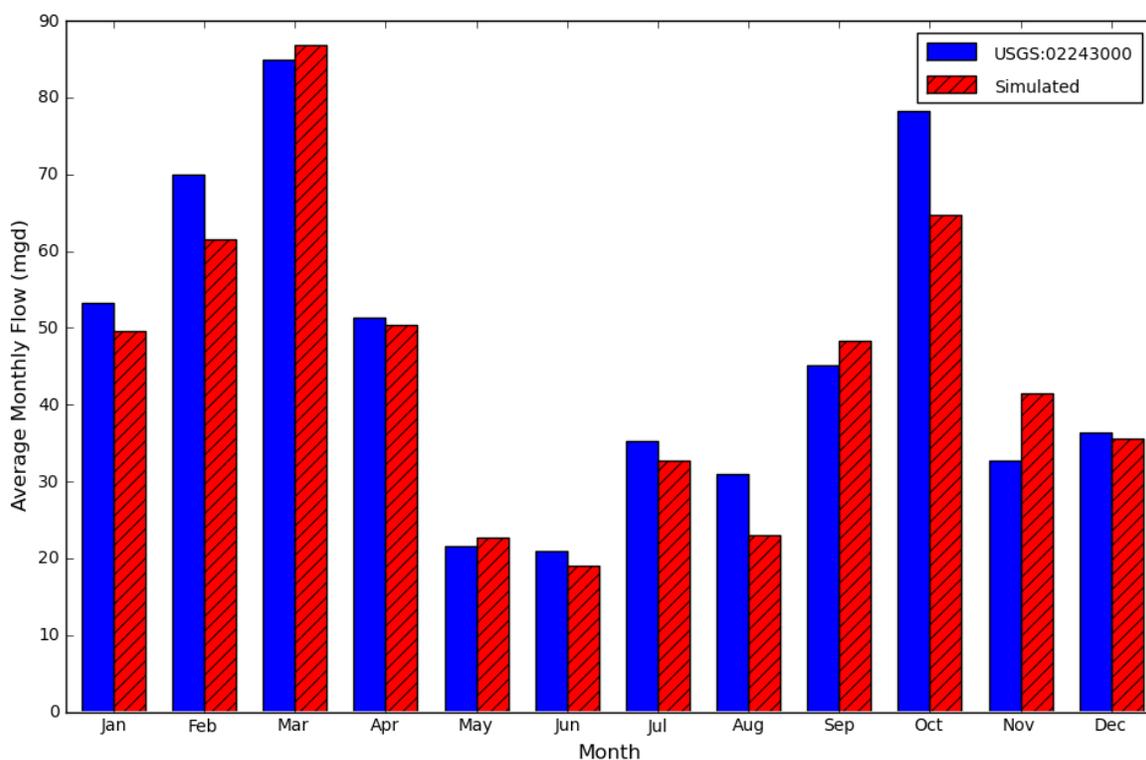


Figure 3.L.63: Lower Orange Creek average monthly flow

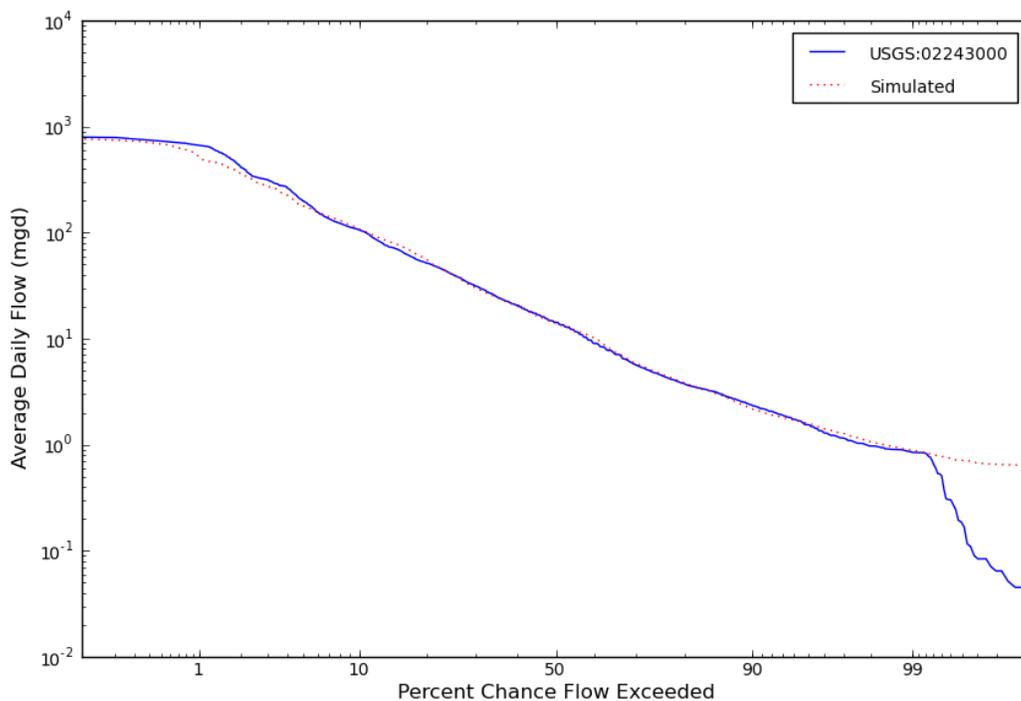


Figure 3.L.64: Lower Orange Creek exceedance probability curve