Memorandum

To: *SCDNR*

From: *CDM Smith*

Date: *June 13, 2023*

Subject: *2023 Salkehatchie SWAM Model Updates*

1.0 Introduction and Overview

The Salkehatchie Basin baseline water quantity model was updated to incorporate newly available water use and return data and to extend the baseline hydrologic period of the model. Model updates included recalculating baseline 10-year average water demands (2012 to 2021) for all water users, adding new water users, removing water users with inactive registrations, removing an inactive discharger, and extending the baseline simulation period from January 2014 through December 2021. Extending the baseline simulation period required using recent USGS streamflow gage data, combined with water use and return data and area transposition methods, to "un-impair" flow records and generate un-impaired model headwater boundary condition flows. Updated downstream flow records were then used to validate model hydrologic parameterization.

The result of this work is an updated model with more recent representation of water demands in the basin and a larger range of hydrologic variability captured by the simulation period. Previously calibrated hydrologic parameters throughout the basin were validated with comparisons of modeled and gaged flows for the simulation extension period.

The Salkehatchie Basin baseline water quantity model was also updated to incorporate recent enhancements to SWAM, the most significant being the addition of a scenario planning module.

2.0 Model Object Changes

Table 1 (all tables and figures are included in **Attachment A**) lists the explicit tributaries and the gages and reference gages used for computing headwater flows. There are no implicit tributes modelled for the Salkehatchie Basin. **Table 2** lists all tributary objects, their confluence location, drainage area, headwater area, drainage area ratio and subbasin flow factors. Note that during the Model updates, the drainage area of the headwater flow to the Choctawhatchee River was remeasured and adjusted from 2,387 acres to 2,560 acres. Drainage area ratios of the downstream gages were subsequently recalculated. There are no modeled reservoirs in the Salkehatchie Basin, and as such no updates to reservoir operating rules, evaporation, reservoir capacity, etc. were needed.

New water users represent those that are newly registered or have just recently surpassed the minimum water use threshold for inclusion in the model of 3 million gallons per month (MGM). Several

new water users were added to the model, and several inactive users/intakes were removed. The updates model framework is shown in Figure 1. The water user and discharge objects added and removed are listed below.

Objects added

- IR: Riddle Dairy
- IR: Withycombe

Objects Removed

- IR: Anilorac
- IR: Connelly (Jackson)
- IR: Coosaw Land
- IR: Gary Hege (Little Salkehatchie)
- Nevamar (a discharge object)

Water demands associated with the new users were quantified based on the South Carolina Department of Health and Environmental Control (SCDHEC) reported water use and discharge databases. **Table 3** lists the surface water user objects included in the model and their sources of supply. Water demands are specified in the baseline model as monthly mean values for all water user objects.

3.0 Baseline Period Extension

The baseline simulation period was extended by eight years through 2021. For the extension, model boundary condition (headwater) flows were developed for the additional eight years, on both a monthly and daily timestep. As done for the original model development, un-impaired gaged flow data were used to estimate flows at ungaged model input locations. The un-impairment process exactly followed the process detailed elsewhere (CDM Smith, 2016) whereby un-impaired flows were calculated by adding in all known upstream consumptive water withdrawals and subtracting out upstream discharges from a downstream USGS gaged flow record. The statistical methods employed, and the assignment of reference gages, are described elsewhere (CDM Smith, 2016).

The USGS gages serve as key reference points for ungaged flow estimates at model input points. Area transposition methods, based on ratios of drainage areas, were used to estimate monthly and daily flows for the period extension, for key model headwater input locations. Again, the assignment of reference gages for this exercise matched that employed during the original model development.

In addition to extending model flow inputs, water demand estimates were updated to more accurately reflect current conditions. New baseline water demand, discharge and consumptive use estimates for the 10-year period 2012 through 2021 were developed using the SCDHEC reported water use and discharge data. These calculations were consistent with methodologies employed for the original baseline model development (CDM Smith, 2017). Updated mean monthly water demands and discharge parameters were entered into the model for all water user objects. The updated baseline water demands are provided in **Table 4,** which consists of only agriculture (IR) users. There are no transbasin imports associated with the Salkehatchie. Model return (discharge) locations are listed in **Table 5**. Updated consumptive use percentages are provided in **Table 6**.

4.0 Model Validation

Existing model hydrologic parameters throughout the basin were validated using data associated with the extended simulation period. Comparison of modeled and gaged flow for the extension period (2014 to 2021) returned satisfactory results for basin gages used in the initial calibration and verification, thereby validating previous calibration work. Model validation results for the extension period that were generated using the updated baseline model are provided in **Attachment B**. Graphs depict the comparison of mean monthly and daily model simulated flows versus reported gage flows in cubic feet per second.

5.0 References

CDM Smith, 2016. Technical Memorandum – Methodology for Unimpaired Flow Development Salkehatchie River Basin, South Carolina

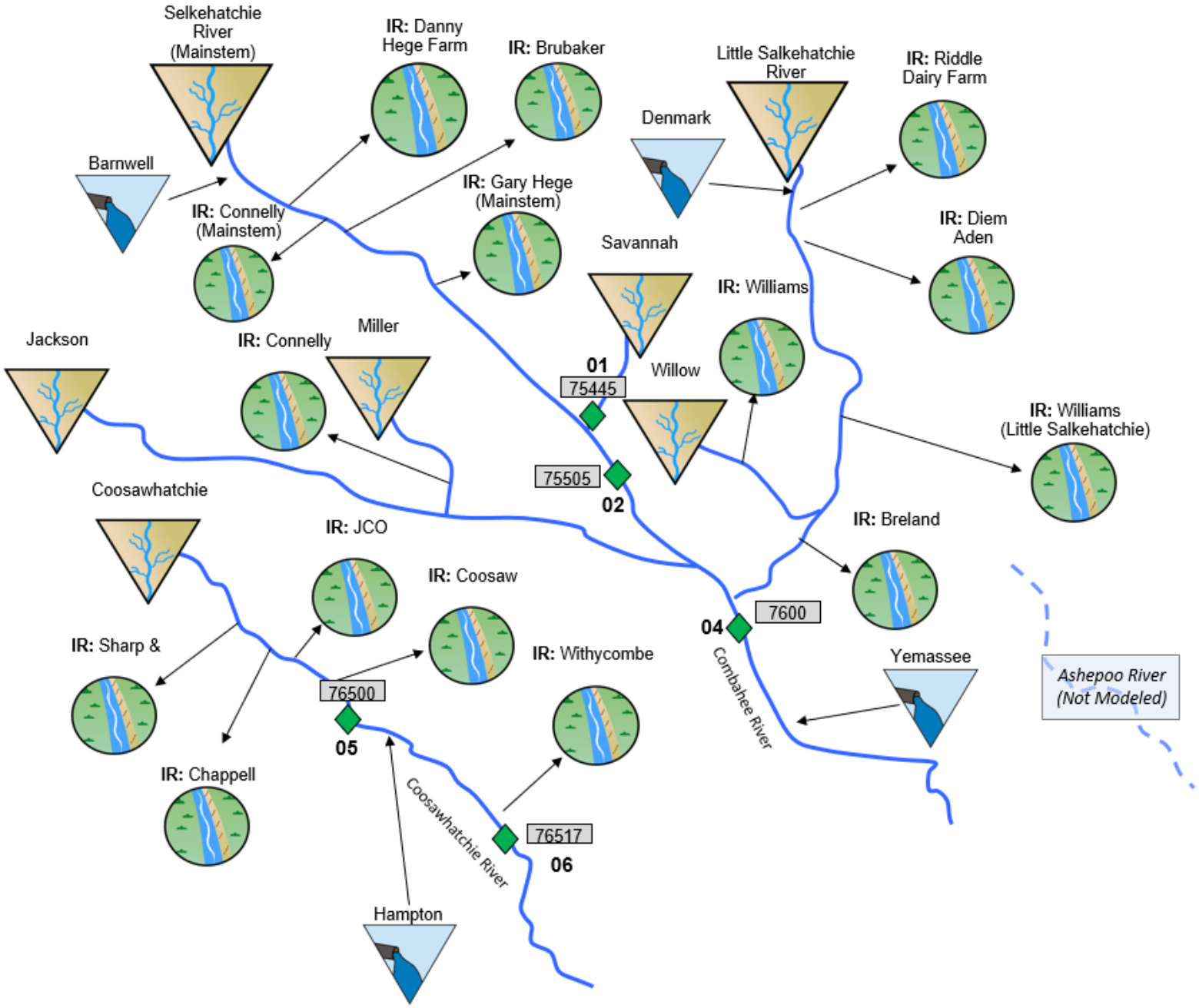
CDM Smith, 2016. Technical Memorandum - Unimpaired Flow Dataset for the Salkehatchie River Basin.

CDM Smith, 2017. South Carolina Surface Water Quantity Models – Salkehatchie River Basin Model.

2023 Salkehatchie SWAM Model Updates

Attachment A

Figure and Tables



Model Objects

Tributary

Current or Former USGS Stream Gage
(with last 5 digits of Gage ID and Model ID

Water User Objects

Agriculture Water User Object (Irrigation)

Discharge Object

Figure 1.Salkehatchie River Basin SWAM Model Framework

Table 1. Gages and Reference Gages Used for Headwater Flows on Explicit Tributaries

	Headwater Input			USGS Reference Gage (Unimpaired)		
Project ID	**Type**	**USGS Number**	**SWAM Tributary**	**Project Gage ID**	**USGS Number**	**Stream**
SLK10	Ungaged	-	Salkehatchie River (Mainstem)	SLK02	02175500	Salkehatchie River
SLK13	Ungaged	-	Little Salkehatchie River			
SLK14	Ungaged	-	Willow Swamp			
SLK11	Ungaged	-	Miller Swamp	SLK05	02176500	Coosawhatchie River
SLK12	Ungaged	-	Jackson Branch			
SLK15	Ungaged	-	Coosawhatchie River			
SLK01	Gaged	02175445	Savannah Creek	-	-	-

Table 2. Model Tributary Inputs

SWAM Tributary Object	Tributary Type	Confluence Stream	Confluence Location (mile)	Confluence Drainage Area (ac)	Headwater ID	End Mile	Drainage Area Ratio	Subbasin Flow Factor (unitless)
Mainstem	Explicit	None	None	695,540	SLK10	29.3	*NA*	0.068*
						56.9		0.04*
						500		0.0*
Coosawhatchie River	Explicit	None (Mainstem)	80	496,000	SLK15	7.4	10.8	10.8
						19.7	49.1	52.6
						34.5	95.7	100.0
Jackson Branch	Explicit	Mainstem	37.5	86,850	SLK12	17.4	4.5	3.0
Little Salkehatchie River	Explicit	Mainstem	46	260,296	SLK13	48.2	12.7	6.0
Miller Swamp	Explicit	Jackson Branch	1.5	12,621	SLK11	4.3	3.2	3.2
Savannah Creek	Explicit	Mainstem	27.1	7,845	SLK01	7.2	4.0	4.0
Willow Swamp	Explicit	Little Salkehatchie	38.4	37,758	SLK14	10	3.1	3.1

** On the Mainstem, these are referrred to as "gain/loss factors", not "subbasin flow factors".*

Table 3. Water User Objects and Sources of Supply Included in the Salkehatchie River Basin Model

Model Object ID	Facility Name	Source of Supply	Intake ID	Diversion Location (mi)	Registration Limit (MGM)
IR: Breland	Breland Farm	Little Salkehatchie River	15IR002S01	39.6	3
IR: Brubaker	Brubaker Farms Inc	Mainstem	05IR007S01	10.8	30
IR: Chappell	Chappell Farms	Coosawhatchie River	03IR002S02	3.3	40.7
IR: Connelly (Mainstem)	Connelly Farms	Mainstem	03IR011S01	18.6	90.8
IR: Connelly (Miller)	Connelly Farms	Miller Swamp	03IR011S02	0.3	107.0
IR: Coosaw Farms	Coosaw Farms	Coosawhatchie River	03IR004S01	8.8	27.5
IR: Danny Hege	Danny Hege Farm Barnwell	Mainstem	06IR007S01	9.1	41.3
IR: Diem Aden	Diem Aden Farm	Little Salkehatchie River	05IR042S01	6	16.9
IR: Gary Hege (Mainstem)	Gary Hege Farm	Mainstem	05IR023S01	13	68.6
IR: JCO Farms	JCO Farms	Coosawhatchie River	03IR010S01	6.7	615.4
IR: Riddle Dairy	Riddle Dairy Farm	Little Salkhatchie River	05IR054S01	1.4	22.7
IR: Sharp & Sharp	Sharp & Sharp Certified Seed	Coosawhatchie River	03IR006S01	6.3	145
			03IR006S02	3.2	41
			03IR006S03	0.3	18
IR: Williams (Little Salkehatchie)	Williams Farms Partnership	Little Salkehatchie River	15IR012S01	37	30
IR: Williams (Willow)	Williams Farms Partnership	Willow Swamp	15IR012S02	2	27
			15IR012S03		27
			15IR012S04		27
			15IR012S05		27
IR: Withycombe	Withycombe Farm	Coosawhatchie River	25IR076S01	30.8	40

Table 4. Baseline Model Average Water Demand for IR Water Users

	Baseline Model Average Monthly Water Demand (MGD)							
Month	IR: Breland	IR: Brubaker	IR: Chappell	IR: Connelly (Mainstem)	IR: Connelly (Miller)	IR: Coosaw Farms	IR: Danny Hege	IR: Diem Aden
Surface Water Registration Limit (MGD)-->	0.1	1.0	1.3	3.0	3.5	0.9	1.4	0.6
Jan	0.000	0.010	0.000	0.000	0.000	0.000	0.001	0.000
Feb	0.000	0.018	0.000	0.000	0.000	0.000	0.004	0.000
Mar	0.000	0.035	0.003	0.000	0.000	0.042	0.009	0.011
Apr	0.000	0.090	0.030	0.000	0.000	0.181	0.116	0.081
May	0.000	0.187	0.042	0.708	0.747	0.486	0.194	0.140
Jun	0.013	0.313	0.051	1.618	1.665	0.581	0.366	0.128
Jul	0.013	0.371	0.055	1.378	1.173	0.504	0.628	0.104
Aug	0.000	0.290	0.003	0.261	0.217	0.292	0.766	0.073
Sep	0.000	0.190	0.000	0.000	0.000	0.200	0.648	0.050
Oct	0.000	0.119	0.000	0.000	0.000	0.044	0.150	0.061
Nov	0.000	0.053	0.000	0.000	0.000	0.000	0.021	0.032
Dec	0.000	0.023	0.000	0.000	0.000	0.000	0.016	0.010

	Baseline Model Average Monthly Water Demand (MGD)						
Month	IR: Gary Hege (Mainstem)	IR: JCO Farms	IR: Riddle Dairy	IR: Sharp & Sharp	IR: Withycombe	IR: Williams (Little Salkehatchie)	IR: Williams (Willow)
Surface Water Registration Limit (MGD)-->	2.3	20.2	0.7	6.7	1.3	1.0	3.6
Jan	0.000	0.000	0.059	0.000	0.000	0.000	0.000
Feb	0.026	0.001	0.091	0.000	0.000	0.000	0.000
Mar	0.029	0.020	0.267	0.352	0.000	0.000	0.000
Apr	0.031	0.065	0.418	0.782	0.000	0.000	0.020
May	0.182	0.088	0.572	1.358	0.000	0.000	0.026
Jun	0.539	0.063	0.679	2.067	0.001	0.000	0.070
Jul	0.487	0.049	0.702	2.203	0.001	0.000	0.081
Aug	0.123	0.031	0.593	2.171	0.000	0.000	0.048
Sep	0.094	0.020	0.474	1.303	0.000	0.000	0.000
Oct	0.202	0.010	0.298	0.226	0.000	0.000	0.000
Nov	0.103	0.002	0.262	0.017	0.000	0.000	0.000
Dec	0.010	0.001	0.049	0.000	0.000	0.000	0.000

Permit limits are shown in MGD rather than MGM for comparative purposes. Actual permit limits are in MGM.

Table 5. Returns and Associated Model Objects

Model Object ID	Facility Name	NPDES Pipe ID	Associated Water Permit	Discharge Tributary	Model River Mile
In-basin Returns Represented by Individual Discharge Objects					
Barnwell	City of Barnwell WWTF	SC0047872-001	06WS003G	Mainstem	0.4
Denmark	City of Denmark	SC0040215-001	05WS002G	Little Salkehatchie River	0.1
Denmark	City of Denmark	SC0040215-002			
Hampton	Town of Hampton	SC0021318-001	25WS001G	Coosawhatchie River	23.3
Yemassee	Town of Yemassee	SC0025950-001	25WS004G	Mainstem	56.8

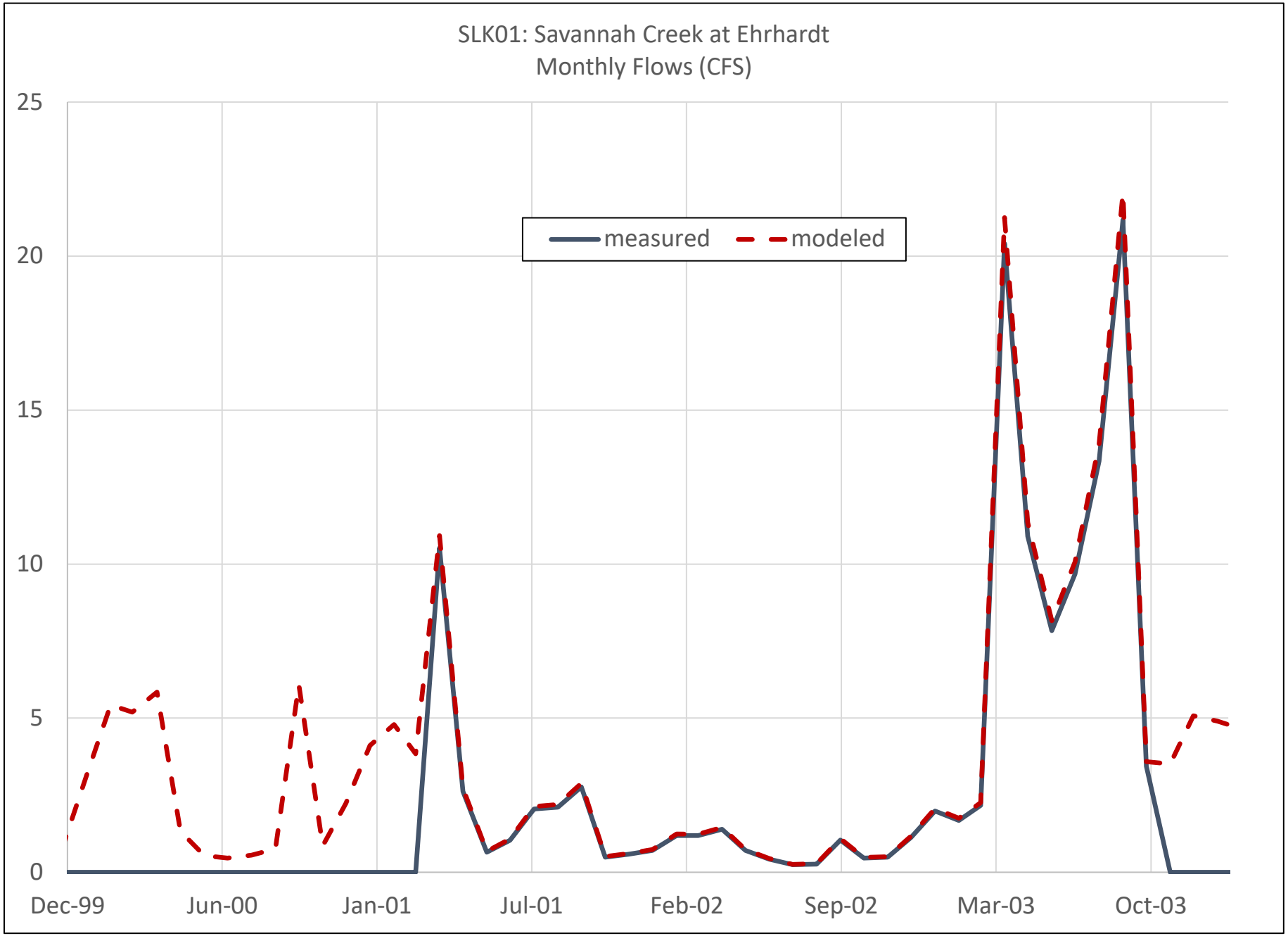
Table 6. Baseline Model Monthly Return Flows for Discharge Objects

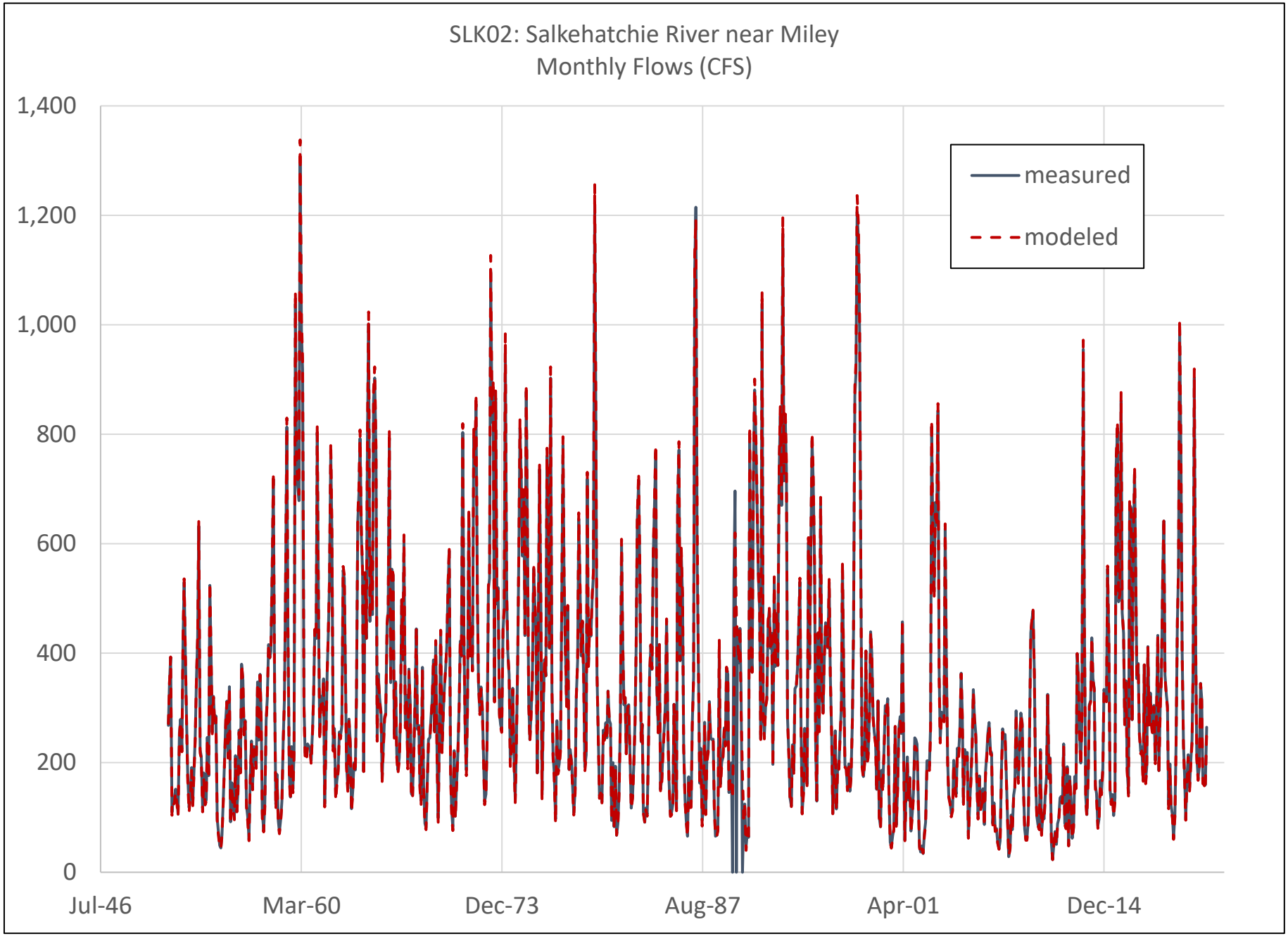
	Monthly Return Flow (MGD)			
Month	Barnwell	Yemassee	Denmark	Hampton
Jan	1.15	0.17	0.38	0.72
Feb	1.35	0.20	0.37	0.92
Mar	1.23	0.18	0.68	0.97
Apr	1.10	0.17	0.50	0.87
May	0.99	0.16	0.38	0.73
Jun	0.98	0.19	0.41	0.79
Jul	1.01	0.18	0.39	0.77
Aug	1.09	0.18	0.35	0.71
Sep	1.07	0.17	0.41	0.72
Oct	1.01	0.18	0.64	0.62
Nov	1.06	0.16	0.30	0.55
Dec	1.15	0.17	0.33	0.68

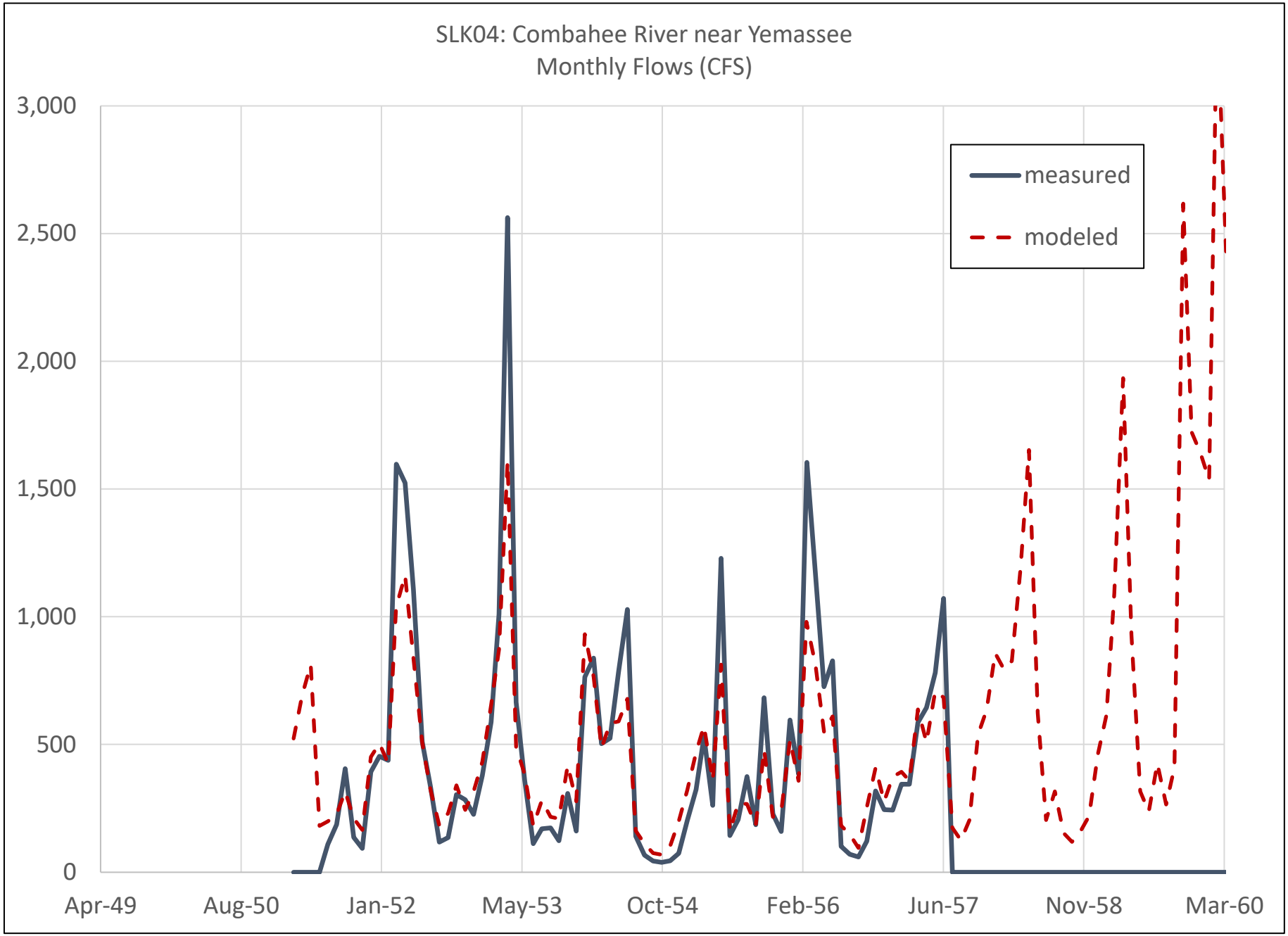
2023 Salkehatchie SWAM Model Updates

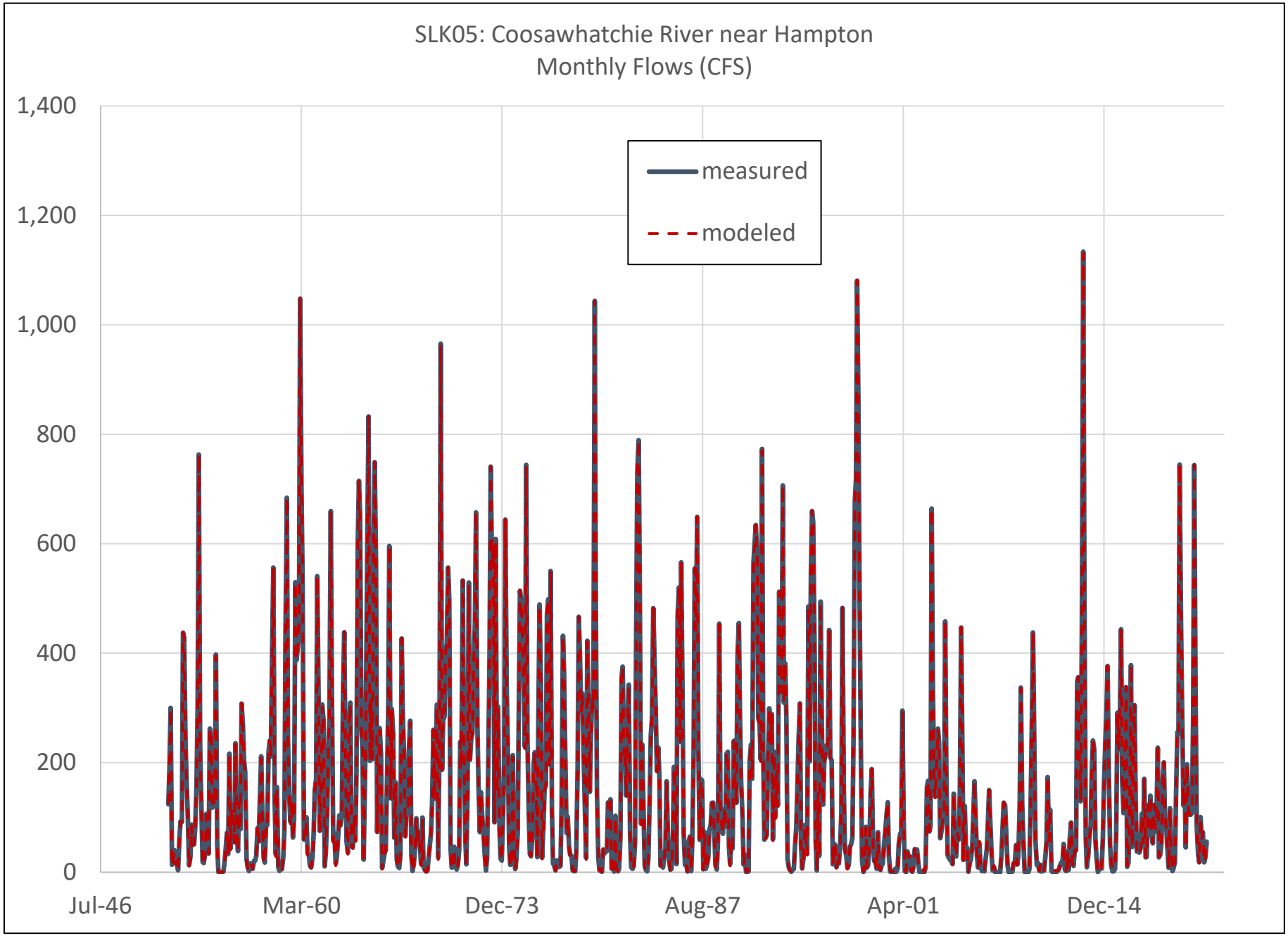
Attachment B

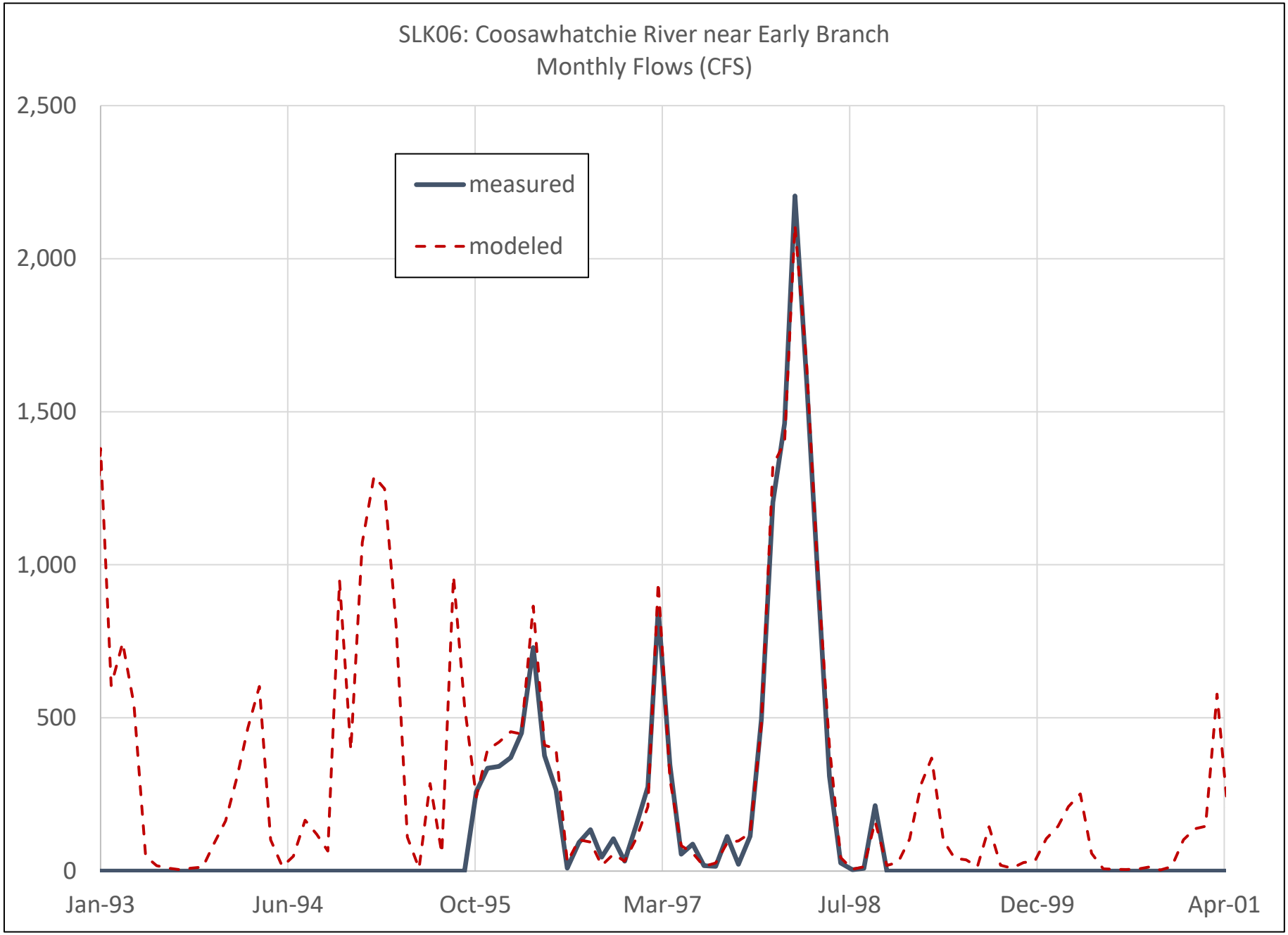
Validation Results

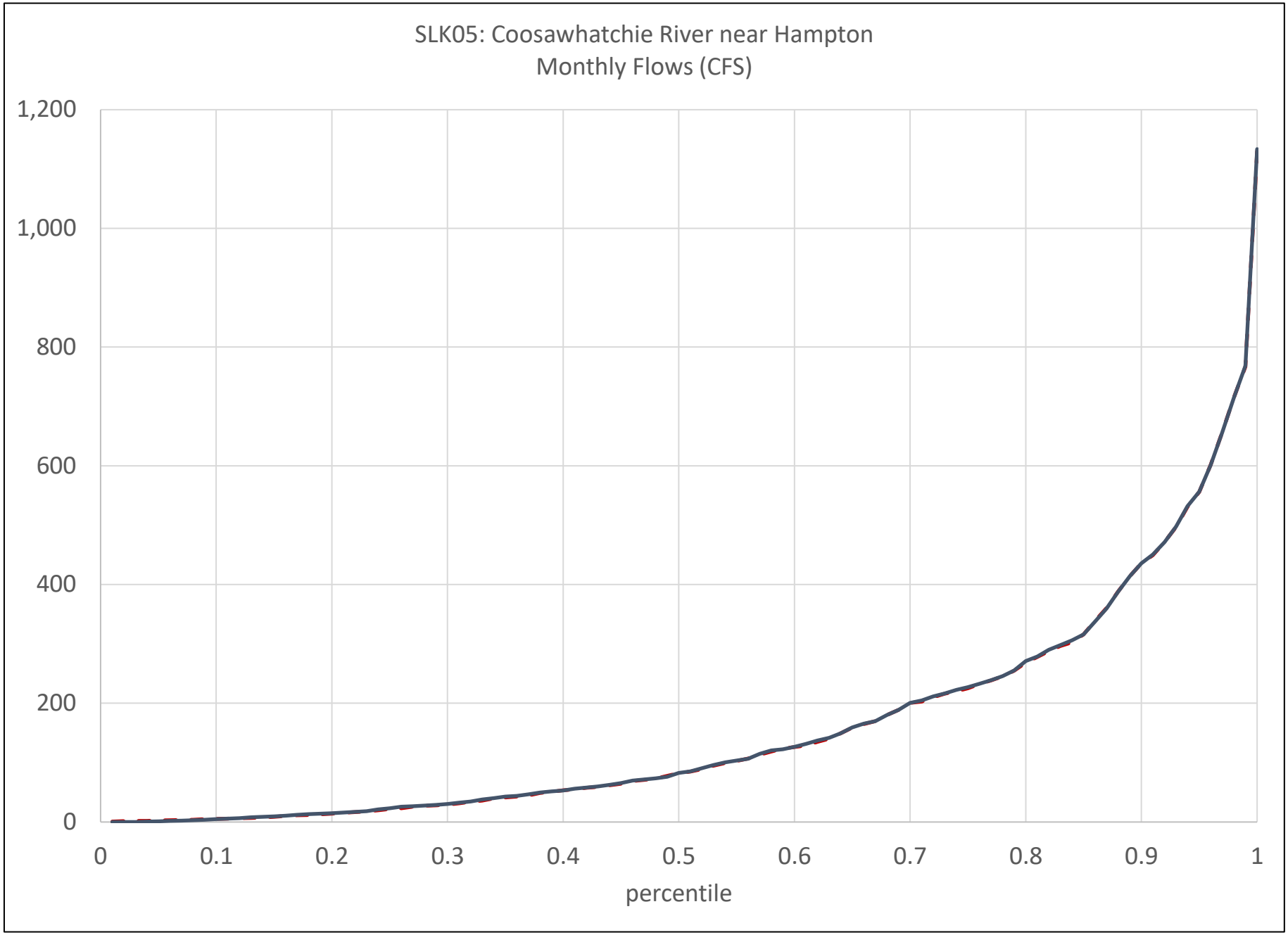

SLK01: Savannah Creek at Ehrhardt
Monthly Flows (CFS)
25
20
15
10
5
0
measured
modeled
Dec-99
Jun-00
Jan-01
Jul-01
Feb-02
Sep-02
Mar-03
Oct-03

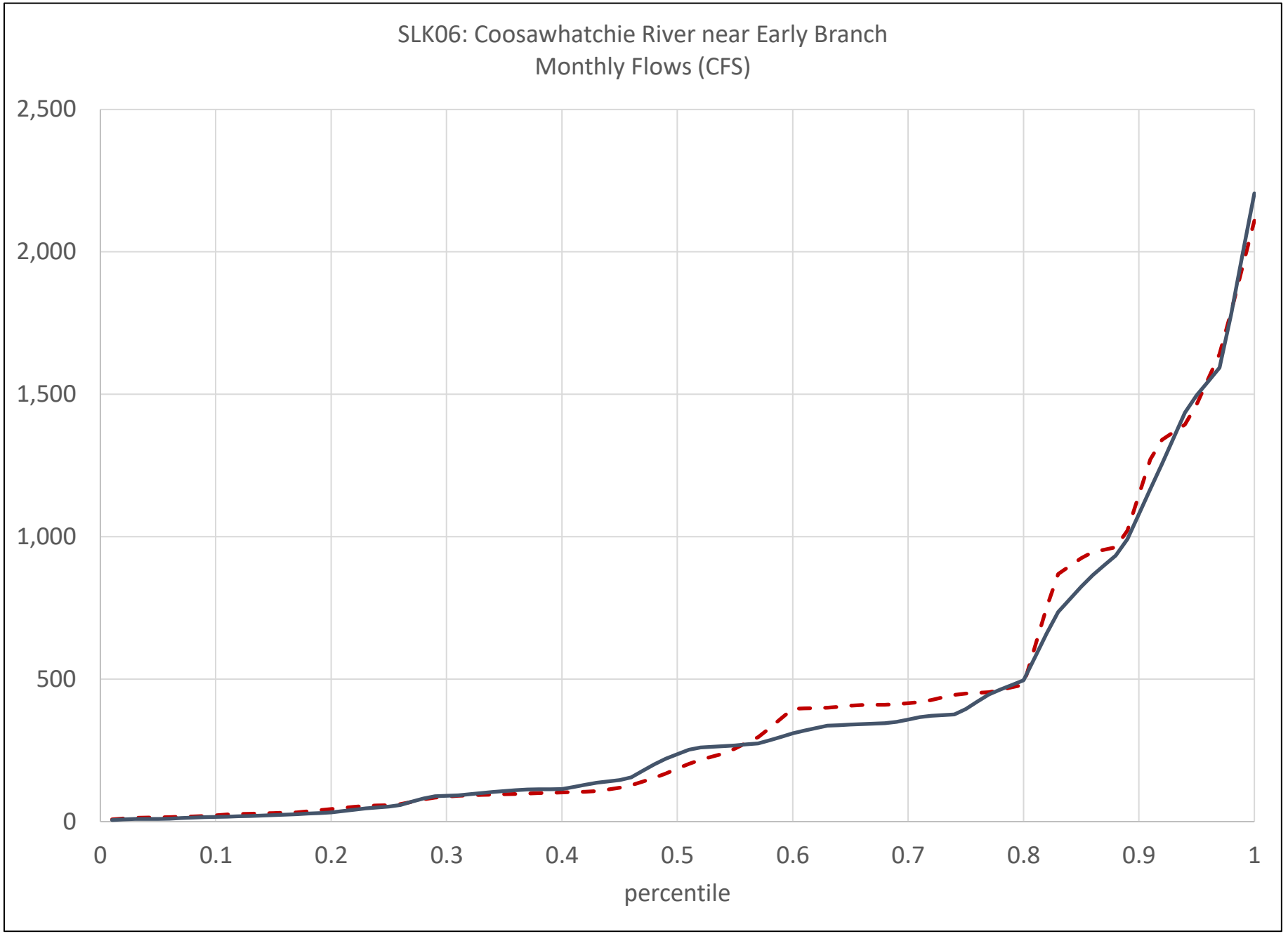

SLK02: Salkehatchie River near Miley
Monthly Flows (CFS)
1,400
1,200
1,000
800
600
400
200
0
Jul-46
Mar-60
Dec-73
Aug-87
Apr-01
Dec-14
measured
modeled


SLK04: Combahee River near Yemassee
Monthly Flows (CFS)
3,000
2,500
2,000
1,500
1,000
500
0
Apr-49
Aug-50
Jan-52
May-53
Oct-54
Feb-56
Jun-57
Nov-58
Mar-60
measured
modeled


SLK05: Coosawhatchie River near Hampton
Monthly Flows (CFS)
1,400
1,200
1,000
800
600
400
200
0
measured
modeled
Jul-46
Mar-60
Dec-73
Aug-87
Apr-01
Dec-14


SLK06: Coosawhatchie River near Early Branch
Monthly Flows (CFS)
measured
modeled
2,500
2,000
1,500
1,000
500
0
Jan-93
Jun-94
Oct-95
Mar-97
Jul-98
Dec-99
Apr-01


SLK05: Coosawhatchie River near Hampton
Monthly Flows (CFS)
1,200
1,000
800
600
400
200
0
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
percentile

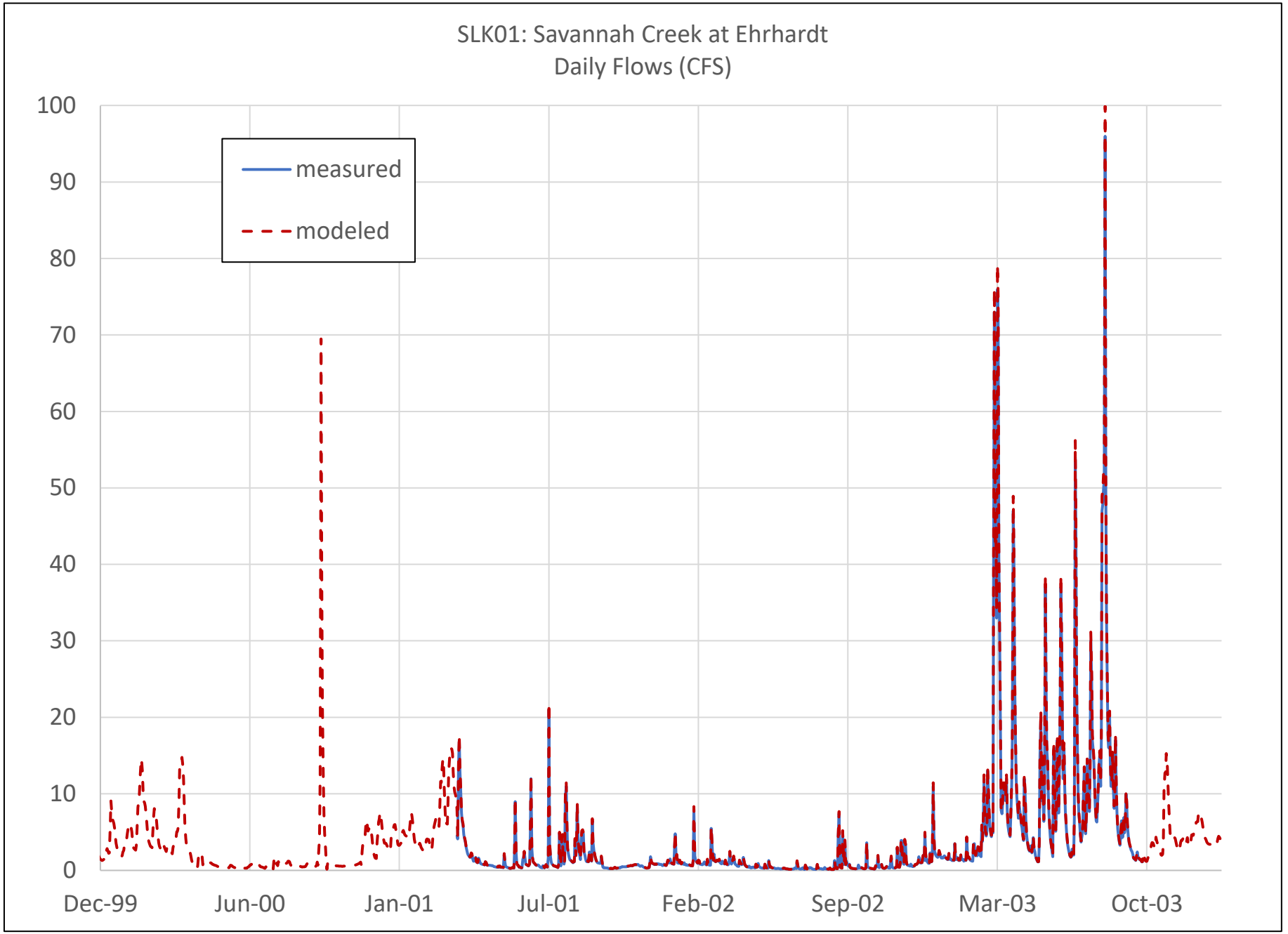

SLK06: Coosawhatchie River near Early Branch
Monthly Flows (CFS)
2,500
2,000
1,500
1,000
500
0
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
percentile

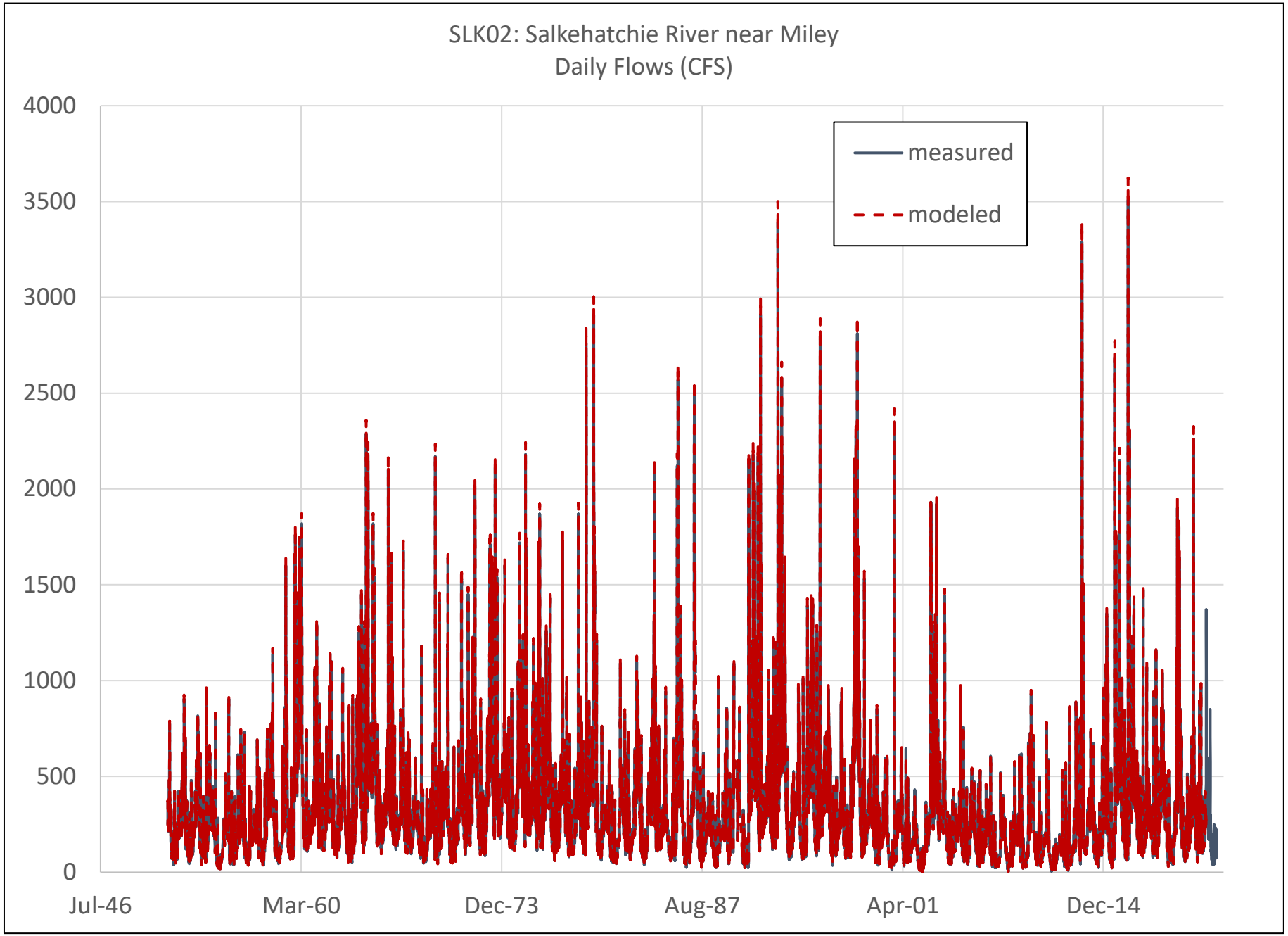
Attachment B

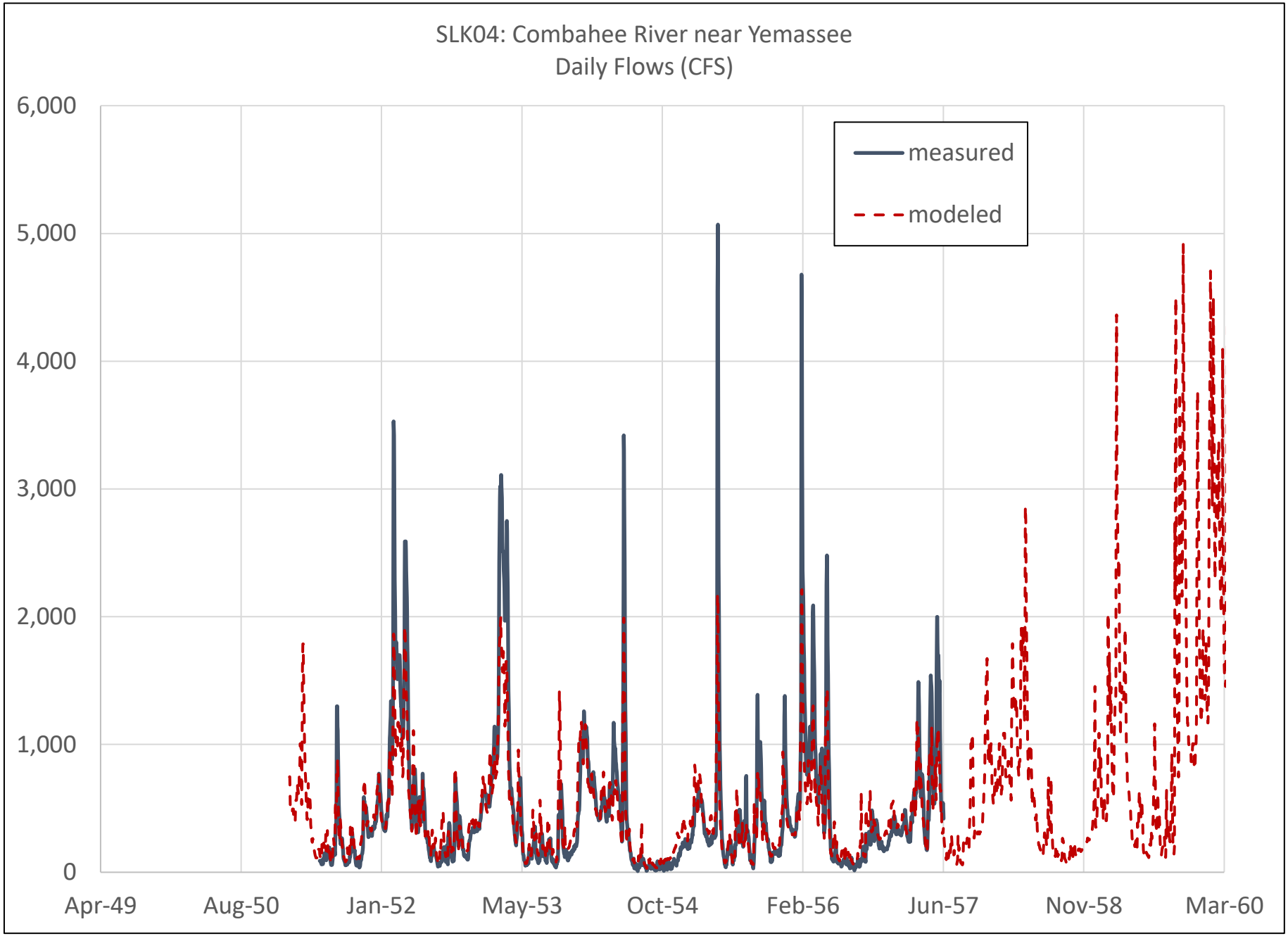
Monthly Validation Results

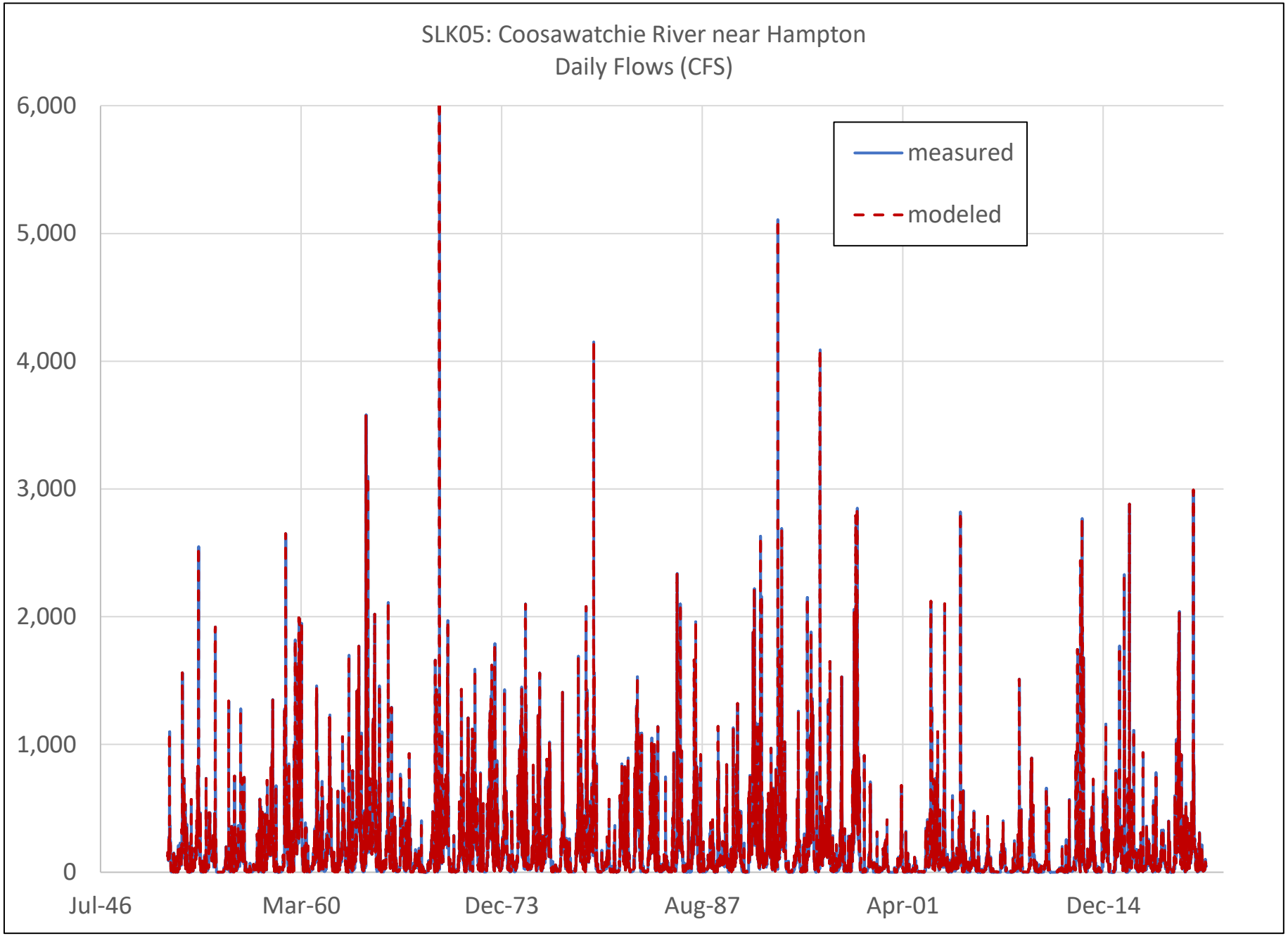
Attachment B

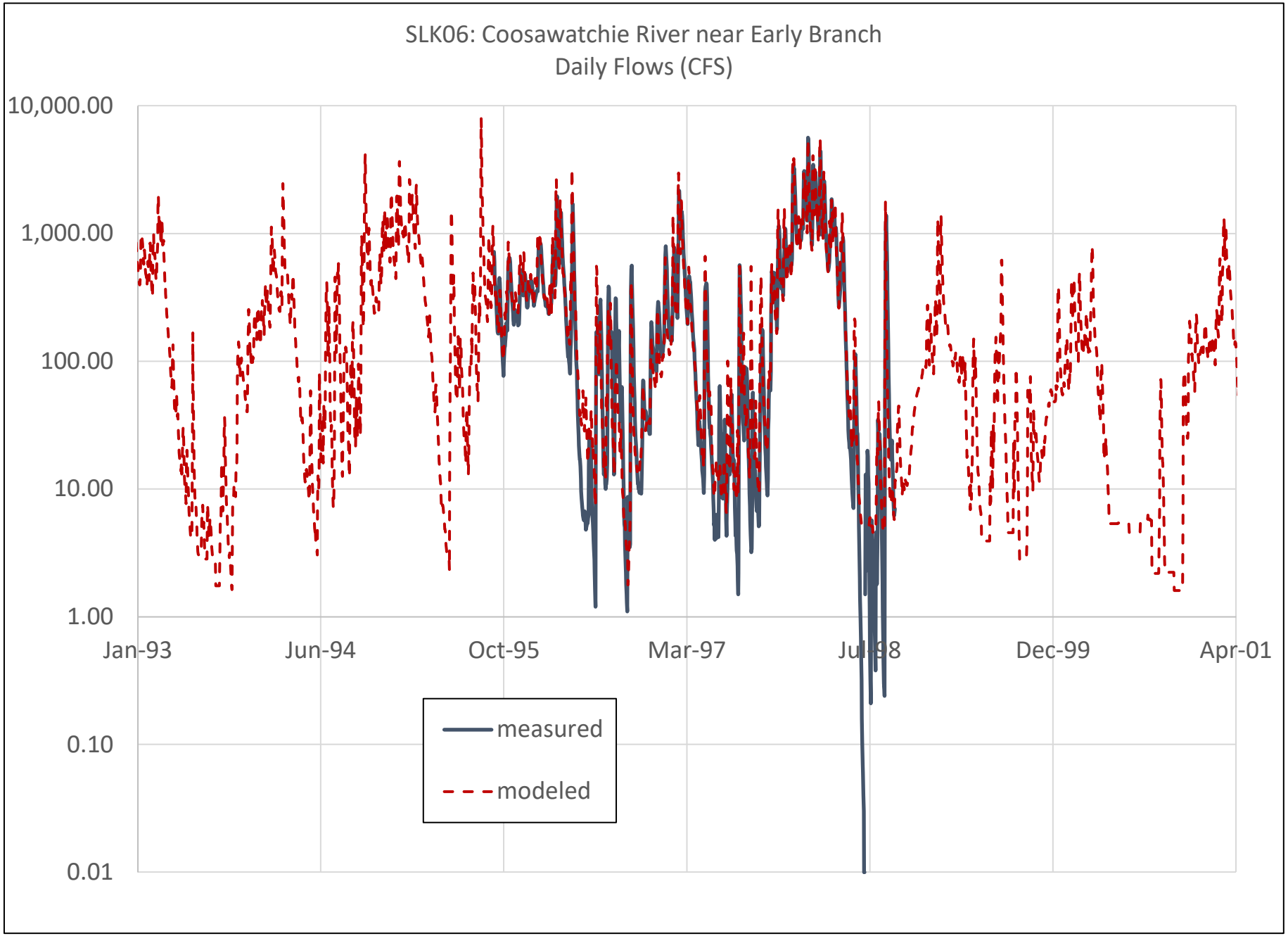
Daily Validation Results

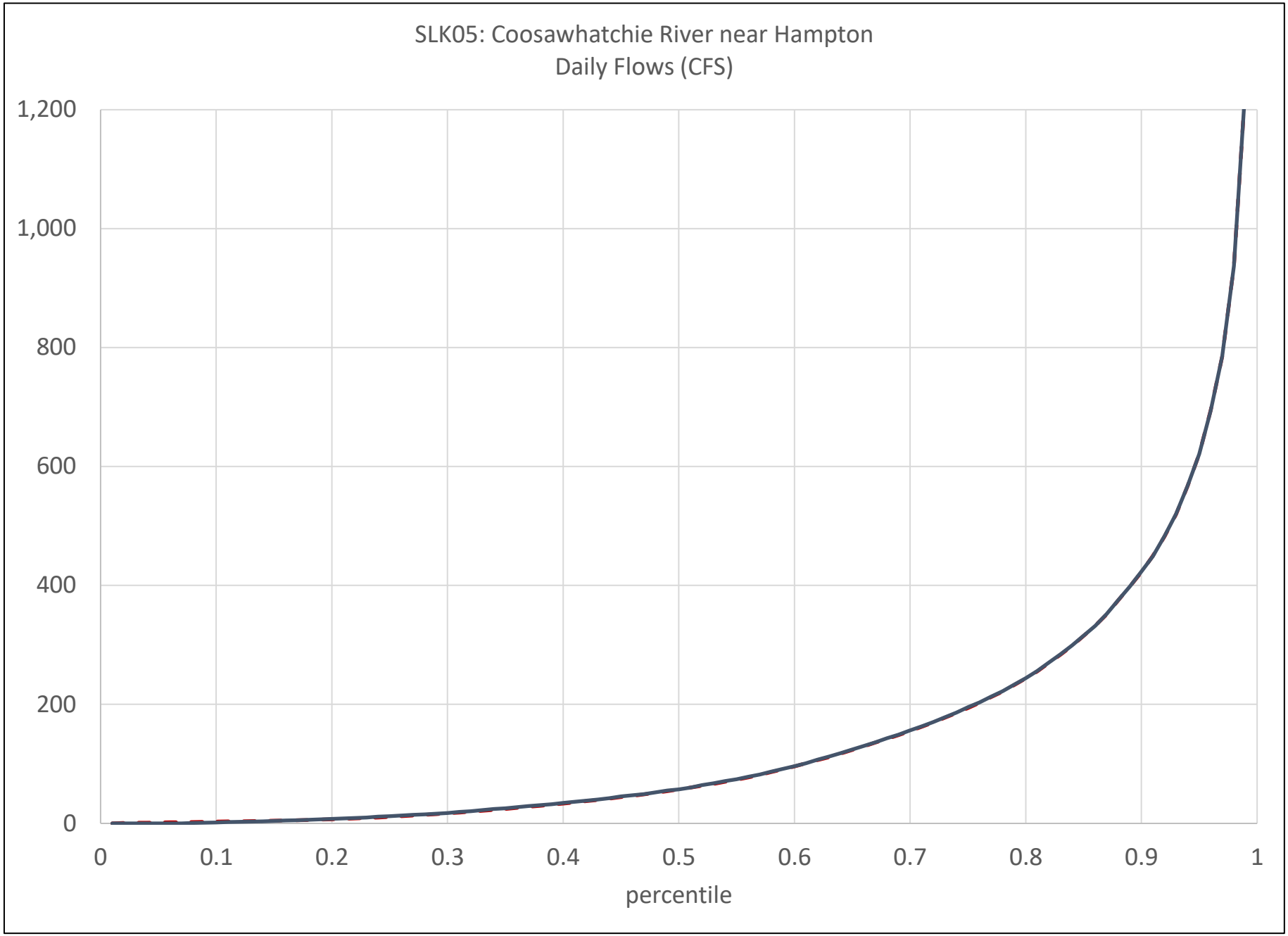

SLK01: Savannah Creek at Ehrhardt
Daily Flows (CFS)
measured
modeled
100
90
80
70
60
50
40
30
20
10
0
Dec-99
Jun-00
Jan-01
Jul-01
Feb-02
Sep-02
Mar-03
Oct-03

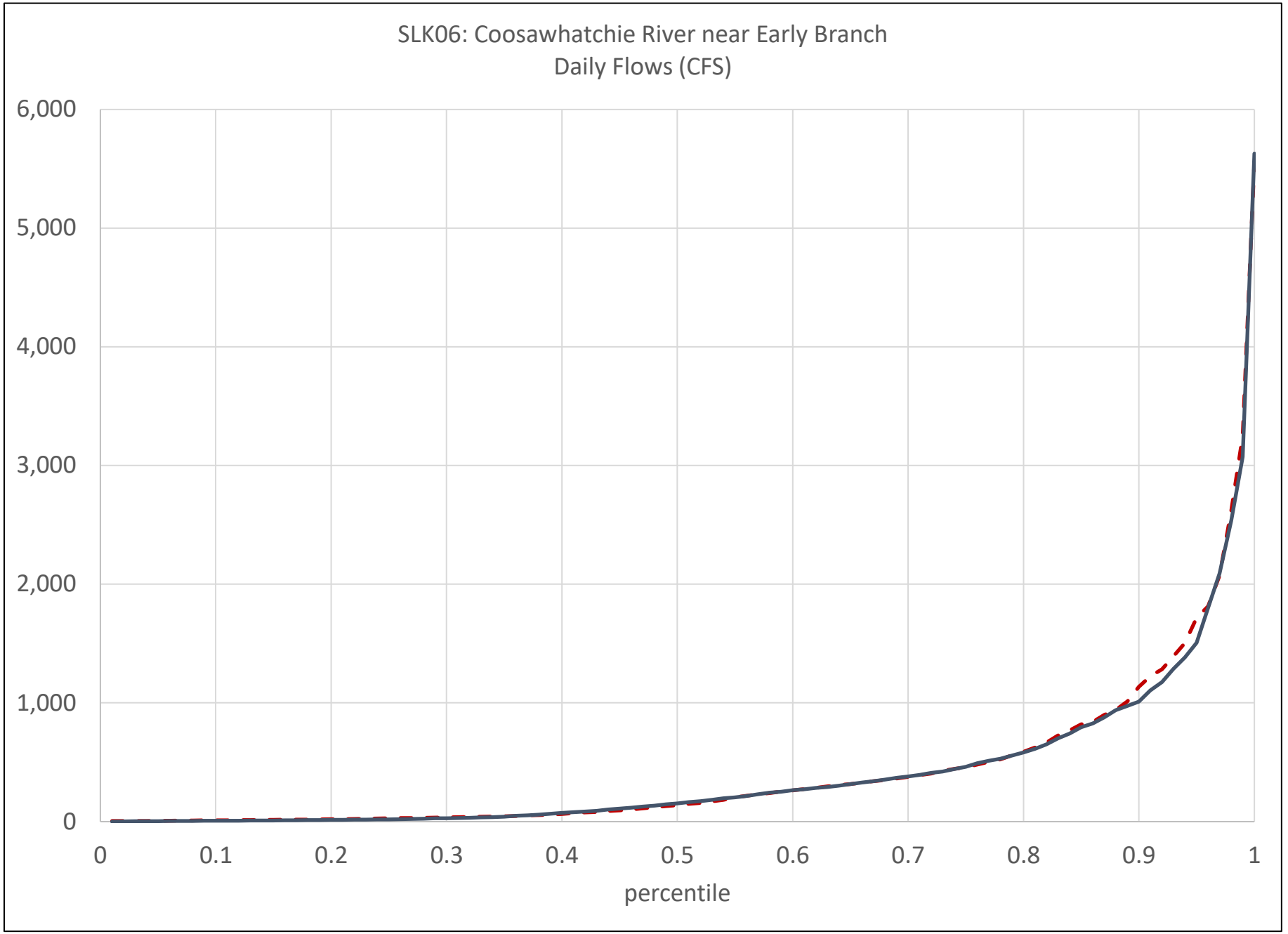

SLK02: Salkehatchie River near Miley
Daily Flows (CFS)
4000
3500
3000
2500
2000
1500
1000
500
0
Jul-46
Mar-60
Dec-73
Aug-87
Apr-01
Dec-14
measured
modeled


SLK04: Combahee River near Yemassee
Daily Flows (CFS)
6,000
5,000
4,000
3,000
2,000
1,000
0
Apr-49
Aug-50
Jan-52
May-53
Oct-54
Feb-56
Jun-57
Nov-58
Mar-60
measured
modeled


SLK05: Coosawatchie River near Hampton
Daily Flows (CFS)
6,000
5,000
4,000
3,000
2,000
1,000
0
Jul-46
Mar-60
Dec-73
Aug-87
Apr-01
Dec-14
measured
modeled


SLK06: Coosawatchie River near Early Branch
Daily Flows (CFS)
10,000.00
1,000.00
100.00
10.00
1.00
0.10
0.01
Jan-93
Jun-94
Oct-95
Mar-97
Jul-98
Dec-99
Apr-01
measured
modeled


SLK05: Coosawhatchie River near Hampton
Daily Flows (CFS)
1,200
1,000
800
600
400
200
0
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
percentile


SLK06: Coosawhatchie River near Early Branch
Daily Flows (CFS)
6,000
5,000
4,000
3,000
2,000
1,000
0
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
percentile