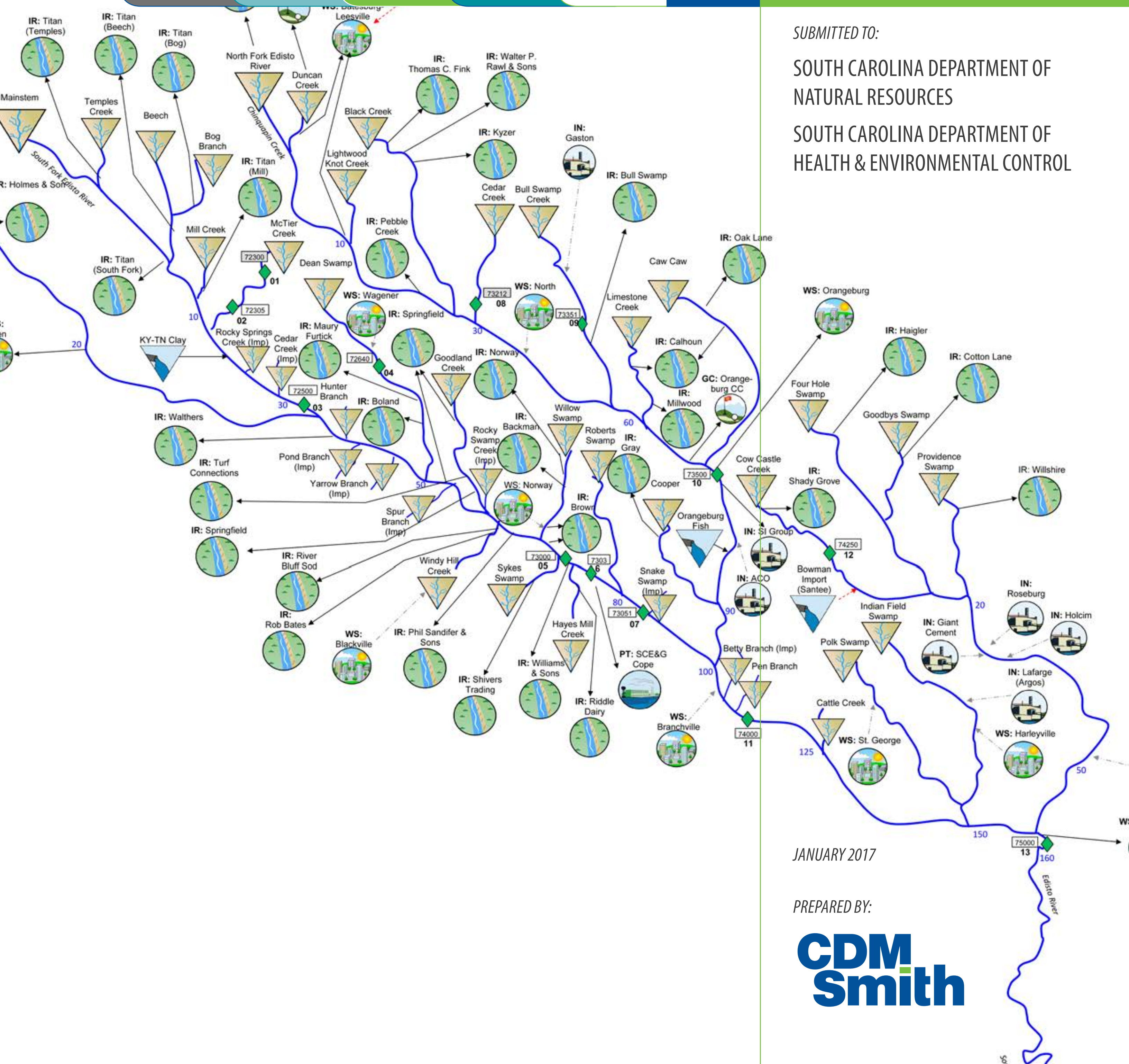
SOUTH CAROLINA
SURFACE WATER QUANTITY MODELS
EDISTO BASIN MODEL



SUBMITTED TO:

SOUTH CAROLINA DEPARTMENT OF NATURAL RESOURCES

SOUTH CAROLINA DEPARTMENT OF HEALTH & ENVIRONMENTAL CONTROL

JANUARY 2017

PREPARED BY:

CDM Smith

Table of Contents

List of Tables

List of Figures

Appendices

Section 1

Purpose

This document, the Edisto River Basin Modeling Report, is provided in support of the Surface Water Availability Assessment for the South Carolina Department of Natural Resources (DNR) and the South Carolina Department of Health and Environmental Control (DHEC). The Surface Water Availability Assessment is part of a broader strategy to augment statewide water planning tools and policies, culminating in the development of regional water plans and the update of the State Water Plan.

The Surface Water Availability Assessment focuses on the development of surface water quantity models. The models are primarily intended to represent the impacts of water withdrawals, return flows, and storage on the usable and reliably available water quantity throughout each major river basin in the state. With this ability, they will be used for regional water planning and management, policy evaluation and permit assessments.

This Edisto River Basin Modeling Report presents the model objectives; identifies revisions made to the initial model framework; summarizes model inputs and assumptions; presents the calibration approach and results; and provides guidelines for model use. Further guidance on use of the Edisto River Basin Model is provided in the *Simplified Water Allocation Model (SWAM) User's Manual* (CDM Smith, 2016).

Additionally, this document is intended to help disseminate the information about how the model represents the Edisto River Basin to parties with a vested interest in water management (stakeholders). To this end, the language is intended to be accessible and explanatory, describing the model development process in clear English without undue reliance on mathematical formulations, programming nuances, or modeling vernacular.

Section 2

Modeling Objectives

The Edisto River Basin Model in SWAM has been developed for multiple purposes, but it is primarily intended to support future permitting, policy, and planning efforts throughout the basin. Fundamentally, the model will simulate the natural hydrology through the network of the Edisto River and its major tributaries, and the impacts to the river flows from human intervention: withdrawals, discharges, impoundment, and interbasin transfers.

The model will simulate historic hydrologic conditions from 1931 through 2013. Defining and developing this hydrologic period of record required numerous assumptions and estimations of past flow and water use patterns, which were vetted during the calibration process. The purpose of the models is not to reproduce with high accuracy the flow on any given day in history. Rather, the purpose is to reproduce with confidence the frequency at which natural and managed flows have reached any given threshold, and by extension, how they might reach these thresholds under future use conditions. To this end, one important objective of model formulation was to reproduce hydrologic peaks and low flows on a monthly and daily basis, recession patterns on a monthly and daily basis, and average flows over months and years.

The end goals of the model are derived specifically from the project scope. The intended uses include:

1. Evaluate surface-water availability in support of the Surface Water Withdrawal, Permitting, Use, and Reporting Act;
2. Predict future surface-water availability using projected demands;
3. Develop regional water-supply plans;
4. Test the effectiveness of new water-management strategies or new operating rules; and
5. Evaluate the impacts of future withdrawals on instream flow needs and minimum instream flows as defined by regulation, and to test alternative instream flow recommendations.

Lastly, the model is intended to support a large user base, including staff at DNR and DHEC along with stakeholders throughout the Edisto River Basin. To this end, the master file will be maintained on a cloud-based server, and will be made accessible to trained users through agreement with DNR and/or DHEC. To support its accessibility, the SWAM model interface is designed to be visual and intuitive, but using the model and extracting results properly will require training for any future user.

Section 3

Review of the Modeling Plan

The modeling approach, data requirements, software, and resolution are described in the *South Carolina Surface Water Quantity Models - Modeling Plan*, (CDM Smith, November 2014).

The Modeling Plan is an overarching approach, intended to guide the development of all eight river basin models for South Carolina by describing consistent procedures, guidelines, and assumptions that will apply to each basin and model. It is not an exhaustive step-by-step procedure for developing a model in SWAM, nor does this address all of the specific issues that may be unique to particular basins. Rather, the Modeling Plan offers strategic guidelines aimed at helping model development staff make consistent judgments and decisions regarding model resolution, data input, and representation of operational variables and priorities.

The Modeling Plan was followed during development of the Edisto River Basin Model. Where appropriate, additional discussion has been included in this report, to elaborate on specific aspects covered in the Modeling Plan.

Section 4

Edisto Model Framework

The initial Edisto River Basin SWAM Model Framework was developed in collaboration with South Carolina DNR and DHEC, and was presented in the memorandum *Edisto Basin SWAM Model Framework* (CDM Smith, June 2015). The proposed framework was developed as a starting point for representing the Edisto Basin river network and its significant water withdrawals and discharges. The guiding principles in determining what elements of the Edisto River Basin to simulate explicitly were:

1. Begin with a simple representation, with the understanding that it is easier to add additional details in the future than to remove unnecessary detail to make the model more efficient.

2. Incorporate all significant withdrawals and discharges. Significant withdrawals include those that have a permit or registration – which indicated that they may withdrawal over 3 million gallons in any month. Significant discharges are those that average over 3 million gallons per month (mg/month). In some instances, discharges that average less than 3 mg/month were included, such as discharges directly associated with a permitted or registered withdrawal.

3. Any tributary with current uses (permitted or registered withdrawals or significant discharge) will be represented explicitly. These include most primary tributaries to the Edisto and its major branches, and some secondary tributaries.

4. Generally, tributaries that are unused are not included explicitly, but the hydrologic contributions from these tributaries are embedded in the unimpaired flows (or reach gains) in downstream locations. As unimpaired flows (UIFs) are developed throughout the Edisto, some additional tributaries may be added explicitly if warranted as candidates to support future use (or these can be easily added at any time in the future as permit applications are received).

During model development, simplifications were made in some areas, while more detail was added in others. **Figure 4-1** visually depicts the SWAM model framework, including tributaries, water users, and dischargers. As the framework is presented in the following paragraphs, changes made to the original model framework are noted.

4.1 Representation of Water Withdrawals

As noted above, significant withdrawals include those that have a permit or registration – which indicated that they may withdraw over 3 million gallons in any month. For several of the municipal water users represented in Edisto Model, withdrawal data includes both water used directly by that water user and water sold to other major municipal or industrial water users. For example, permit #10WS004 associated with the Charleston Water User object, includes water used directly by Charleston as well as water sold to KapStone Charleston Kraft, who has their own withdrawal permit in the Santee River Basin.

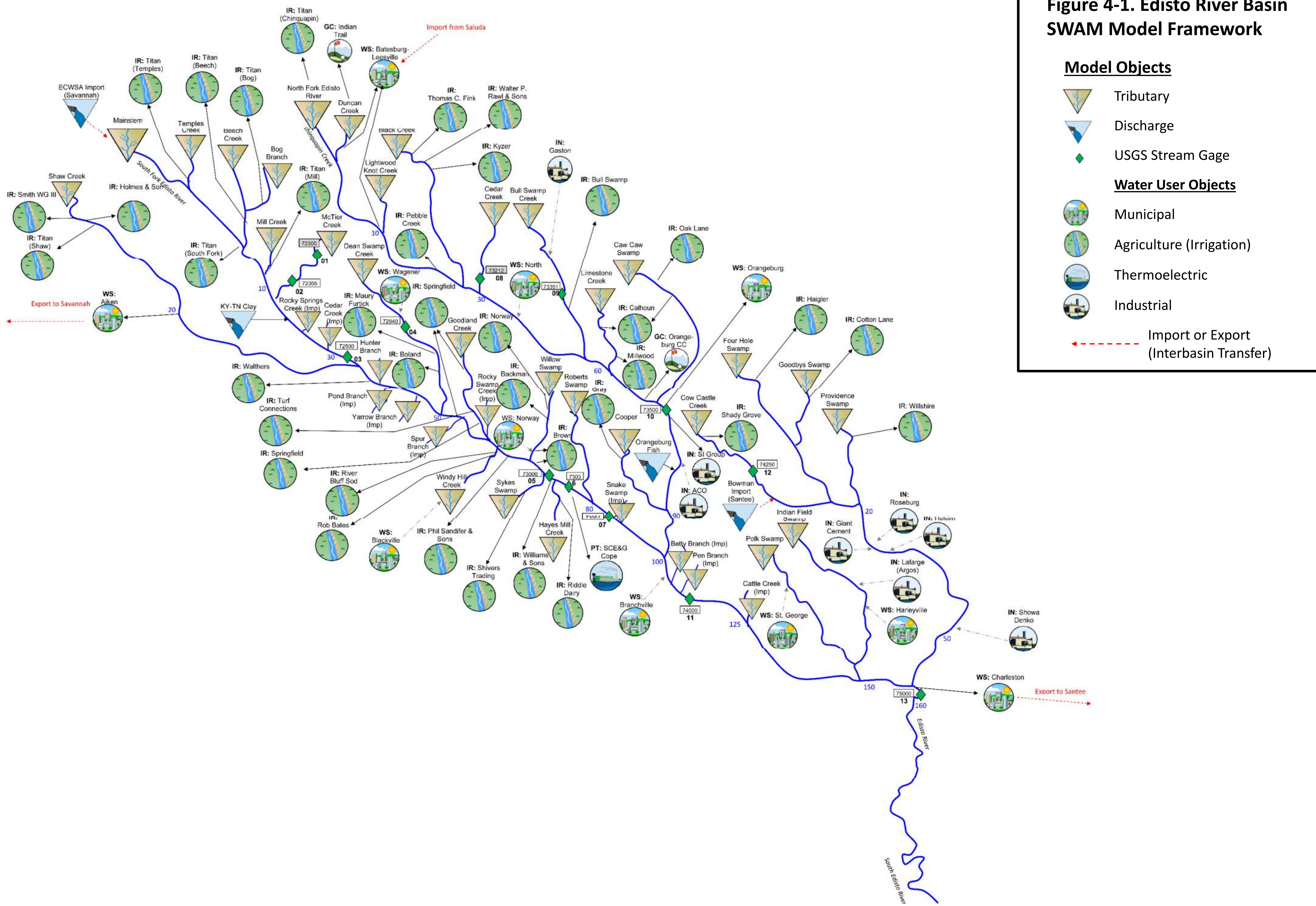


Figure 4-1. Edisto River Basin SWAM Model Framework

CDM Smith

Based on feedback from DNR, DHEC, and the Technical Advisory Committee (TAC), the decision was made to represent water withdrawals based on the permit holder rather than the ultimate water user. In this regard, the Water User objects reflect the withdrawals associated with their permit. In the example above, the water purchased by KapStone from Charleston Water System is accounted for under Charleston's Water User object. The alternative approach would have been to associate all of KapStone's demand as part of their own Water User object, including the water purchased from Charleston. The disadvantage of this approach is that the withdrawal permits associated with these conditions would be somewhat disaggregated in the model. Changes to a single permit limit, for example, would need to be applied for multiple users in the model. For this reason, the permit-based approach was selected for representing water withdrawals.

4.2 Representation of Discharges

Water and wastewater discharges can be simulated two ways in SWAM. First, they can be associated with a Water User object, each of which may specify five points of discharge anywhere in the river network. These discharges are not represented with visual model objects, but are identified within the dialogue box for the associated Water User object. Alternatively, discharges can be specified within a Discharge object. There are advantages and disadvantages with both methods. Associating discharges with withdrawals helps to automatically maintain a reasonable water balance because discharges are specified as seasonally-variable percentage of the withdrawal. However, it may be more difficult to test a maximum discharge permit level using this approach. Alternatively, using a tributary object to specify outflows allows for more precise representation of discharge variability, but does not automatically preserve the water balance (the user will need to adjust withdrawals to match simulated discharge). This second approach is also appropriate for interbasin transfers, in which source water resides in another basin but is discharged in the basin represented by the model.

In the Edisto River Basin Model, discharges are most often represented within the Water User object. The several exceptions, where a Discharge object was used, include the following:

- Several industrial discharges were deemed significant enough to include in the model; however, these industries do not withdraw surface water and do not have a registration to withdraw groundwater. These include Kentucky-Tenn Clay/Gentry Pitt and Orangeburg National Fish Hatchery.
- Water withdrawn by Edgefield County Water & Sewer Authority in the Savannah Basin, and then discharged in the Edisto Basin is represented by a Discharge object.
- Water withdrawn by the Santee Cooper Regional Water System in the Santee River Basin, and then discharged in the Edisto Basin by the Town of Bowman is represented by a Discharge object.

4.3 Groundwater Users and Associated Discharge

Although the Edisto Model focuses on surface water, representation of groundwater withdrawal (demand) within the model can be useful when the return flows, which are greater than 3 mg/month, are to surface water. In these cases, representation of the groundwater withdrawal by a Water User object, especially for municipalities, is useful because the (monthly) discharge percentage is specified with the Water User object. Since model scenarios typically focus on changes to water demand/use, the user can simply update the demand (in the Water User object, "Water Usage" tab), and the return flows will automatically be re-calculated. For water users who withdraw groundwater, the "Groundwater" option is selected in the Source Water Type section of the "Source Water" tab.

In the Edisto Basin, several significant, municipal and industrial groundwater withdrawals were identified which had a corresponding, significant discharge to surface water. These are represented by a Water User object, and include the following:

- Roseburg Forest Products
- Holcim Inc., Holly Hill Plant
- Giant Cement Company
- Lafarge Building Materials
- Town of Harleyville
- Aco Distribution
- Town of Blackville
- Town of Branchville
- Town of North
- Showa Denko Carbon
- Town of St. George
- Town of Wagener
- Town of Norway

4.4 Implicit Tributaries

At certain locations along the South Fork Edisto River and North Fork Edisto River, new implicit tributary objects were added to capture ungaged drainage areas and tributary inputs not included in the original model framework. The list of implicit tributaries included in the Edisto Model is provided in Section 6. These are tributaries which are not as likely to support future use as the explicitly represented tributaries; however, their contribution of flow to the main stem is important to include.

Section 5

Model Versions

For each river basin, two model versions were developed: a calibration model and a baseline model. The two models have different objectives and purposes, and, consequently, employ different parameter assignments, as described below.

The calibration model was developed to determine the "best fit" value of key model hydrologic parameters, as described in Section 7. Its utility beyond the calibration exercise is limited as the calibration model has been developed to recreate historical conditions which are not necessarily representative of current or planned future conditions. This model was parameterized using historical water use data to best reflect past conditions in the basin. These data include time-varying river withdrawals and consumptive use estimates. Also included in the calibration version of the model are water users that may be no longer active but were active during the selected calibration period. As discussed in Section 7, the simulation period for this version of the model focuses on the recent past (1983 – 2013) rather than the full record of estimated hydrology.

In contrast, the baseline model is intended to represent current demands and operations in the basin combined with an extended period of estimated hydrology. This model will serve as the starting point for any future predictive simulations with the model (e.g., planning or permitting support) and should be maintained as a useful "baseline" point of reference. For this model, the simulation period extends back to 1931, the start of the hydrologic record for the Edisto River Basin. Each element in the baseline model is assigned water use rates that reflect current demands only and are not time variable (except seasonal). Current demands were estimated by averaging water use data over the past ten years (2004 – 2013), on a monthly basis. These monthly demands are repeated in the baseline model for each simulation year. A final difference between the two models is that only active water users are included in the baseline model. Inactive user objects included in the calibration model have been removed from the baseline model.

Section 6

Model Inputs

SWAM inputs include unimpaired flows (UIFs); reservoir characteristics such as operating rule curves, storage-area-relationships, and evaporation rates; and water user information, including withdrawals, consumptive use, and return flows. This section summarizes the inputs used in both the calibration and baseline Edisto River Basin Models. As explained in Section 5, the calibration model incorporates historical water withdrawal and return data so that UIF flows and reach gains and losses can be calibrated to USGS gage flows. In contrast, the baseline model represents current demands and operations in the basin combined with an extended period of estimated hydrology. For future uses of the model, users can adjust the inputs, including demands, permit limits, and operational strategies, to perform "what if" simulations of basin water availability.

The following subsections describe the specific inputs to the Edisto models. Unless specifically noted, the inputs discussed below are the same in both the calibration model and baseline model.

6.1 Model Tributaries

The primary hydrologic inputs to the model are unimpaired flows for each tributary object. These flows, entered as a continuous timeseries of monthly and daily average data, represent either the flow at the top of each tributary object reach (headwater flows; explicit tributary objects) or at the bottom of the reach (confluence flows; implicit tributary objects). Additionally, mid-stream UIFs, though not used directly in the SWAM model construction, can serve as useful references in the model calibration process, particularly with respect to quantified reach gains and losses (discussed in Section 7).

6.1.1 Explicit Tributary Objects: Headwater Flows

Explicit tributary objects in SWAM are tributaries that include any number of Water User objects and/or reservoir objects with operations and water use explicitly simulated in the model. Conversely, implicit tributary objects (discussed below) are treated as simple point inflows to receiving streams in the model, without any simulated water use or operations. For further discussion on explicit versus implicit tributary objects in SWAM, please refer to the SWAM User's Manual.

Explicit tributary objects are parameterized in SWAM with headwater flows, representing unimpaired flows at the top of the given modeled reach. These flows may be raw gage flow, or area-prorated from calculated UIFs elsewhere in the basin. **Table 6-1** summarizes the gages, or in many instances, the reference gages used to develop headwater flows. **Figure 6-1** highlights the upstream drainage areas associated with the explicit tributary headwater flows. Green polygons correspond to unimpaired USGS gaged flow and purple polygons correspond to estimated ungaged flows. The inset table designates the project ID for each flow point, whether it was gaged or ungaged, the name of the tributary, and the corresponding drainage area in acres.

6.1.2 Implicit Tributary Objects: Confluence Flows

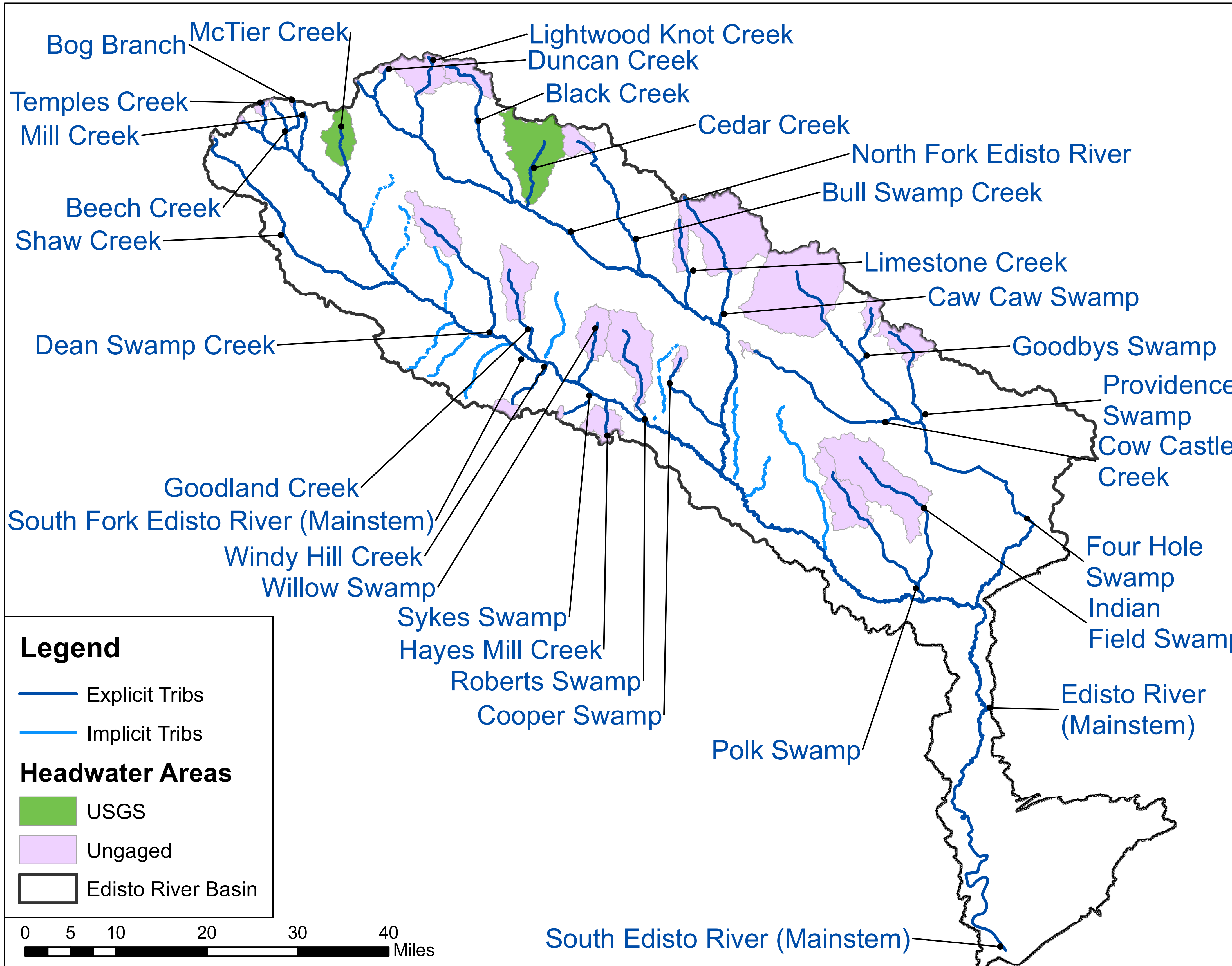
For implicit tributaries, all input confluence flows were estimated from reference UIFs. **Table 6-2** lists which unimpaired USGS gage was used as a reference gage for calculating flows for each implicit tributary object. **Figure 6-2** shows drainage areas for 12 implicit tributaries.

Table 6-1. 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
EDO220	Ungaged	-	Dean Swamp Creek	EDO04	02172640	Dean Swamp Creek
EDO202	Ungaged	-	Temples Creek	EDO05	02173000	South Fork Edisto River
EDO208	Ungaged	-	S. Fork Edisto River (Mainstem)			
EDO204	Ungaged	-	Beech Creek			
EDO206	Ungaged	-	Bog Branch			
EDO210	Ungaged	-	Mill Creek			
EDO218	Ungaged	-	Sykes Swamp			
EDO224	Ungaged	-	Goodland Creek			
EDO228	Ungaged	-	Windy Hill Creek			
EDO232	Ungaged	-	Willow Swamp			
EDO214	Ungaged	-	Shaw Creek			
EDO236	Ungaged	-	Hayes Mill Creek	EDO06	02173030	South Fork Edisto River
EDO240	Ungaged	-	Roberts Swamp	EDO07	02173051	South Fork Edisto River
EDO256	Ungaged	-	Bull Swamp Creek	EDO09	02173351	Bull Swamp Creek
EDO226	Ungaged	-	N. Fork Edisto River (with Chinquapin Creek)	EDO10	02173500	North Fork Edisto River
EDO242	Ungaged	-	Duncan Creek			
EDO246	Ungaged	-	Long Branch			
EDO248	Ungaged	-	Black Creek			
EDO260	Ungaged	-	Limestone Creek			
EDO266	Ungaged	-	Caw Caw Swamp			
EDO278	Ungaged	-	Cooper Swamp	EDO11	02174000	Edisto River
EDO280	Ungaged	-	Four Hole Swamp	EDO12	02174250	Cow Castle Creek
EDO282	Ungaged	-	Goodbys Swamp			
EDO284	Ungaged	-	Cow Castle Creek			
EDO288	Ungaged	-	Providence Swamp			
EDO296	Ungaged	-	Polk Swamp			
EDO298	Ungaged	-	Indian Field Swamp			
EDO01	Gaged	02172300	McTier Creek	-	-	-
EDO08	Gaged	02173212	Cedar Creek	-	-	-

Table 6-2. Reference Gages Used for Confluence Flows on Implicit Tributaries

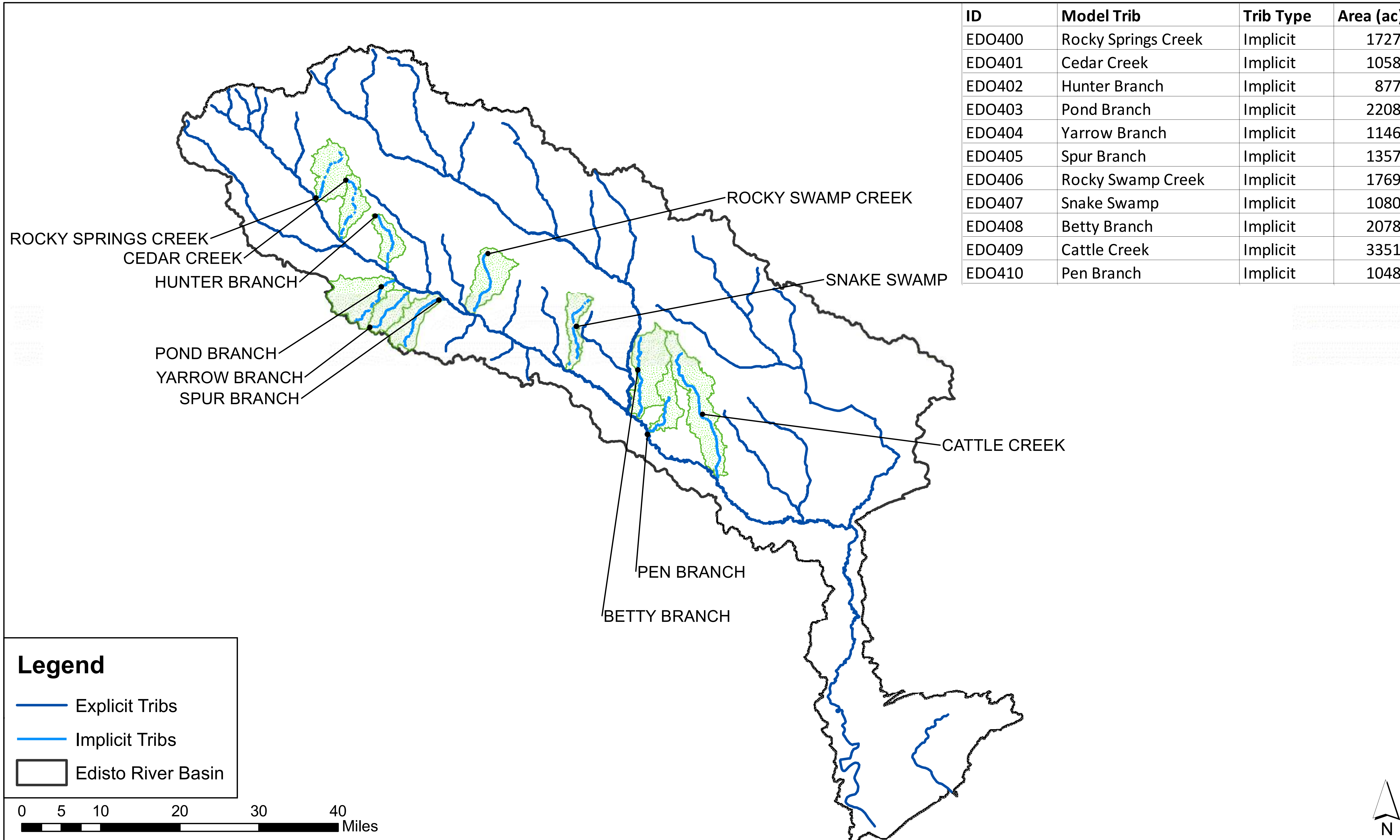
	Ungaged Basin	USGS Reference Gage (Unimpaired)		
Project ID	SWAM Tributary	Project Gage ID	USGS Number	Stream
EDO400	Rocky Springs Creek	EDO03	02172500	South Fork Edisto River
EDO401	Cedar Creek (Implicit)	EDO05	02173000	South Fork Edisto River
EDO402	Hunter Branch			
EDO403	Pond Branch			
EDO404	Yarrow Branch			
EDO405	Spur Branch			
EDO406	Rocky Swamp Creek			
EDO407	Snake Swamp			
EDO408	Betty Branch			
EDO410	Pen Branch			
EDO409	Cattle Creek	EDO12	02174250	Cow Castle Creek



ID	SWAM Trib	Type	Area (ac)
EDO01	McTier Creek	USGS	9963
EDO08	Cedar Creek	USGS	27372
EDO202	Temples Creek	Ungaged	1093
EDO204	Beech Creek	Ungaged	96
EDO206	Bog Branch	Ungaged	311
EDO208	South Fork Edisto River	Ungaged	405
EDO210	Mill Creek	Ungaged	204
EDO214	Shaw Creek	Ungaged	97
EDO218	Sykes Swamp	Ungaged	580
EDO220	Dean Swamp Creek	Ungaged	14046
EDO224	Goodland Creek	Ungaged	12995
EDO226	Chinquapin Creek	Ungaged	121
EDO228	Windy Hill Creek	Ungaged	2350
EDO232	Willow Swamp	Ungaged	9955
EDO236	Hayes Mill Creek	Ungaged	7070
EDO240	Roberts Swamp	Ungaged	21047
EDO242	Duncan Creek	Ungaged	717
EDO246	Lightwood Knot Creek	Ungaged	11778
EDO248	Black Creek	Ungaged	8096
EDO256	Bull Swamp Creek	Ungaged	5142
EDO260	Limestone Creek	Ungaged	5361
EDO266	Caw Caw Swamp	Ungaged	37038
EDO278	Cooper Swamp	Ungaged	1869
EDO280	Four Hole Swamp	Ungaged	50480
EDO282	Goodbys Swamp	Ungaged	3366
EDO284	Cow Castle Creek	Ungaged	2296
EDO288	Providence Swamp	Ungaged	10659
EDO296	Polk Swamp	Ungaged	17202
EDO298	Indian Field Swamp	Ungaged	30743

CDM Smith

Figure 6-1: Headwater Areas for Explicit Tributaries in the Edisto River Basin



ID	Model Trib	Trib Type	Area (ac)
EDO400	Rocky Springs Creek	Implicit	17277
EDO401	Cedar Creek	Implicit	10585
EDO402	Hunter Branch	Implicit	8779
EDO403	Pond Branch	Implicit	22085
EDO404	Yarrow Branch	Implicit	11468
EDO405	Spur Branch	Implicit	13577
EDO406	Rocky Swamp Creek	Implicit	17699
EDO407	Snake Swamp	Implicit	10802
EDO408	Betty Branch	Implicit	20789
EDO409	Cattle Creek	Implicit	33511
EDO410	Pen Branch	Implicit	10489

CDM Smith

Figure 6-2: Implicit Tributaries in the Edisto River Basin

6.1.3 Reach Gains and Losses

In SWAM, mainstem gain/loss factors and tributary sub-basin flow factors capture ungaged flow gains and losses associated with increasing drainage area with distance downstream and/or interaction with subsurface flow (leakage, seepage). These reach-specific factors are the primary parameters adjusted during model calibration, as further explained in Section 7. The gain/loss and sub-basin flow factors are applied to the input headwater flows and represent a steady and uniform gain/loss percentage relevant to the designated reach. Actual flow volume changes are calculated for a specific location based on these reach-specific factors and in proportion to stream length and the object headwater flow for the given timestep.

There are subtle differences in the way in which these gains and losses are characterized in the model inputs for non-mainstem tributary objects versus the mainstem tributary object, although they effectively achieve the same thing in the model calculations. For the mainstem, gain/loss factors are specified on a per unit mile basis. For example, if the mainstem headwater flow is 10 cfs in a given timestep with a gain factor of 0.1 per mile specified for the entire mainstem reach, then the model applies a rate of gain of 1 cfs/mile throughout the length of the mainstem. At the end of a 5 mile reach with no other inflows or outflow, the flow would be 15 cfs. For all other tributary objects, sub-basin flow factors are specified as a total subbasin flow gain factor, used to calculate total natural (unimpaired) flow at the end of the designated reach. For example, if a tributary flow is 10 cfs in a given timestep, with a sub-basin flow factor of 5, then the end-of-reach flow (with no other inflows or outflows) is 50 cfs. The model linearly interpolates when calculating the unimpaired flow at intermediary points in the reach. The differences between mainstem vs. non-mainstem factors reflect physical differences between the two types of tributary objects as represented in SWAM. For non-mainstem tributaries, flow gains are usually dominated by easily-quantifiable increases in drainage area with distance downstream and therefore easily parameterized with drainage area-based sub-basin flow factors. For the mainstem, however, the bulk of the drainage area changes are already captured by the tributary objects and any additional changes in flow are more likely to be attributable to subsurface hydrologic interactions or localized surface runoff. Such flow changes are more easily represented with per mile gain/loss factors. Both mainstem and tributary flow factors can be spatially variable in the model for up to five different sub-reaches. For further discussion on SWAM reach gain/loss factors, please refer to the SWAM User's Manual.

Tributary object gain/loss and sub-basin flow factors are the primary calibration parameters in the model, as discussed in Section 7. Recognizing the uncertainty in these parameters, factors are adjusted, as appropriate, to achieve a better match of modeled vs. measured downstream flows. As a starting point in the model, however, overall non-mainstem tributary sub-basin flow factors were prescribed in the model based only on drainage area ratios (headwater vs. confluence). Drainage areas are shown in Figures 6-1 and 6-2 and corresponding tributary and mainstem flow factors are summarized in **Table 6-3.**

6.2 Water Users

6.2.1 Sources of Supply

Table 6-4 summarizes the sources of supply for all Water User objects included in the model. This information includes withdrawal tributaries, diversion locations, and permit limits. As noted in the table, only several minor differences exist between the calibration and baseline model with respect to water users. Most notably, SCE&G Canadys Station came off-line in 2014, and therefore it is not

Table 6-3. Model Tributary Inputs

SWAM Tributary Object	Tributary Type	Confluence Stream	Confluence Location (mile)	Area (ac)	Headwater ID	End Mile	Drainage Area Ratio	Subbasin Flow Factor (unitless)
Beech Creek	Explicit	Mainstem	6.5	3,808	EDO204	3.9	39.7	39.7
				5,152		6.2	53.7	53.7
Black Creek	Explicit	North Fork Edisto River	27.4	22,279	EDO248	3.8	2.8	2.8
				37,033		9.2	4.6	4.6
				43,746		14.9	5.4	5.4
Bog Branch	Explicit	Beech Creek	4	1,865	EDO206	1.6	6.0	6.0
				2,229		2.7	7.2	7.2
				3,188		3.7	10.3	10.3
Bull Swamp Creek	Explicit	North Fork Edisto River	52.3	21,685	EDO256	4.9	4.2	4.2
				55,704		12.3	10.8	10.8
				61,543		17.4	12.0	12.0
Caw Caw Swamp	Explicit	North Fork Edisto River	68.3	48,088	EDO266	3.5	1.3	1.3
				51,268		6.6	1.4	1.4
Cedar Creek	Explicit	North Fork Edisto River	29.9	27,372	EDO08	1	1.0	1.0
Cooper Swamp	Explicit	North Fork Edisto River	89.3	9,131	EDO278	6	4.9	4.9
				17,029		10.3	9.1	9.1
Cow Castle Creek	Explicit	Four Hole Swamp	14.9	15,472	EDO284	9.6	6.7	6.6
				43,706		19.5	19.0	19.0
Dean Swamp Creek	Explicit	Mainstem	50	19,894	EDO220	2.1	1.4	1.4
				41,752		11.7	3.0	3.0
Duncan Creek	Explicit	North Fork Edisto River	2.7	3,256	EDO242	1.9	4.5	4.5
				4,179		3.4	5.8	5.8
Mainstem (South Fork Edisto River)	Explicit	None	None	1,715,508	EDO208	69.3	-	5.1*
						77		4.5*
						81.9		3*
						114		7.6*
						218		0*
Four Hole Swamp	Explicit	Mainstem	157	112,968	EDO280	15	2.2	2.2
				178,520		30.4	3.5	3.5
				314,308		52.4	6.2	5.5
Goodbys Swamp	Explicit	Four Hole Swamp	6.7	8,004	EDO282	2	2.4	2.4
				9,519		4.6	2.8	2.8
Goodland Creek	Explicit	Mainstem	59.7	24,123	EDO224	2.1	1.9	1.9
				28,412		6.1	2.2	2.2
Hayes Mill Creek	Explicit	Mainstem	72.6	7,627	EDO236	1.1	1.1	1.1
Indian Field Swamp	Explicit	Polk Swamp	10	48,786	EDO298	5.4	1.6	1.6
				59,696		9.6	1.9	1.9
Lightwood Knot Creek	Explicit	North Fork Edisto River	10.7	18,675	EDO246	2.6	1.6	1.6
				23,233		5.6	2.0	2.0
Limestone Creek	Explicit	North Fork Edisto River	62	10,587	EDO260	1	2.0	2.0
				12,184		2.5	2.3	2.3
				12,602		3.5	2.4	2.4
				12,979		4.8	2.4	2.4
McTier Creek	Explicit	Mainstem	17.5	9,963	EDO01	0.1	1.0	1.0
				22,318		3.4	2.2	2.0
				24,632		5.5	2.5	2.3
Mill Creek	Explicit	Mainstem	8.4	6,386	EDO210	2	31.3	31.3
				9,467		4.6	46.5	46.5
North Fork Edisto River	Explicit	Mainstem	100.3	82,729	EDO226	27.5	685	685
				169,659		52.4	1405	1405
				213,997		71	1772	2240
				247,676		99.6	2051	2240

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

CDM Smith

Table 6-3. Model Tributary Inputs (continued)

SWAM Tributary Object	Tributary Type	Confluence Stream	Confluence Location (mile)	Area (ac)	Headwater ID	End Mile	Drainage Area Ratio	Subbasin Flow Factor (unitless)
Polk Swamp	Explicit	Mainstem	146.6	30,692	EDO296	4.2	1.8	1.8
				40,334		11.7	2.3	2.3
Providence Swamp	Explicit	Four Hole Swamp	17.6	17,726	EDO288	2.5	1.7	1.7
				39,712		6.8	3.7	3.7
Roberts Swamp	Explicit	Mainstem	80.3	22,018	EDO240	1.7	1.1	4.5
Shaw Creek	Explicit	Mainstem	32.3	21,360	EDO214	8.5	220	220
				43,744		19.7	450	558
				85,370		34.5	878	878
Sykes Swamp	Explicit	Mainstem	69.2	2,281	EDO218	1.7	3.9	3.9
				5,705		4.4	9.8	9.8
Temples Creek	Explicit	Mainstem	2.4	1,894	EDO202	0.7	1.7	1.7
				2,492		1.4	2.3	2.3
				3,533		2.3	3.2	3.2
Willow Swamp	Explicit	Mainstem	67	13,812	EDO232	3	1.4	1.4
Windy Hill Creek	Explicit	Mainstem	61	6,152	EDO228	3	2.6	2.6
				12,388		7	5.3	5.3
Betty Branch	Implicit	Mainstem	103.6	20,789	EDO408	1	1.0	1.0
Cattle Creek	Implicit	Mainstem	125.1	33,511	EDO409	1	1.0	1.0
Cedar Creek	Implicit	Mainstem	31	27,372	EDO401	1	1.0	1.0
Hunter Branch	Implicit	Mainstem	40.5	8,779	EDO402	1	1.0	1.0
Pen Branch	Implicit	Mainstem	107.3	10,489	EDO410	1	1.0	1.0
Pond Branch	Implicit	Mainstem	43	22,085	EDO403	1	1.0	1.0
Rocky Springs Creek	Implicit	Mainstem	22.9	17,277	EDO400	1	1.0	1.0
Rocky Swamp Creek	Implicit	Mainstem	59.8	17,699	EDO406	1	1.0	1.0
Snake Swamp	Implicit	Mainstem	82.4	10,802	EDO407	1	1.0	1.0
Spur Branch	Implicit	Mainstem	53.3	13,577	EDO405	1	1.0	1.0
Yarrow Branch	Implicit	Mainstem	46	11,468	EDO404	1	1.0	1.0

included in the baseline model. Several out-of-basin sources are represented as Discharge objects (discussed below) and therefore don't appear in Table 6-4.

6.2.2 Demands

Table 6-5 presents the monthly demand for Municipal (WS), Industrial (IN) and Thermopower (PT) Water User objects in the baseline model. Monthly irrigation demands for Golf Course (GC) and Agricultural (IR) Water User objects are presented in **Table 6-6**. The baseline model monthly demand assigned to each Water User object was calculated by averaging monthly demands (as reported to DHEC) over the ten-year period from 2004 through 2013. Demands for the calibration period (1983 through 2013) were input as a timeseries of monthly values based on monthly withdrawals reported to DHEC and supplemented by data collected from each water user by CDM Smith.

Table 6-4. Water User Objects and Sources of Supply Included in the Edisto River Basin Model

Model Object ID	Facility Name	Source of Supply	Intake ID	Diversion Location (mi)	Permit Limit (MGM)	Note
GC: Indian Trail	INDIAN TRAIL GOLF CLUB	Duncan Creek	32GC011S01	3.0	3	1
GC: Orangeburg CC	ORANGEBURG COUNTRY CLUB	North Fork Edisto River	38GC004S01	66.0	11	1
IN: JM Huber	J M HUBER CORP EDISTO PLANT	South Fork Edisto River	02IN005S02	22.1	-	2
			02IN005S01	22.1	-	2
IN: SI Group	SI GROUP (FORMERLY ALBEMARLE)	North Fork Edisto River	38IN002S01	72	2743.3	1
IR: Backman	BACKMAN FARMS	Willow Swamp	38IR020S01	2.8	60.5	1,3
IR: Boland	BOLAND FARM	Dean Swamp Creek	38IR081S01	10.0	8.5	1,3
			38IR081S02		6.0	1,3
IR: Brown	BROWN FARMS	Willow Swamp	38IR015S01	2.0	4.2	1,3
		South Fork Edisto River	38IR015S02	69.0	13.0	1,3
IR: Bull Swamp	BULL SWAMP PLANTATION	Bull Swamp Creek	38IR014S01	13.0	12.0	1,3
			38IR014S02		14.9	1,3
			38IR014S03		16.0	1,3
IR: Calhoun	CALHOUN TRADING CO	Limestone Creek	09IR004S02	1.0	14.7	1,3
		Caw Caw Swamp	09IR004S01	3.0	3.5	1,3
IR: Cotton Lane	COTTON LANE FARMS	Goodby's Swamp	09IR003S01	1.0	-	1,3
			09IR003S02		30.1	1,3
			09IR003S03		19.5	1,3
IR: Gray	GRAY FARM	Cooper Swamp	38IR042S01	0.3	7.0	1,3
IR: Haigler	HAIGLER FARMS INC	Four Hole Swamp	09IR009S01	2.0	55.0	1,3
			09IR009S02		28.0	1,3
			09IR009S03		36.0	1,3
			09IR009S04		28.4	1,3
IR: Holmes & Son	HOLMES & SON LEWIS FARM	Shaw Creek	19IR002S01	5.0	16.1	1,3
			19IR002S02		32.6	1,3
IR: Kyzer	KYZER FARMS	Black Creek	32IR004S01	7.0	3.0	1,3
IR: Maury Furtick	MAURY FURTICK FARM	Dean Swamp Creek	02IR028S01	8.0	6.0	1,3
IR: Millwood	MILLWOOD FARM	Limestone Creek	38IR004S01	2.0	94.5	1,3
			38IR004S02	3.0	98.4	1,3
			38IR004S03	3.1	78.6	1,3
IR: Norway	NORWAY FARM	Willow Swamp	38IR067S01	2.6	30.0	1,3
IR: Oak Lane	OAK LANE FARM HALFWAY SWAMP	Caw Caw Swamp	09IR011S01	1.0	39.1	1,3
IR: Pebble Creek	PEBBLE CREEK ENTERPRISES	North Fork Edisto River	02IR027S01	26.0	4.0	1,3
IR: Phil Sandifer & Sons	PHIL SANDIFER & SONS, LLC	South Fork Edisto River	05IR012S01	66.0	50.0	1,3
IR: Riddle Dairy	RIDDLE DAIRY FARM	Hayes Mill Creek	05IR054S01	0.1	22.7	1,3
IR: River Bluff Sod	RIVER BLUFF SOD FARM	South Fork Edisto River	38IR077S01	61.0	13.0	1,3
IR: Rob Bates	ROB BATES FARM	Windy Hill Creek	06IR020S01	3.0	20.0	1,3
IR: Shady Grove	SHADY GROVE PLANTATION & NURSERY INC	Cow Castle Creek	38IR040S01	0.1	100.6	1,3
IR: Shivers Trading	SHIVERS TRADING AND OPERATING COMPANY	Sykes Swamp	05IR005S01	0.1	23.7	1,3
IR: Smith WG III	SMITH W G III	Shaw Creek	19IR012S02	1.0	16.0	1,3
			19IR012S03		12.0	1,3
			19IR012S04		3.2	1,3
IR: Springfield	SPRINGFIELD FARM	Goodland Creek	38IR066S01	3.0	11.0	1,3
IR: Springfield Grain Co	SPRINGFIELD GRAIN CO BROWN KIRBY & SONS	South Fork Edisto River	38IR026S02	53.0	114.0	1,3
		Goodland Creek	38IR026S01	1.0	96.0	1,3
			38IR026S03		69.1	1,3
IR: Thomas C. Fink	THOMAS C. FINK FARM	Black Creek	32IR050S01	1.0	40.0	1,3

Table 6.4 Water User Objects and Sources of Supply Included in the Edisto River Basin Model (continued)

Model Object ID	Facility Name	Source of Supply	Intake ID	Diversion Location (mi)	Permit Limit (MGM)	Note
IR: Titan (Beech)	TITAN FARMS	Beech Creek	41IR014S07	5.0	30.0	1,3
			41IR014S09		25.0	1,3
			19IR004S03		20.0	1,3
			19IR004S08		20.0	1,3
IR: Titan (Bog)		Bog Branch	41IR014S02	1.0	35.0	1,3
			41IR014S06		20.0	1,3
			19IR004S06		40.0	1,3
			19IR004S15		15.0	1,3
			19IR004S05	2.0	42.0	1,3
			19IR004S01	3.0	42.0	1,3
			19IR004S07		15.0	1,3
IR: Titan (Chinquapin)		Chinquapin Creek	41IR010S01	1.0	71.0	1,3
IR: Titan (Mill)		Mill Creek	41IR014S05	1.0	40.0	1,3
IR: Titan (Shaw)		Shaw Creek	41IR014S10	6.0	36.0	1,3
			19IR004S12		26.0	1,3
IR: Titan (South Fork)		South Fork Edisto River	19IR004S09	6.0	25.0	1,3
			19IR004S13		42.0	1,3
			19IR004S14		42.0	1,3
			02IR024S02		25.0	1,3
IR: Titan (Temples)		Temples Creek	19IR004S02	0.1	44.0	1,3
			19IR004S04		20.0	1,3
			19IR004S11		30.0	1,3
			19IR004S10	1.0	15.0	1,3
			19IR004S16	1.1	44.0	1,3
IR: Turf Connections	TURF CONNECTIONS	Goodland Creek	38IR078S01	2.8	15.0	1,3
IR: Walter P. Rawl & Sons	WALTER P. RAWL & SONS/WP FARL FARM	Black Creek	32IR013S08	3.1	19.3	1,3
IR: Walthers	WALTHERS FARMS	South Fork Edisto River	02IR025S01	37.0	400.0	1,3
IR: Williams & Sons	WILLIAMS & SONS FARMS	South Fork Edisto River	38IR021S01	70.0	27.1	1,3
			38IR021S02		21.7	1,3
IR: Willshire	WILLSHIRE FARMS INC	Providence Swamp	38IR043S01	1.0	9.6	1,3
			38IR043S02		8.5	1,3
PT: SCE&G Canadys	SCE&G-CANADYS STATION	South Fork Edisto River	15PT001S02	135.2	-	2
			15PT001S01		-	2
PT: SCE&G Cope	SCE&G - COPE STATION	South Fork Edisto River	38PT001S01	76.9	670	1
WS: Aiken	CITY OF AIKEN	Shaw Creek	02WS002S01	20.0	248	1
WS: Batesburg-Leesville	BATESBURG WATER PLANT	Lightwood Knots Creek	32WS003S01	1.0	-	1
		Duncan Creek	32WS003S02	0.1	-	1
WS: Charleston	CHARLESTON CPW - HANAHAN WTP	Edisto River	10WS004S03	159.0	8729.36	1
WS: Orangeburg	CITY OF ORANGEBURG WTP	North Fork Edisto River	38WS002S03	70.0	372	1
			38WS002S01		1116	1
			38WS002S02		263.5	1

Note 1 indicates the withdrawal is currently active, and was included in both the baseline and calibration model.
Note 2 indicates the withdrawal was previously active, and was included in the calibration model.
Note 3 indicates registered limit for irrigation.

6.2.3 Transbasin Imports

In South Carolina, there are many examples of water users who access source waters in multiple river basins and/or discharge return flows to multiple basins. In order to consistently represent transbasin imports and exports in the SWAM models, a set of guidelines were developed, which are summarized in **Appendix C – Guidelines for Representing Multi-Basin Water Users in SWAM**. In the Edisto River Basin Model, several water users import water from outside the basin. These include:

- Edgefield County Water and Sewer Authority (ECWSA) is represented as a Discharge object (**ECWSA Import)**, as its water is sourced exclusively from the Savannah River Basin, with return flow discharges to the Edisto River Basin.
- The Town of Bowman is represented as a Discharge object (**Bowman Import)**, as its water is sourced exclusively from the Santee River Basin, with return flow discharges to the Edisto River Basin.
- In addition to its surface water withdraws in the Edisto Basin, **Batesburg-Leesville** purchases some water from the Gilbert Summit Rural Water District, which withdraws groundwater from both within and outside of the Edisto Basin.

6.2.4 Consumptive Use and Return Flows

As discussed in Section 4.2, return flows (discharges) can be simulated two ways in SWAM. They can be associated with a Water User object or specified within a Discharge object. **Table 6-7** summarizes the calibration and baseline model objects representing return flows, their location, and the percent of return flow assigned to each location. In this table, the "*% of Return Flow*" represents the allocation to one or more discharge locations, not the consumptive use percentage. In many instances, multiple NPDES discharge locations associated with a unique Water User object were lumped together, based on their close proximity to one another (e.g., SCE&G's Canadys Station Discharges were lumped together in the calibration model). No returns are assumed for golf course and agricultural irrigation (i.e., 100% consumptive use).

Table 6-8 presents the monthly percent consumptive use for water users with known return flows. For all municipal and industrial water users, consumptive use was calculated from DHEC-reported withdrawals and discharges over the baseline period (2004 through 2013).

Table 6-9 presents the baseline model monthly average returns represented by a Discharge object. The returns were calculated by averaging the DHEC-reported discharges for the baseline period (2004 through 2013).

6.3 Summary

This section has presented the form and numerical values of data that are input into the Edisto River Basin Model, in the context of the model framework discussed in Section 4. Data descriptions are organized according to the model objects which house the data. For more details on SWAM model input requirements and mechanics, readers are referred to the SWAM User's Manual. Note that, as discussed in Section 7, a small portion of these input data may be adjusted as part of the calibration process. For the Edisto River Basin model, these calibration inputs only include reach hydrologic gain/loss factors. UIFs were also adjusted during calibration, when it was determined that a different reference gage was able to provide a better match of downstream gage flows, compared to the originally selected reference gage for a specific tributary.

Table 6-5. Baseline Model Average Monthly Demand for IN, PT, and WS Water Users

Baseline Model Average Monthly Demand (MGD)							
Month	IN: SI Group	PT: SCE&G - Cope	WS: Aiken	WS: Batesburg-Leesville	WS: Charleston	WS: Orangeburg	IN: Roseburg
Permit Limit (MGD)	90.2	22.0	8.2	NA	287.2	57.6	NA
Jan	0.45	4.59	6.10	1.18	34.94	7.27	0.00
Feb	0.45	4.48	6.21	1.21	35.80	7.22	0.00
Mar	0.44	4.12	7.01	1.29	35.71	7.17	0.00
Apr	0.42	3.67	8.72	1.32	41.61	7.52	0.00
May	0.41	4.53	10.20	1.29	45.65	8.04	0.00
Jun	0.45	5.20	10.67	1.44	41.74	8.63	0.00
Jul	0.43	5.29	10.89	1.35	38.46	9.07	0.00
Aug	0.41	5.20	10.56	1.35	37.57	8.93	0.00
Sep	0.41	4.30	10.18	1.27	39.24	8.94	0.00
Oct	0.35	4.16	9.07	1.20	40.19	8.33	0.00
Nov	0.39	4.12	7.53	1.09	36.58	7.79	0.00
Dec	0.39	4.48	6.34	1.15	32.88	7.35	0.00

Baseline Model Average Monthly Demand (MGD)							
Month	IN: Holcim	IN: Giant Cement	IN: Lafarge (Argos)	WS: Harleyville	IN: ACO	WS: Blackville	WS: Branchville
Permit Limit (MGD)	NA	NA	NA	NA	NA	NA	NA
Jan	4.53	3.23	2.44	0.07	0.00	0.33	0.12
Feb	5.15	3.23	2.97	0.07	0.00	0.35	0.12
Mar	4.79	3.30	2.41	0.07	0.00	0.32	0.11
Apr	4.43	3.19	2.31	0.08	0.00	0.32	0.13
May	4.26	3.21	2.42	0.06	0.00	0.35	0.13
Jun	4.70	3.44	2.68	0.07	0.00	0.37	0.15
Jul	4.92	3.59	3.30	0.06	0.00	0.35	0.14
Aug	4.68	3.46	3.31	0.06	0.00	0.35	0.13
Sep	4.17	3.34	2.71	0.09	0.00	0.34	0.15
Oct	3.86	3.47	2.62	0.06	0.00	0.29	0.14
Nov	3.53	2.89	1.91	0.06	0.00	0.34	0.14
Dec	4.27	3.11	2.63	0.06	0.00	0.30	0.13

Baseline Model Average Monthly Demand (MGD)						
Month	IN: Gaston	WS: North	IN: Showa Denko	WS: St. George	WS: Wagener	WS: Norway
Permit Limit (MGD)	NA	NA	NA	NA	NA	NA
Jan	0.58	0.13	0.18	0.33	0.09	0.03
Feb	0.49	0.12	0.17	0.35	0.09	0.03
Mar	0.53	0.13	0.16	0.31	0.08	0.03
Apr	0.50	0.13	0.15	0.33	0.09	0.03
May	0.56	0.14	0.18	0.33	0.10	0.03
Jun	0.57	0.17	0.18	0.35	0.10	0.03
Jul	0.58	0.16	0.17	0.35	0.09	0.03
Aug	0.59	0.16	0.16	0.34	0.10	0.04
Sep	0.58	0.16	0.18	0.33	0.10	0.03
Oct	0.54	0.15	0.15	0.32	0.09	0.03
Nov	0.55	0.14	0.17	0.33	0.08	0.03
Dec	0.52	0.12	0.16	0.32	0.08	0.03

Permit limits shown in MGD rather than MGM for comparative purposes. Actual permit limits are in MGM. SCE&G - Cope holds a surface water permit but currently primarily uses groundwater. Aiken uses both groundwater and surface water and the demand listed includes both sources. All remaning listed users except SI Group, Batesburg-Leesville, Charleston, and Orangeburg use groundwater only.

Table 6-6. Baseline Model Average Monthly Demand for GC and IR Water Users

	Baseline Model Average Monthly Demand (MGD)										
Month	**IR: Cotton Lane**	**IR: Backman**	**IR: Bull Swamp**	**IR: Calhoun**	**IR: Gray**	**IR: Haigler**	**IR: Holmes & Son**	**IR: Mill-wood**	**IR: Norway**	**IR: Oak Lane**	**IR: Phil Sandifer & Sons**
Registered Limit (MGD)	**1.6**	**2.0**	**1.4**	**0.6**	**0.2**	**4.8**	**1.6**	**8.9**	**1.0**	**1.3**	**1.6**
Jan	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.01	0.00	0.00
Feb	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00
Mar	0.00	0.03	0.01	0.00	0.00	0.02	0.00	0.06	0.01	0.00	0.06
Apr	0.00	0.42	0.04	0.01	0.02	0.06	0.00	1.70	0.05	0.06	0.25
May	0.02	0.75	0.20	0.01	0.03	0.27	0.02	2.62	0.06	0.18	0.38
Jun	0.16	1.27	0.40	0.01	0.09	0.49	0.08	5.61	0.13	0.27	0.48
Jul	0.28	1.06	0.40	0.01	0.08	0.58	0.09	5.81	0.23	0.33	0.49
Aug	0.32	0.90	0.27	0.01	0.05	0.29	0.06	5.95	0.17	0.22	0.49
Sep	0.15	0.68	0.12	0.00	0.01	0.05	0.00	2.01	0.12	0.09	0.31
Oct	0.00	0.32	0.02	0.00	0.00	0.00	0.00	0.19	0.15	0.00	0.07
Nov	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.02	0.10	0.00	0.00
Dec	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00

	Baseline Model Average Monthly Demand (MGD)										
Month	**IR: Riddle Dairy**	**IR: Rob Bates**	**IR: Shady Grove**	**IR: Shivers Trading**	**IR: Smith WG III**	**IR: Spring-field**	**IR: Spring-field Grain Co**	**IR: Thomas C. Fink**	**IR: Titan (Beech)**	**IR: Titan (Bog)**	**IR: Titan (Chinq-uapin)**
Registered Limit (MGD)	**0.7**	**0.7**	**3.3**	**0.8**	**1.0**	**0.4**	**9.2**	**1.3**	**3.1**	**6.9**	**2.3**
Jan	0.05	0.00	0.30	0.00	0.00	0.01	0.00	0.00	0.00	0.05	0.00
Feb	0.07	0.00	0.34	0.00	0.00	0.01	0.00	0.00	0.00	0.10	0.00
Mar	0.10	0.00	0.20	0.12	0.00	0.01	0.00	0.00	0.22	0.83	0.00
Apr	0.11	0.03	0.29	0.33	0.00	0.02	0.06	0.00	0.59	1.50	0.00
May	0.13	0.03	0.34	0.44	0.06	0.05	0.42	0.08	1.04	2.26	0.47
Jun	0.18	0.11	0.46	0.55	0.17	0.09	0.84	0.20	1.36	3.27	0.93
Jul	0.22	0.13	0.46	0.56	0.18	0.14	0.84	0.18	1.45	3.61	0.99
Aug	0.21	0.13	0.31	0.58	0.11	0.08	0.43	0.20	1.41	3.44	0.65
Sep	0.17	0.09	0.21	0.53	0.00	0.05	0.18	0.16	0.64	2.59	0.10
Oct	0.11	0.00	0.18	0.05	0.00	0.07	0.02	0.03	0.01	1.20	0.02
Nov	0.09	0.00	0.18	0.00	0.00	0.02	0.00	0.00	0.00	0.52	0.00
Dec	0.02	0.00	0.16	0.00	0.00	0.01	0.00	0.00	0.00	0.11	0.00

	Baseline Model Average Monthly Demand (MGD)							
Month	**IR: Titan (Mill)**	**IR: Titan (Shaw)**	**IR: Titan (South Fork)**	**IR: Titan (Temples)**	**IR: Walter P. Rawl & Sons**	**IR: Willshire**	**GC: Indian Trails**	**GC: Orange-burg CC**
Registered Limit (MGD)	**1.3**	**2.0**	**4.4**	**5.0**	**0.6**	**0.6**	**0.1**	**0.4**
Jan	0.02	0.00	0.02	0.03	0.05	0.05	0.00	0.00
Feb	0.09	0.00	0.02	0.21	0.02	0.07	0.00	0.00
Mar	0.27	0.10	0.50	0.92	0.05	0.09	0.00	0.00
Apr	0.55	0.43	1.31	1.70	0.17	0.12	0.02	0.00
May	0.77	0.91	2.10	2.01	0.31	0.15	0.03	0.00
Jun	0.92	1.28	2.51	2.89	0.38	0.21	0.04	0.00
Jul	0.89	1.10	2.52	3.26	0.29	0.24	0.04	0.00
Aug	0.89	0.44	2.25	3.36	0.29	0.26	0.04	0.00
Sep	0.72	0.07	1.09	2.54	0.28	0.24	0.03	0.00
Oct	0.34	0.00	0.45	1.41	0.33	0.18	0.02	0.00
Nov	0.08	0.00	0.31	0.61	0.28	0.12	0.00	0.00
Dec	0.05	0.00	0.02	0.09	0.16	0.06	0.00	0.00

Note: The following agricultural users are included in the baseline model, but have not reported surface water usage: Kyzer Farms, Walthers, Maury Furtick, Boland, Brown, Pebble Creek, River Bluff Sod, Turf Connections, and Williams & Sons.

Table 6-7. Returns and Associated Model Objects

Model Object ID	Facility Name	NPDES Pipe ID	Associated Surface Water Permit	Associated Groundwater Withdrawal ID	Discharge Tributary	Model River Mile	% of Return Flow
Returns Represented Within Water User Objects with a Surface Water Withdrawal (and may include a Groundwater Withdrawal)							
WS: Aiken	AIKEN/SHAW CREEK WTP	SCG641003-001	02WS002	02WS002G	Shaw Creek	21	100
WS: Batesburg-Leesville	BATESBURG-LEESVILLE WWTF	SC0024465-001	32WS003S01/ 32WS003SO2	32WS002G	Duncan Creek	2.6	100
WS: Charleston	CHARLESTON CPW - HANAHAN WTP	SC0021229 SC0024783 SC0040771 SC0046060 SC0038822	10WS004S03	*none*	**Out of basin (Santee)**	160	-
WS: Orangeburg	ORANGEBURG WWTF	SC0024481-001	38WS002	*none*	North Fork Edisto River	76.4	100
IN: SI Group	SI GROUP *(FORMERLY ALBEMARLE)*	SC0001180-001	38IN002	*none*	North Fork Edisto River	73	100
PT: SCE&G Cope	SCE&G/COPE POWER PLANT	SC0045772-001 SC0045772-002 SC0045772-003 SC0045772-005 SC0045772-006	38PT001S01	38PT001G	Roberts Swamp	0.6	100
PT: SCE&G Canadys*	SCE&G/CANADYS POWER PLANT*	SC0002020-001 SC0002020-002 SC0002020-003 SC0002020-04A SC0002020-005 SC0002020-006	15PT001S01/ 15PT001S02	*none*	Edisto River	135.2	100
IN: JM Huber**	JM HUBER CORP**	SC0024341-001	02IN005S01/ 02IN005S02	*none*	South Fork Edisto River	22.1	100
Returns Represented Within Water User Objects with a Groundwater Withdrawal							
IN: Roseburg	ROSEBURG FOREST PRODUCTS S/HOLLY HILL MDF	SC0001147-001 SC0001147-002 SC0001147-003	*none*	38IN005G	Four Hole Swamp	25.3	100
IN: Holcim	HOLCIM (US) INC/HOLLY HILL PLT	SC0002992-001 SC0002992-002 SC0002992-003 SC0002992-02A	*none*	38IN001G	Four Hole Swamp	26.6	100
IN: Giant Cement	GIANT CEMENT COMPANY INC	SC0022667-001 SC0022667-002 SC0022667-003 SC0022667-004 SC0022667-004 SC0022667-005	*none*	18WS014G/ 18IN001G	Four Hole Swamp	25.9	100
IN: Lafarge (Argos)	LAFARGE BUILDING MATERIALS INC	SC0022586-001 SC0022586-002	*none* *none*	18IN0040G 18IN0040G	Indian Field Swamp Indian Field Swamp	2.4	100
WS: Harleyville	TOWN OF HARLEYVILLE	SC0038504-001	*none*	18WS003G	Indian Field Swamp		
IN: ACO	ACO DISTRIBUTION & WAREHOUSE INC	SC0043419-001	*none*	38IN004G	North Fork Edisto River	76	100
WS: Blackville	BLACKVILLE WWTF	SC0026417-001	*none*	06WS002G	Windy Hill Creek	0.1	100
WS: Branchville	TOWN OF BRANCHVILLE	SC0047333-001	*none*	38WS007G	Edisto River	106.9	100
IN: Gaston	GASTON COPPER RECYCLING CORP	SC0034541-001	*none*	32IN002G	Bull Swamp Creek	0.1	100
IN: Showa Denko	SHOWA DENKO CARBON	SC0038555-001 SC0038555-01A	*none*	18IN002G	Four Hole Swamp	45.6	100
WS: North	TOWN OF NORTH	SC0047821-001	*none*	38WS003G	North Fork Edisto River	43.2	100
WS: North	TOWN OF NORTH	SC0047821-002	*none*	38WS003G	North Fork Edisto River		
WS: St. George	TOWN OF ST. GEORGE	SC0025844-001	*none*	18WS002G	Polk Swamp	0.3	100
WS: Wagener	TOWN OF WAGENER	SC0026204-001	*none*	02WS001G	Dean Swamp Creek	0.1	100
WS: Norway	TOWN OF NORWAY	SC0045993-001	*none*	38WS006G	Willow Swamp	0.2	100

Table 6-7. Returns and Associated Model Objects (continued)

Model Object ID	Facility Name	NPDES Pipe ID	Associated Surface Water Permit	Associated Groundwater Withdrawal ID	Discharge Tributary	Model River Mile	% of Return Flow
In-basin Returns Represented by Discharge Objects							
KY-TN Clay	KENTUCKY-TENN CLAY/GENTRY PIT	SC0046388-001 SC0046388-002	*none*	*none*	South Fork Edisto River	19.7	-
Orangeburg Fish	ORANGEBURG NTL FISH HATCHERY	SC0047023-001 SC0047023-002	*none*	*none*	North Fork Edisto River	76.2	- -
Returns of Withdrawals from Outside the Basin Represented by Discharge Objects							
ECWSA Import	EDGEFIELD COUNTY WATER & SEWER AUTHORITY	SC0025691-001	19WS001	*none*	South Fork Edisto River	0.3	100
Bowman Import	LAKE MARION REGIONAL WATER SYSTEM	SC0040037-001	38WS052	*none*	Cow Castle Creek	11.6	100

*Note: Returns outside of the Edisto River Basin are indicated in **bold**.*

** Only represented in the calibration model (came off-line in 2014).*

*** Only represented in the calibration model (came off-line in 1998).*

Table 6-8. Baseline Model Monthly Consumptive User Percentage

Monthly Consumptive Use (%)							
Month	IN: SI Group	PT: SCE&G - Cope	WS: Aiken	WS: Batesburg-Leesville	WS: Charleston	WS: Orangeburg	IN: Roseburg
Jan	0.23	66.23	82.83	12.58	100.00	43.59	26.32
Feb	0.23	60.46	82.04	6.65	100.00	34.94	16.98
Mar	0.24	51.56	83.81	1.20	100.00	29.82	24.66
Apr	0.26	55.83	87.20	7.43	100.00	40.66	23.10
May	0.26	62.66	89.58	20.98	100.00	51.96	28.59
Jun	0.23	58.92	89.01	27.98	100.00	53.94	23.43
Jul	0.24	62.78	89.58	30.97	100.00	57.20	23.77
Aug	0.26	57.37	89.53	34.18	100.00	55.65	25.15
Sep	0.25	52.79	89.55	31.77	100.00	60.74	23.18
Oct	0.31	63.44	88.82	31.71	100.00	58.98	24.17
Nov	0.29	63.15	86.72	26.82	100.00	57.58	27.33
Dec	0.29	63.44	83.74	15.49	100.00	48.66	31.21

Monthly Consumptive Use (%)							
Month	IN: Holcim	IN: Giant Cement	IN: Lafarge (Argos)	WS: Harleyville	IN: ACO	WS: Blackville	WS: Branchville
Jan	0.00	0.00	0.00	9.52	0.37	38.52	39.89
Feb	0.00	0.00	0.00	8.62	0.41	34.93	37.78
Mar	0.00	0.00	0.00	10.14	0.28	22.06	46.88
Apr	0.00	0.00	0.00	11.05	0.19	27.39	36.45
May	0.00	0.00	0.00	13.94	0.20	44.51	34.38
Jun	0.00	0.00	0.00	15.87	0.21	56.53	39.03
Jul	0.00	0.00	0.00	12.16	0.41	53.51	37.49
Aug	0.00	0.00	0.00	18.20	0.01	48.07	34.68
Sep	0.00	0.00	0.00	19.41	0.05	55.44	40.49
Oct	0.00	0.00	0.00	20.94	0.03	57.14	42.61
Nov	0.00	0.00	0.00	9.43	0.01	57.26	35.16
Dec	0.00	0.00	0.00	8.40	0.12	50.30	36.49

Table 6-8. Baseline Model Monthly Consumptive User Percentage (continued)

Monthly Consumptive Use (%)						
Month	IN: Gaston	WS: North	IN: Showa Denko	WS: St. George	WS: Wagener	WS: Norway
Jan	0.00	46.39	30.00	2.06	41.86	0.00
Feb	0.00	36.77	27.31	0.80	37.53	0.00
Mar	0.00	47.57	22.81	0.33	23.71	0.00
Apr	0.00	51.43	25.38	0.30	32.06	0.00
May	0.00	63.18	21.01	0.30	52.99	0.00
Jun	0.00	63.91	26.20	2.09	48.36	0.00
Jul	0.00	60.60	19.68	1.63	54.69	0.00
Aug	0.00	58.20	29.54	1.47	48.70	0.00
Sep	0.00	56.35	39.82	1.30	50.13	0.00
Oct	0.00	52.63	32.36	4.22	47.90	0.00
Nov	0.00	49.40	49.52	7.95	48.72	0.00
Dec	0.00	43.39	47.25	5.73	40.50	0.00

Table 6-9. Baseline Model Monthly Return Flows for Discharge Objects

Monthly Return Flow (MGD)				
Month	KY-TN Clay	Orangeburg Fish	ECWSA Import	Bowman Import
Jan	0.00	0.41	0.33	0.10
Feb	0.00	0.41	0.34	0.12
Mar	0.00	0.42	0.43	0.12
Apr	0.00	0.42	0.46	0.12
May	0.00	0.42	0.40	0.10
Jun	0.00	0.42	0.30	0.12
Jul	0.00	0.38	0.33	0.09
Aug	0.00	0.39	0.32	0.09
Sep	0.00	0.39	0.27	0.11
Oct	0.00	0.39	0.23	0.09
Nov	0.00	0.44	0.23	0.08
Dec	0.00	0.44	0.24	0.10

Section 7

Model Calibration/Verification

7.1 Philosophy and Objectives

SWAM is a water allocation model that moves simulated water from upstream to downstream, combines flows at confluence points, routes water through reservoirs (if present), and allocates water to a series of water user nodes. It is designed for applications at a river basin scale. In common with all water allocation models, neither rainfall-runoff, nor reach routing, are performed in SWAM. As such, the "calibration" process should be viewed differently compared to catchment or river hydrologic modeling.

The overriding objective of the SWAM calibration process is to verify that the model is generally accurately representing water availability in the basin; i.e. that ungaged flow estimates are roughly accurate, that flows are being combined correctly, and that basin operations and water use are well captured. More specifically, the objectives include:

- extending the hydrologic input drivers of the model (headwater unimpaired flows) spatially downstream to adequately represent the unimpaired hydrology of the entire basin by incorporating hydrologic gains and losses below the headwaters;
- refining, as necessary and appropriate, a small number of other model parameter estimates within appropriate ranges of uncertainty, potentially including: consumptive use percentages, and nonpoint (outdoor use) return flow locations; and
- gaining confidence in the model as a predictive tool by demonstrating its ability to adequately replicate past hydrologic conditions, operations, and water use.

In many ways, the exercise described here is more about model verification than true model calibration. The model parameterization is supported by a large set of known information and data – including tributary flows, drainage areas, water use and return data. These primary inputs are not changed during model calibration. In fact, only a small number of parameters are modified as part of this process. This is a key difference compared to hydrologic model calibration exercises, where a large number of parameters can be adjusted to achieve a desired modeled vs. measured fit. Because SWAM is a data-driven model and not a parametric reproduction of the physics that govern streamflow dynamics, care is taken so that observed data used to create model inputs are not altered. In calibrating SWAM, generally the primary parameters adjusted are reach gain/loss factors for select tributary objects. These factors capture ungaged flow gains associated with increasing drainage area with distance downstream. Flow gains through a sub-basin are initially assumed to be linearly proportional to drainage area, in line with common ungaged flow estimation techniques. However, there is significant uncertainty in this assumption and it is therefore appropriate to adjust these factors, within a small range, as part of the model calibration process. These are often the only parameters changed in the model during calibration, though adjustments can also be made if needed to consumptive use rates and flow estimates in ungaged headwater basins.

Consideration also needs to be given to the accuracy of the measured or reported data that serve as key inputs to the model and are not adjusted as part of the calibration exercise. For example, historical water withdrawals are reported to DHEC by individual water users based on imperfect measurement or estimation techniques. Even larger errors may exist in the USGS flow gage data used to characterize headwater flows in the model. These errors are known to be upwards of 20% at some gages and under some conditions (USGS, http://wdr.water.usgs.gov/current/documentation.html). The uncertainty of model inputs merits consideration in the evaluation of model output accuracy.

Lastly, in considering the model calibration and verification, it is also important to keep in mind the ultimate objectives of the models. The final models are intended to support planning and permitting decision making. Planners will use the models to quantify impacts of future demand increases on water availability. For example, if basin municipal demands increase by 50%, how will that generally impact river flows and is there enough water to sustain that growth? Planners might also use the models to analyze alternative solutions to meeting projected growth, such as conservation, reservoir projects, and transbasin imports. With respect to permitting, regulators will look to the model to identify any potential water availability problems with new permit requests and to quantify the impacts of new or modified permits on downstream river flows. In other words, they will look to the model to answer the question of: if a new permit is granted, how will it impact downstream critical river flows and downstream existing users?

Given the methods and objectives described above, there is no expectation that downstream gaged flows, on a monthly or daily basis, will be replicated exactly. The lack of reach routing, in particular, limits the accuracy of the models at a daily timestep. Rather, the questions are only whether the representation of downstream flows is adequate for the model's intended purposes, key dynamics and operations of the river basin are generally captured (as measured by the frequency of various flow thresholds and reasonable representation of the timing and magnitude of the rise and fall of hydrographs), and whether the models will ultimately be useful as supporting tools for the State.

7.2 Methods

For the model calibration exercise, the fully constructed and parameterized Edisto Basin model, as described in Sections 5 and 6, was used to simulate the 1983 to 2013 historical period. As described in these sections, the calibration model includes input data representative of past conditions, rather than current conditions in the basin. The specific simulation time period was selected because of a higher confidence in reported withdrawal and discharge data for this period compared to earlier periods. The 31 year record also provides a good range of hydrologic and climate variability in the basin to adequately test the model, including extended high and low flow periods.

Guided by the principles described in Section 7.1, the following specific steps were followed (in order) as part of the calibration/verification process:

1. Tributary headwater flows were extended to the tributary confluence points using drainage area ratios to calculate tributary object subbasin flow factors (see Section 6).

2. New implicit tributary objects were added, as needed and based on visual inspection of GIS mapping, to capture ungaged drainage areas and tributary inputs not included in the original model framework. Note that a list of implicit tributaries included in the Edisto basin model is provided in Section 6.

3. Intermediary subbasin flow factors were adjusted for tributary objects to achieve adequate modeled vs. measured comparisons at selected tributary gage targets, based on monthly timestep modeling.

4. Mainstem reach gain/loss factors (per unit length) were adjusted to better achieve calibration at mainstem gage locations, based on monthly timestep modeling. This factor can be varied in multiple locations along the main stem.

5. The adequacy of the daily timestep model was verified by reviewing daily output once the monthly model was calibrated.

All USGS flow gages at downstream locations in the basin with reasonable records within the targeted simulation period were used to assess model performance and guide the model calibration steps described above. These gages are summarized in **Table 7-1**. Note that in order to minimize the uncertainty in our calibration targets, only gaged (i.e. measured) flow records were used to assess model performance as part of this exercise. No ungaged flow estimates or record filling techniques were used to supplement this data set (although many of the input flows were developed through various record extensions techniques). Note also that all upstream basin water use and operations are implicitly represented in these gaged data, thereby providing an ideal target to which the combination of estimated UIFs and historic water uses could be compared.

Table 7-1. USGS Streamflow Gages Used in Calibration

Project Gage ID	USGS Number	Tributary Object	Period(s) of Record	Basin Area (sq. mi.)	River Mile
EDO01	02172300	McTier Creek	10/1995 - 10/1997 2/2001 - 12/2013	16	0.1
EDO02	02172305	McTier Creek	6/2007 - 11/2009	35	3.5
EDO04	02172640	Dean Swamp Creek	10/1980 - 3/1987 3/1988 - 9/2000	31	2.2
EDO05	02173000	South Fork Edisto River	8/1931 - 9/1971 10/1980 - 12/2013	733	69.4
EDO06	02173030	South Fork Edisto River	6/1991 - 12/2013	766	76.9
EDO07	02173051	South Fork Edisto River	4/1991 - 12/2013	813	82
EDO08	02173212	Cedar Creek	4/2008 - 12/2013	44	0.1
EDO09	02173351	Bull Swamp Creek	2/2001 - 9/2003	34	4.9
ED010	02173500	North Fork Edisto River	12/1938 - 12/2013	686	71.1
ED011	02174000	Edisto River	10/1945 - 9/1996	1,728	114.3
EDO12	02174250	Cow Castle Creek	10/1970 - 9/1981 10/1995 - 2/2013	24	9.7
EDO13	02175000	Edisto River	1/1939 - 12/2013	2,714	159.4

Lastly, all water users in the model were checked to ensure that historical demands were being fully met in the model or, alternatively, if demands were not being met during certain periods, that there was a sensible explanation for the modeled shortfalls.

As indicated above, options for model calibration parameters (i.e. those that are adjusted to achieve better modeled vs. measured matches) are limited to a very small group of inputs with relatively high associated uncertainty. In general, and for future basin models, these might include any of the following: mainstem hydrologic gain/loss factors, tributary sub-basin flow factors, assumed consumptive use percentages, and return flow locations and/or lag times associated with outdoor use. However, the primary calibration parameters in SWAM are the sub-basin flow factors and mainstem gain/loss factors. The final model sub-basin flow factors and mainstem gains/losses are presented in Section 6, Table 6-3. The use of alternative reference gages to estimate an ungaged headwater tributary flow is also considered during calibration. Similarly, the method used to extend a headwater UIF may also be re-evaluated, and an alternative extension method may be found to produce a better match of modeled vs. measured flows at a downstream gage. Adjustments to most other parameters are secondary and often not required.

A number of performance metrics were used to assess the model's ability to reproduce past basin hydrology and operations. These include: monthly and daily water user supply delivery and/or shortfalls; monthly and daily timeseries plots of river flow; cumulative flow plots, annual and monthly mean flow values; monthly and daily percentile plots of river flow values; annual 7-day low flows with a 10 year recurrence interval (7Q10); and mean flow values averaged over the entire period of record.

The reliability of past water supply to meet specific water user demands is an important consideration in the calibration process to ensure that water user demands and supply portfolios are properly represented in the model, as well as providing checks on supply availability at specific points of withdrawal. Timeseries plots, both monthly and daily, are used to assess the model's ability to simulate observed temporal variation and patterns in flow and to capture an appropriate range of high and low flow values. Percentile plots are useful for assessing the model's ability to reproduce the range of flows, including extreme events, observed in the past (and are particularly important when considering that the value of a long-term planning model like this is its ability to predict the frequency at which future flow thresholds might be exceeded, or the frequency that various amounts of water will be available). Monthly statistics provide valuable information on the model's ability to generally reproduce seasonal patterns, while annual totals and period of record mean flows help confirm the overall water balance represented in the model. Lastly, regulatory low flows (7Q10) are of specific interest as the model could be used to predict such low flows as a function of future impairment. However, the limitations of the daily model and supporting data should be properly considered in assessing model performance on this particular metric. Note that for the purposes of this exercise a simplified 7Q10 calculation was employed. Our approach used the Excel percentile function to estimate the 10 year recurrence interval (10th percentile) of modeled and measured 7 day low flows. This differs from the more standard methods often using specific fitted probability distributions (e.g. log-Pearson).

Assessment of performance and adequacy of calibration was primarily based on graphical comparisons (modeled vs. measured) of the metrics described above. It is our opinion that graphical results, in combination with sound engineering judgement, provide the most comprehensive view of model performance for this type of model. Reliance on specific statistical metrics can result in a skewed and/or shortsighted assessments of model performance. In addition to the graphical assessments, period of record flow averages and 7Q10 values were assessed based on tabular comparisons and percent differences. Ultimately, keeping in mind the philosophies and objectives described in Section 7.1, consideration was given as to whether the model calibration could be significantly improved with further parameter adjustments, given the limited calibration "knobs" available in the process. In actuality, a clear point of "diminishing returns" was reached whereby no significant improvements in performance could be achieved without either: a) adjusting parameters outside of their range of uncertainty or, b) constructing an overly prescriptive historical model that then becomes less useful for future predictive simulations. At this point, the calibration exercise was considered completed.

In the Edisto Basin, the impact of selected reference gages for SWAM tributary object inflows were carefully evaluated. While the average flow at a particular calibration point may be within acceptable limits regardless of the reference gage(s) used, the minimum and maximum flows generated by the Edisto model were found to be sensitive to the reference gage. For example, early iterations which relied more heavily on tributary reference gages such as McTier Creek EDO 01 (USGS 2172300), resulted in increased "flashiness" on the mainstem. In other words, modeled results showed higher peak flows than measured flows along the mainstem. Subsequent iterations showed that agreement between modeled peak flows and measured peak flows increased significantly along the mainstem with the use of mainstem reference gages (EDO 05 - USGS 2173000 on the South Fork and EDO 10 - USGS 2173500 on the North Fork).

Ultimately, keeping in mind the philosophies and objectives described in Section 7.1, consideration was given as to whether the model calibration could be significantly improved with further parameter adjustments, given the limited calibration "knobs" available in the process. In actuality, a clear point of "diminishing returns" was reached whereby no significant improvements in performance could be achieved without either: a) adjusting parameters outside of their range of uncertainty or, b) constructing an overly prescriptive historical model that then becomes less useful for future predictive simulations. As previously noted, the use of different reference gages was carefully evaluated, and the results were discussed with DNR, DHEC, and the Technical Advisory Committee. At the point where the two scenarios with the most promising options for references gages was identified, a verification exercise, as described in Section 7.4 below, was conducted and the results were evaluated. Only then, was the final scenario of reference gages selected, and the calibration exercise was considered completed.

7.3 Results

Detailed monthly and daily model calibration results are provided in **Appendix A** and **B**, respectively. In general, a strong agreement between modeled and measured data is observed for all targeted sites. Discrepancies between modeled and measured flow data are generally within the reported range of uncertainty associated with the USGS flow data used to drive the models (5 – 20%) (USGS http://wdr.water.usgs.gov/current/documentation.html). Seasonal and annual patterns in flow data are reproduced well by the model. Monthly fluctuations (timeseries) and extreme conditions (percentiles) are also very well reproduced by the model for most sites.

For all sites, modeled mean flow values, averaged over the full period of record, were within 2% of measured mean flows. This indicates that the overall water balance is very well simulated in the model and there are no obvious missing or excess sources of flow in the model.

Monthly flow percentiles are also well captured by the model across nearly all sites. Monthly flow percentile deviations are all generally within 10 - 20% with no clear bias one way or the other.

In terms of daily timestep simulations, daily flow fluctuations are generally well captured by the model – in some cases surprisingly well, given the lack of reach routing. Modeled daily percentile plots exhibit excellent agreement with measured data throughout all but the very highest percentiles. Similar to the monthly flow calibration results, the daily model's flow percentile deviations are all generally within 10 - 20% with no clear bias one way or the other. An exception to this is EDO 13 which showed slightly higher deviation in modeled vs observed flow percentile values.

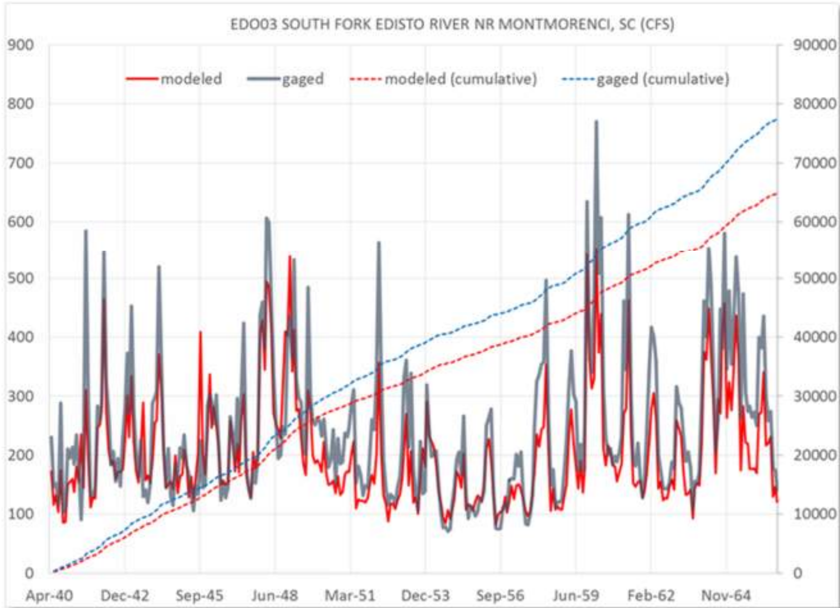
Modeled regulatory low flow values (7Q10) are within 20% of measured values at mainstem calibration locations EDO 05 and EDO 06. Further downstream at EDO 07, EDO 11 and EDO 13 modeled regulatory low flow values are 36% and 75% greater than observed. For most tributaries (see EDO 01, EDO 02, EDO 04, EDO 08, and EDO 09) the modeled low flow values are also within 3% of observed. On the North Fork (see EDO 10), modeled 7Q10 values are within 10%. The model over predicts the 7Q10 on Cow Castle Creek (see EDO 12) by approximately 240%. This location is challenging because the volume of water associated with EDO 12 deviation is very small (less than 1 cfs). Further, it is important to realize that low flows in the model are highly sensitive to modeled basin water use and other assumptions. Small errors in estimated (or reported) withdrawals can have a significant impact on modeled annual low flows. Consequently, model uncertainty associated with this metric is relatively high and additional model adjustments to improve this calibration metric are not justified.

7.4 1940-1966 Verification Exercise

To verify the model calibration parameters and to help select from the two most promising reference gage scenarios, a historical comparison covering the period from 1940 through 1966 at the (now inactive) Montmorenci gage (EDO 03) was conducted using the monthly calibration model. Although this period falls outside of the calibration period and thus programmed impairments such as withdrawals and discharges were not accurately represented, the comparison still provided insight on the unique flow dynamics in the basin. A sample of the results from this comparison are shown below in **Figure 7-1.** In the figure, Scenario A represents the set of reference gages based on mainsteam gages EDO 05 (South Fork) and EDO 10 (North Fork). Scenario B represents a "hybrid" set of reference gages based on a combination of mainstem and tributary reference gages. In part, based on this comparison, Scenario A was ultimately selected, as it provides a more conservative estimate of flows in the upper parts of the basin. It should be recognized that, due to the lack of gage data on tributaries to the North and South Forks of the Edisto River and the complex hydrology in the basin, there is a greater amount of uncertainty in the Edisto Basin, compared to other South Carolina basins. This uncertainty suggested that the use of reference gages that provide the more conservative estimate of flows was most appropriate.

Scenario A

EDO5 (on the N. Fork Edisto) used as the reference gage for N. Fork Edisto tributaries



Scenario B

EDO1 (on McTier Creek) used as the reference gage for N. Fork Edisto tributaries (except the Mainstem headwater)

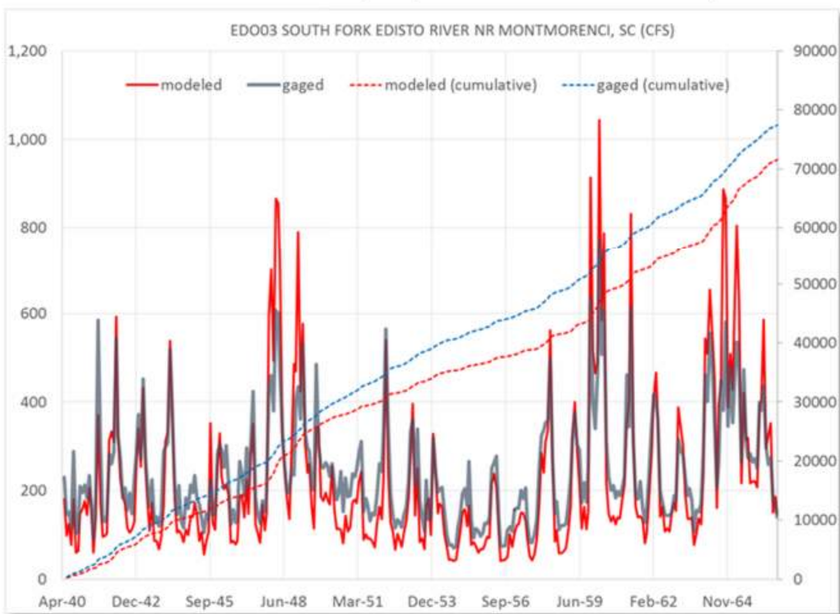


Figure 7-1. Comparison of Scenario A and B modeled vs. measured flows at EDO3

Section 8

User Guidelines for the Baseline Model

The baseline Edisto River Basin Model will be located on a cloud-based server which can be accessed using a virtual desktop approach. Interested stakeholders will be provided access to the model by DNR and/or DHEC upon completion of a model training course.

This model will be useful for the following types of scenarios:

- Comparison of water availability resulting from managed flow (future or current) to unimpaired flow throughout the basin.
- Comparison of current use patterns to fully permitted use of the allocated water (or any potential future demand level), and resulting flow throughout the river network.
- Evaluation of new withdrawal and discharge permits, and associated minimum streamflow requirements.
- Alternative management strategies for basin planning activities.

Users will also be able to change the duration of a model run in order to focus on specific years or hydrologic conditions. For example, the default model will run on a daily or monthly time step from 1931 through 2013 in order to test scenarios over the full historic period of recorded hydrologic conditions. In some cases, though, it may be useful to compile output over just the period corresponding to the drought of record, or an unusually wet period.

Flow conditions can also be changed by the user, though it will be important for the user to understand implications when unimpaired flows (naturalized flows) are replaced with other time series. In certain basins outside the Edisto, it will be useful to examine flows with either managed or unimpaired flows coming across state lines into South Carolina. In the Edisto Basin, it may be useful (for example) to alter boundary condition flows to test the impacts of potential climate variability.

Regardless of the type of scenario to be run, it is important to understand how to interpret the output. Whether running long-duration or short-duration runs, the output of the model will represent time series of flows, reservoir levels, and water uses. As such, the results can be interpreted by how frequently flow or reservoir levels are above or below certain thresholds, or how often demands are satisfied. This frequency, when extrapolated into future use, can then be translated into probabilities of occurrence in the future. It will be the user's responsibility to manipulate the output to present appropriate interpretations for the questions being asked, as illustrated in the following example:

> *Example: For a 10-year model run over a dry historic decade, a user is interested in knowing the frequency that a water user may experience a shortage of water, relative to current and future demand. Results indicate that under current demand patterns, there will be a shortage (demand is greater than supply) in one month out of the ten years. Under future demand projections (modified by the user), the results indicate that there will be a shortage in six months during the driest of the ten years. If the results are presented annually, both scenarios would be the same: a 10% probability of dropping*

below that level in any given year. If they are presented monthly, they will, of course, be different. Depending on the nature of the question, it will be important for users to be aware of how output can be used, interpreted, and misinterpreted.

Further guidance on use of the Model is provided in the *Simplified Water Allocation Model (SWAM) User's Manual* (CDM Smith, 2016). The User's Guide provides a description of the model objects, inputs, and outputs and provides guidelines for their use. A technical documentation section is included which provides detailed descriptions of the fundamental equations and algorithms used in SWAM.

Section 9

References

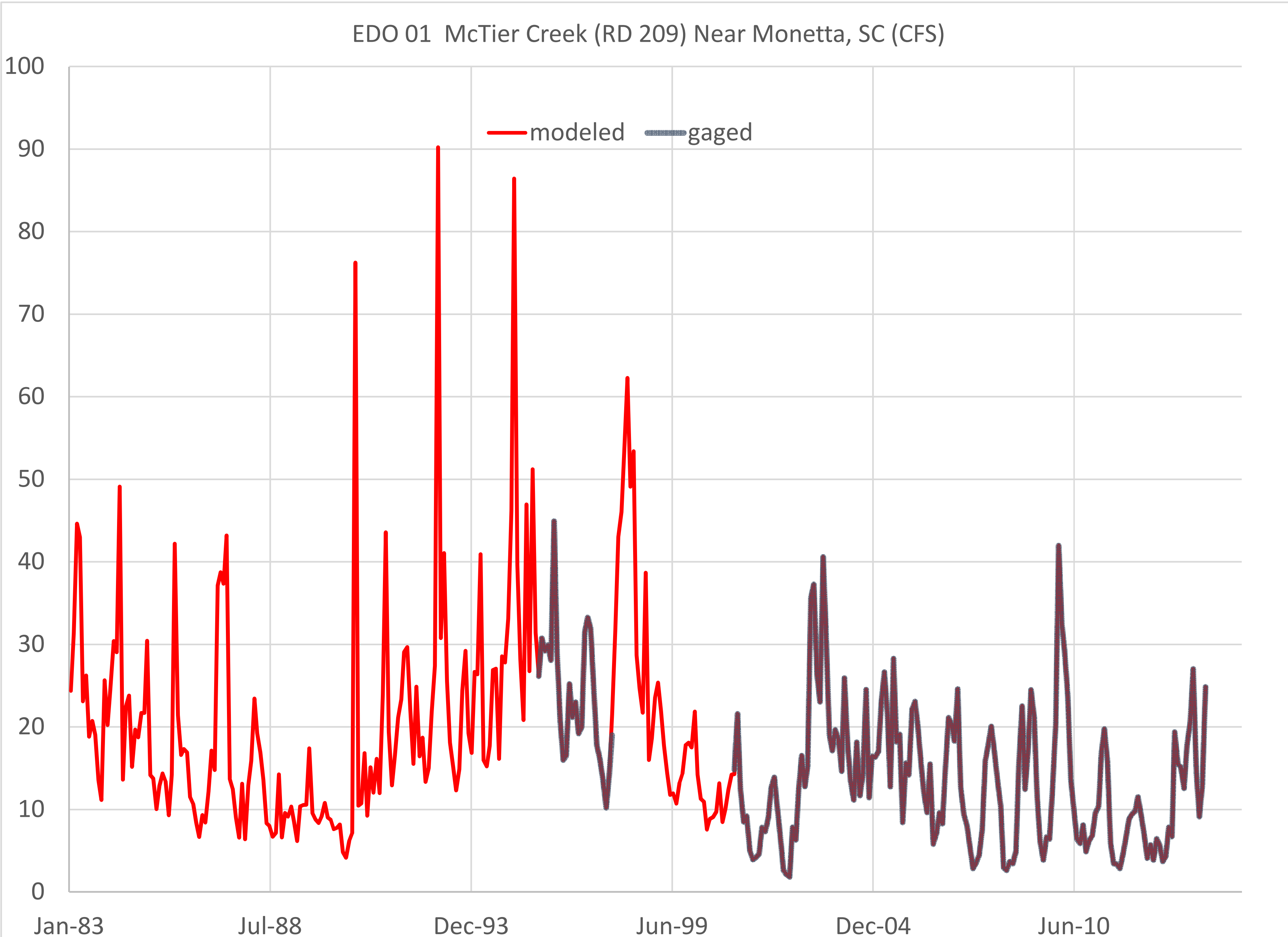
CDM Smith, 2016. *Simplified Water Allocation Model (SWAM) User's Manual, Version 3.0.*

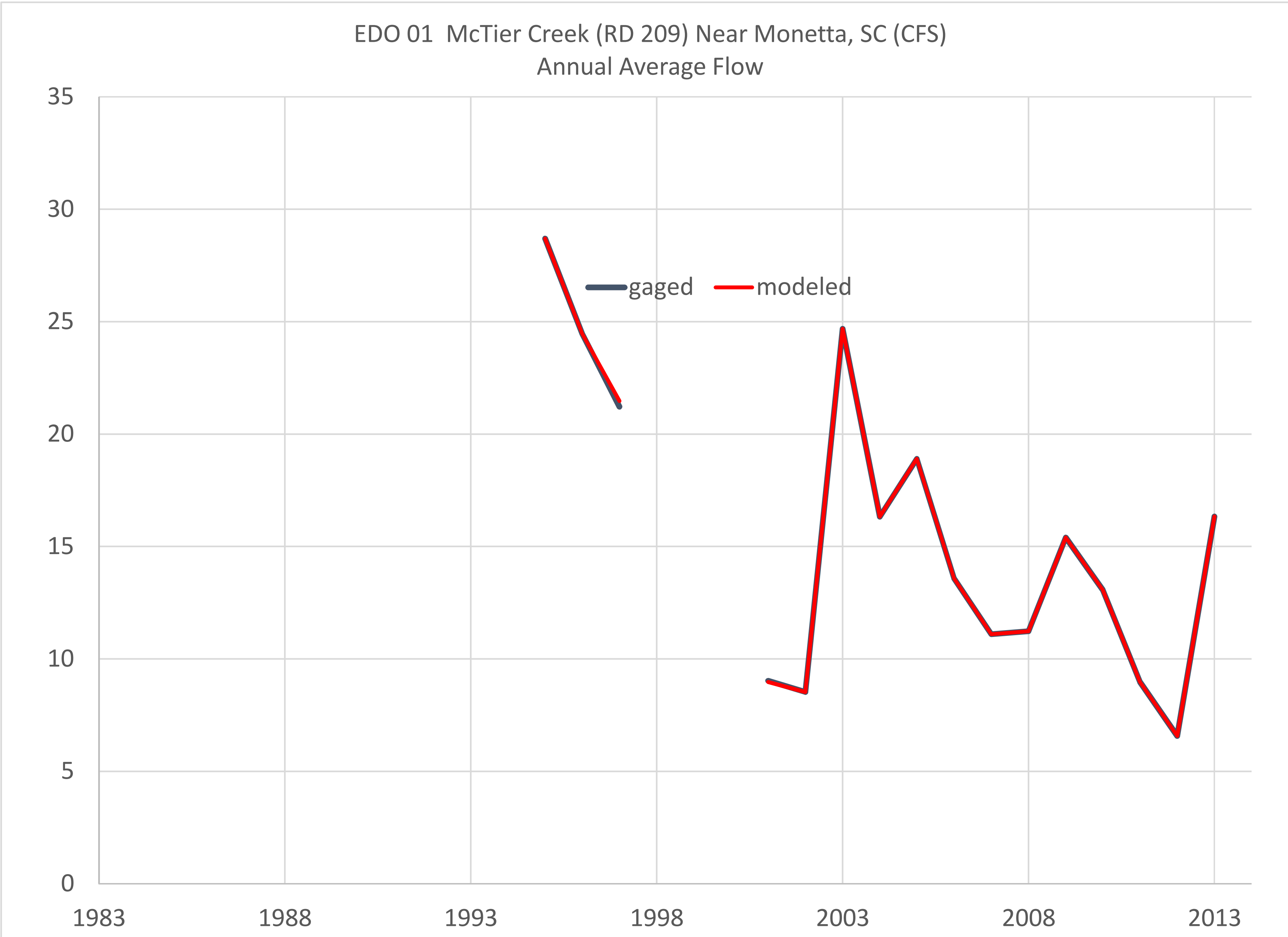
Appendix A

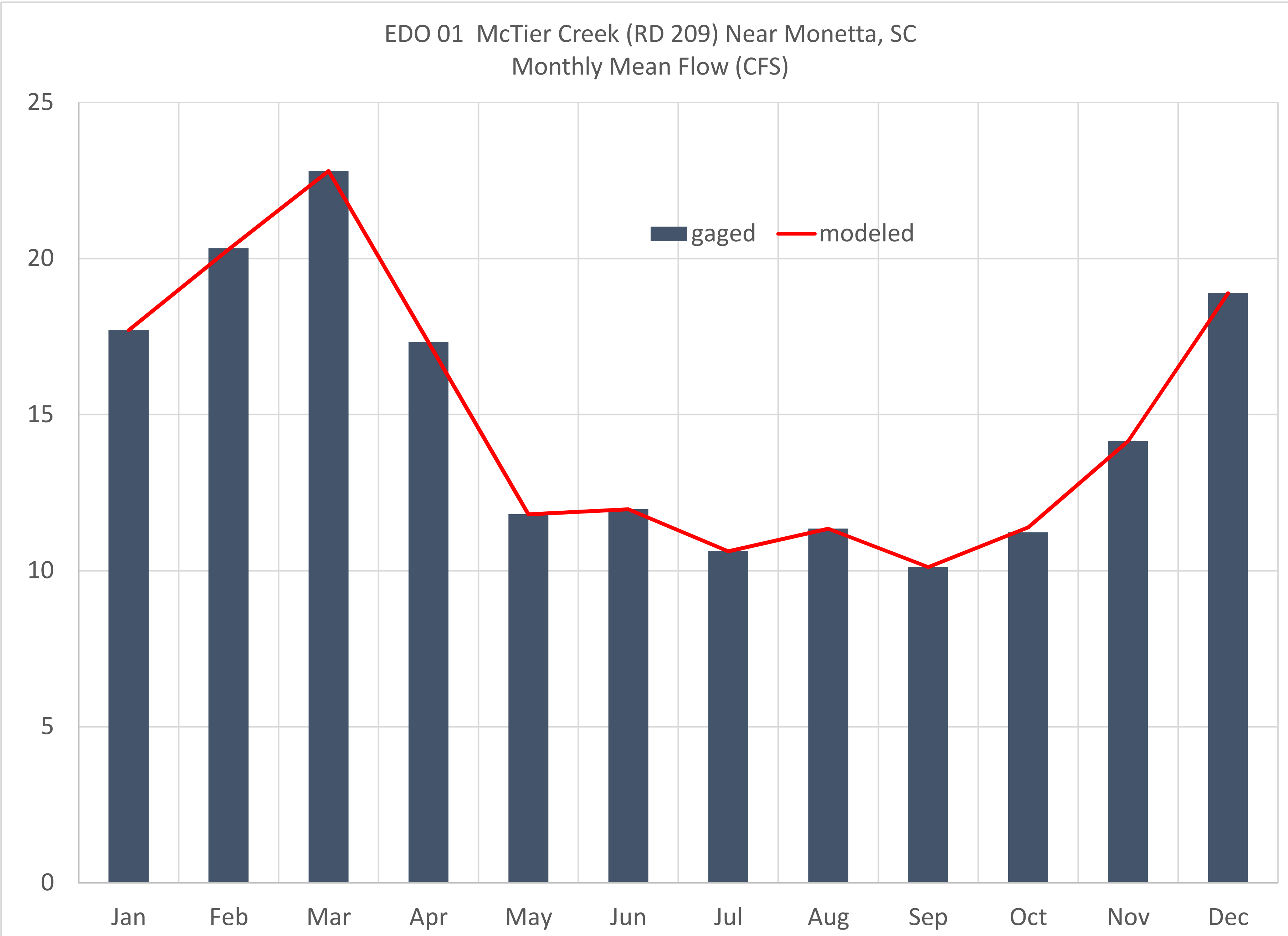
Edisto River Basin Model

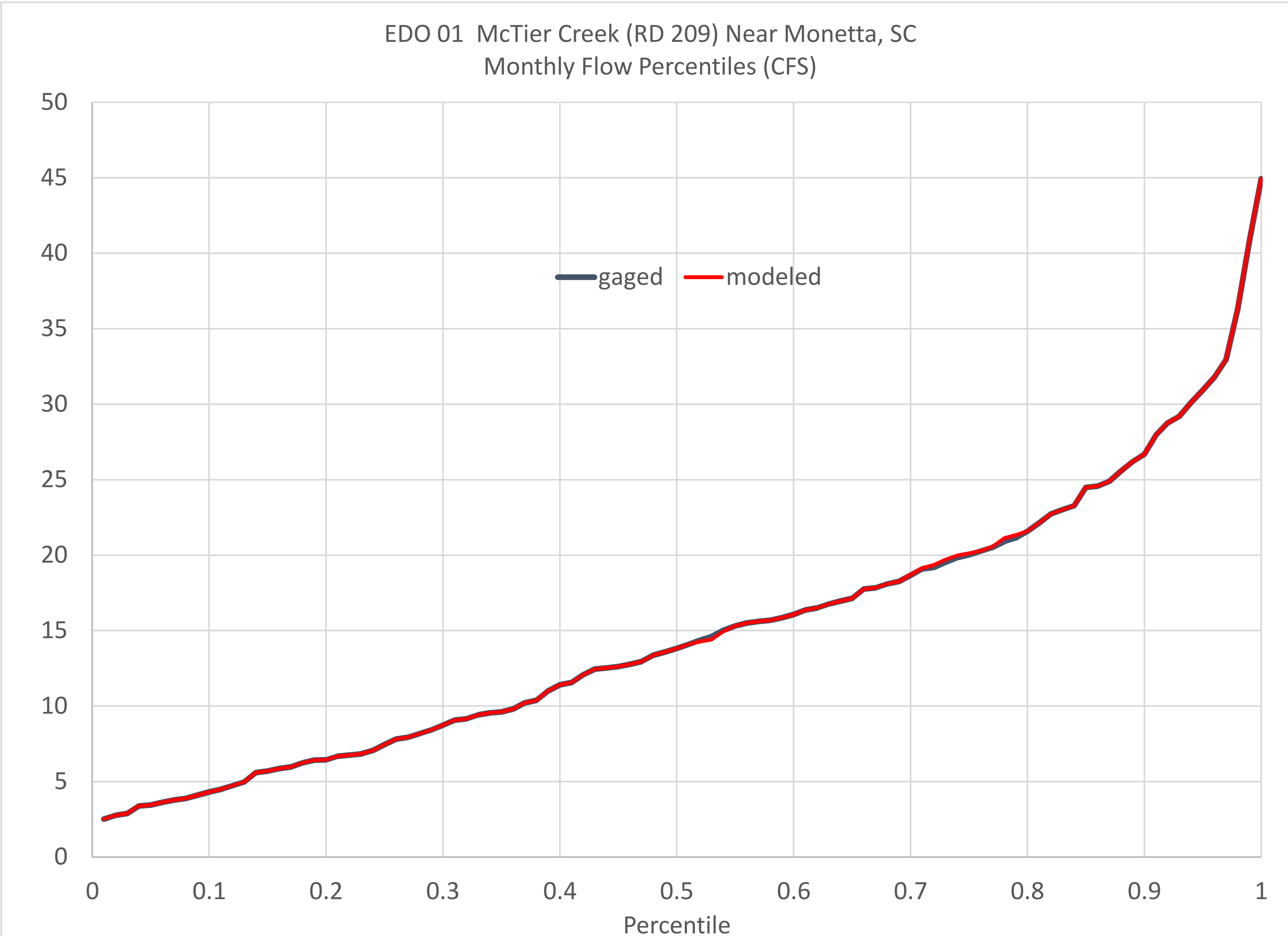
Monthly Calibration Results

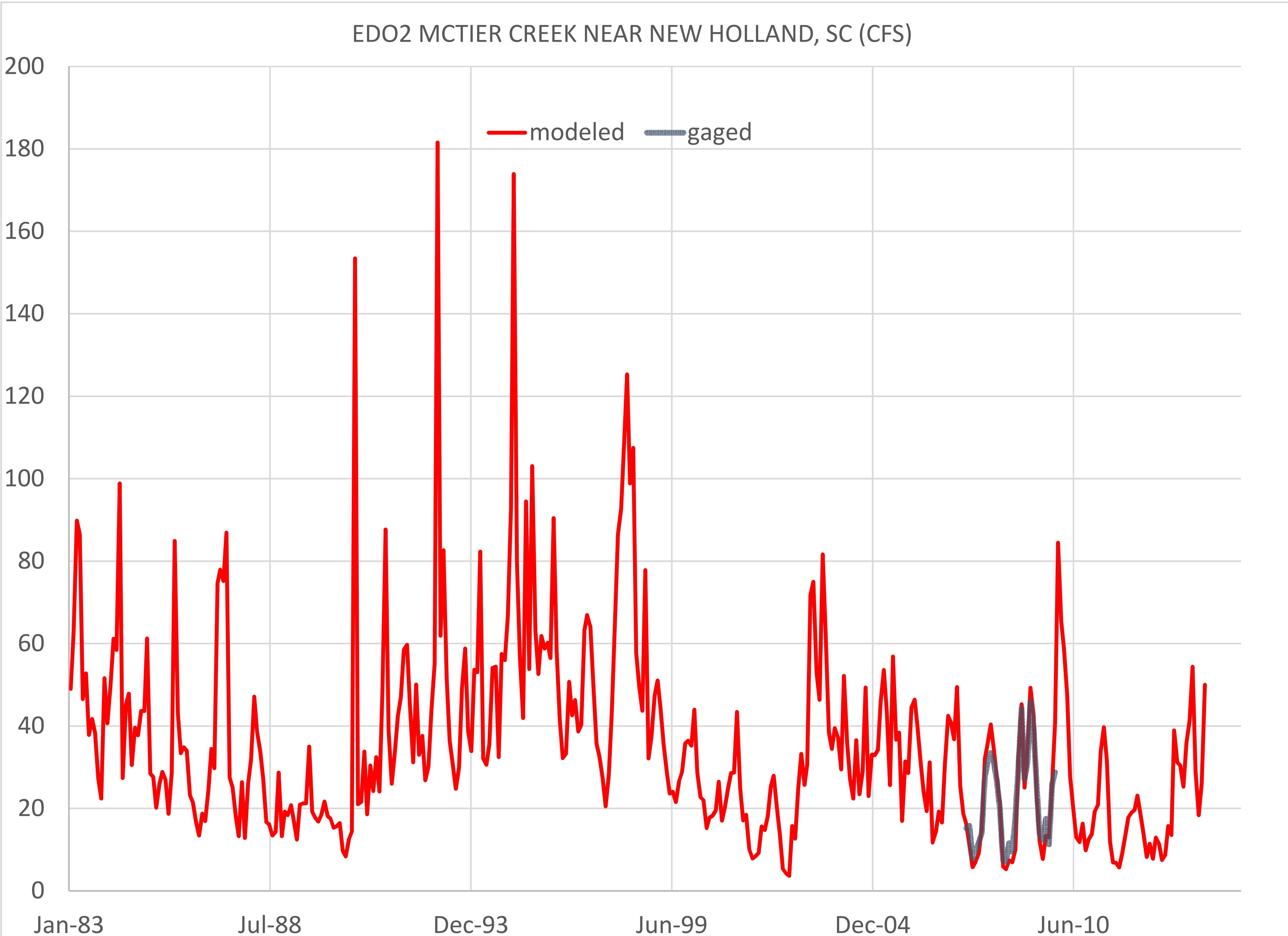
CDM Smith


EDO 01 McTier Creek (RD 209) Near Monetta, SC (CFS)
modeled
gaged
100
90
80
70
60
50
40
30
20
10
0
Jan-83
Jul-88
Dec-93
Jun-99
Dec-04
Jun-10

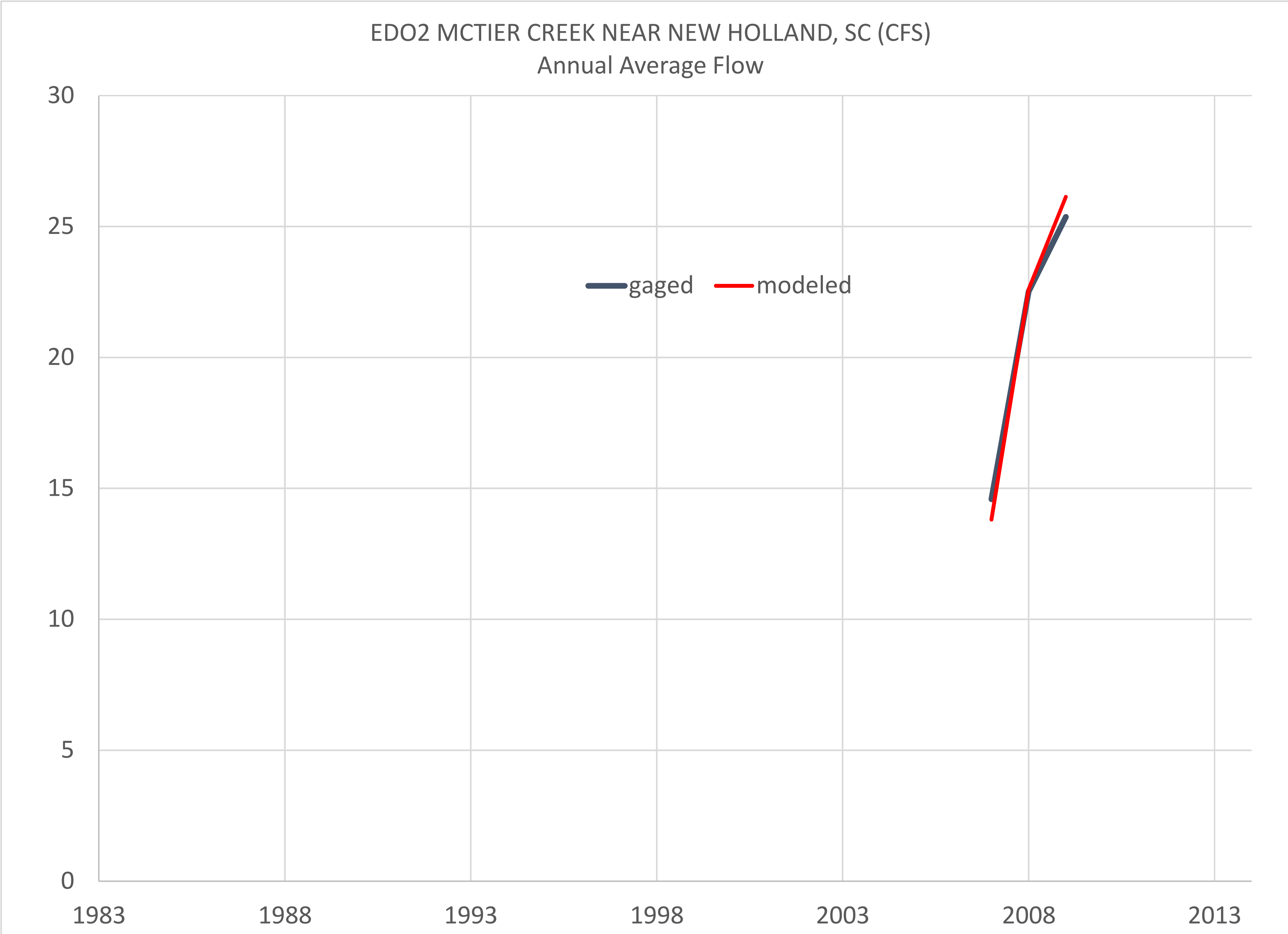

EDO 01 McTier Creek (RD 209) Near Monetta, SC (CFS)
Annual Average Flow
gaged
modeled
35
30
25
20
15
10
5
0
1983
1988
1993
1998
2003
2008
2013

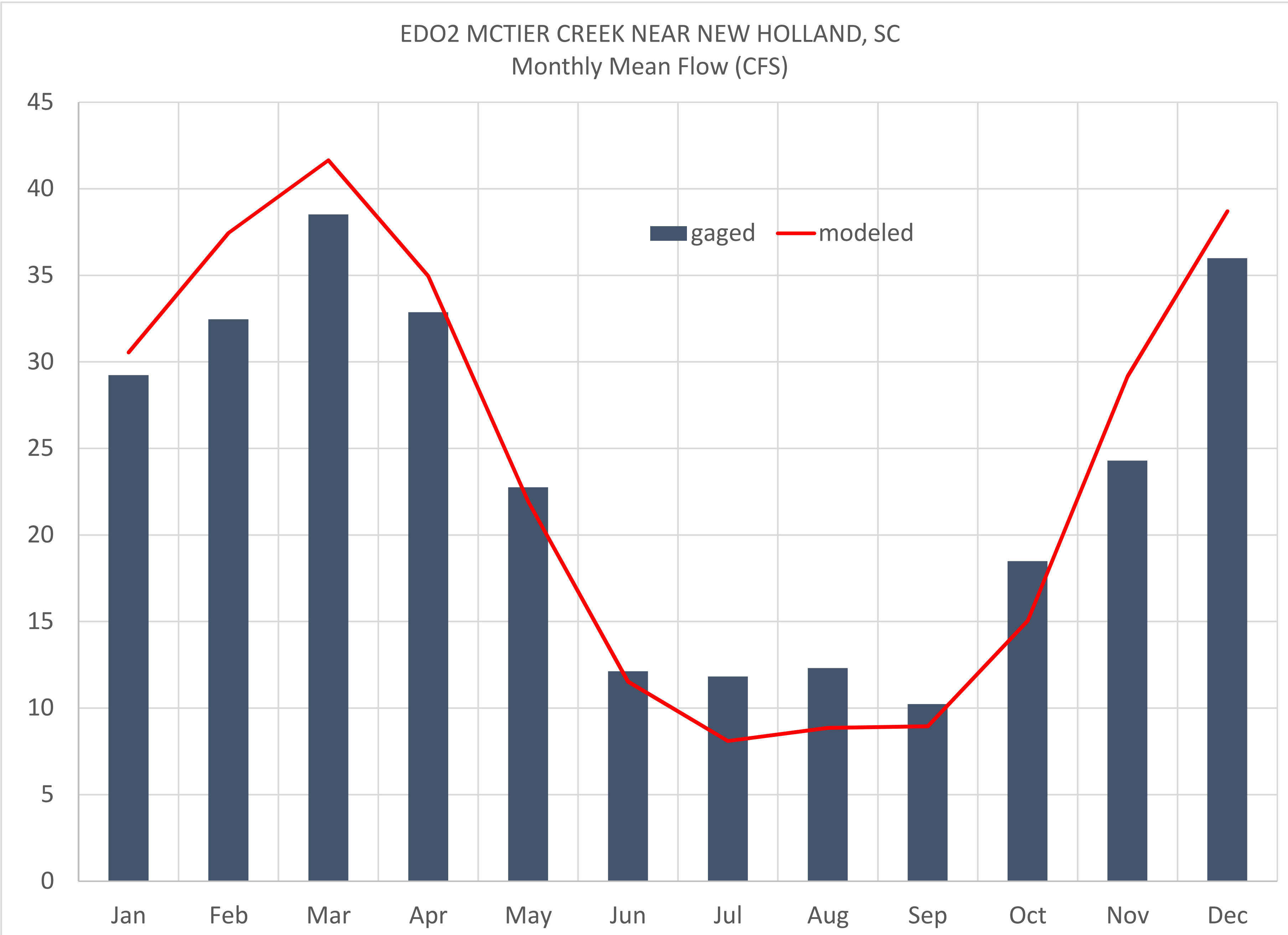

EDO 01 McTier Creek (RD 209) Near Monetta, SC
Monthly Mean Flow (CFS)
gaged
modeled
25
20
15
10
5
0
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec

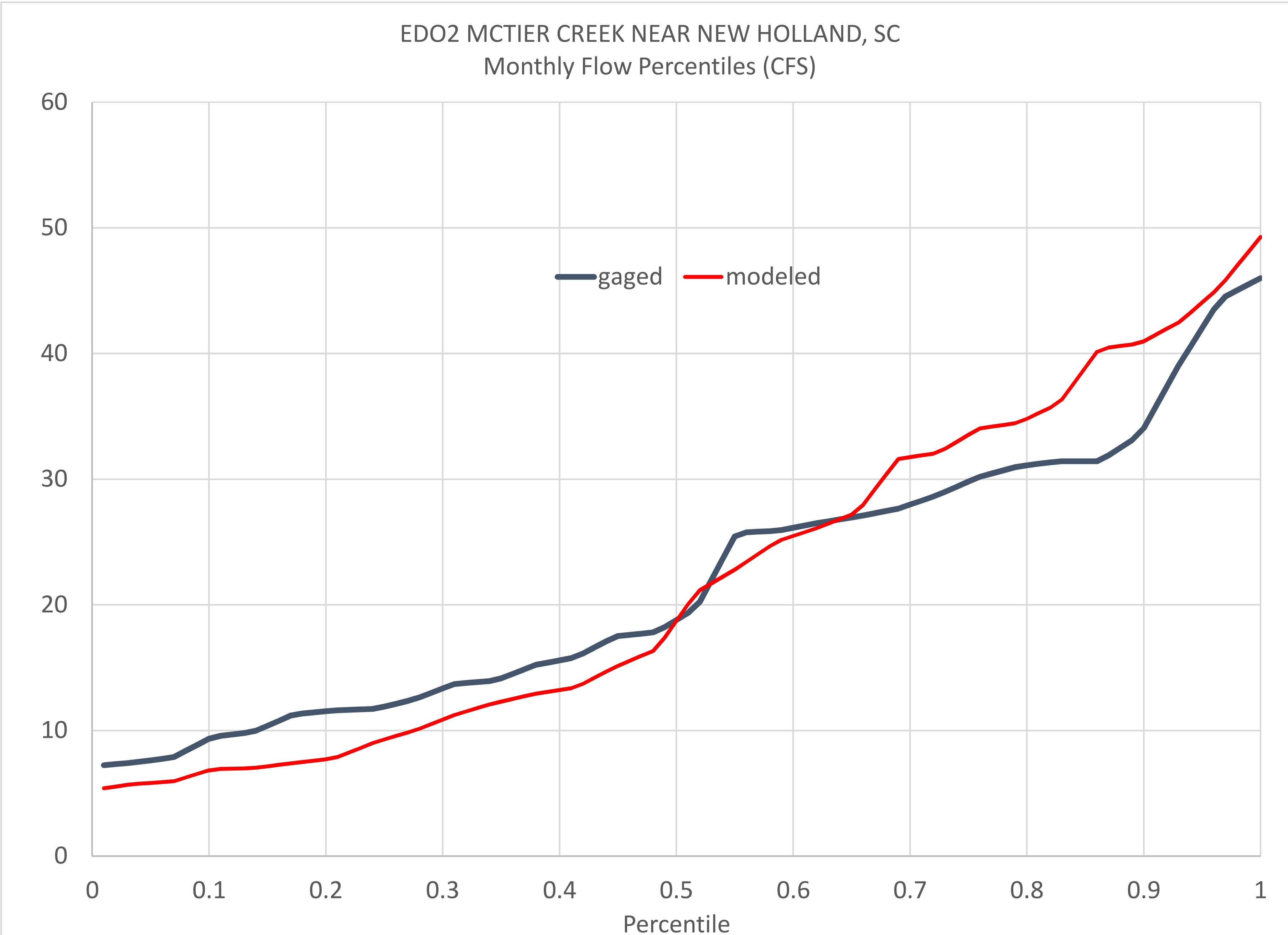

EDO 01 McTier Creek (RD 209) Near Monetta, SC
Monthly Flow Percentiles (CFS)
gaged
modeled
0
5
10
15
20
25
30
35
40
45
50
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
Percentile



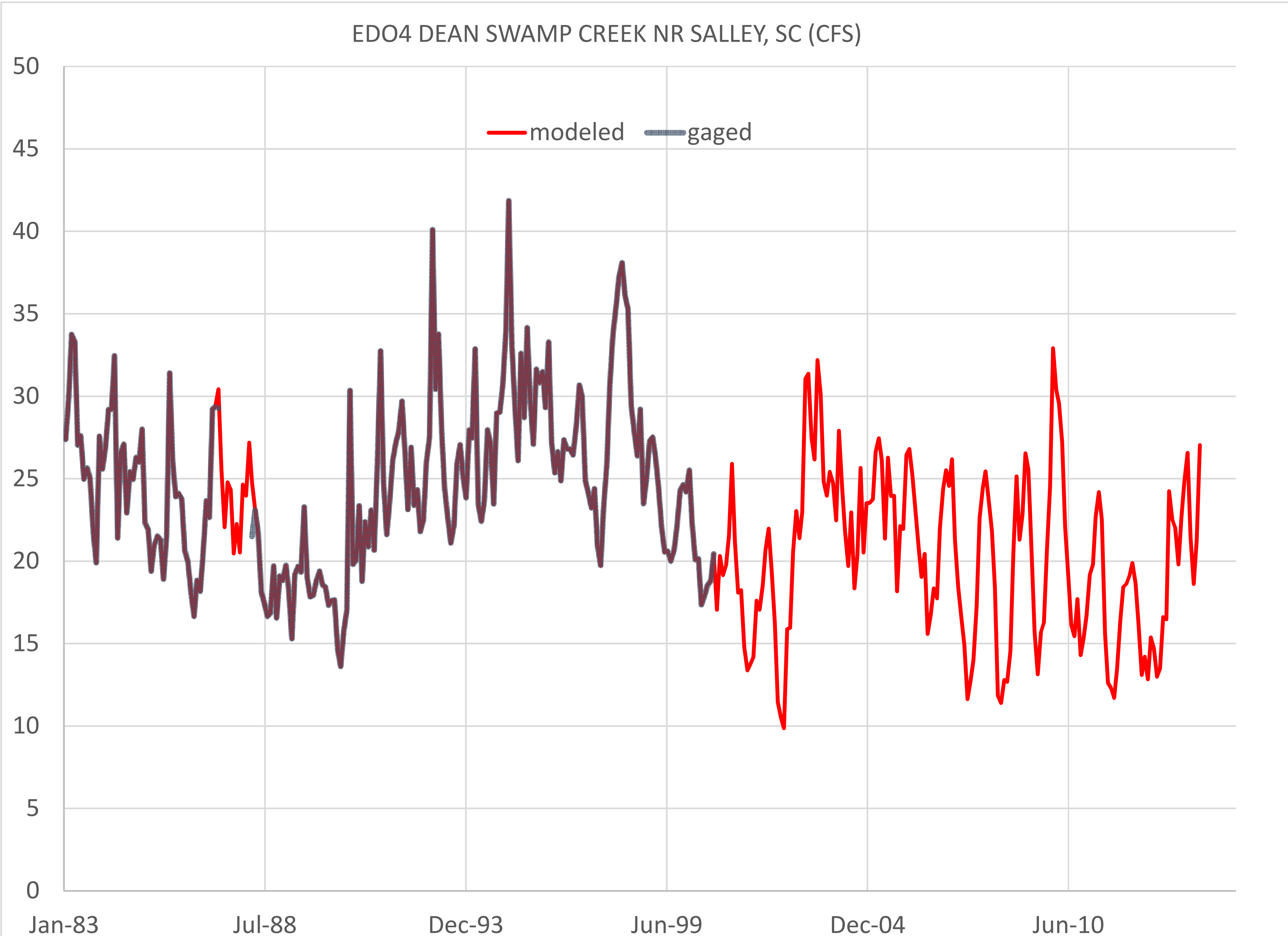
EDO2 MCTIER CREEK NEAR NEW HOLLAND, SC (CFS)
modeled
gaged
200
180
160
140
120
100
80
60
40
20
0
Jan-83
Jul-88
Dec-93
Jun-99
Dec-04
Jun-10

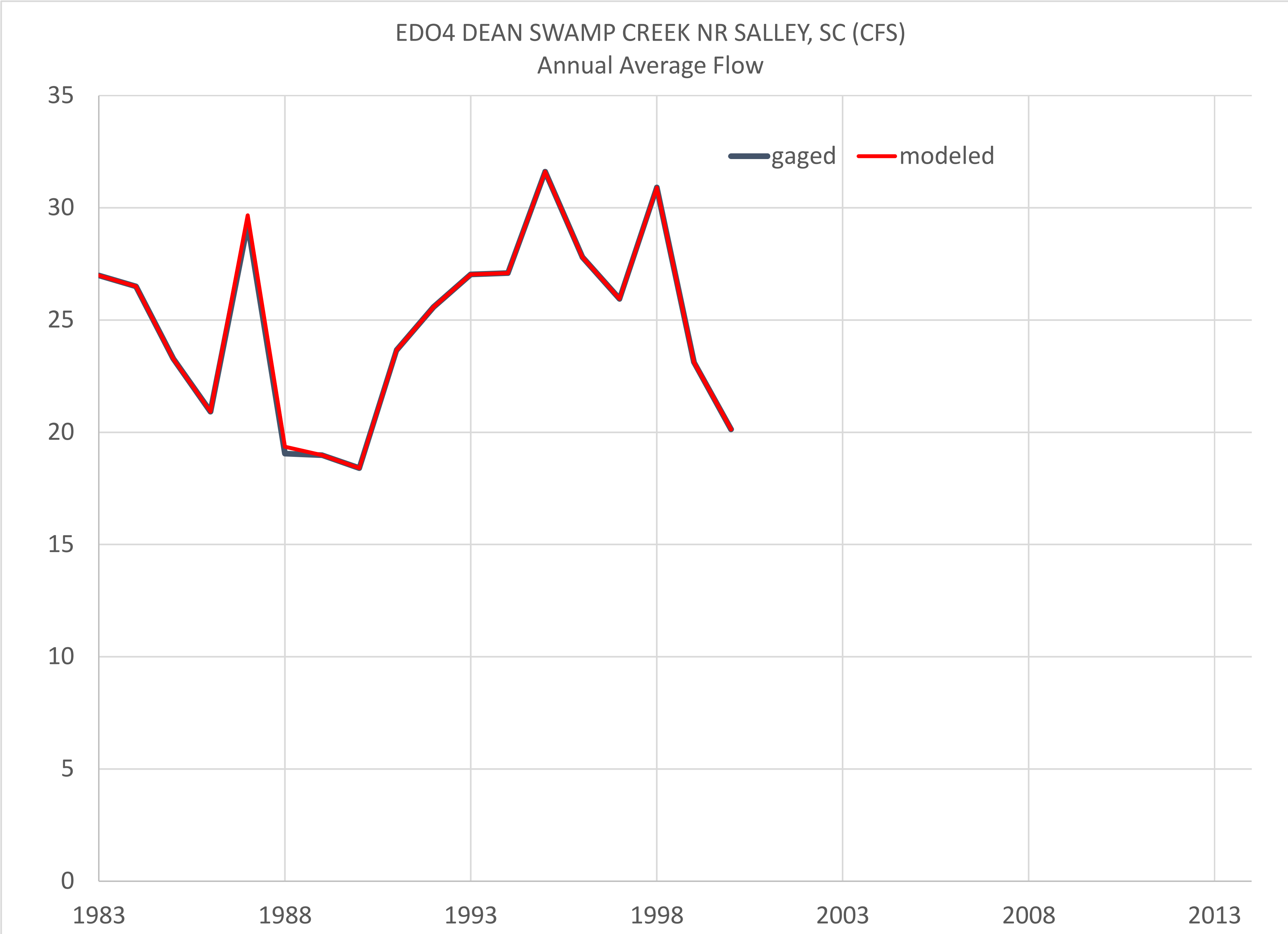

EDO2 MCTIER CREEK NEAR NEW HOLLAND, SC (CFS)
Annual Average Flow
30
25
20
15
10
5
0
1983
1988
1993
1998
2003
2008
2013
gaged
modeled

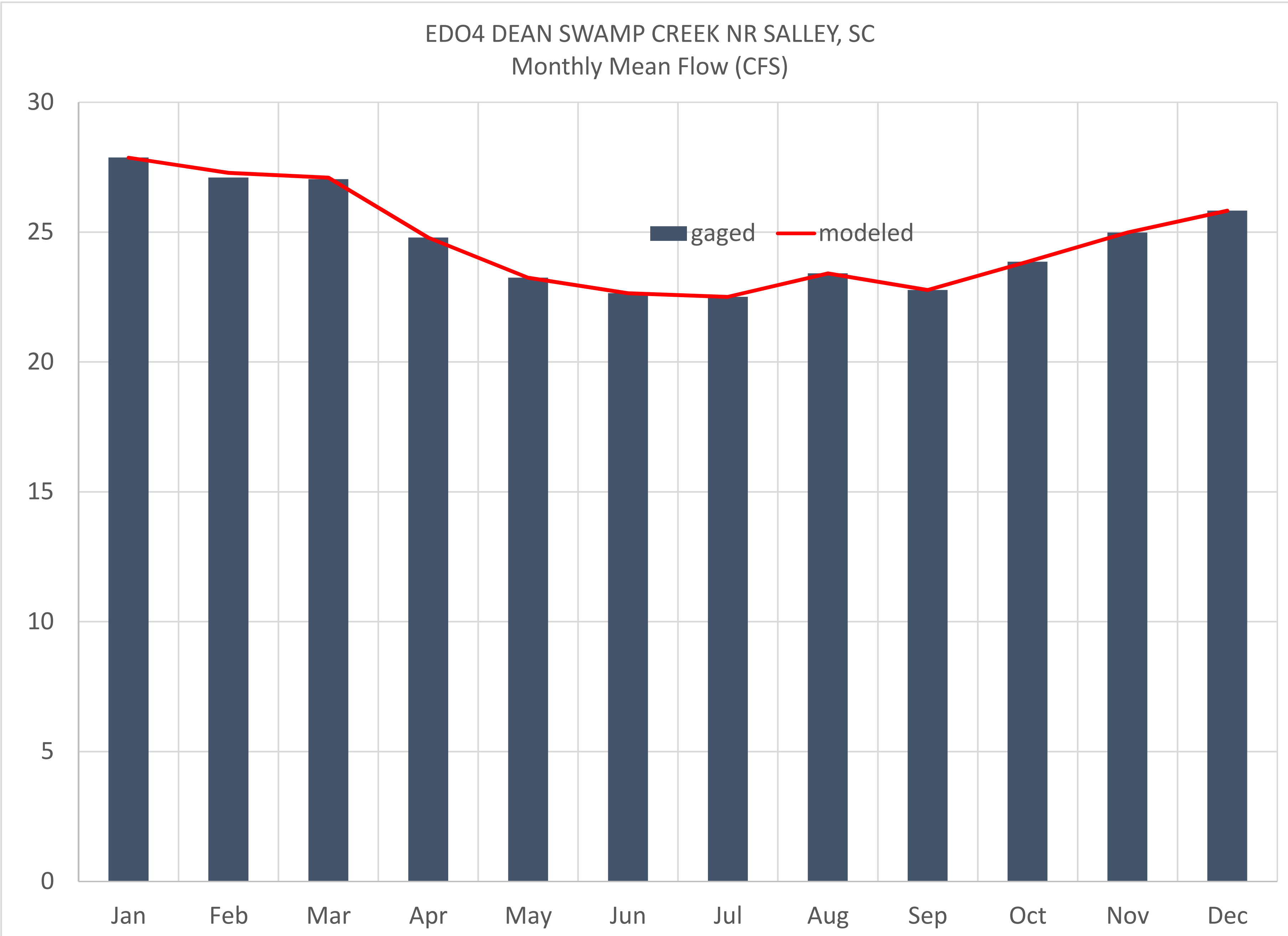

EDO2 MCTIER CREEK NEAR NEW HOLLAND, SC
Monthly Mean Flow (CFS)
45
40
35
30
25
20
15
10
5
0
gaged
modeled
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec

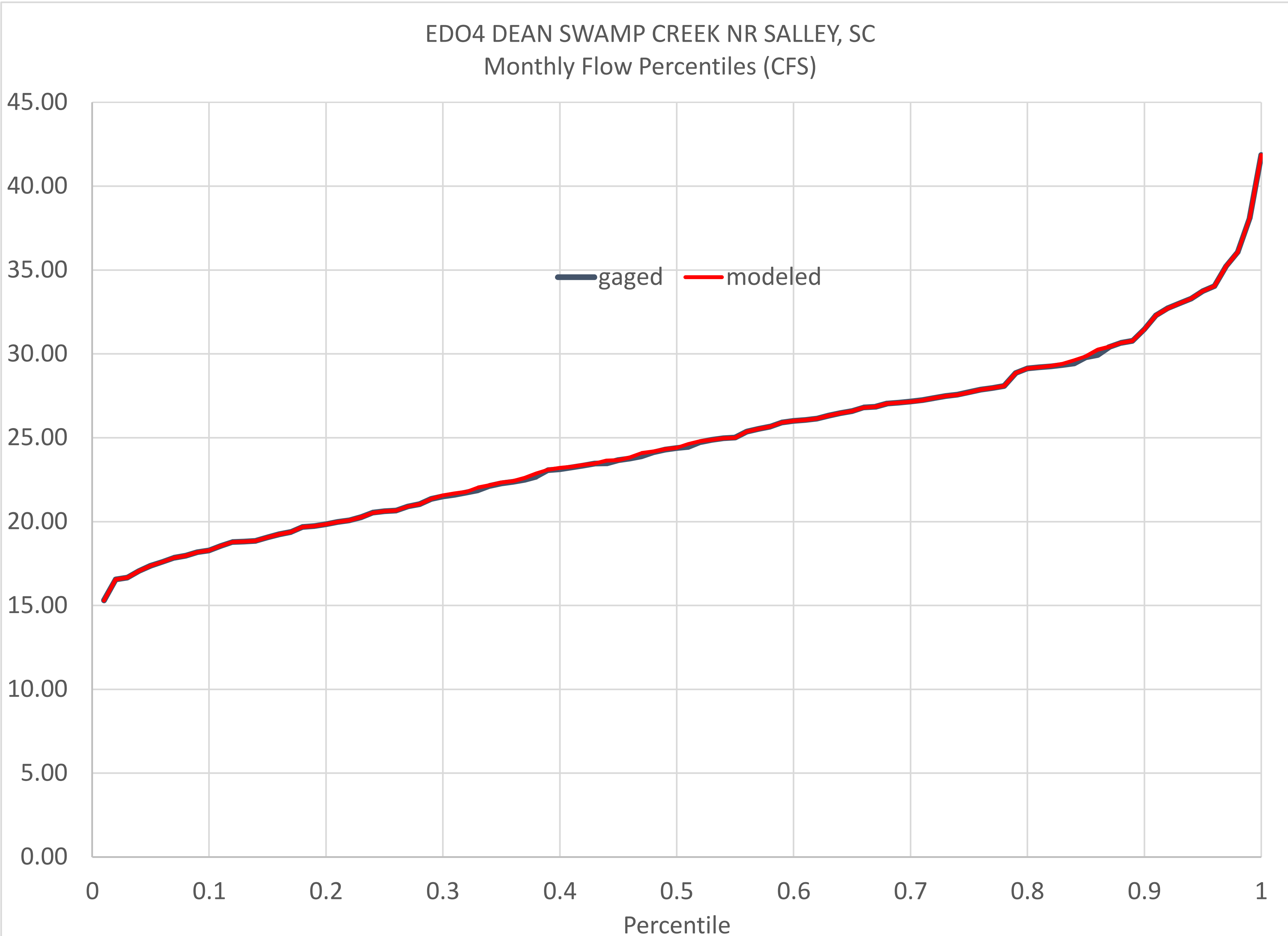


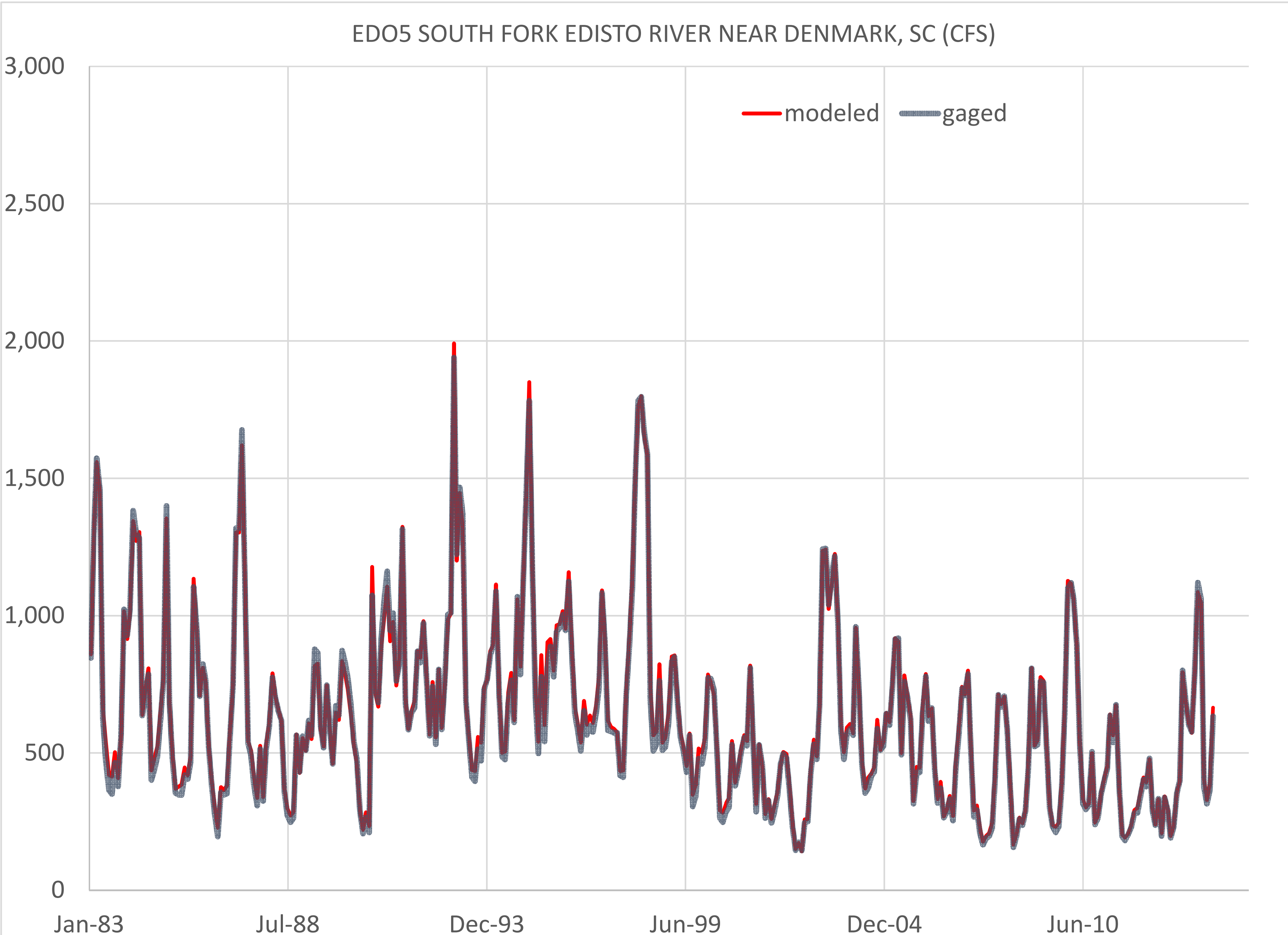
EDO2 MCTIER CREEK NEAR NEW HOLLAND, SC
Monthly Flow Percentiles (CFS)
gaged
modeled
0
10
20
30
40
50
60
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
Percentile


EDO4 DEAN SWAMP CREEK NR SALLEY, SC (CFS)
modeled
gaged
50
45
40
35
30
25
20
15
10
5
0
Jan-83
Jul-88
Dec-93
Jun-99
Dec-04
Jun-10

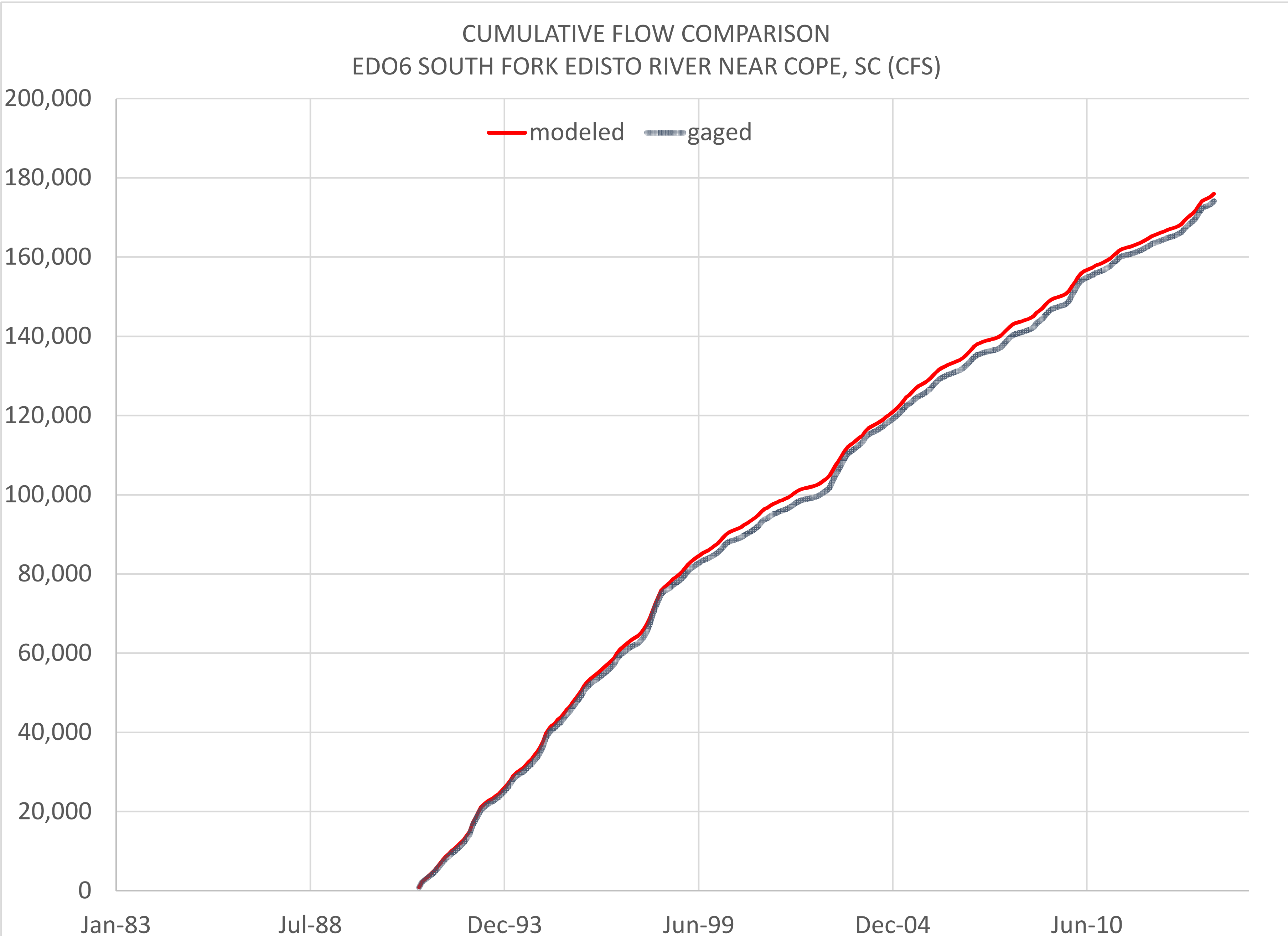

EDO4 DEAN SWAMP CREEK NR SALLEY, SC (CFS)
Annual Average Flow
gaged
modeled
35
30
25
20
15
10
5
0
1983
1988
1993
1998
2003
2008
2013

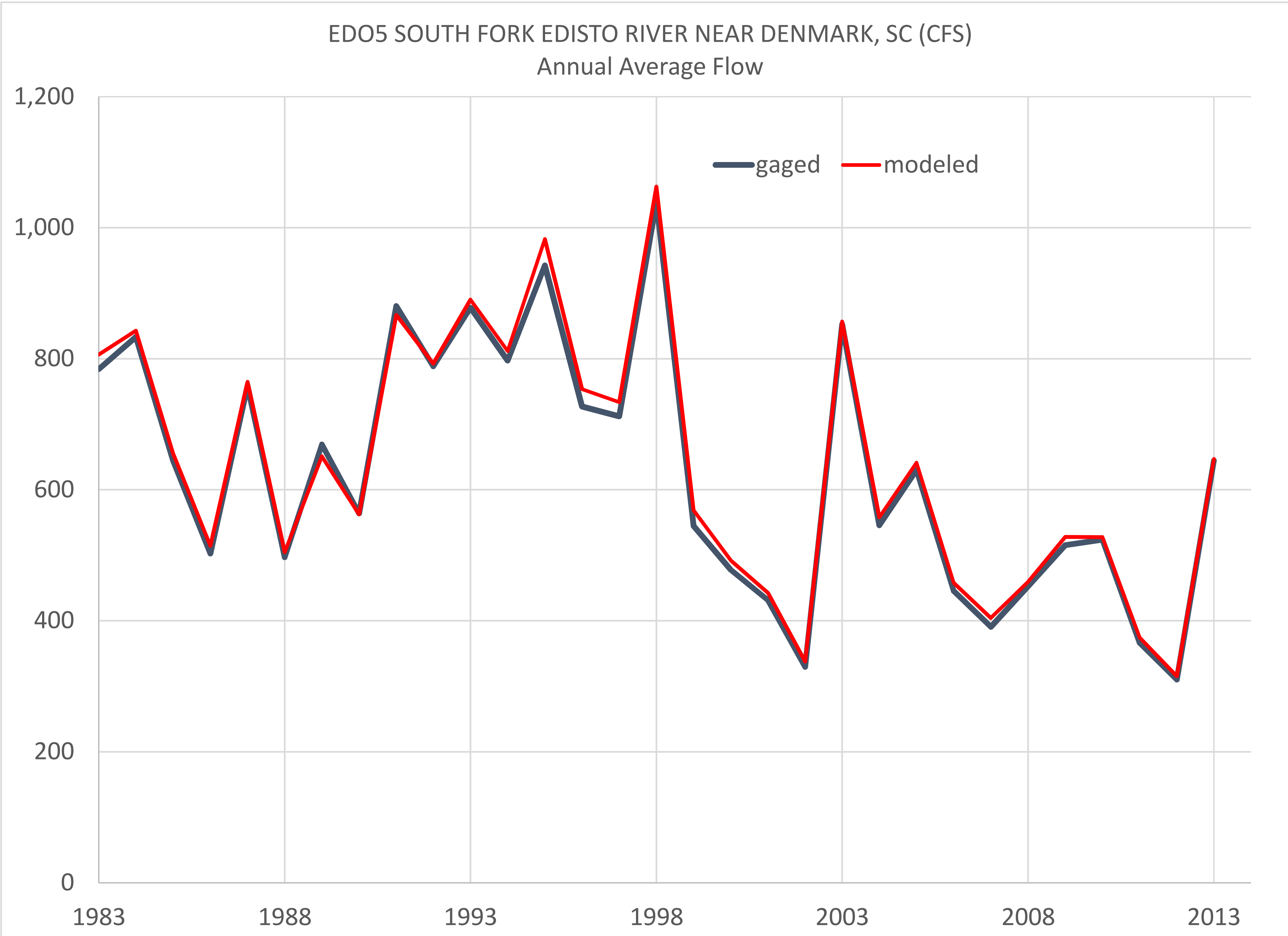

EDO4 DEAN SWAMP CREEK NR SALLEY, SC
Monthly Mean Flow (CFS)
30
25
20
15
10
5
0
gaged
modeled
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec

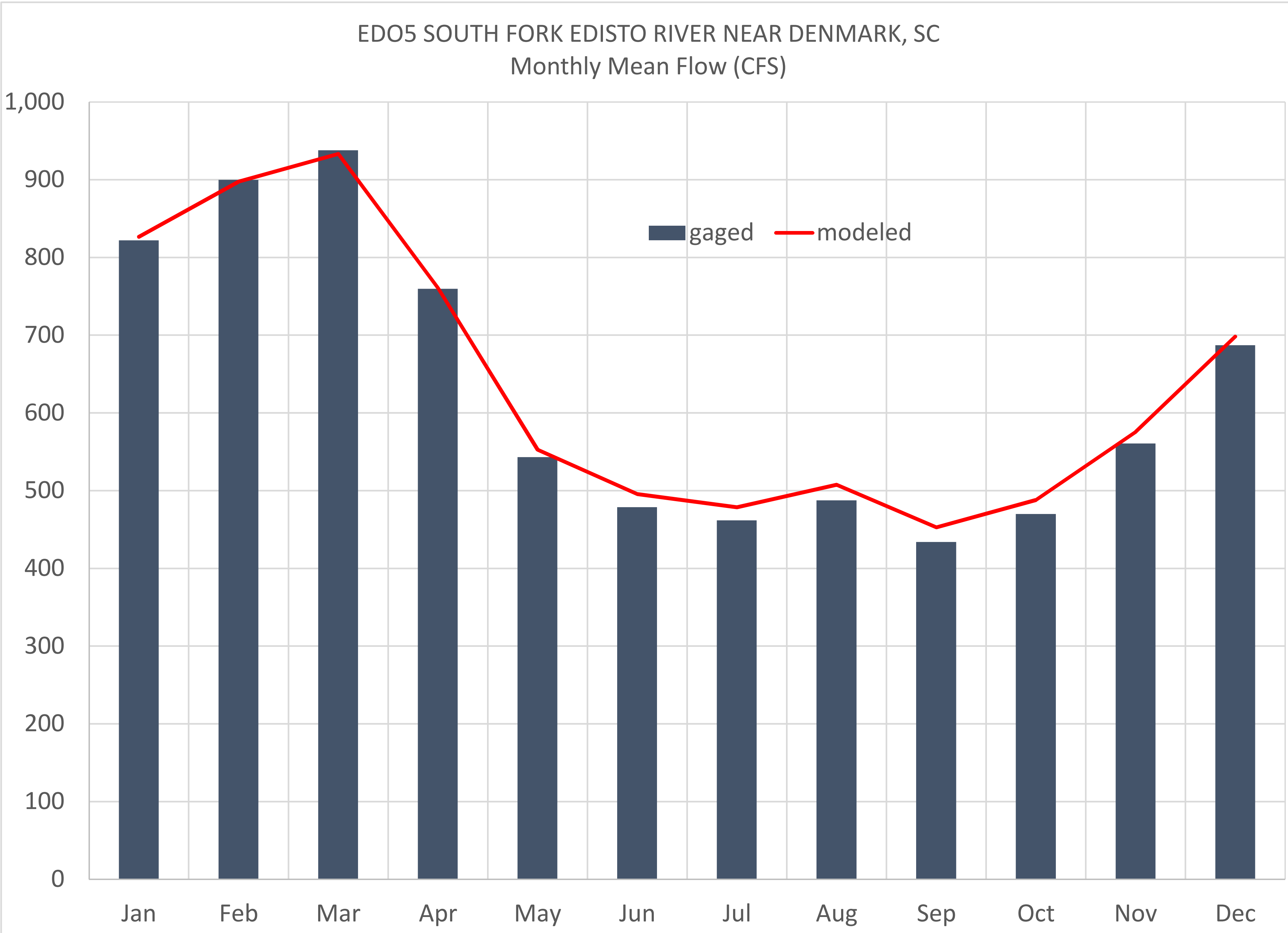

EDO4 DEAN SWAMP CREEK NR SALLEY, SC
Monthly Flow Percentiles (CFS)
gaged
modeled
45.00
40.00
35.00
30.00
25.00
20.00
15.00
10.00
5.00
0.00
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
Percentile



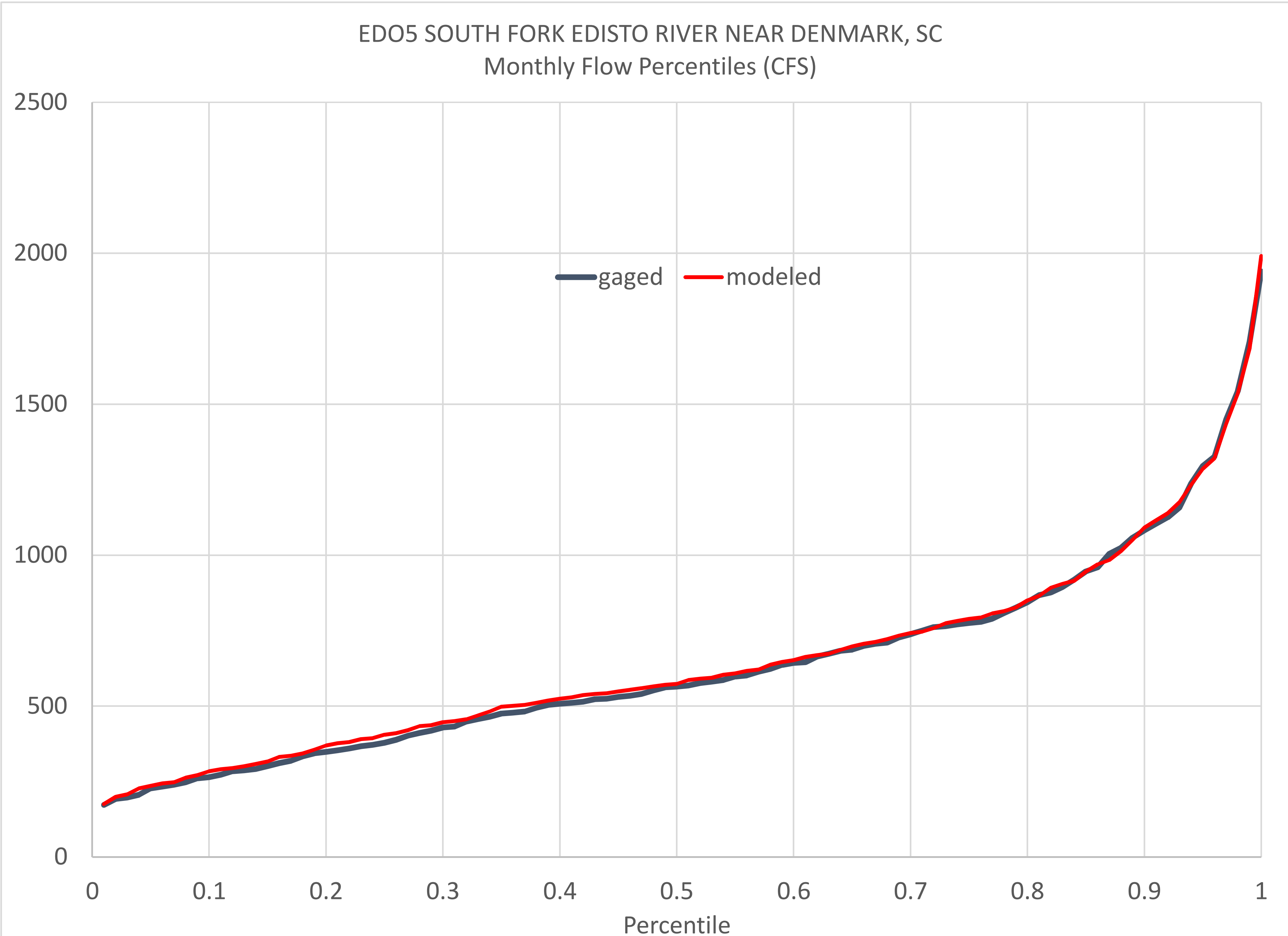
EDO5 SOUTH FORK EDISTO RIVER NEAR DENMARK, SC (CFS)
3,000
2,500
2,000
1,500
1,000
500
0
modeled
gaged
Jan-83
Jul-88
Dec-93
Jun-99
Dec-04
Jun-10

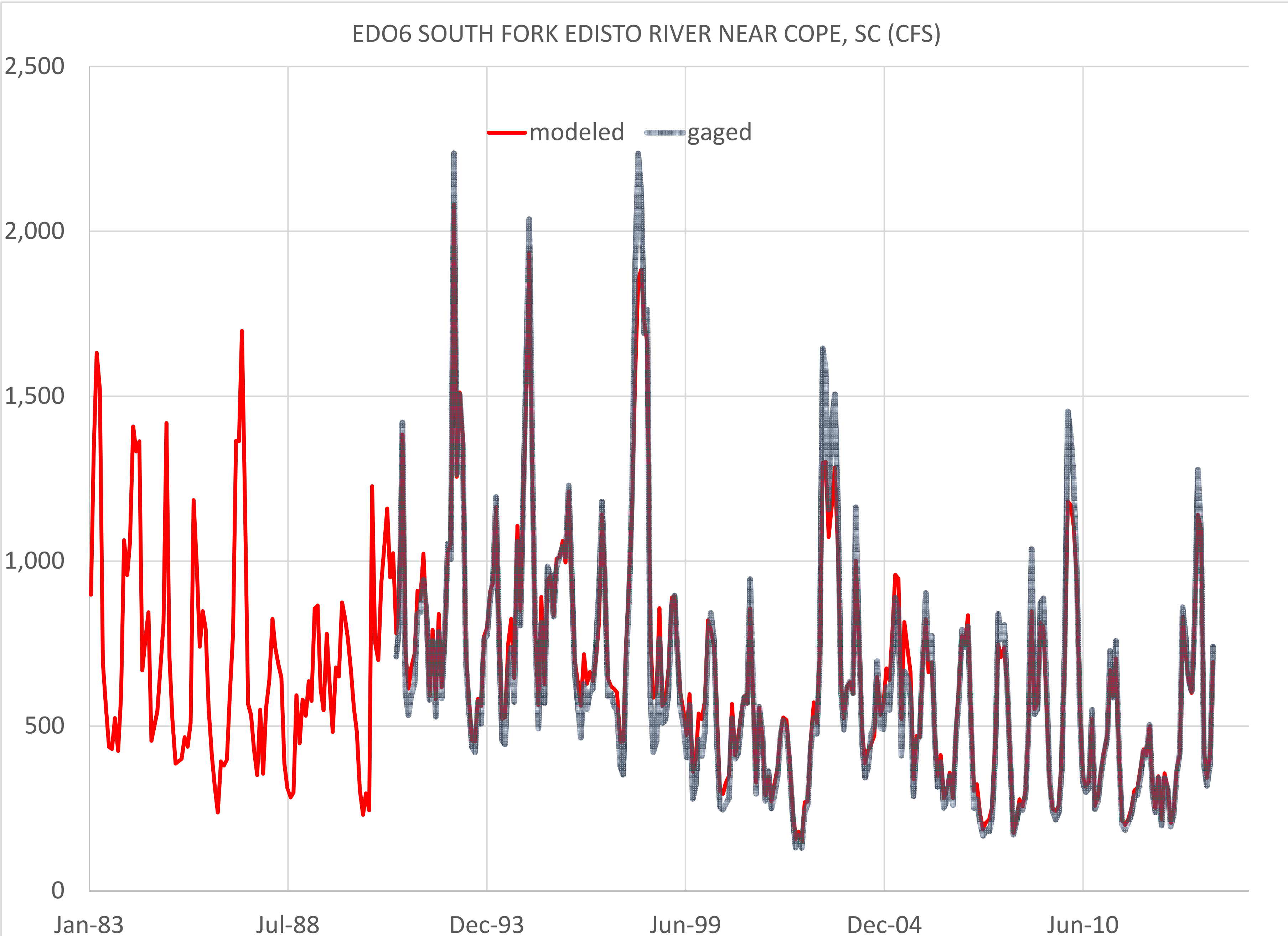

CUMULATIVE FLOW COMPARISON
EDO6 SOUTH FORK EDISTO RIVER NEAR COPE, SC (CFS)
modeled
gaged
200,000
180,000
160,000
140,000
120,000
100,000
80,000
60,000
40,000
20,000
0
Jan-83
Jul-88
Dec-93
Jun-99
Dec-04
Jun-10

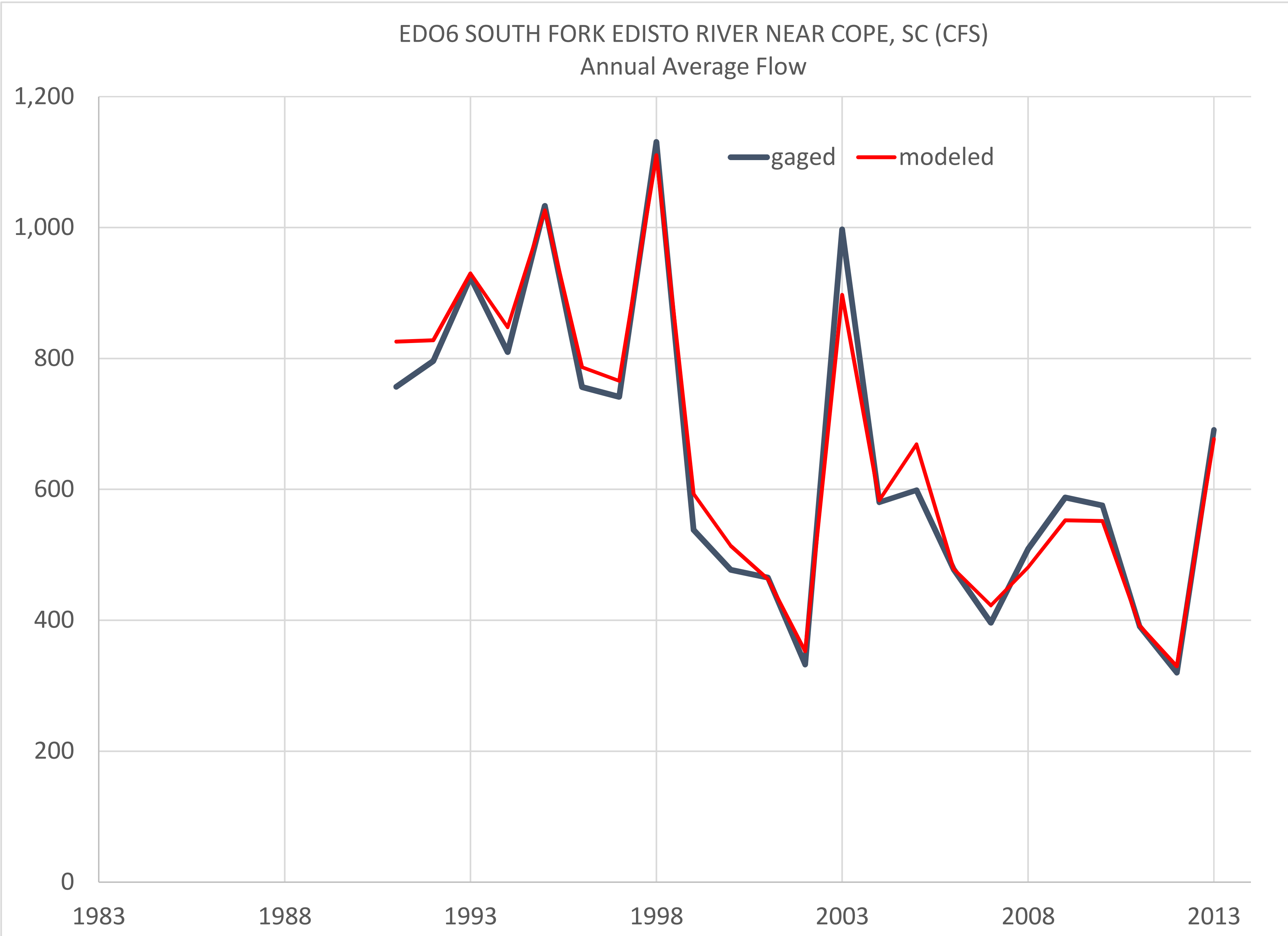

EDO5 SOUTH FORK EDISTO RIVER NEAR DENMARK, SC (CFS)
Annual Average Flow
gaged
modeled
1,200
1,000
800
600
400
200
0
1983
1988
1993
1998
2003
2008
2013

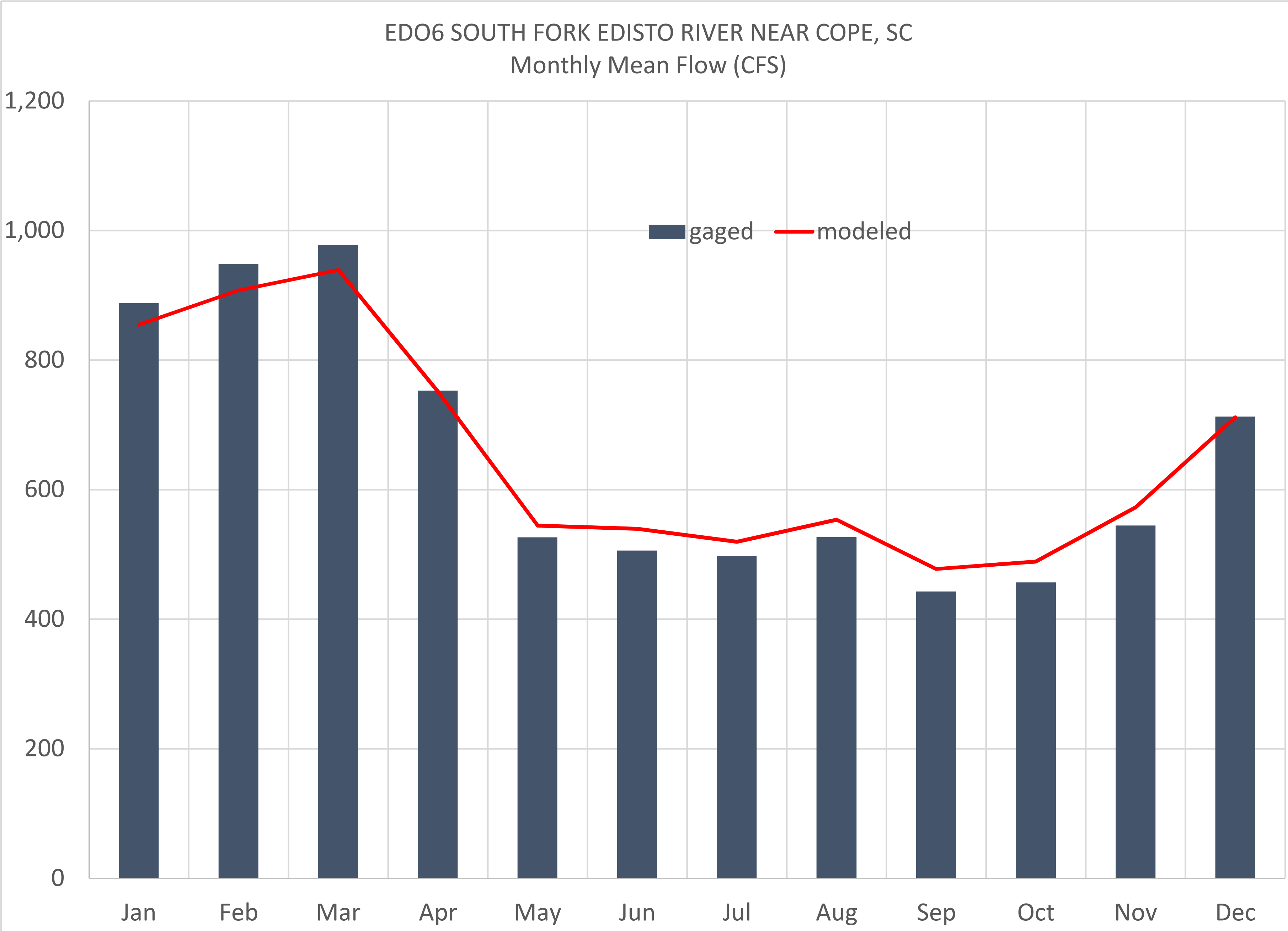


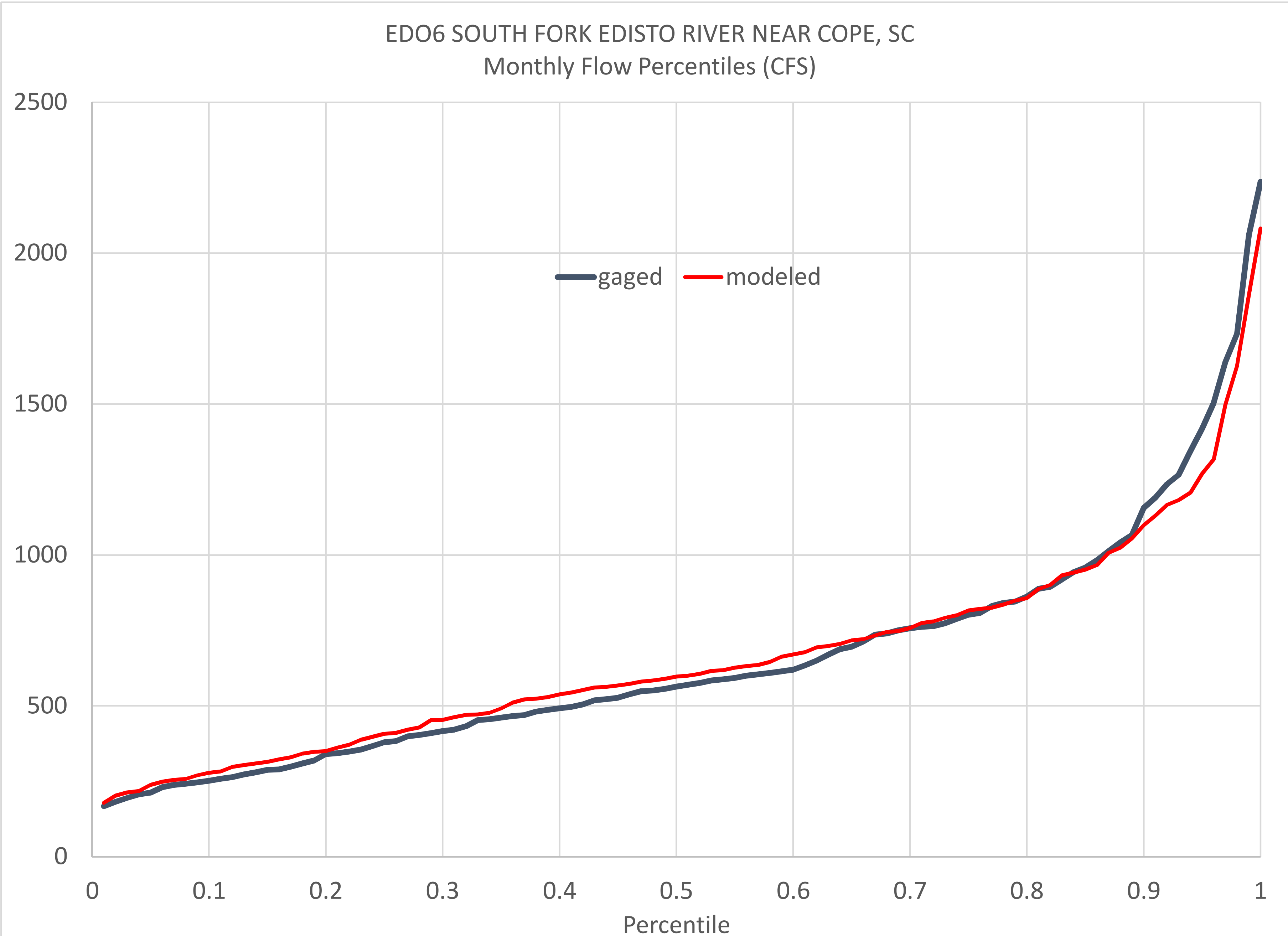
EDO5 SOUTH FORK EDISTO RIVER NEAR DENMARK, SC
Monthly Mean Flow (CFS)
1,000
900
800
700
600
500
400
300
200
100
0
gaged
modeled
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec

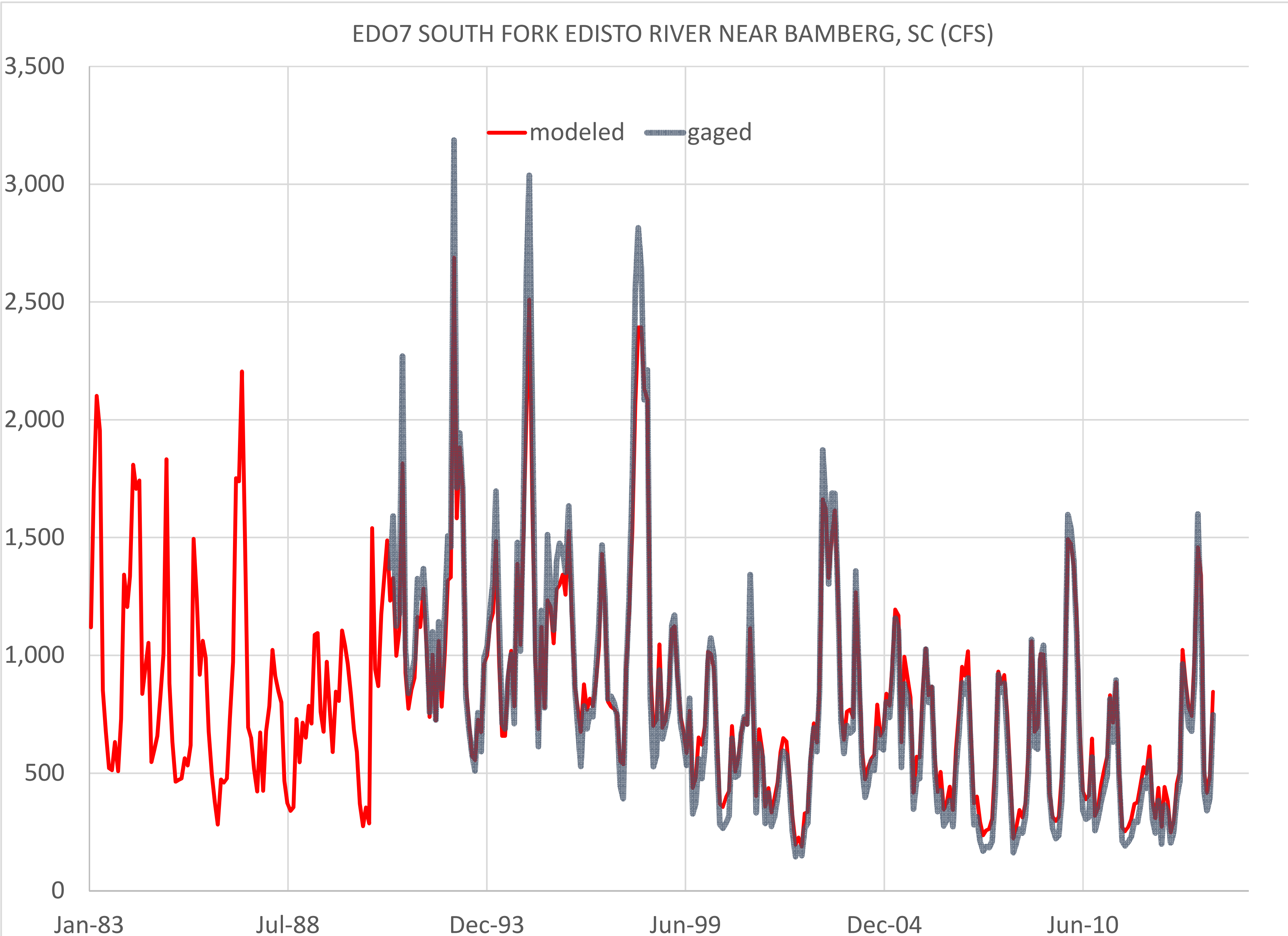

EDO5 SOUTH FORK EDISTO RIVER NEAR DENMARK, SC
Monthly Flow Percentiles (CFS)
gaged
modeled
2500
2000
1500
1000
500
0
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
Percentile

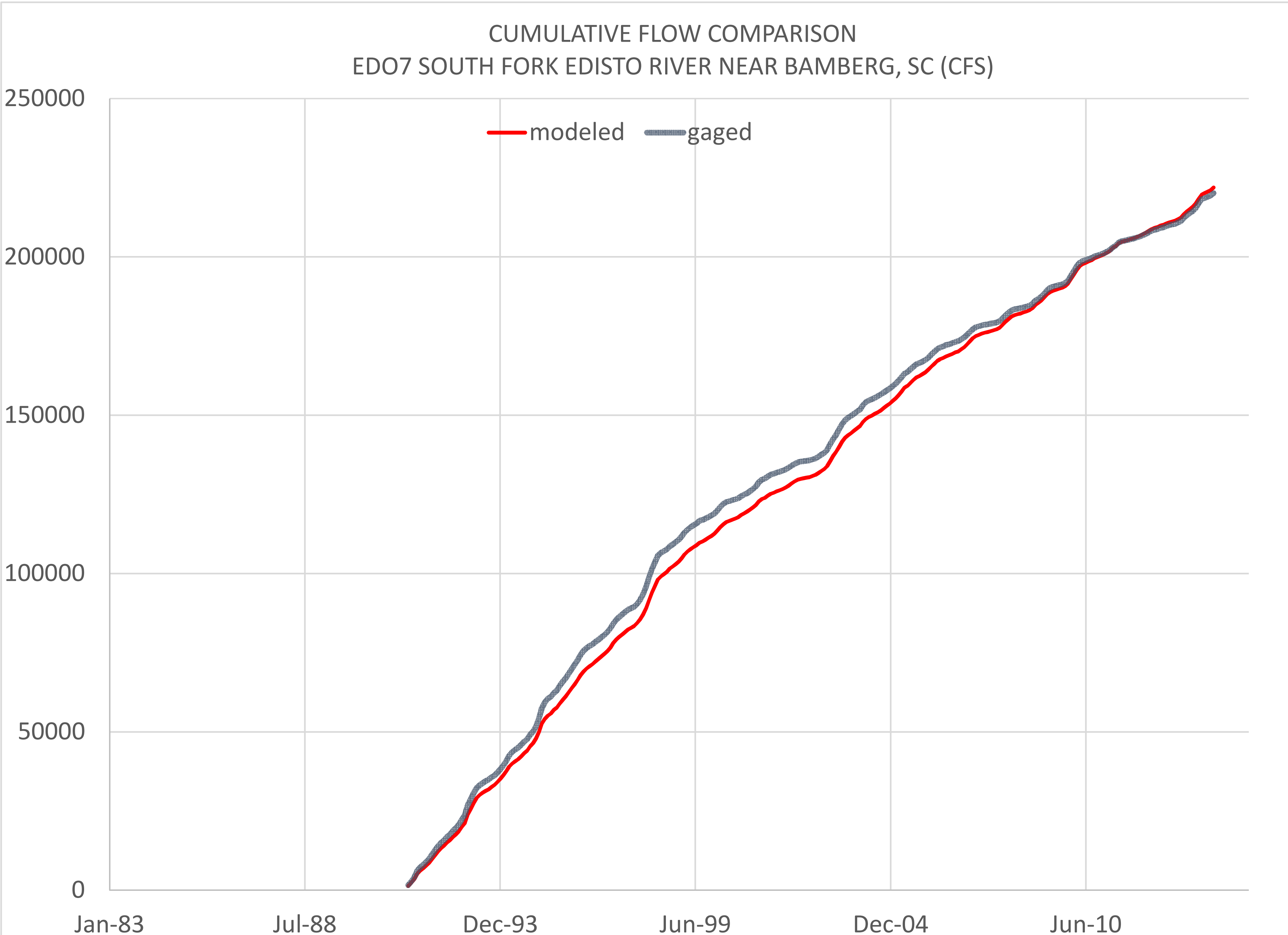

EDO6 SOUTH FORK EDISTO RIVER NEAR COPE, SC (CFS)
modeled
gaged
2,500
2,000
1,500
1,000
500
0
Jan-83
Jul-88
Dec-93
Jun-99
Dec-04
Jun-10


EDO6 SOUTH FORK EDISTO RIVER NEAR COPE, SC (CFS)
Annual Average Flow
gaged
modeled
1,200
1,000
800
600
400
200
0
1983
1988
1993
1998
2003
2008
2013

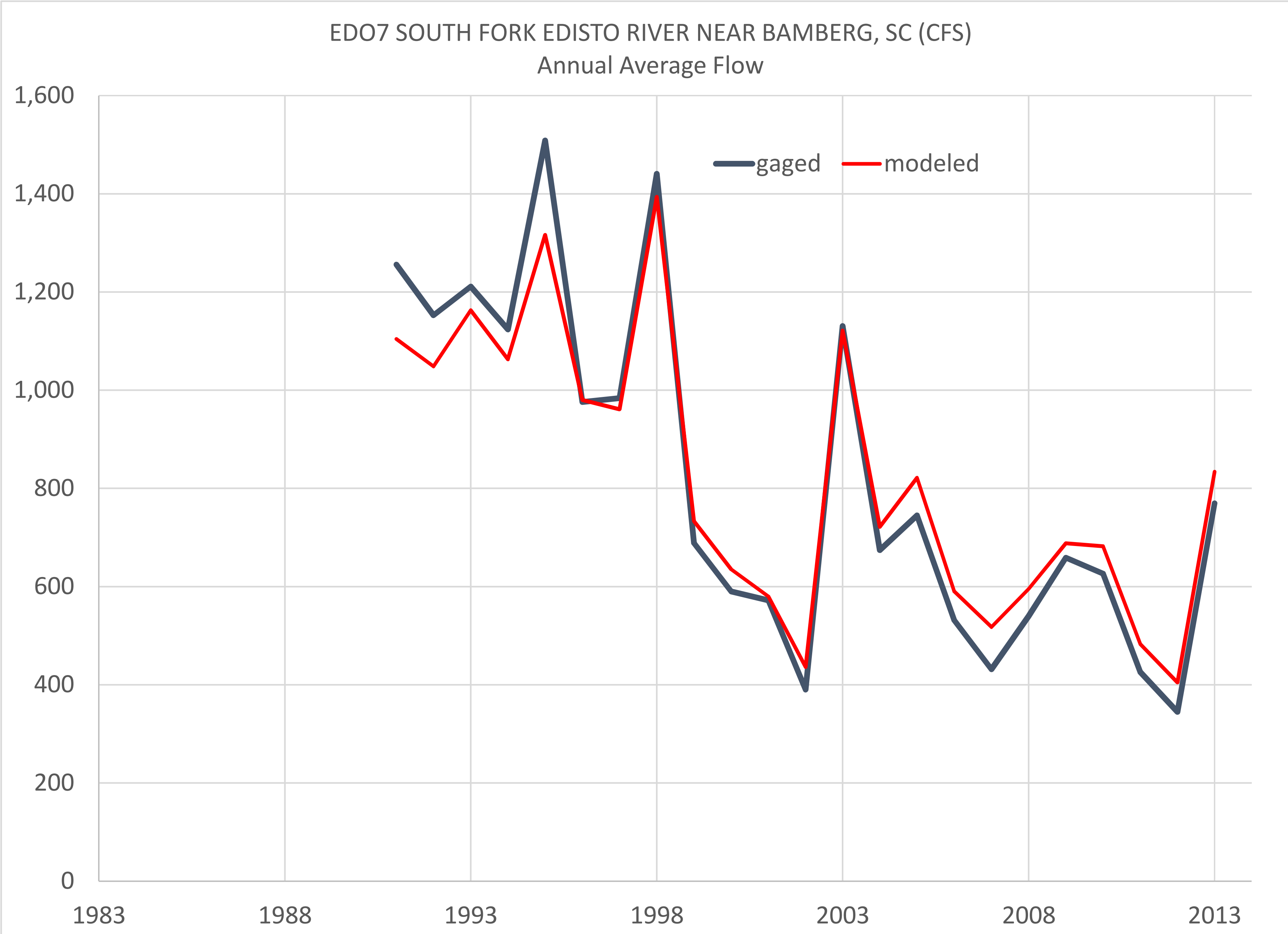

EDO6 SOUTH FORK EDISTO RIVER NEAR COPE, SC
Monthly Mean Flow (CFS)
1,200
1,000
800
600
400
200
0
gaged
modeled
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec

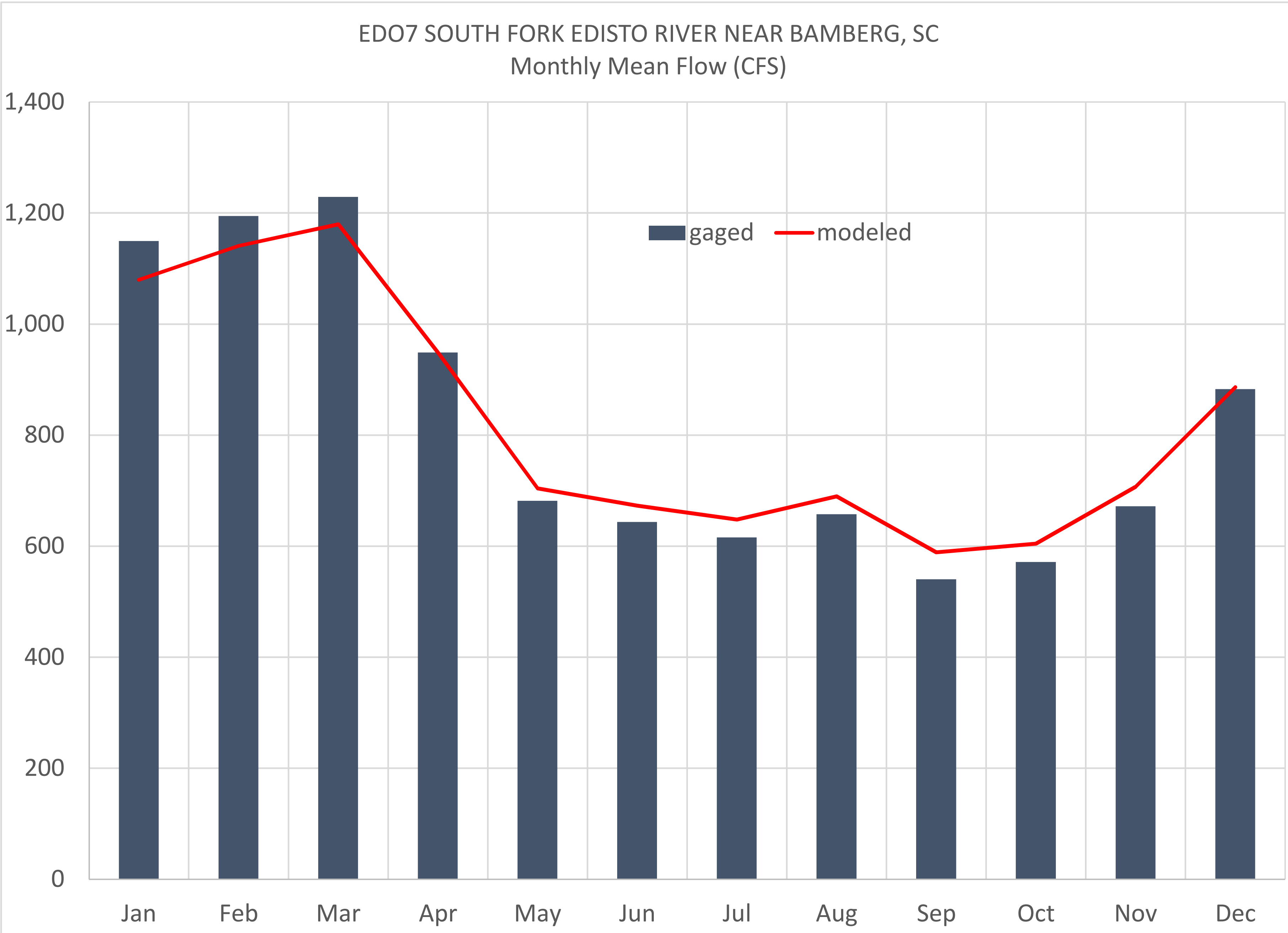

EDO6 SOUTH FORK EDISTO RIVER NEAR COPE, SC
Monthly Flow Percentiles (CFS)
gaged
modeled
2500
2000
1500
1000
500
0
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
Percentile

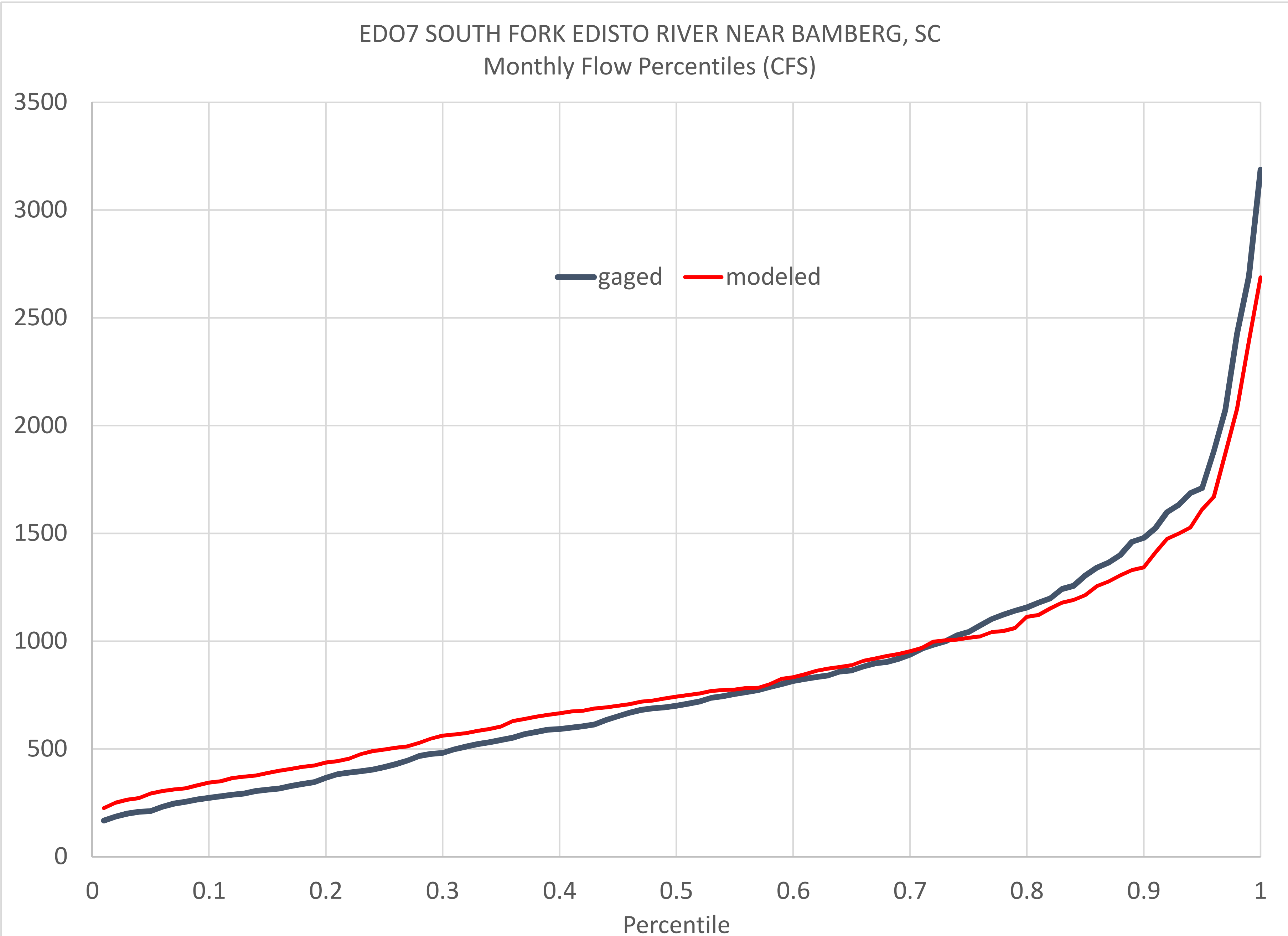

EDO7 SOUTH FORK EDISTO RIVER NEAR BAMBERG, SC (CFS)
modeled
gaged
3,500
3,000
2,500
2,000
1,500
1,000
500
0
Jan-83
Jul-88
Dec-93
Jun-99
Dec-04
Jun-10



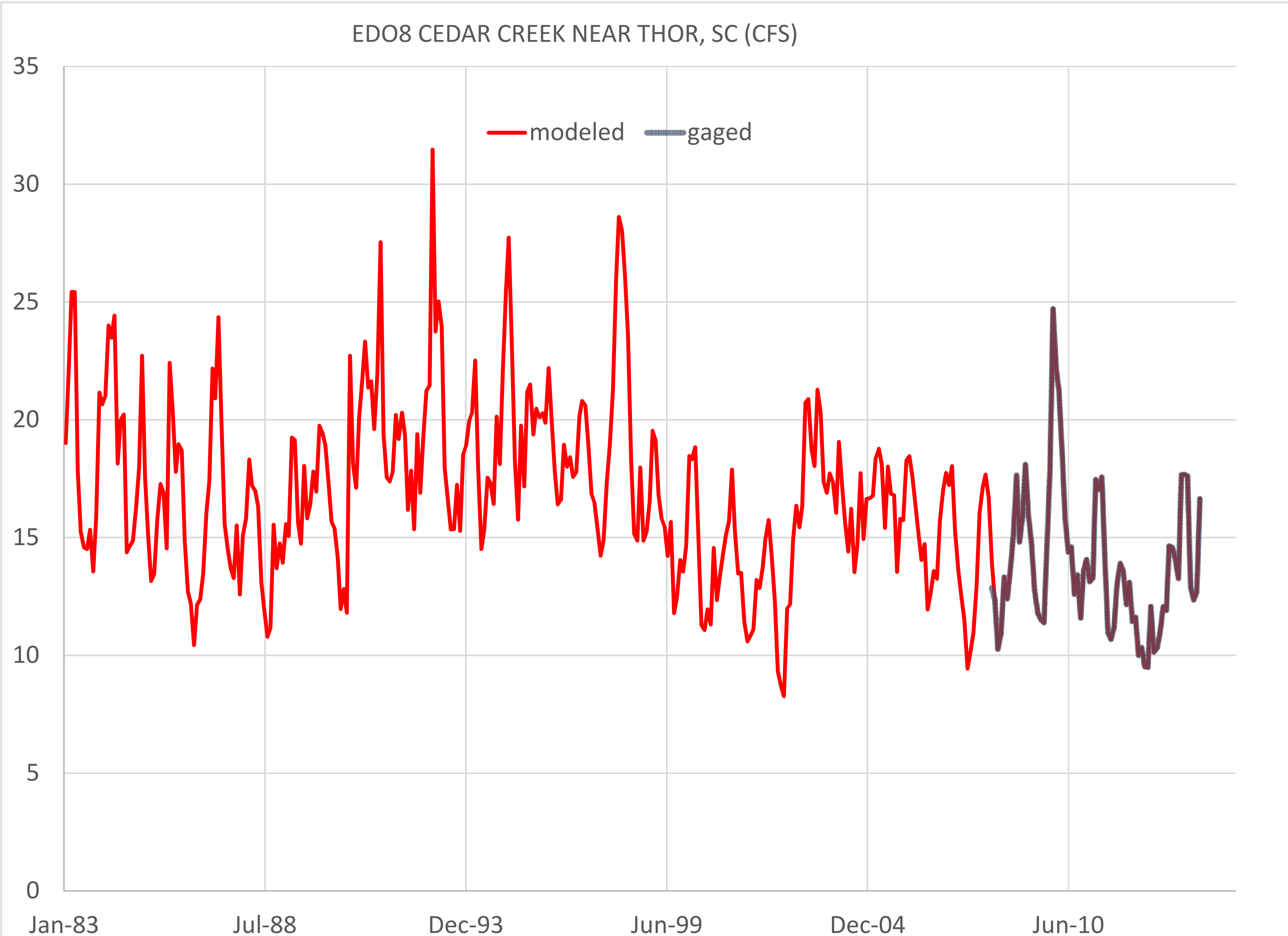
CUMULATIVE FLOW COMPARISON
EDO7 SOUTH FORK EDISTO RIVER NEAR BAMBERG, SC (CFS)
modeled
gaged
250000
200000
150000
100000
50000
0
Jan-83
Jul-88
Dec-93
Jun-99
Dec-04
Jun-10

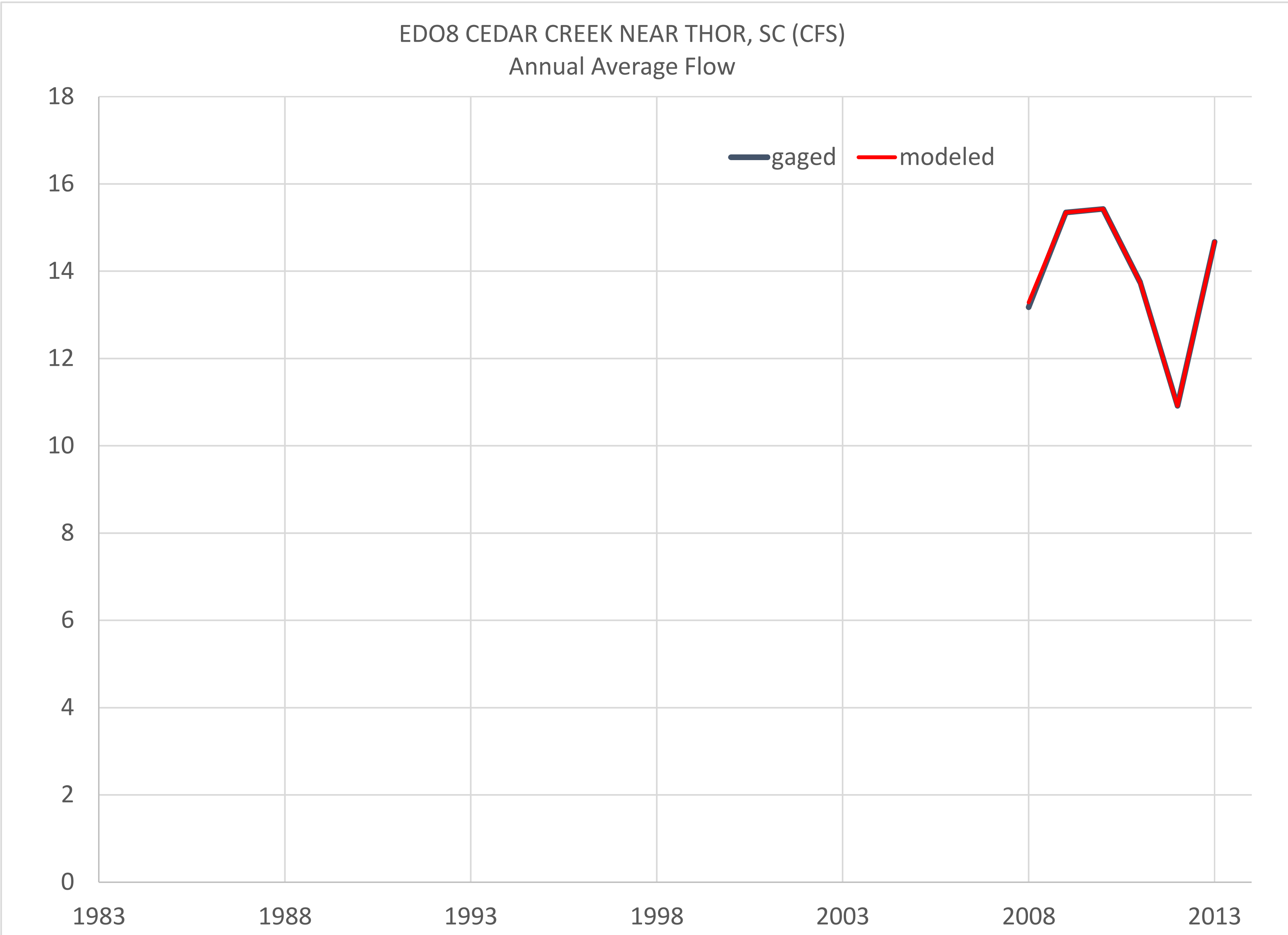

EDO7 SOUTH FORK EDISTO RIVER NEAR BAMBERG, SC (CFS)
Annual Average Flow
gaged
modeled
1,600
1,400
1,200
1,000
800
600
400
200
0
1983
1988
1993
1998
2003
2008
2013

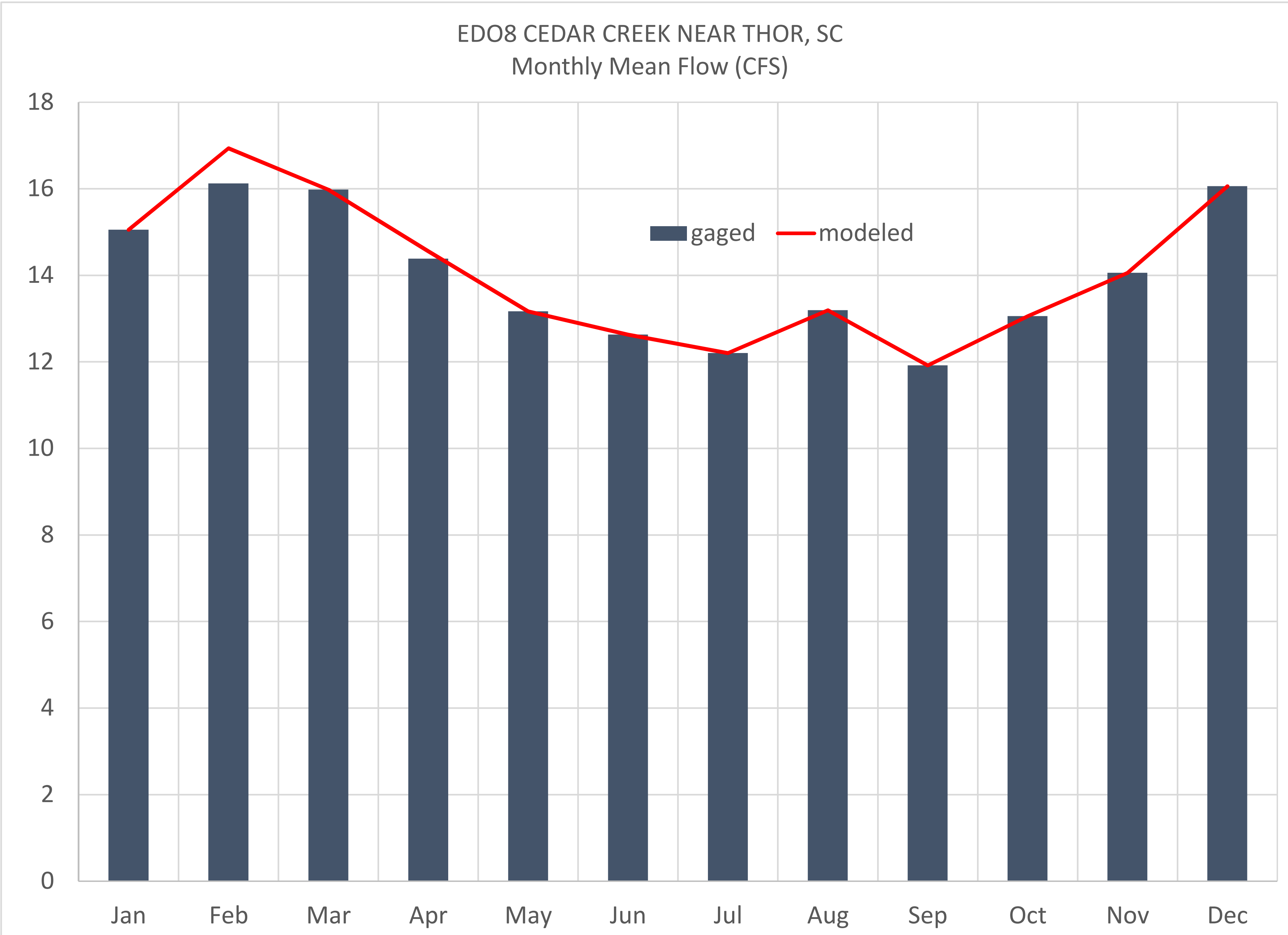

EDO7 SOUTH FORK EDISTO RIVER NEAR BAMBERG, SC
Monthly Mean Flow (CFS)
gaged
modeled
1,400
1,200
1,000
800
600
400
200
0
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec

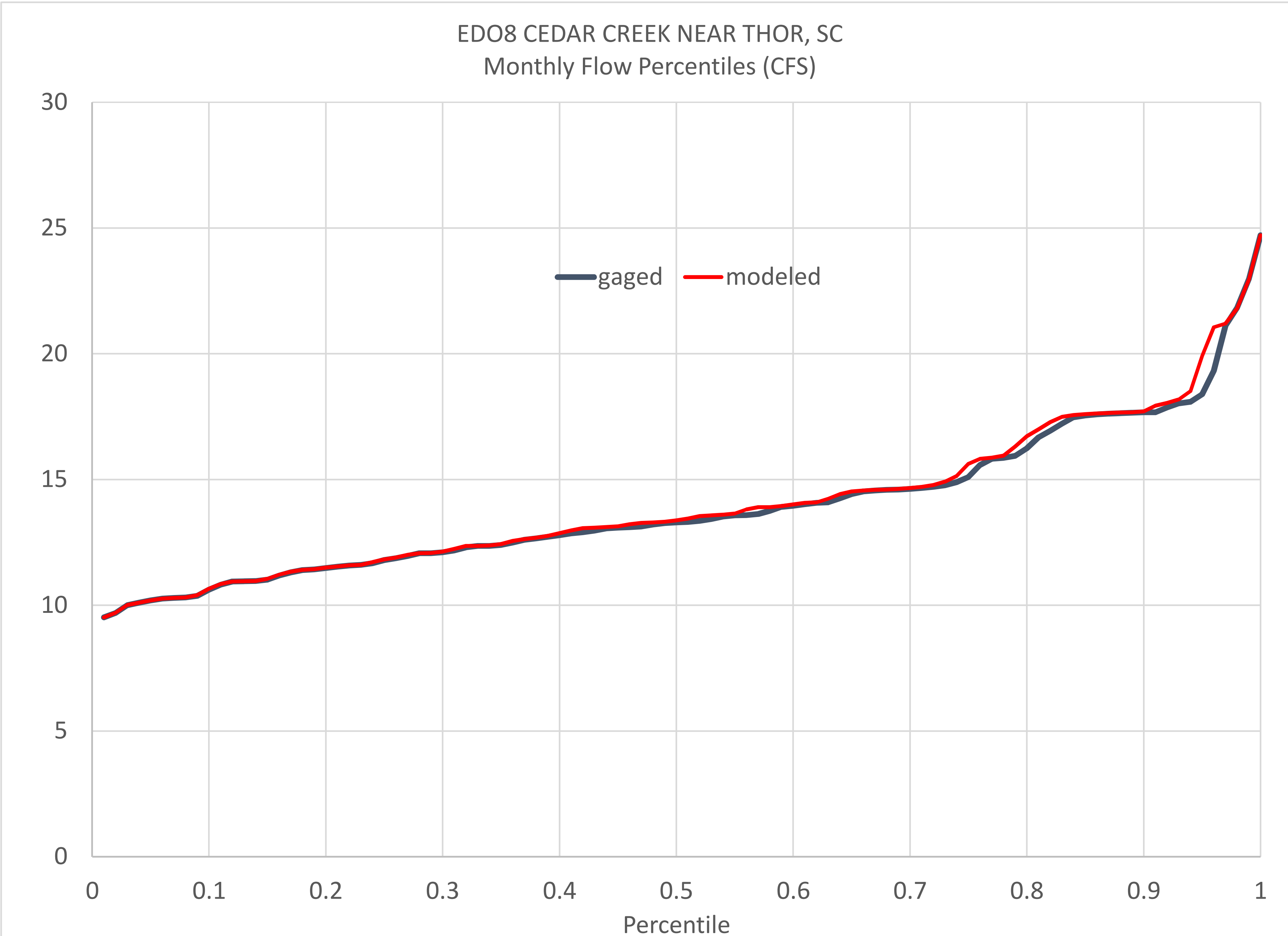


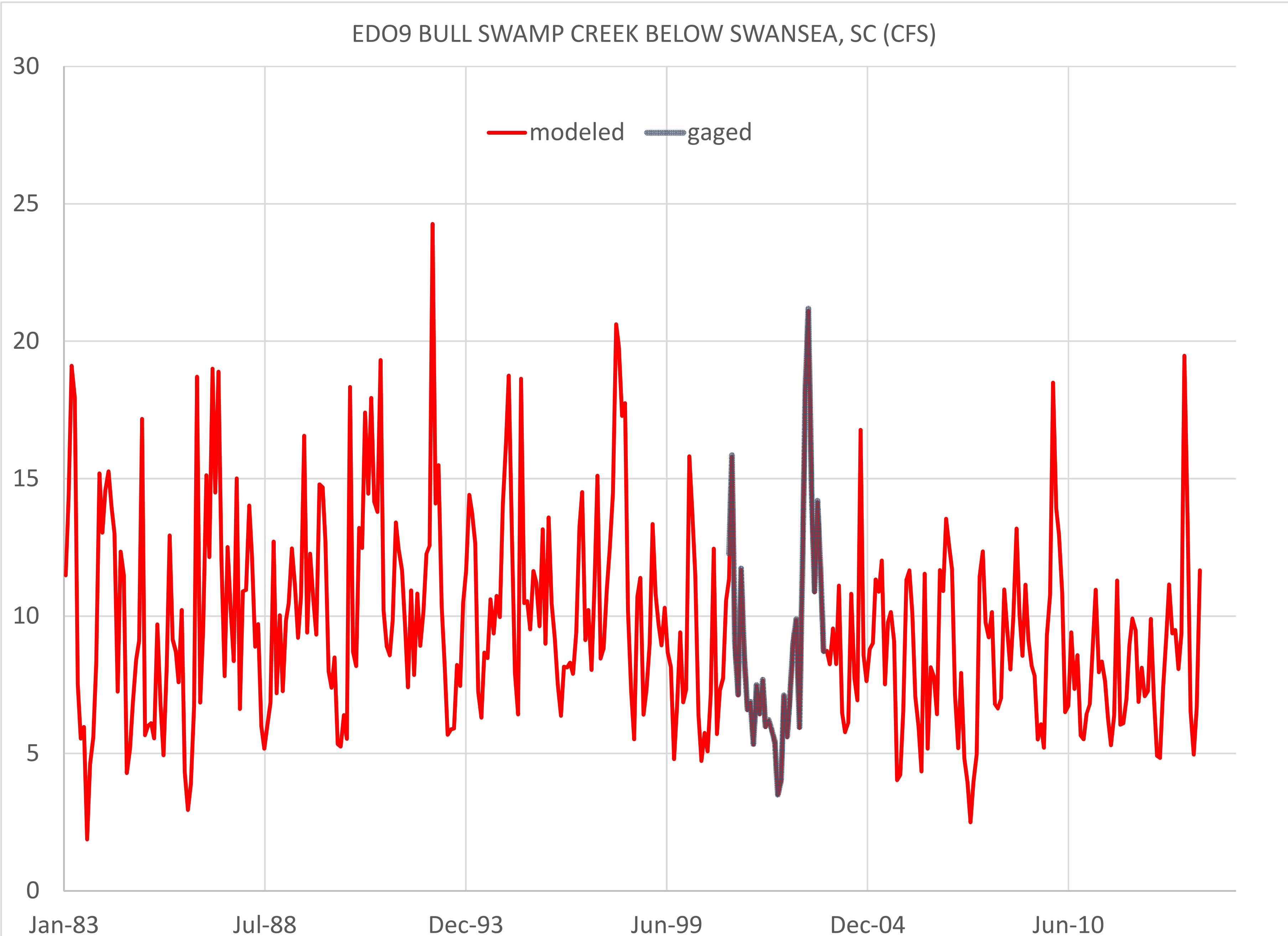
EDO7 SOUTH FORK EDISTO RIVER NEAR BAMBERG, SC
Monthly Flow Percentiles (CFS)
gaged
modeled
3500
3000
2500
2000
1500
1000
500
0
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
Percentile


EDO8 CEDAR CREEK NEAR THOR, SC (CFS)
modeled
gaged
35
30
25
20
15
10
5
0
Jan-83
Jul-88
Dec-93
Jun-99
Dec-04
Jun-10

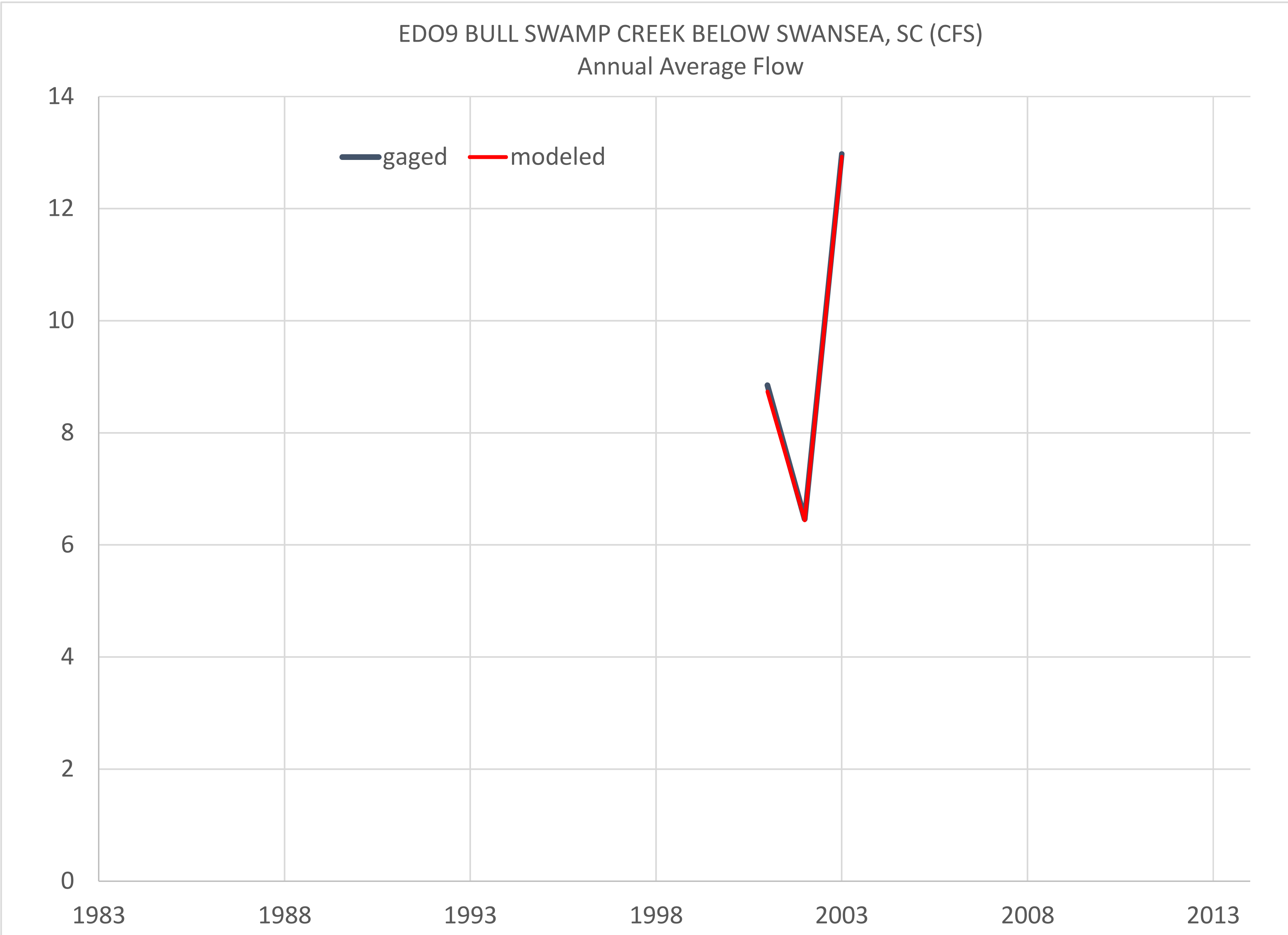

EDO8 CEDAR CREEK NEAR THOR, SC (CFS)
Annual Average Flow
gaged
modeled
18
16
14
12
10
8
6
4
2
0
1983
1988
1993
1998
2003
2008
2013


EDO8 CEDAR CREEK NEAR THOR, SC
Monthly Mean Flow (CFS)
gaged
modeled
18
16
14
12
10
8
6
4
2
0
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec

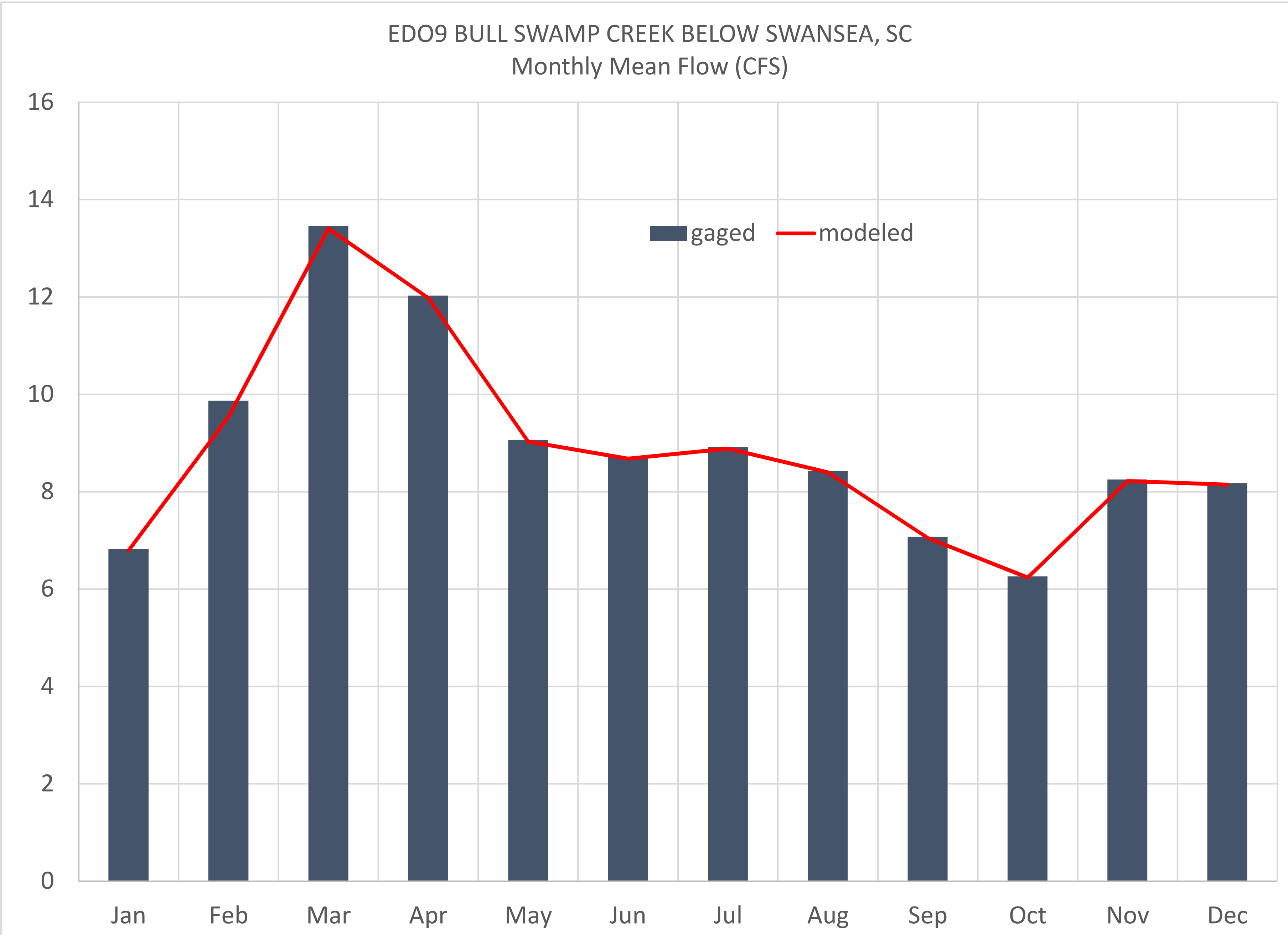

EDO8 CEDAR CREEK NEAR THOR, SC
Monthly Flow Percentiles (CFS)
gaged
modeled
30
25
20
15
10
5
0
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
Percentile

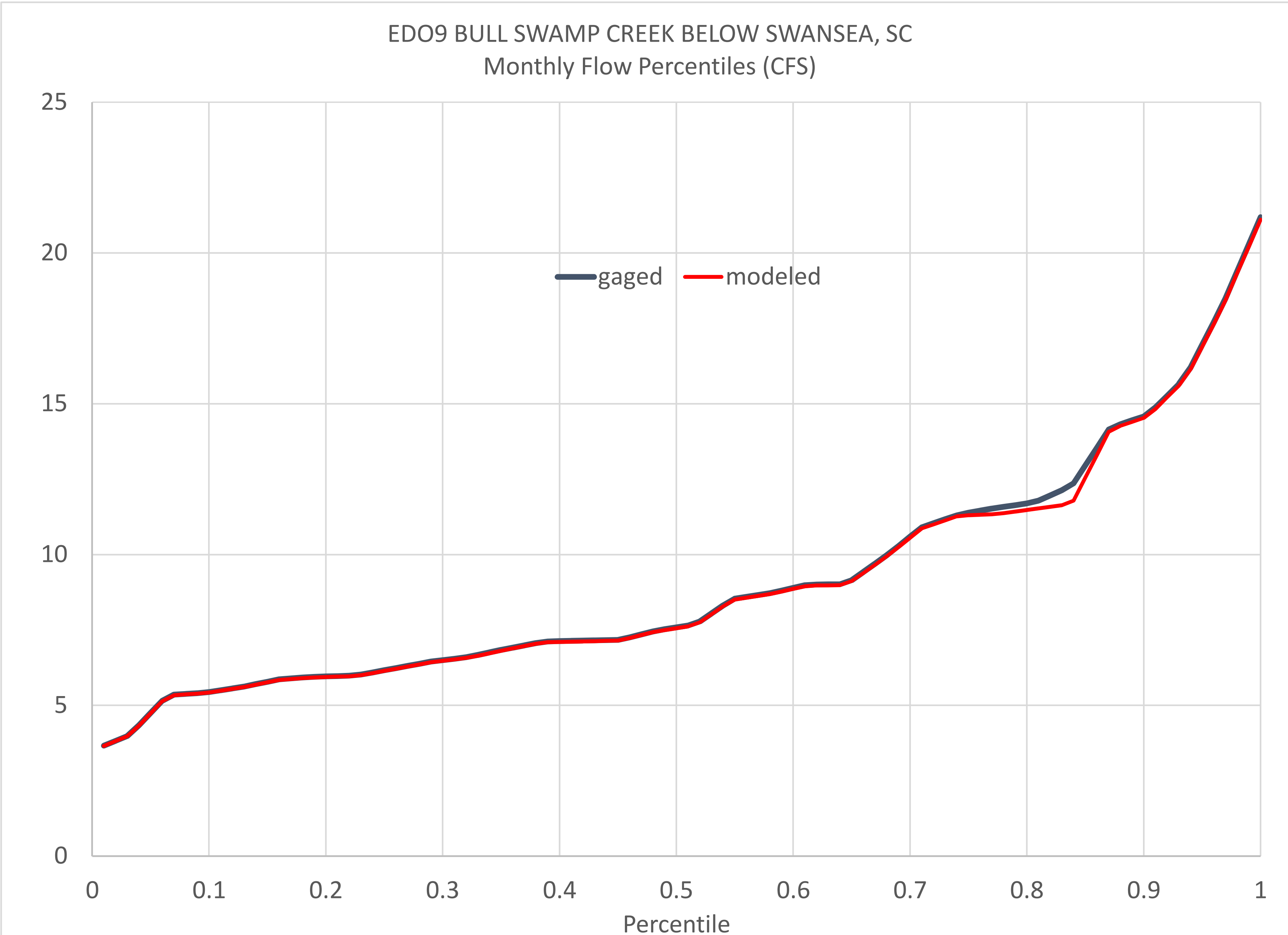


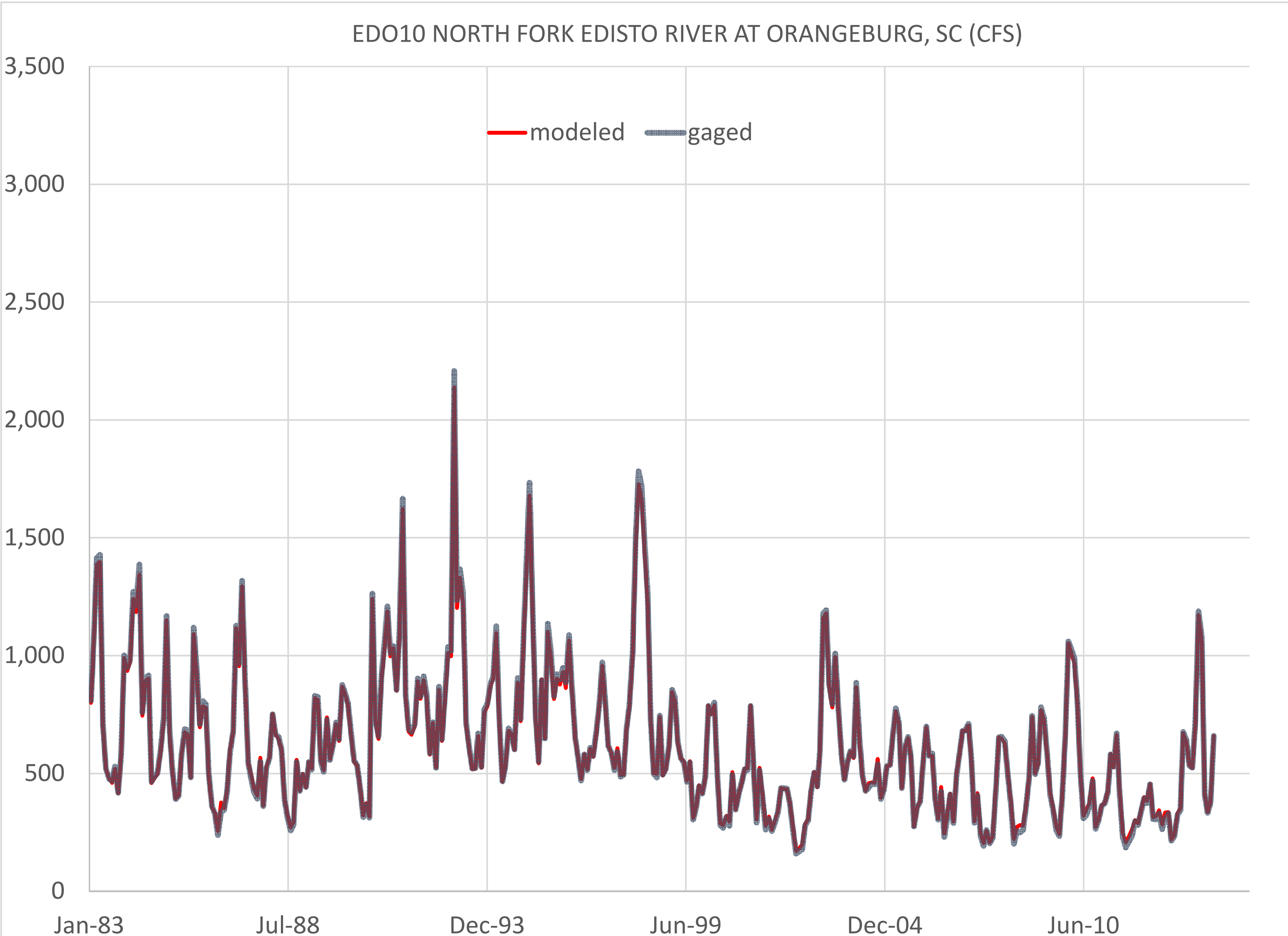
EDO9 BULL SWAMP CREEK BELOW SWANSEA, SC (CFS)
modeled
gaged
30
25
20
15
10
5
0
Jan-83
Jul-88
Dec-93
Jun-99
Dec-04
Jun-10

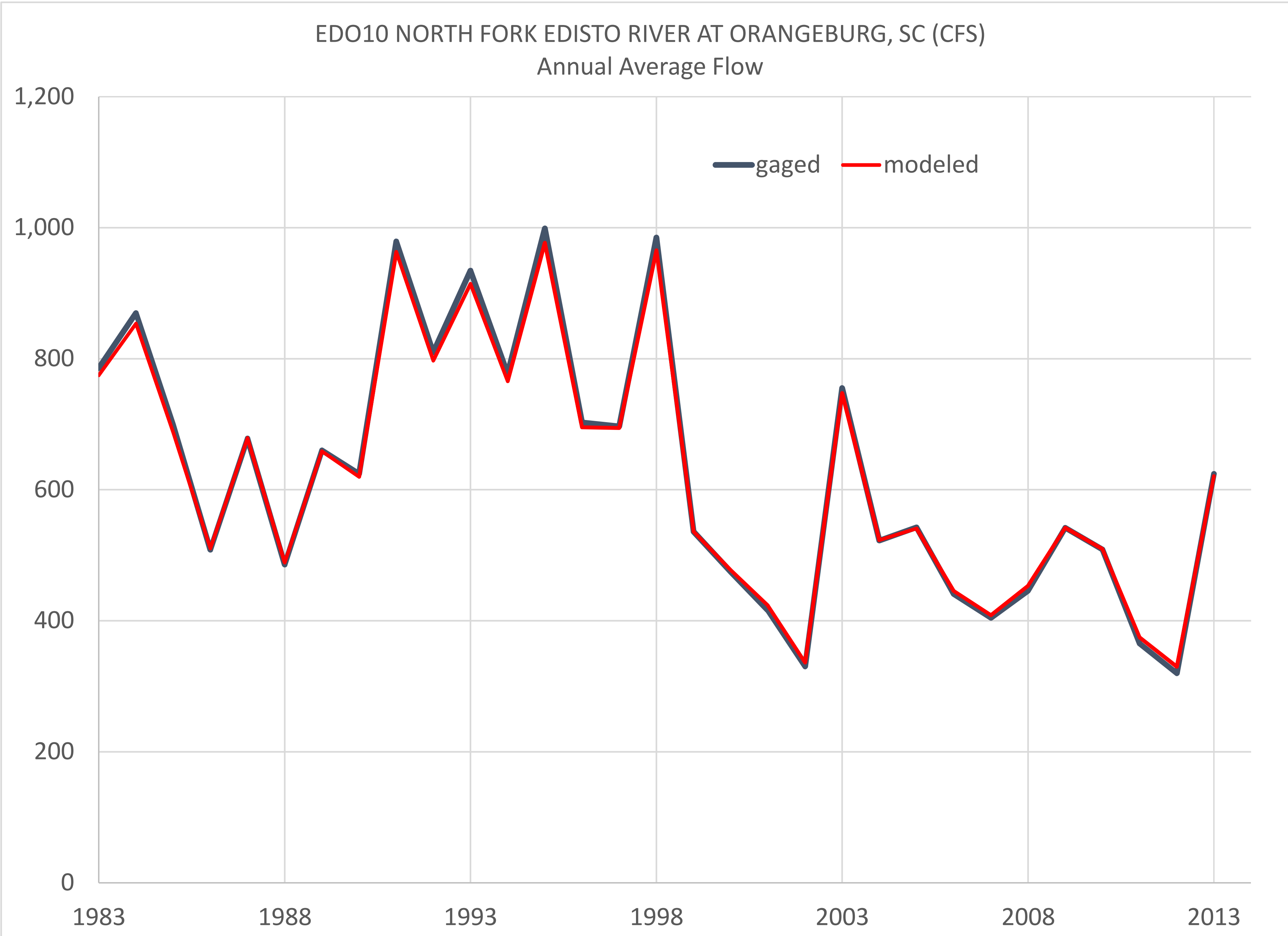


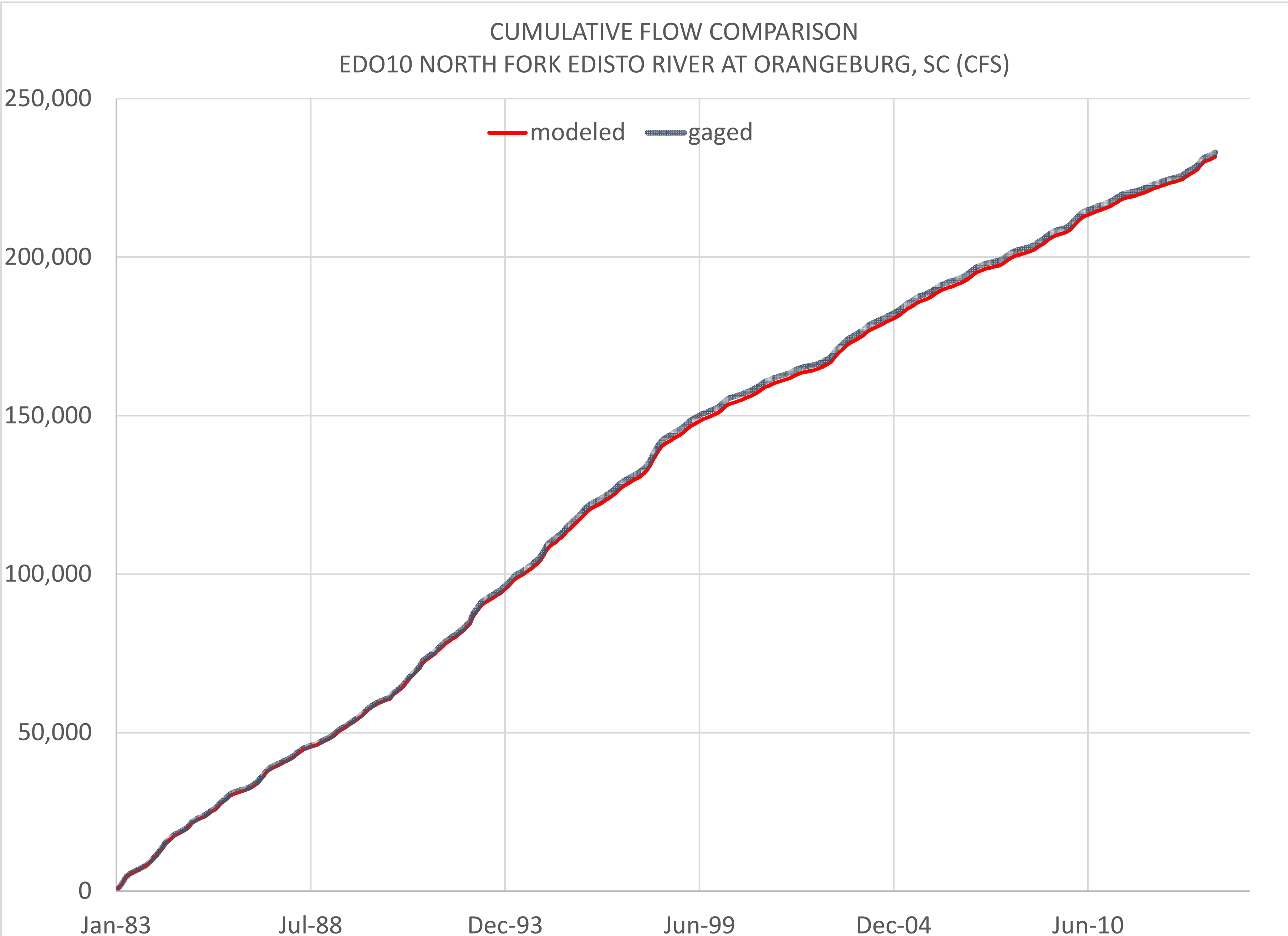
EDO9 BULL SWAMP CREEK BELOW SWANSEA, SC (CFS)
Annual Average Flow
gaged
modeled
0
2
4
6
8
10
12
14
1983
1988
1993
1998
2003
2008
2013

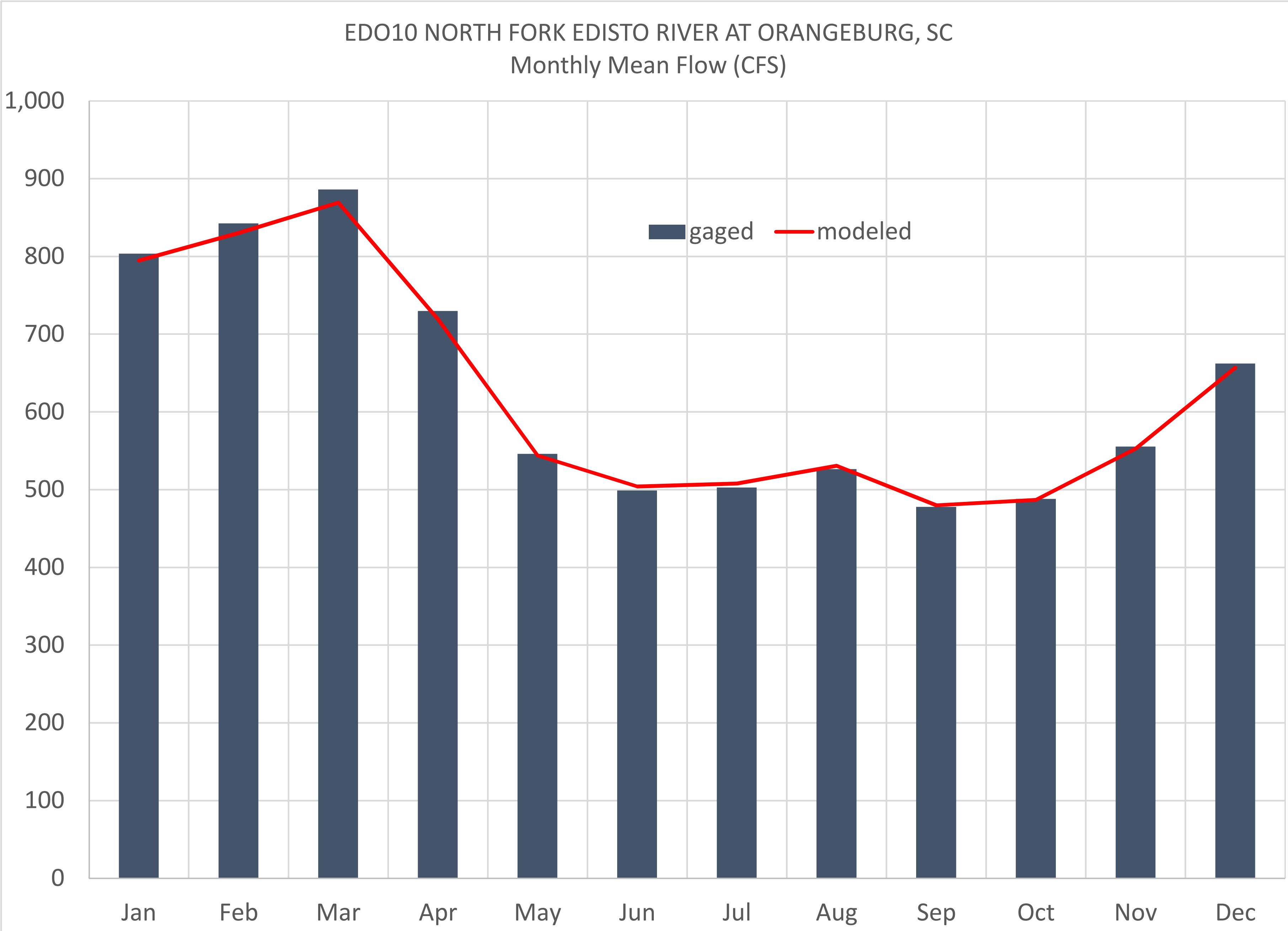

EDO9 BULL SWAMP CREEK BELOW SWANSEA, SC
Monthly Mean Flow (CFS)
gaged
modeled
16
14
12
10
8
6
4
2
0
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec

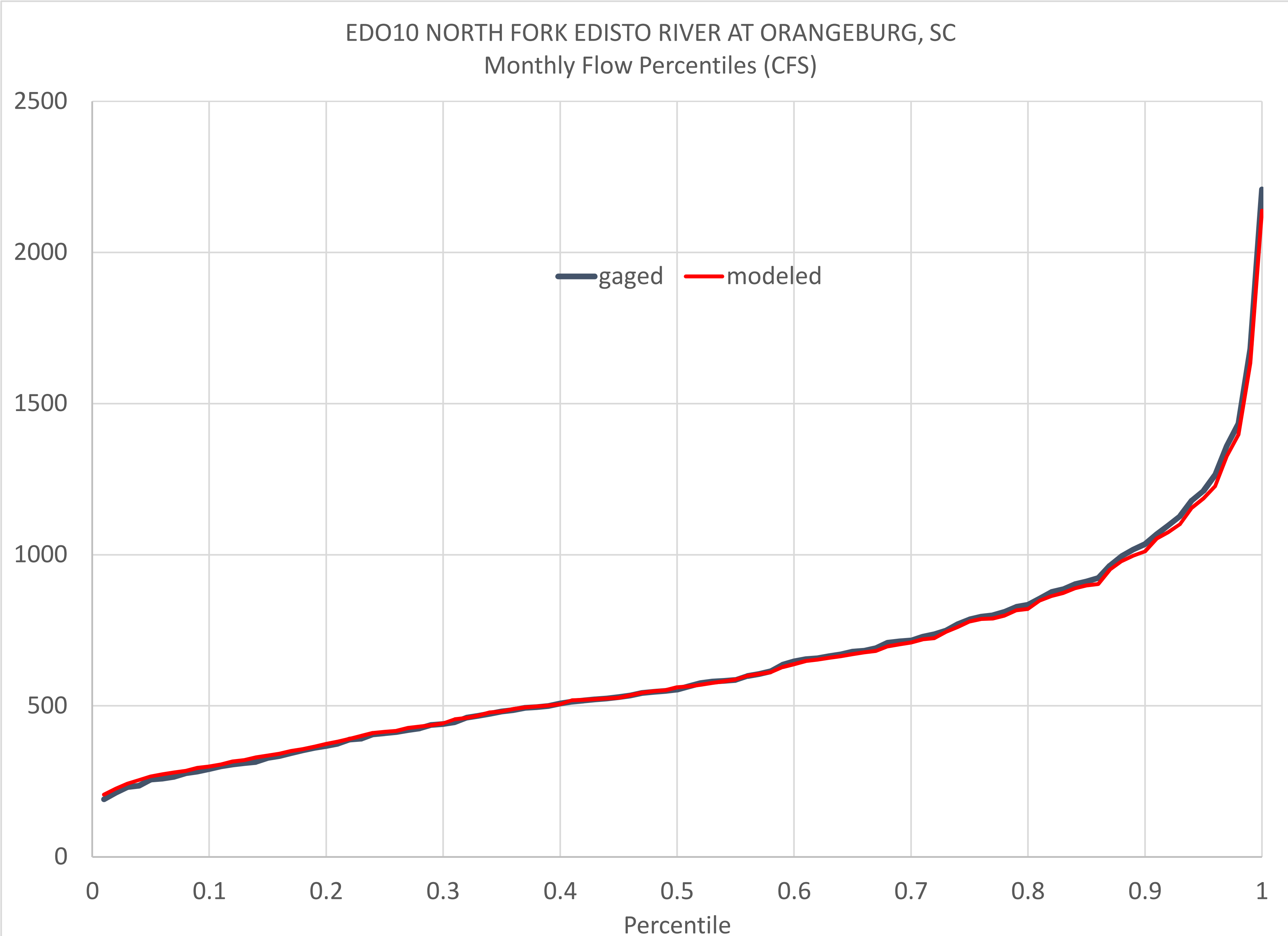

EDO9 BULL SWAMP CREEK BELOW SWANSEA, SC
Monthly Flow Percentiles (CFS)
gaged
modeled
25
20
15
10
5
0
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
Percentile

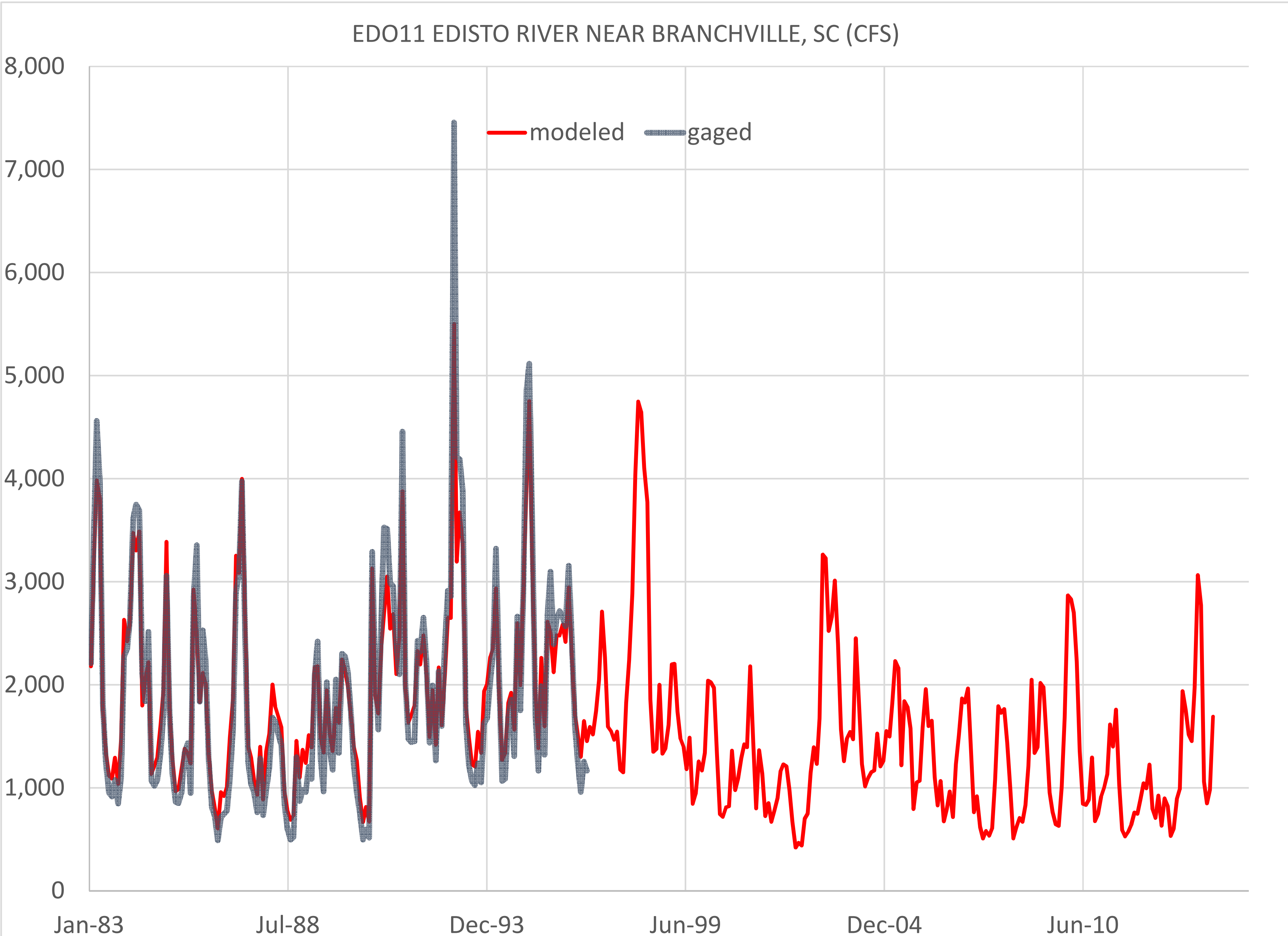

EDO10 NORTH FORK EDISTO RIVER AT ORANGEBURG, SC (CFS)
3,500
3,000
2,500
2,000
1,500
1,000
500
0
modeled
gaged
Jan-83
Jul-88
Dec-93
Jun-99
Dec-04
Jun-10


EDO10 NORTH FORK EDISTO RIVER AT ORANGEBURG, SC (CFS)
Annual Average Flow
gaged
modeled
1,200
1,000
800
600
400
200
0
1983
1988
1993
1998
2003
2008
2013

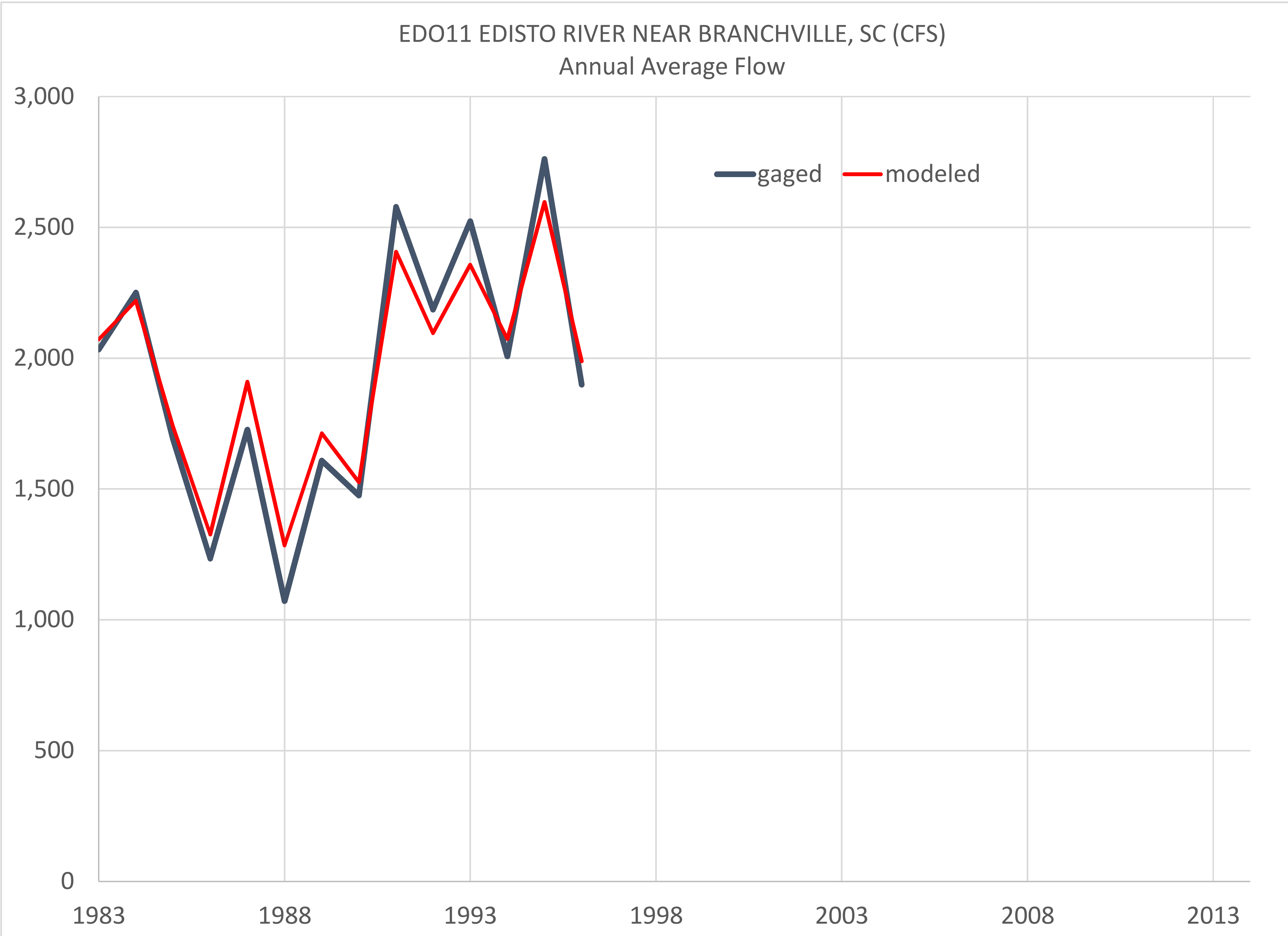

CUMULATIVE FLOW COMPARISON
EDO10 NORTH FORK EDISTO RIVER AT ORANGEBURG, SC (CFS)
modeled
gaged
250,000
200,000
150,000
100,000
50,000
0
Jan-83
Jul-88
Dec-93
Jun-99
Dec-04
Jun-10

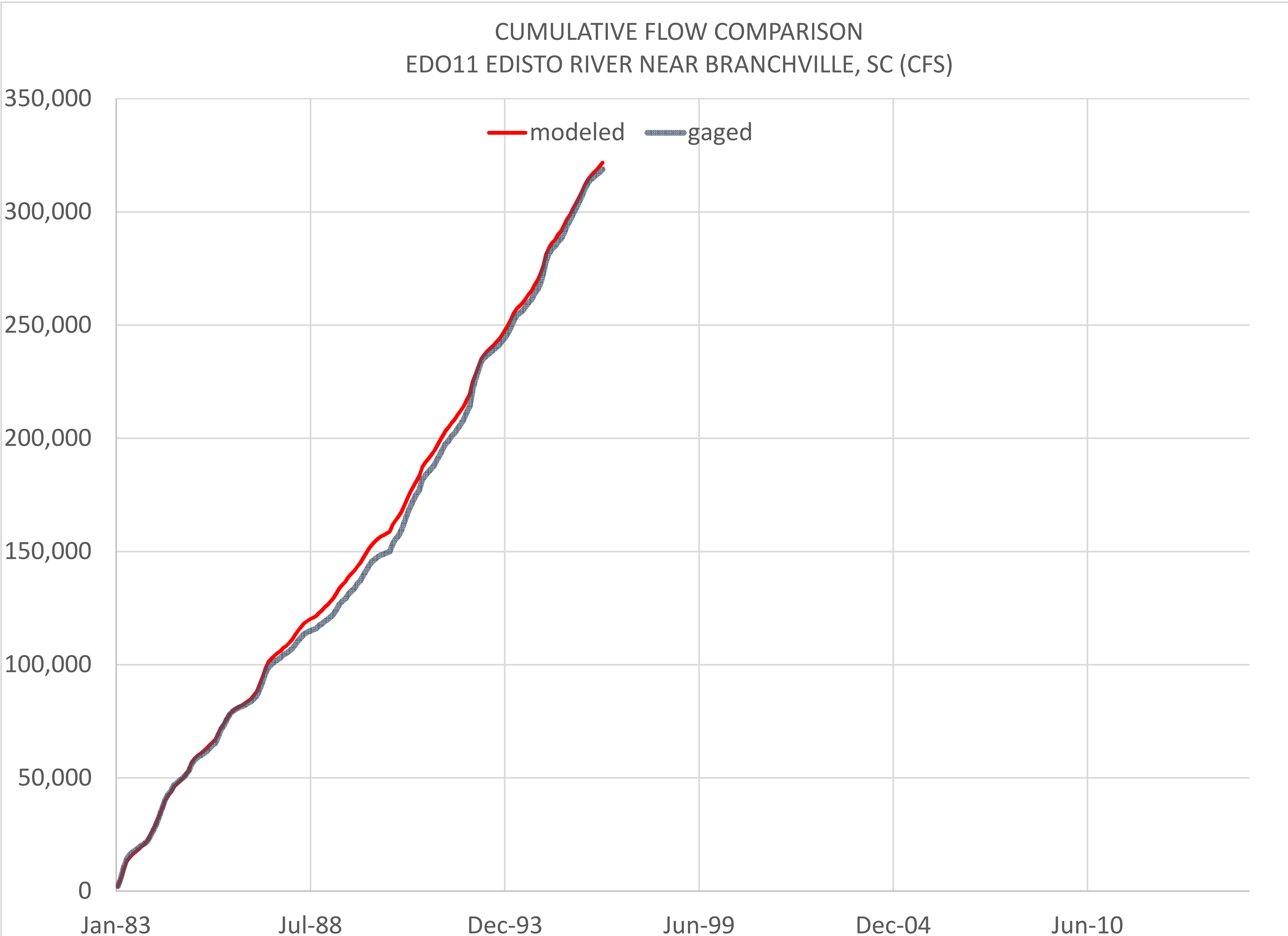

EDO10 NORTH FORK EDISTO RIVER AT ORANGEBURG, SC
Monthly Mean Flow (CFS)
gaged
modeled
1,000
900
800
700
600
500
400
300
200
100
0
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec

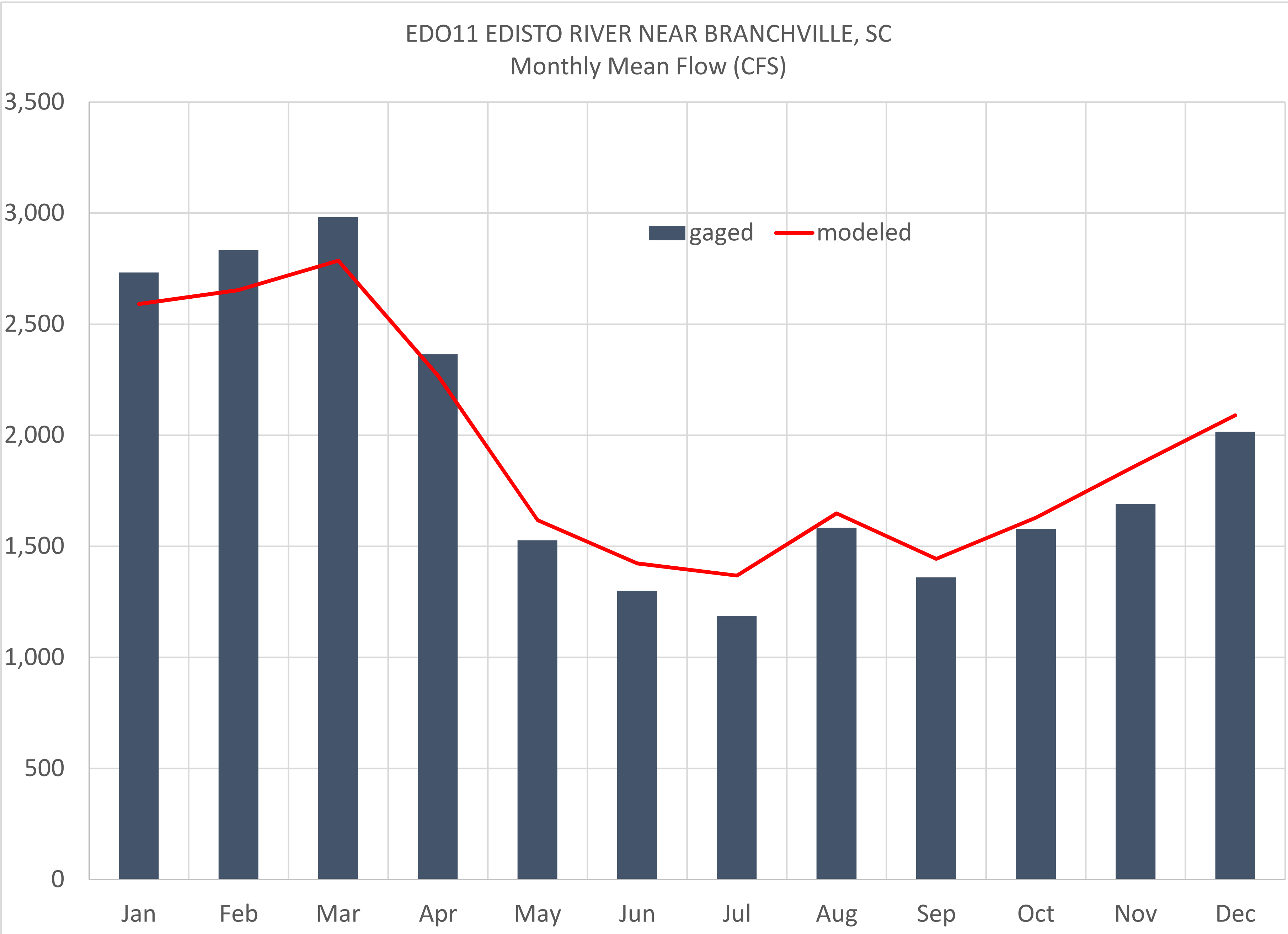

EDO10 NORTH FORK EDISTO RIVER AT ORANGEBURG, SC
Monthly Flow Percentiles (CFS)
2500
2000
1500
1000
500
0
gaged
modeled
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
Percentile

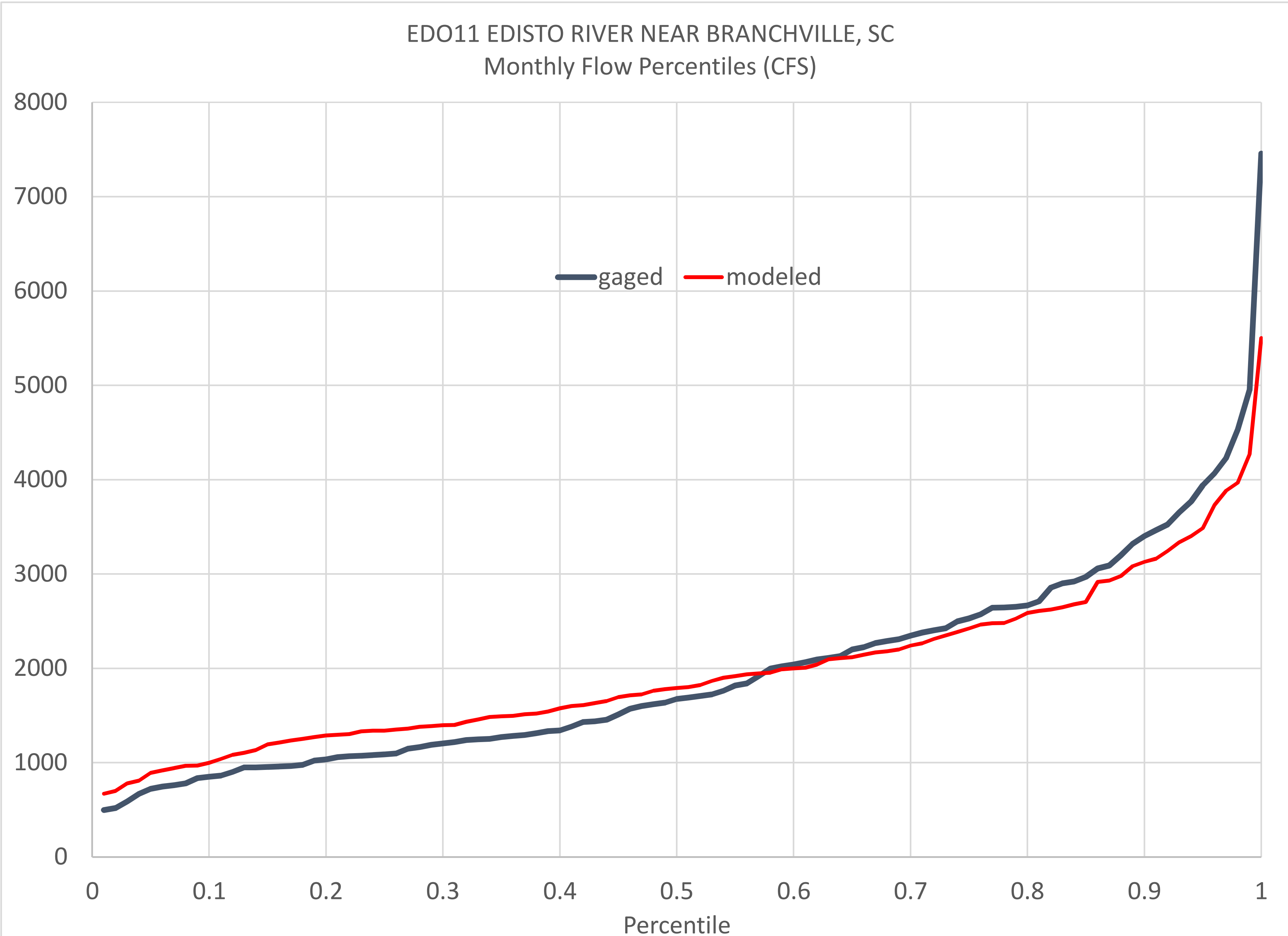


EDO11 EDISTO RIVER NEAR BRANCHVILLE, SC (CFS)
modeled
gaged
8,000
7,000
6,000
5,000
4,000
3,000
2,000
1,000
0
Jan-83
Jul-88
Dec-93
Jun-99
Dec-04
Jun-10

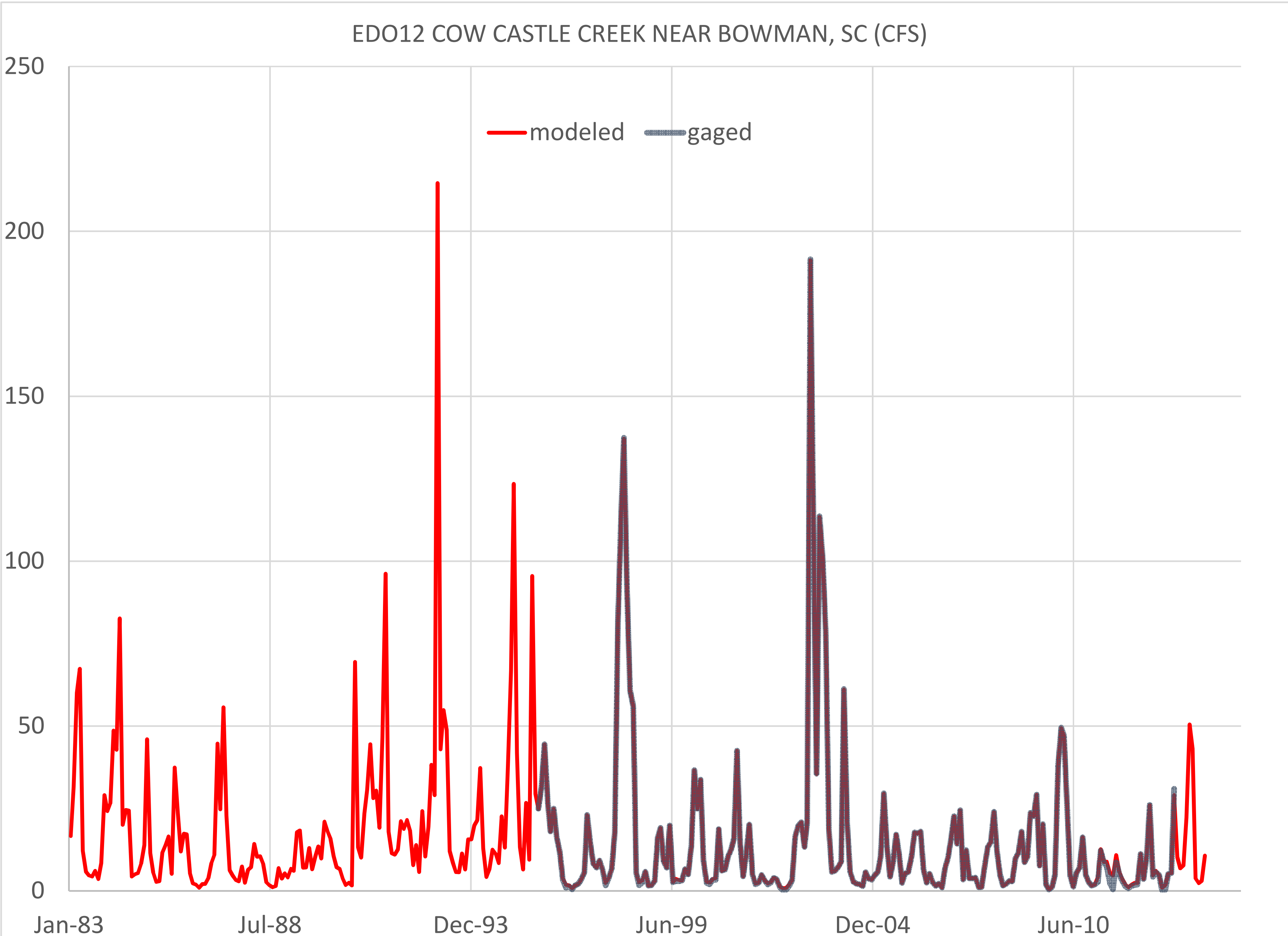

EDO11 EDISTO RIVER NEAR BRANCHVILLE, SC (CFS)
Annual Average Flow
gaged
modeled
3,000
2,500
2,000
1,500
1,000
500
0
1983
1988
1993
1998
2003
2008
2013

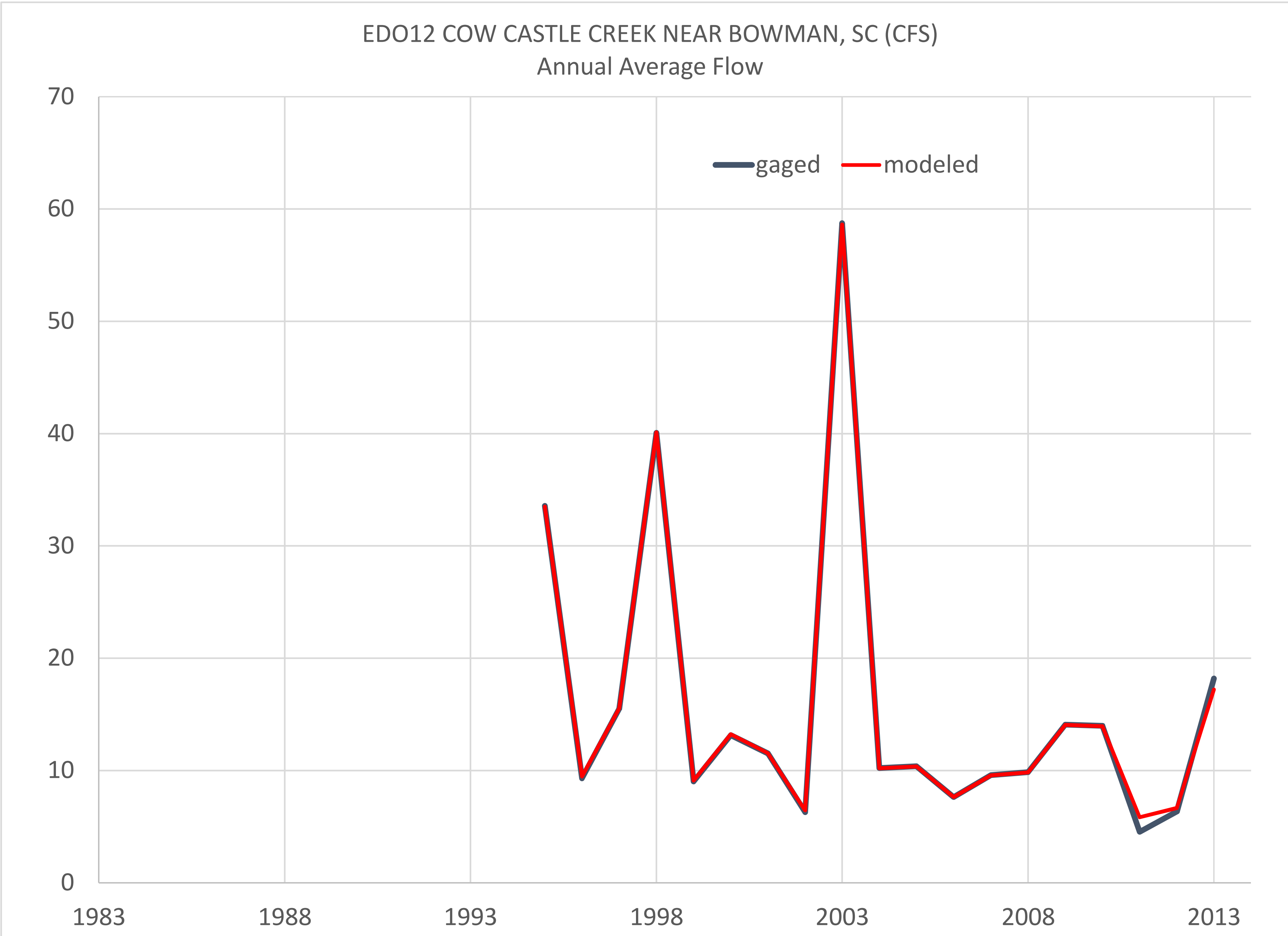

CUMULATIVE FLOW COMPARISON
EDO11 EDISTO RIVER NEAR BRANCHVILLE, SC (CFS)
modeled
gaged
350,000
300,000
250,000
200,000
150,000
100,000
50,000
0
Jan-83
Jul-88
Dec-93
Jun-99
Dec-04
Jun-10


EDO11 EDISTO RIVER NEAR BRANCHVILLE, SC
Monthly Mean Flow (CFS)
gaged
modeled
3,500
3,000
2,500
2,000
1,500
1,000
500
0
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec

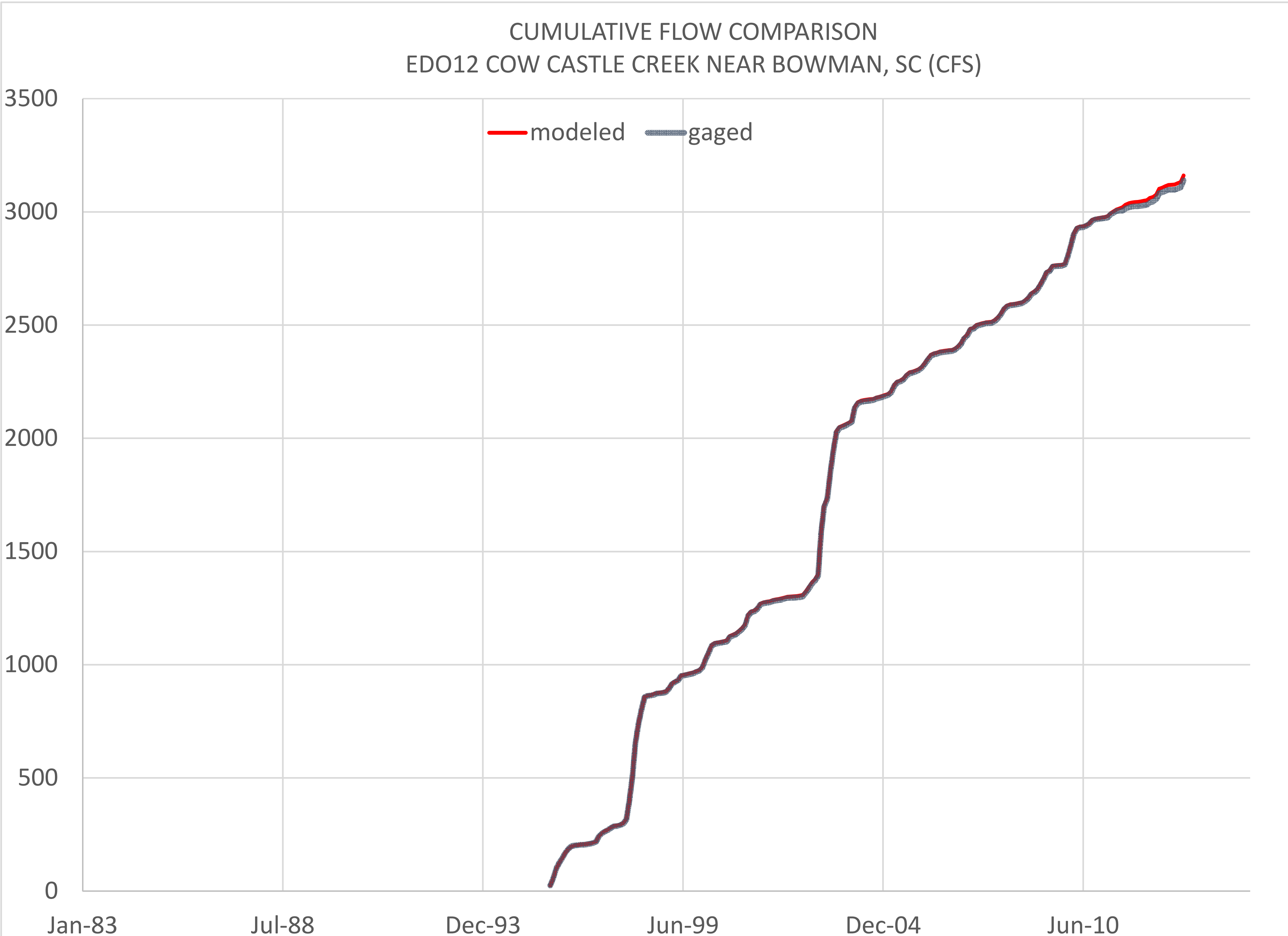


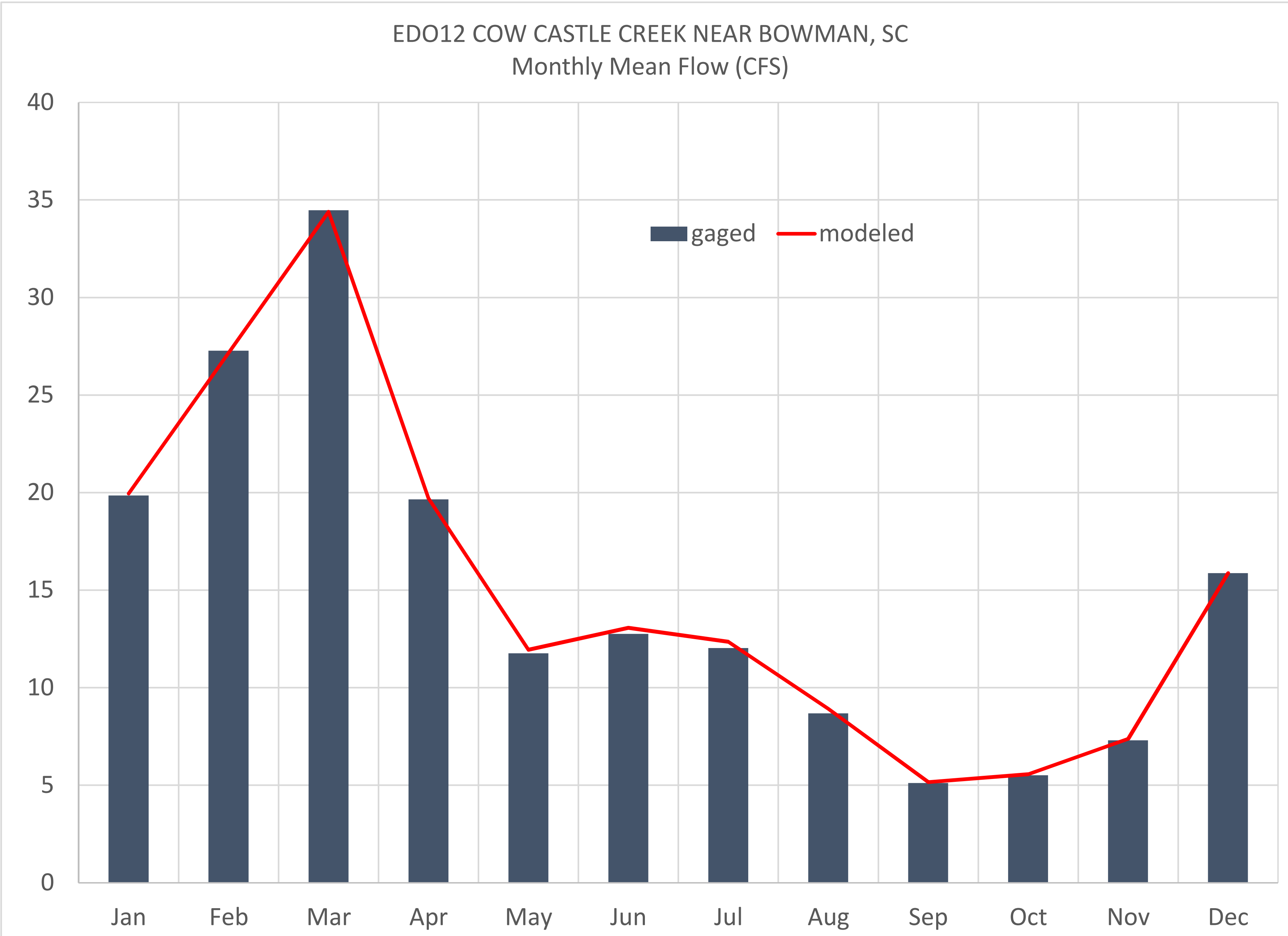
EDO11 EDISTO RIVER NEAR BRANCHVILLE, SC
Monthly Flow Percentiles (CFS)
gaged
modeled
8000
7000
6000
5000
4000
3000
2000
1000
0
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
Percentile

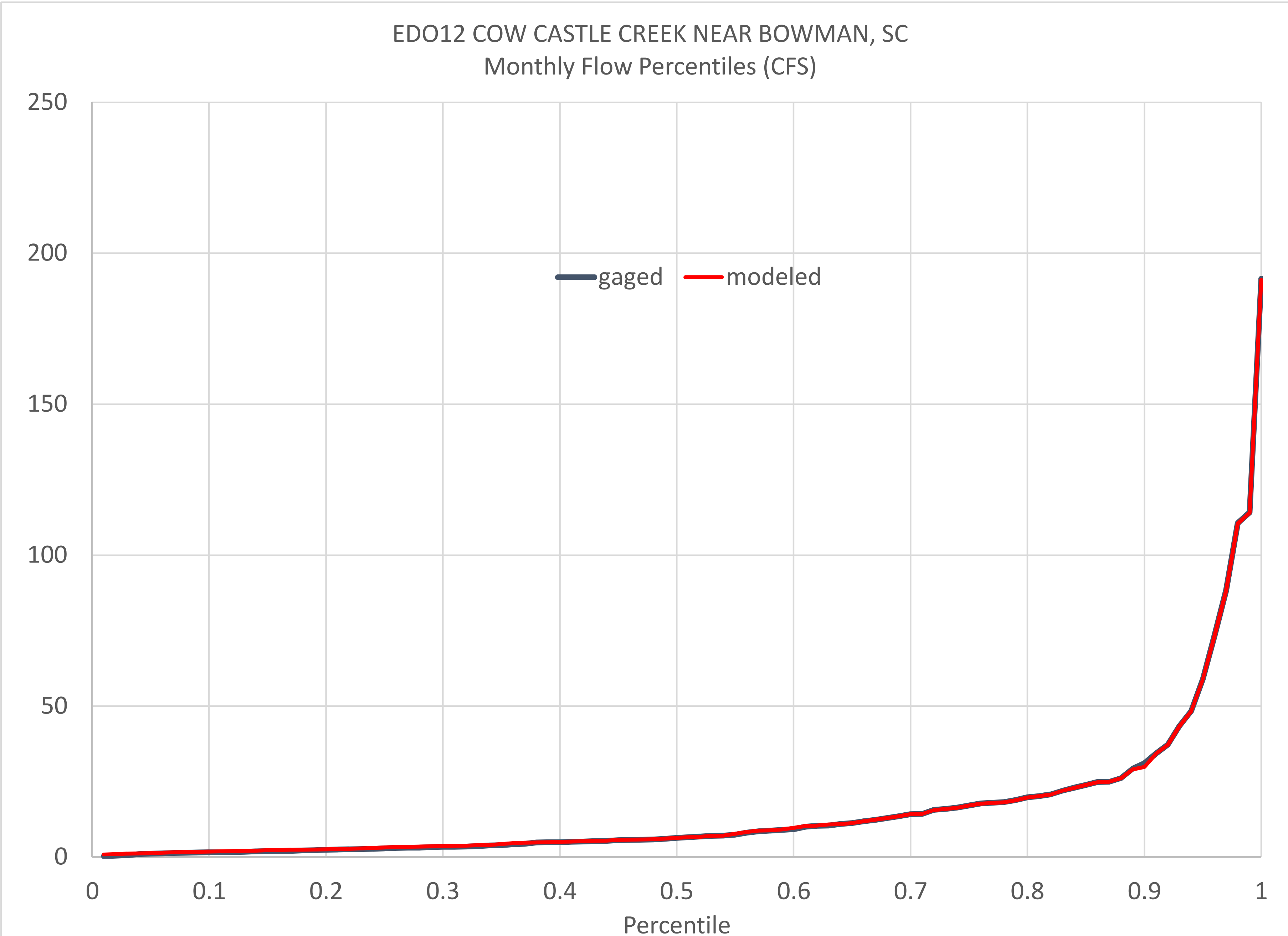

EDO12 COW CASTLE CREEK NEAR BOWMAN, SC (CFS)
modeled
gaged
250
200
150
100
50
0
Jan-83
Jul-88
Dec-93
Jun-99
Dec-04
Jun-10

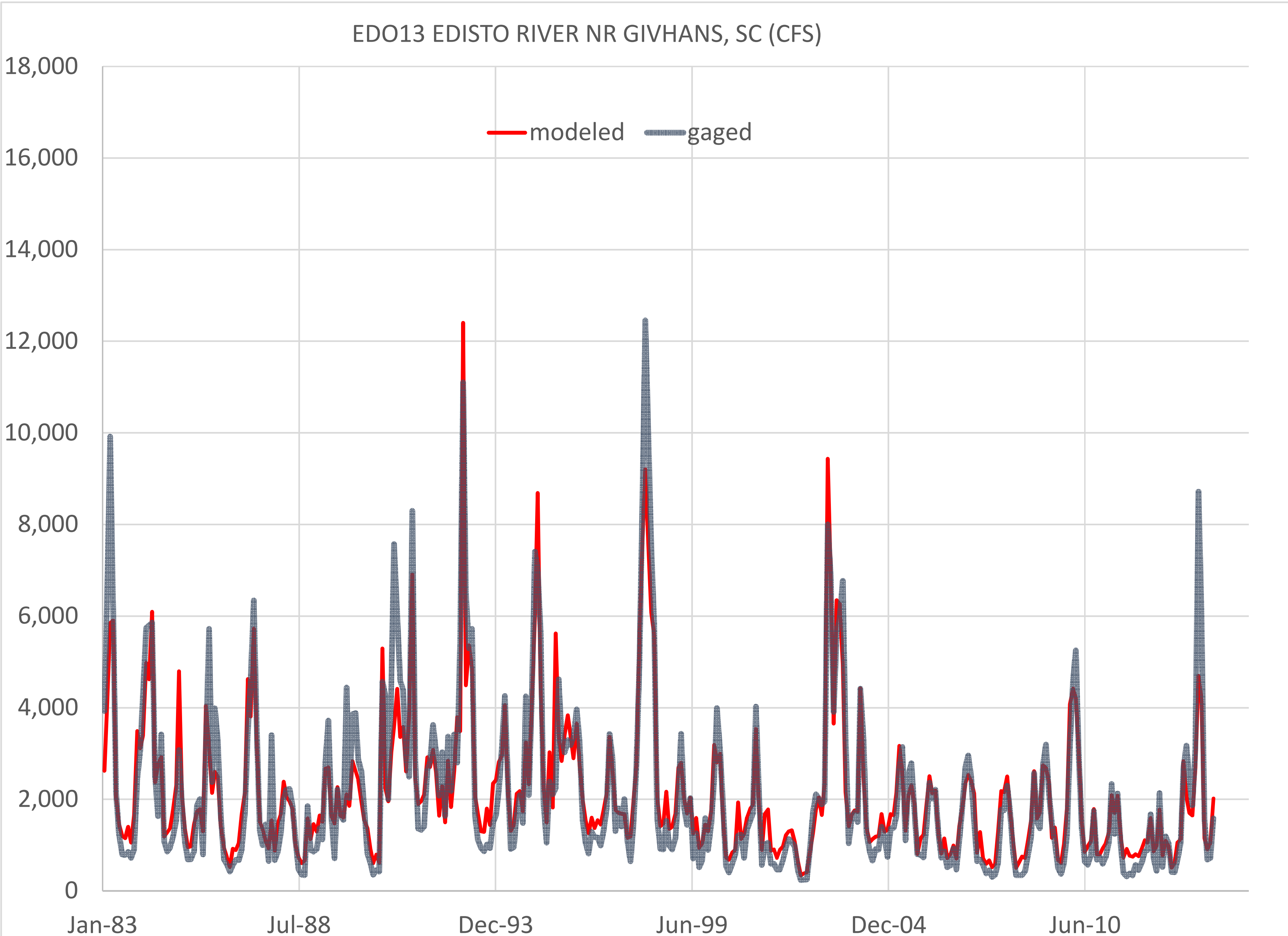


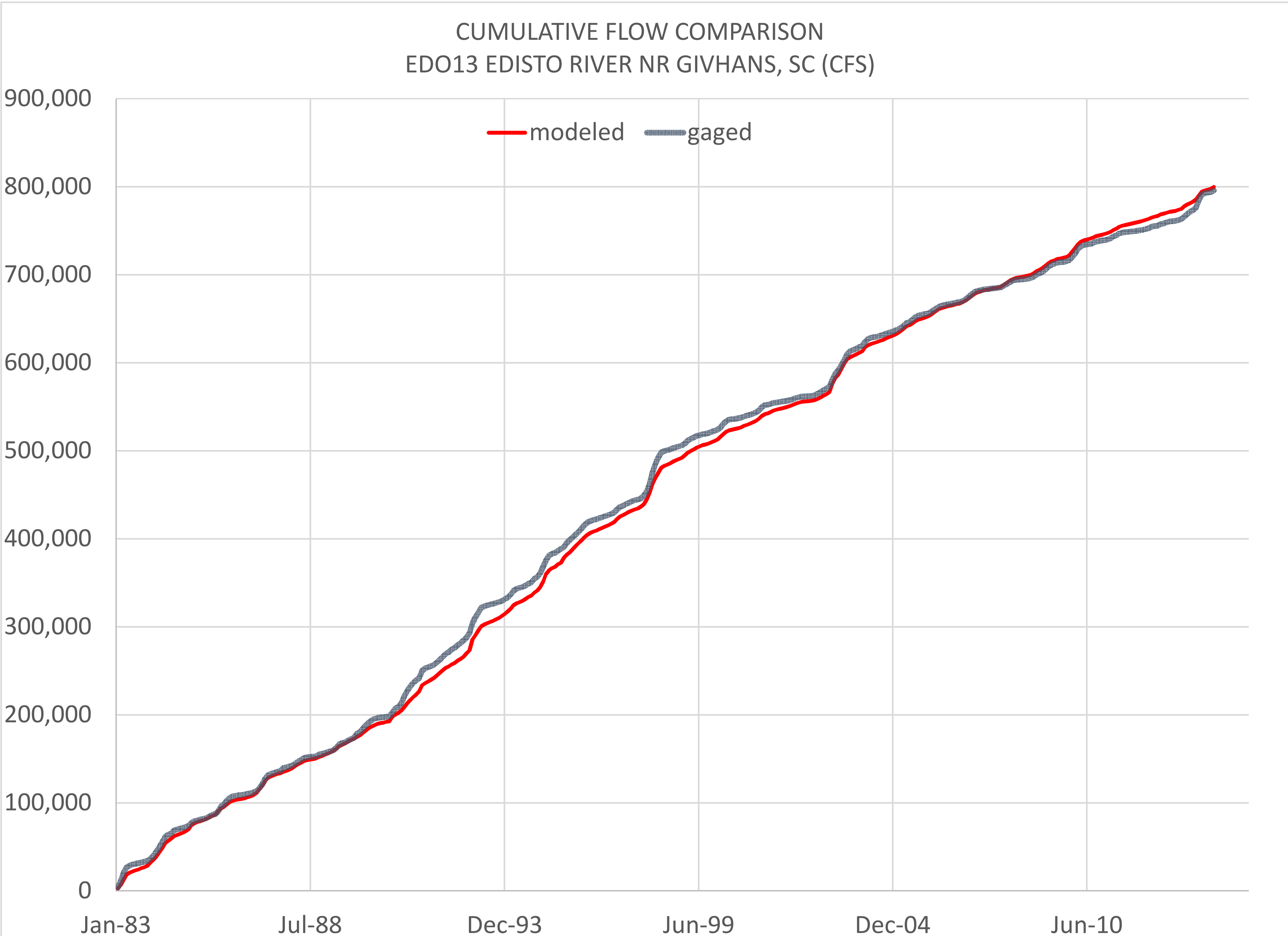
EDO12 COW CASTLE CREEK NEAR BOWMAN, SC (CFS)
Annual Average Flow
gaged
modeled
70
60
50
40
30
20
10
0
1983
1988
1993
1998
2003
2008
2013

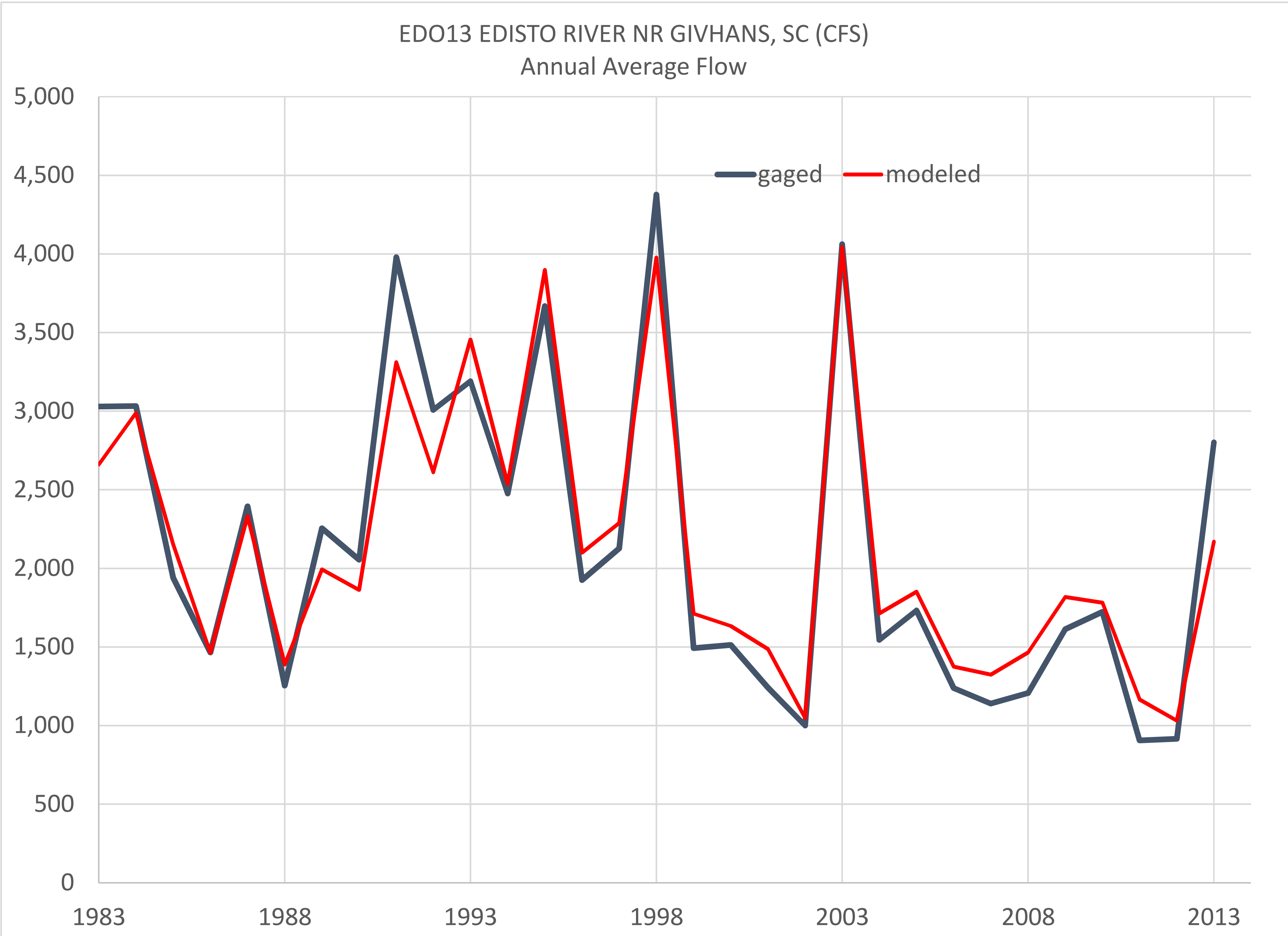

CUMULATIVE FLOW COMPARISON
EDO12 COW CASTLE CREEK NEAR BOWMAN, SC (CFS)
modeled
gaged
3500
3000
2500
2000
1500
1000
500
0
Jan-83
Jul-88
Dec-93
Jun-99
Dec-04
Jun-10

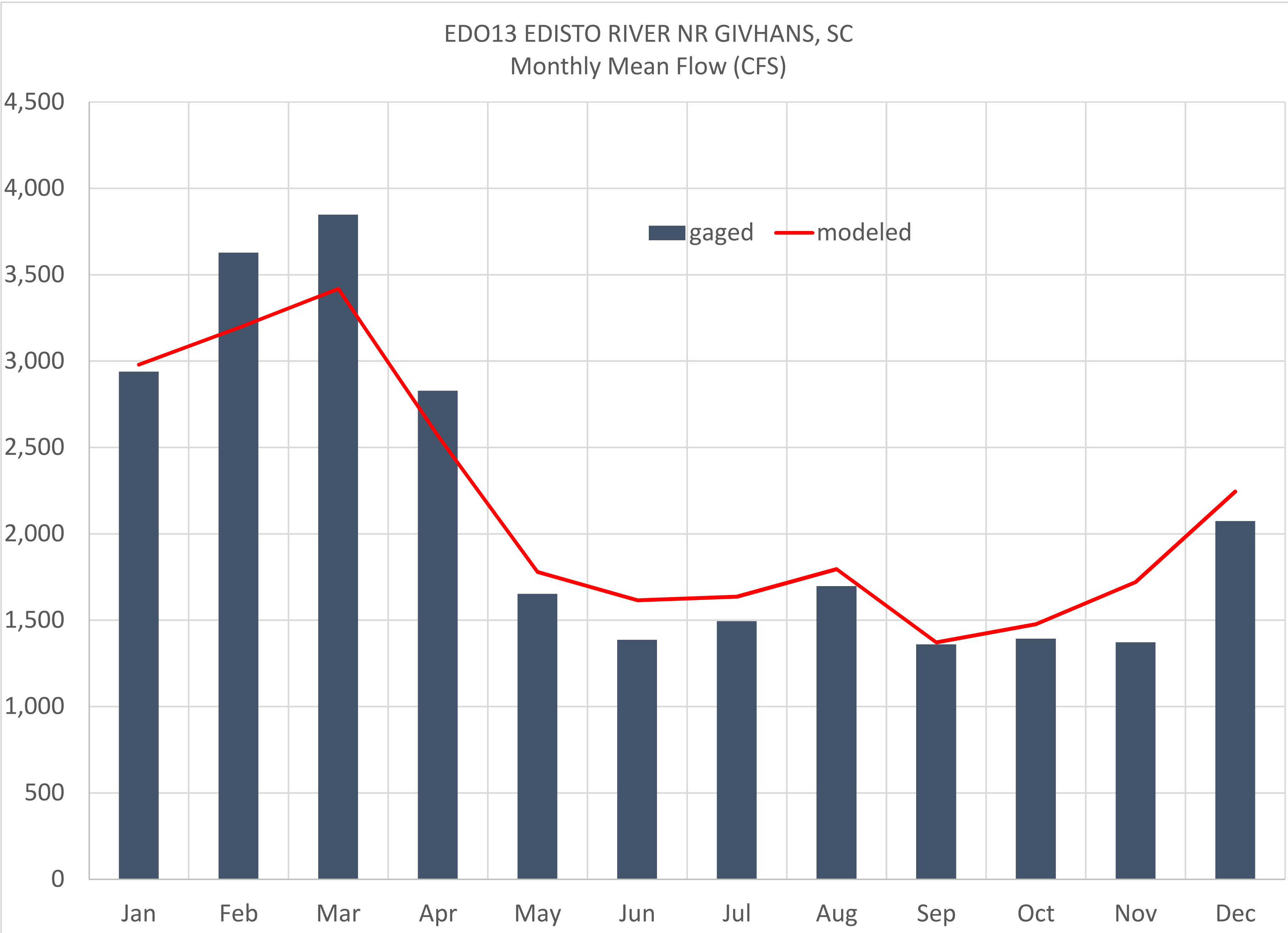

EDO12 COW CASTLE CREEK NEAR BOWMAN, SC
Monthly Mean Flow (CFS)
gaged
modeled
0
5
10
15
20
25
30
35
40
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec

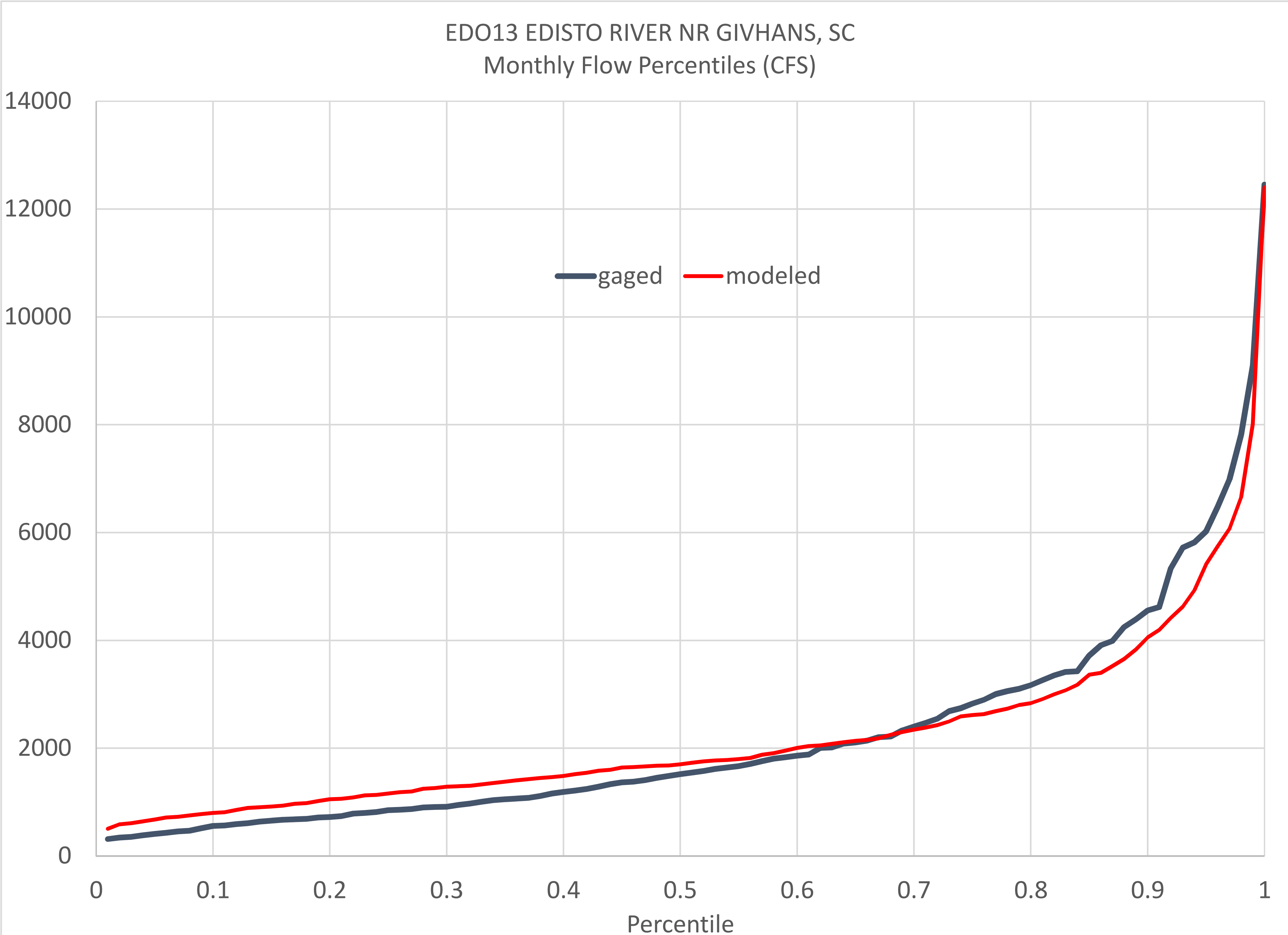

EDO12 COW CASTLE CREEK NEAR BOWMAN, SC
Monthly Flow Percentiles (CFS)
250
200
150
100
50
0
gaged
modeled
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
Percentile


EDO13 EDISTO RIVER NR GIVHANS, SC (CFS)
modeled
gaged
18,000
16,000
14,000
12,000
10,000
8,000
6,000
4,000
2,000
0
Jan-83
Jul-88
Dec-93
Jun-99
Dec-04
Jun-10


CUMULATIVE FLOW COMPARISON
EDO13 EDISTO RIVER NR GIVHANS, SC (CFS)
modeled
gaged
900,000
800,000
700,000
600,000
500,000
400,000
300,000
200,000
100,000
0
Jan-83
Jul-88
Dec-93
Jun-99
Dec-04
Jun-10


EDO13 EDISTO RIVER NR GIVHANS, SC (CFS)
Annual Average Flow
gaged
modeled
5,000
4,500
4,000
3,500
3,000
2,500
2,000
1,500
1,000
500
0
1983
1988
1993
1998
2003
2008
2013


EDO13 EDISTO RIVER NR GIVHANS, SC
Monthly Mean Flow (CFS)
gaged
modeled
4,500
4,000
3,500
3,000
2,500
2,000
1,500
1,000
500
0
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec

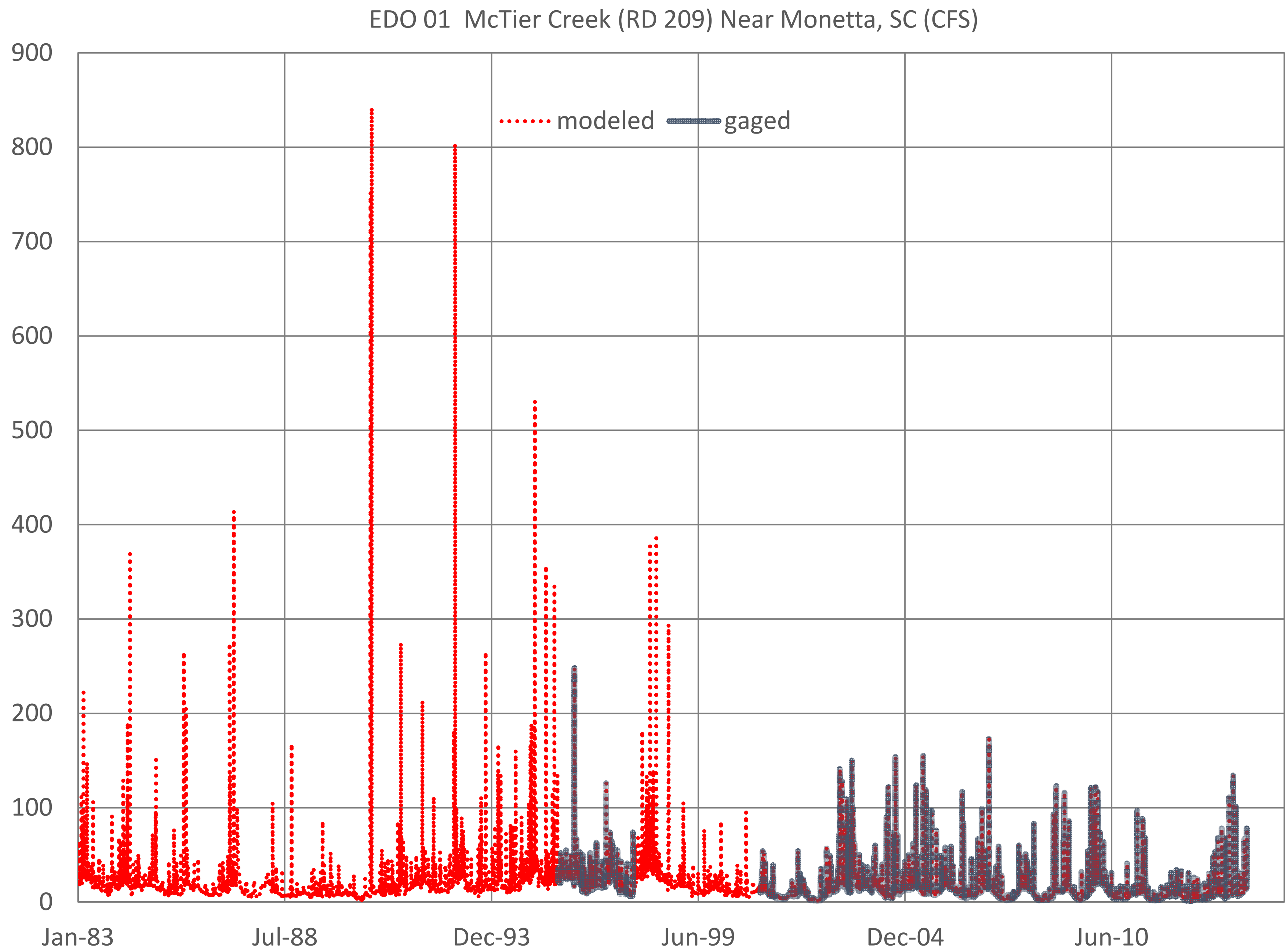


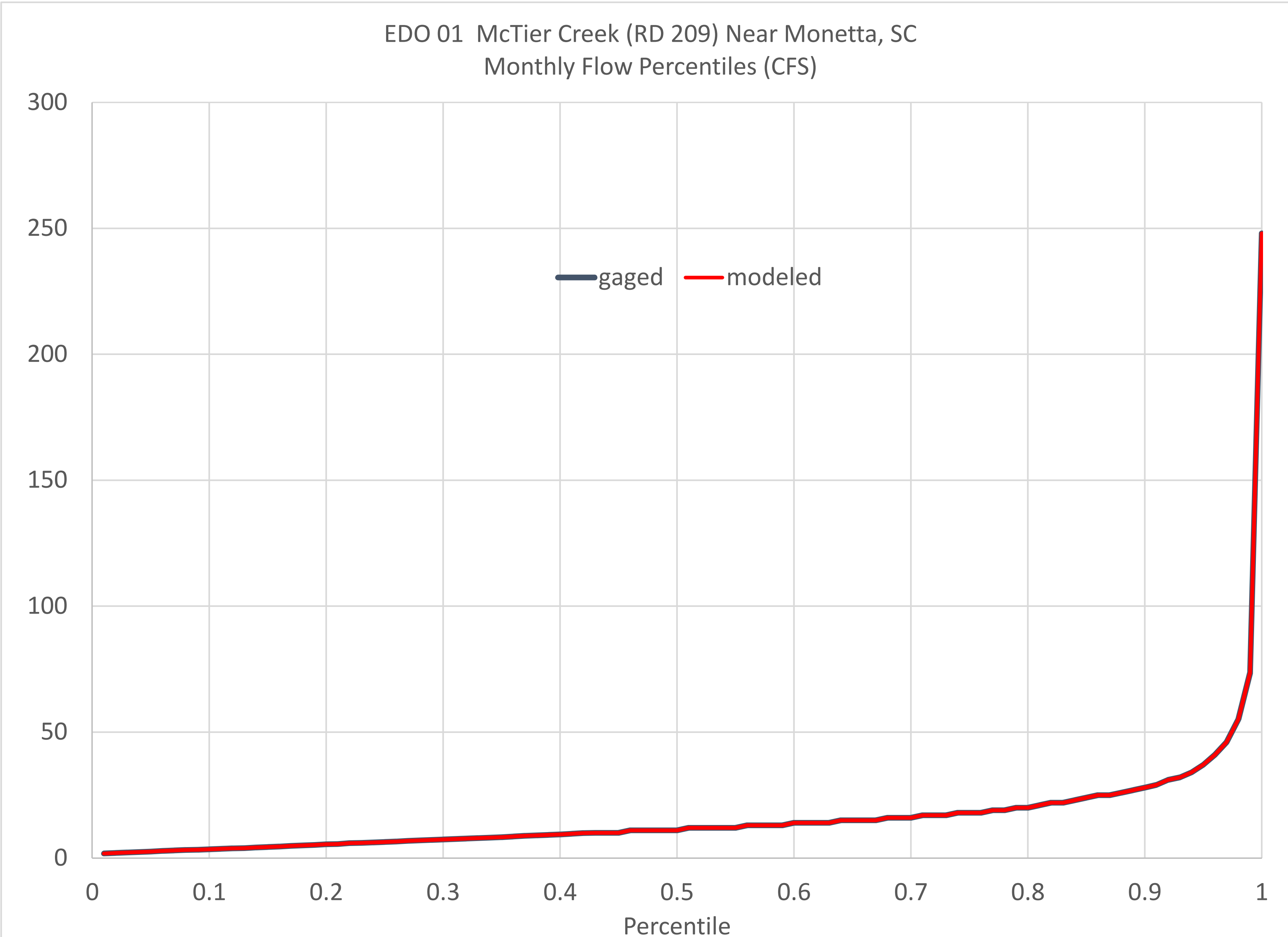
EDO13 EDISTO RIVER NR GIVHANS, SC
Monthly Flow Percentiles (CFS)
gaged
modeled
14000
12000
10000
8000
6000
4000
2000
0
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
Percentile

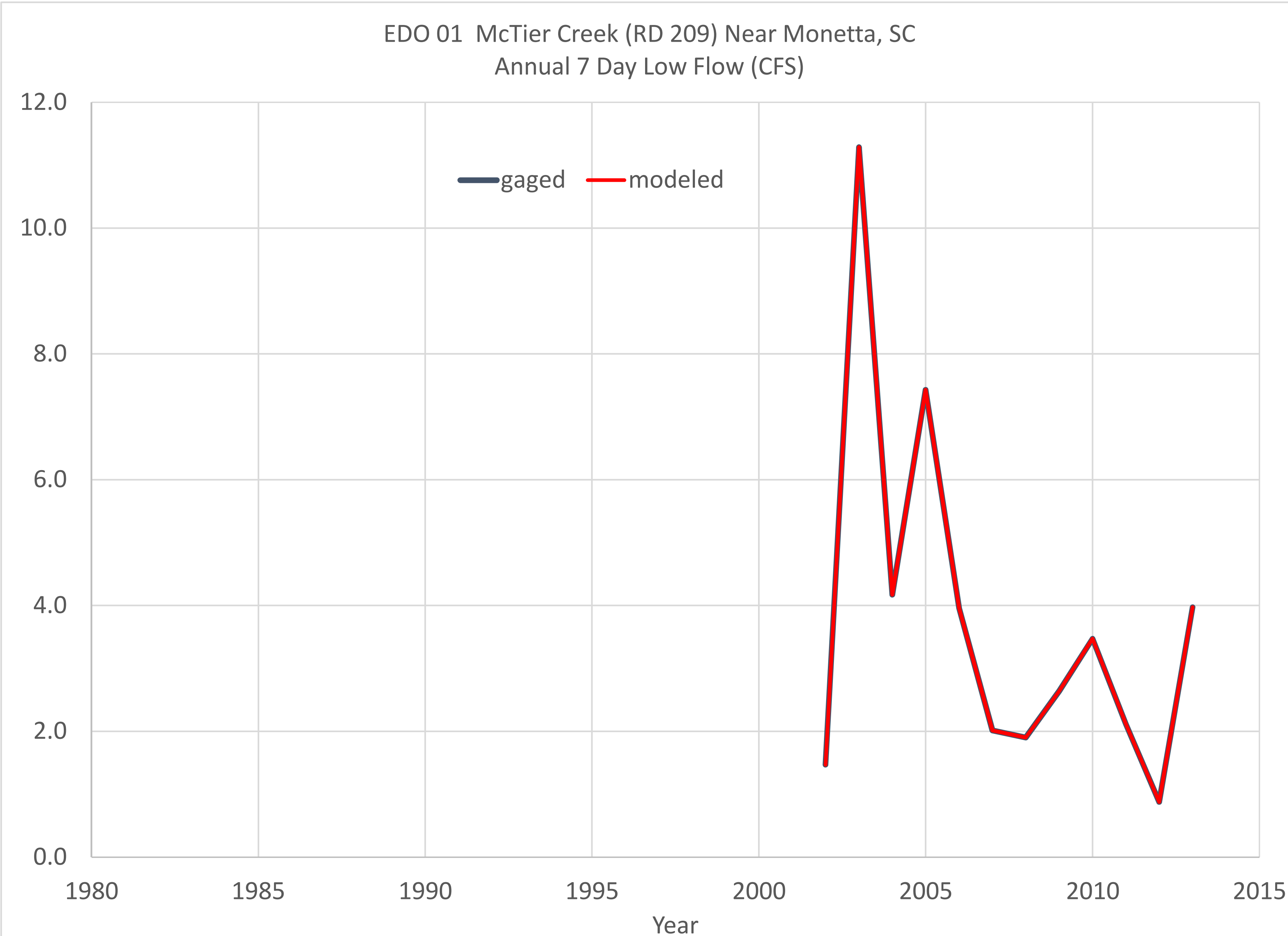
Appendix B

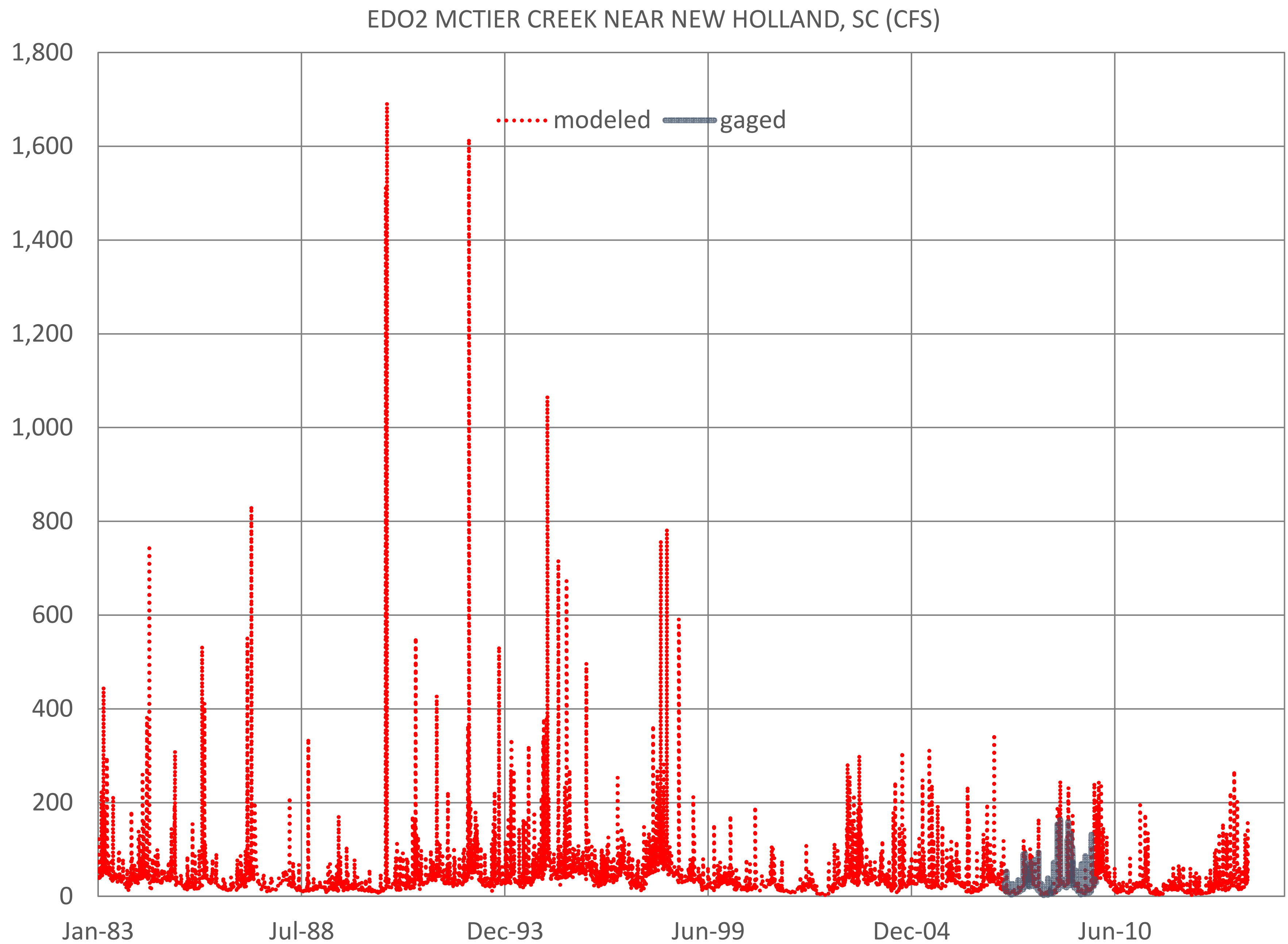
Edisto River Basin Model

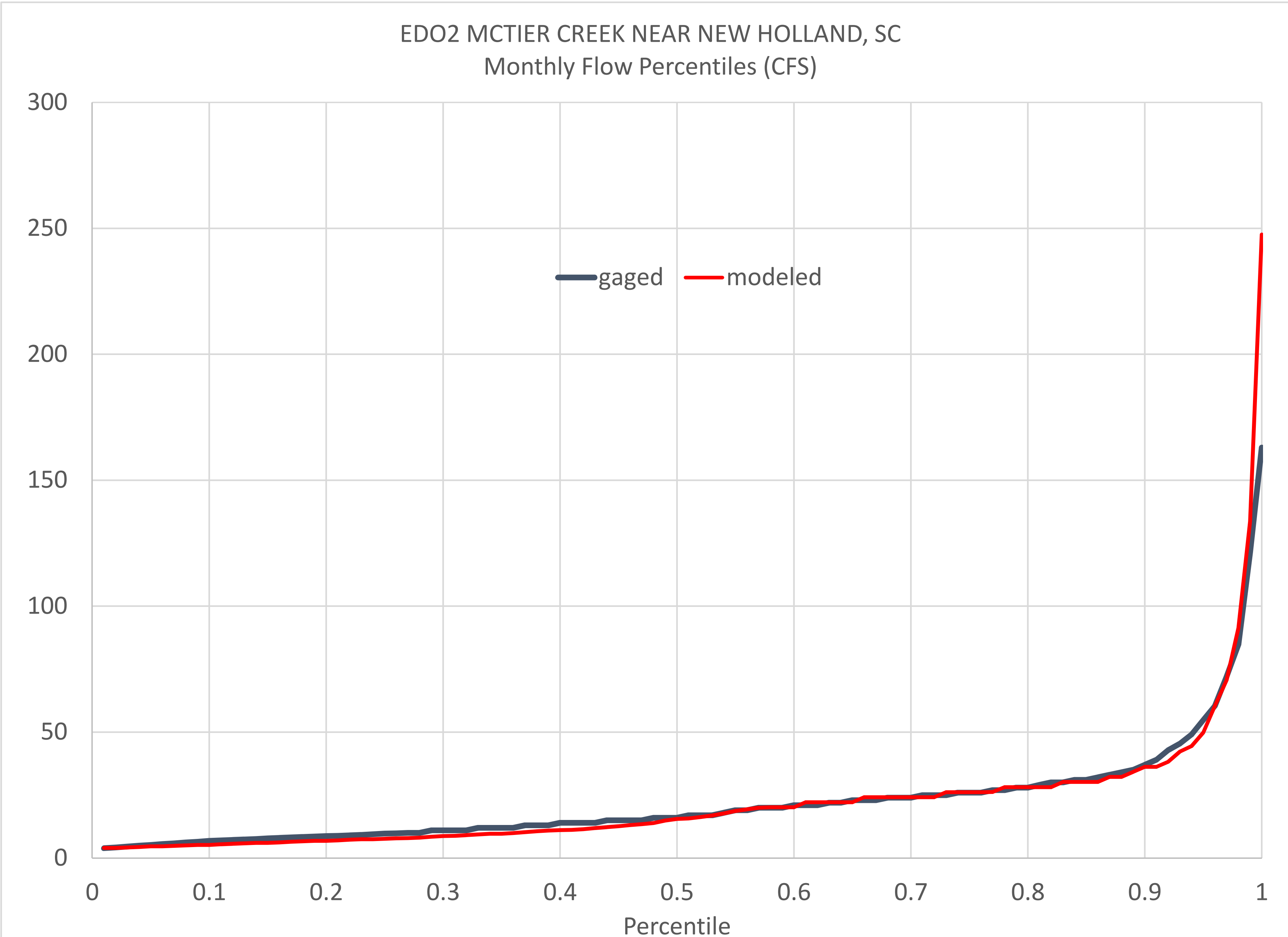
Daily Calibration Results

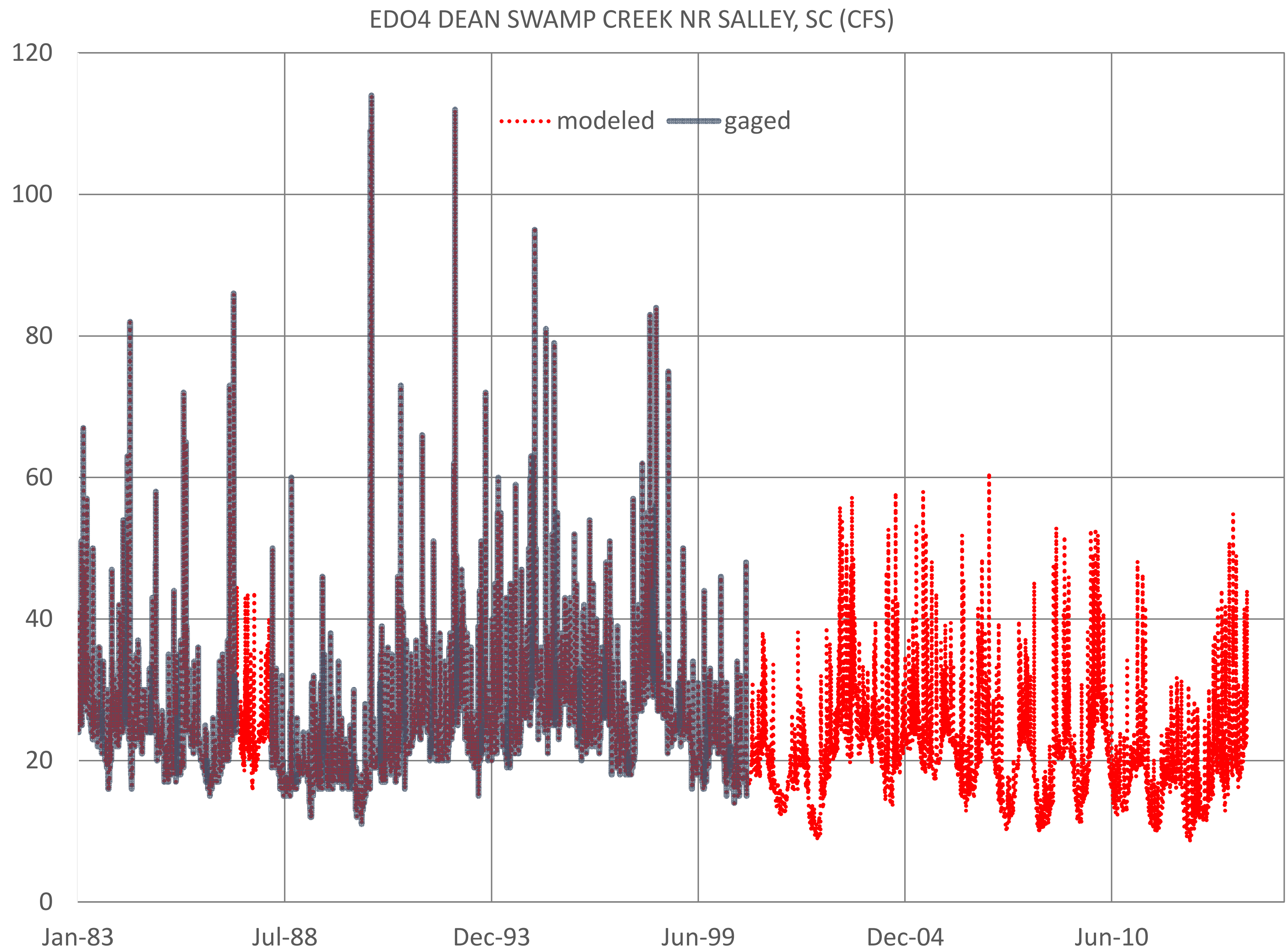

EDO 01 McTier Creek (RD 209) Near Monetta, SC (CFS)
modeled
gaged
900
800
700
600
500
400
300
200
100
0
Jan-83
Jul-88
Dec-93
Jun-99
Dec-04
Jun-10


EDO 01 McTier Creek (RD 209) Near Monetta, SC
Monthly Flow Percentiles (CFS)
300
250
200
150
100
50
0
gaged
modeled
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
Percentile

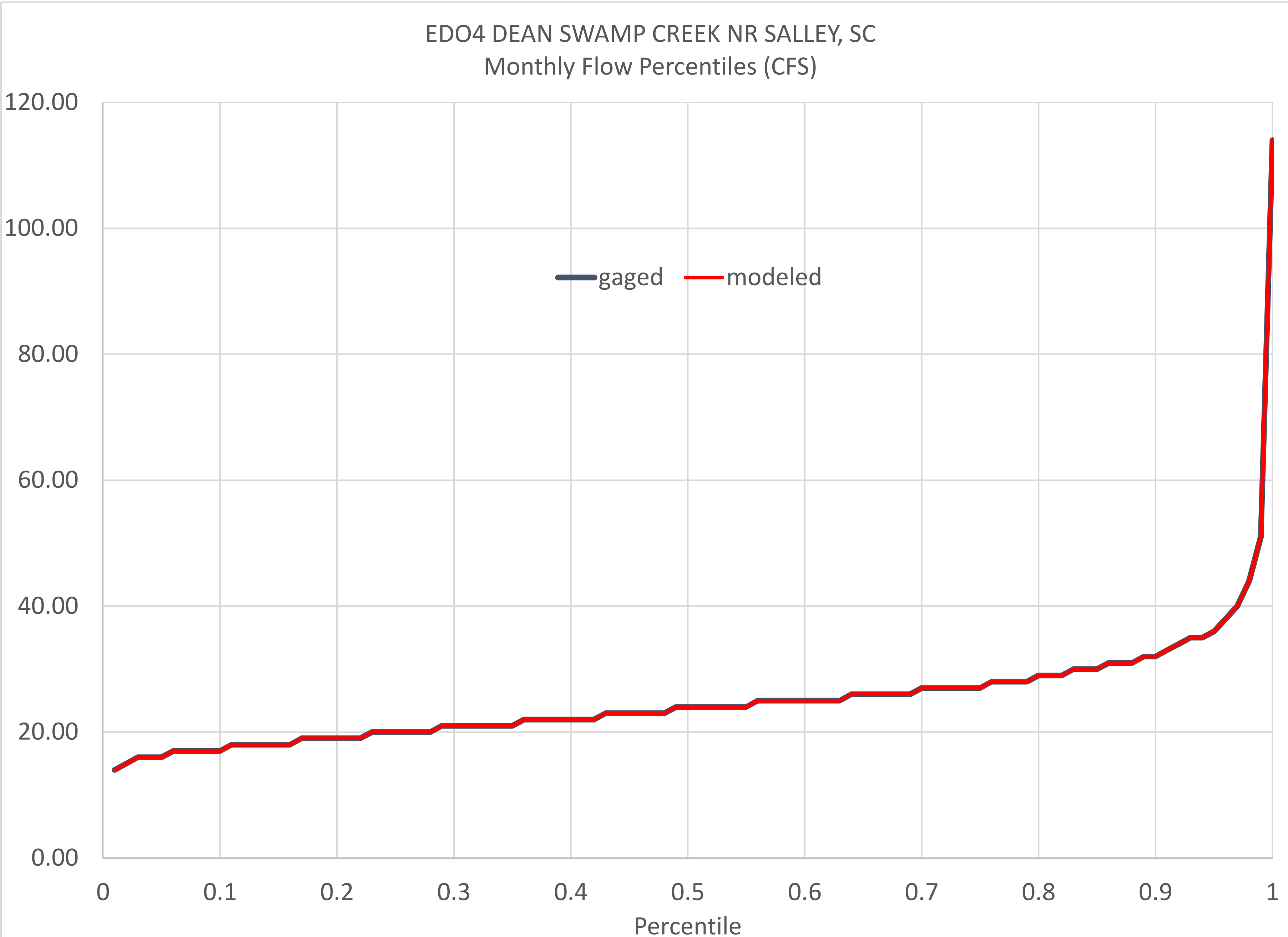

EDO 01 McTier Creek (RD 209) Near Monetta, SC
Annual 7 Day Low Flow (CFS)
gaged
modeled
12.0
10.0
8.0
6.0
4.0
2.0
0.0
1980
1985
1990
1995
2000
2005
2010
2015
Year

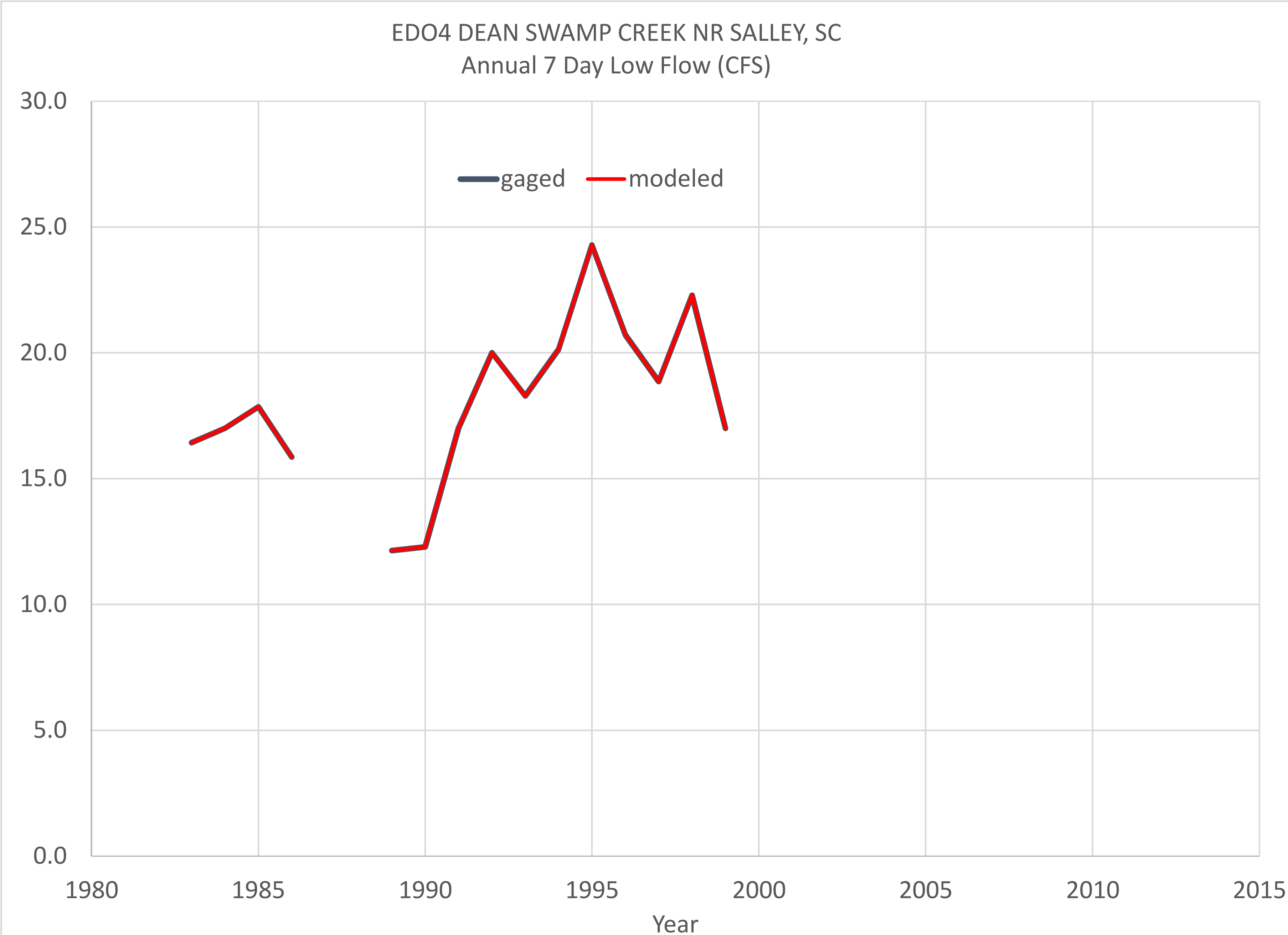

EDO2 MCTIER CREEK NEAR NEW HOLLAND, SC (CFS)
modeled
gaged
1,800
1,600
1,400
1,200
1,000
800
600
400
200
0
Jan-83
Jul-88
Dec-93
Jun-99
Dec-04
Jun-10

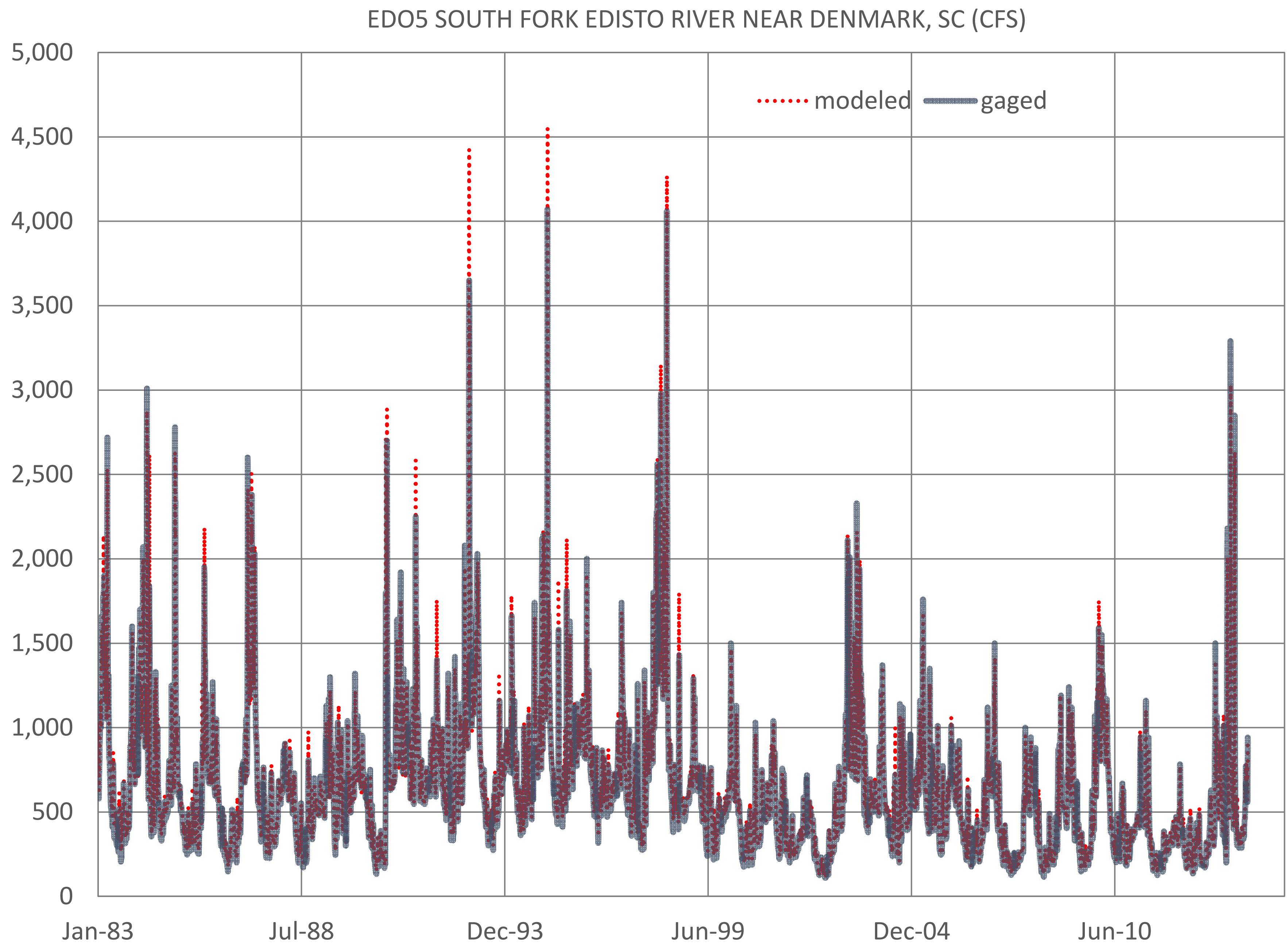

EDO2 MCTIER CREEK NEAR NEW HOLLAND, SC
Monthly Flow Percentiles (CFS)
gaged
modeled
300
250
200
150
100
50
0
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
Percentile

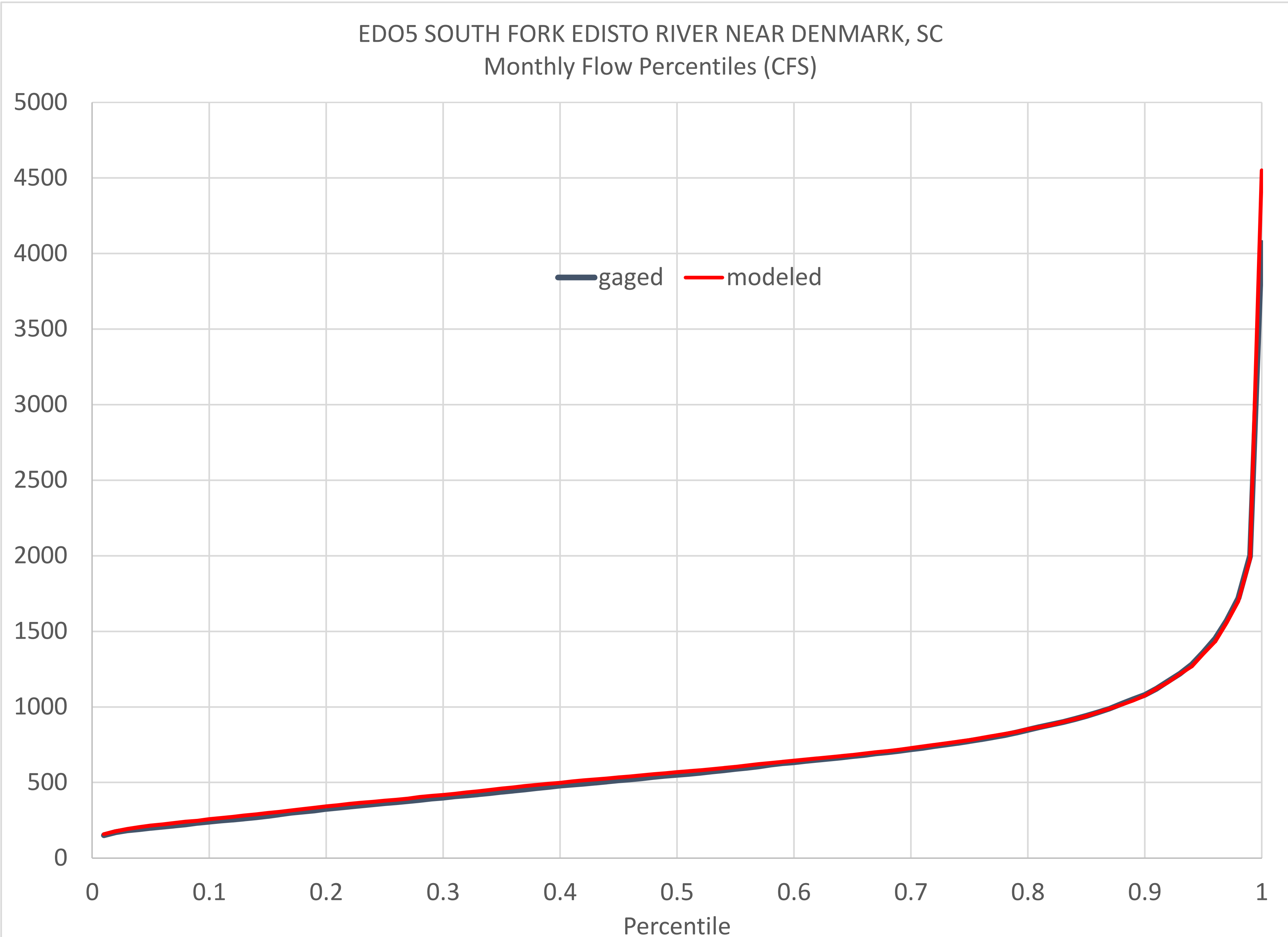


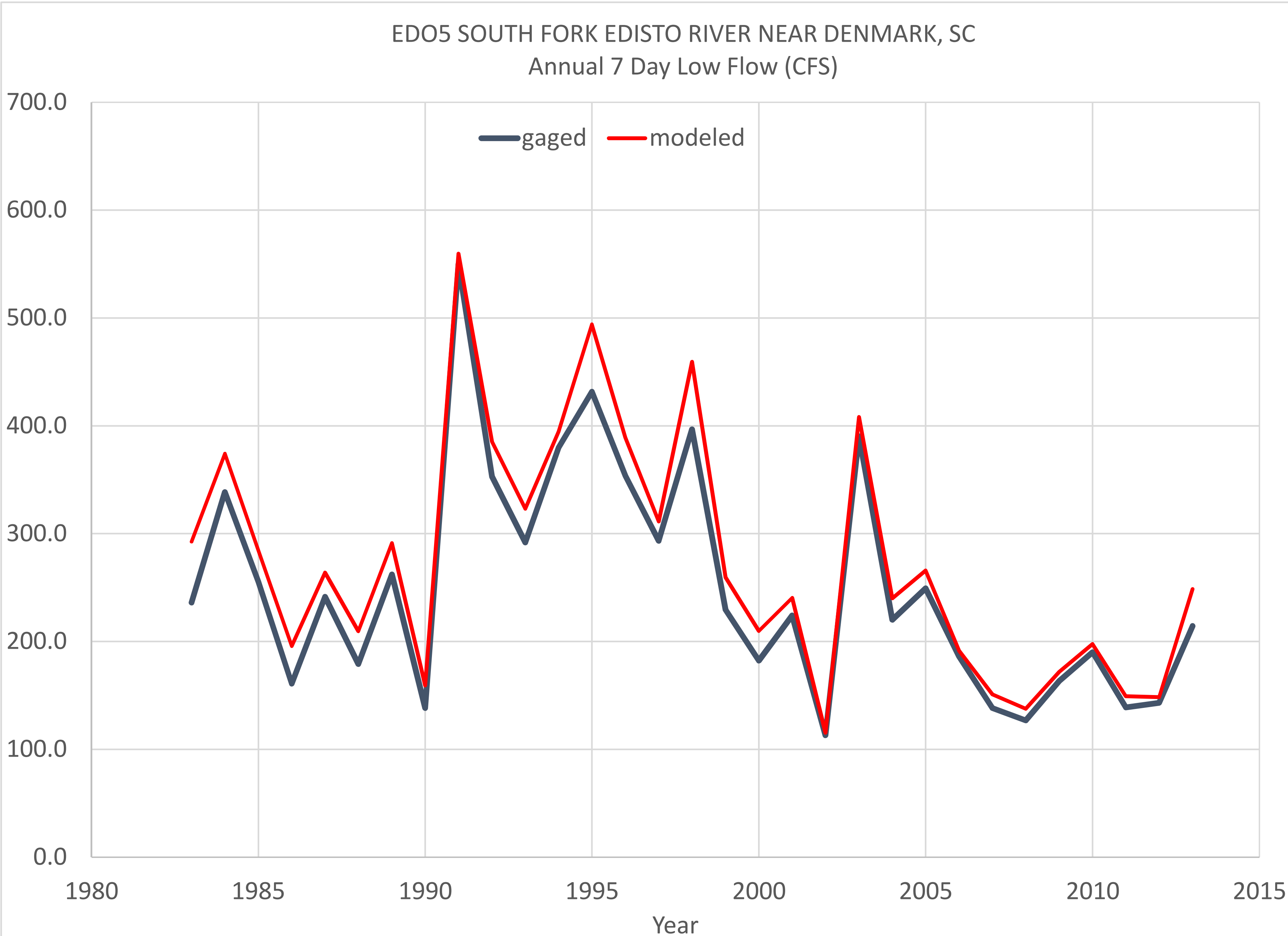
EDO4 DEAN SWAMP CREEK NR SALLEY, SC (CFS)
modeled
gaged
120
100
80
60
40
20
0
Jan-83
Jul-88
Dec-93
Jun-99
Dec-04
Jun-10

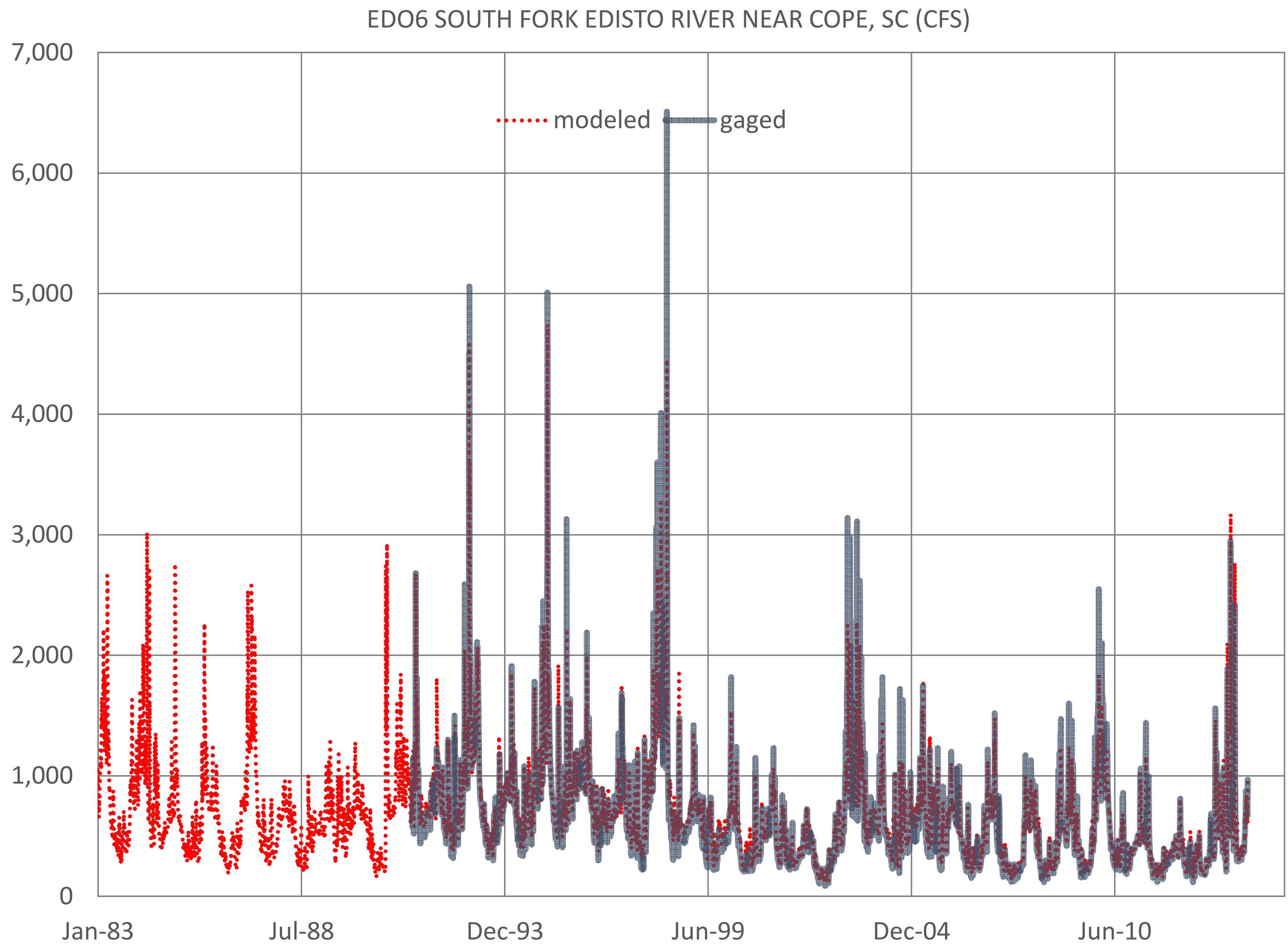

EDO4 DEAN SWAMP CREEK NR SALLEY, SC
Monthly Flow Percentiles (CFS)
120.00
100.00
80.00
60.00
40.00
20.00
0.00
gaged
modeled
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
Percentile

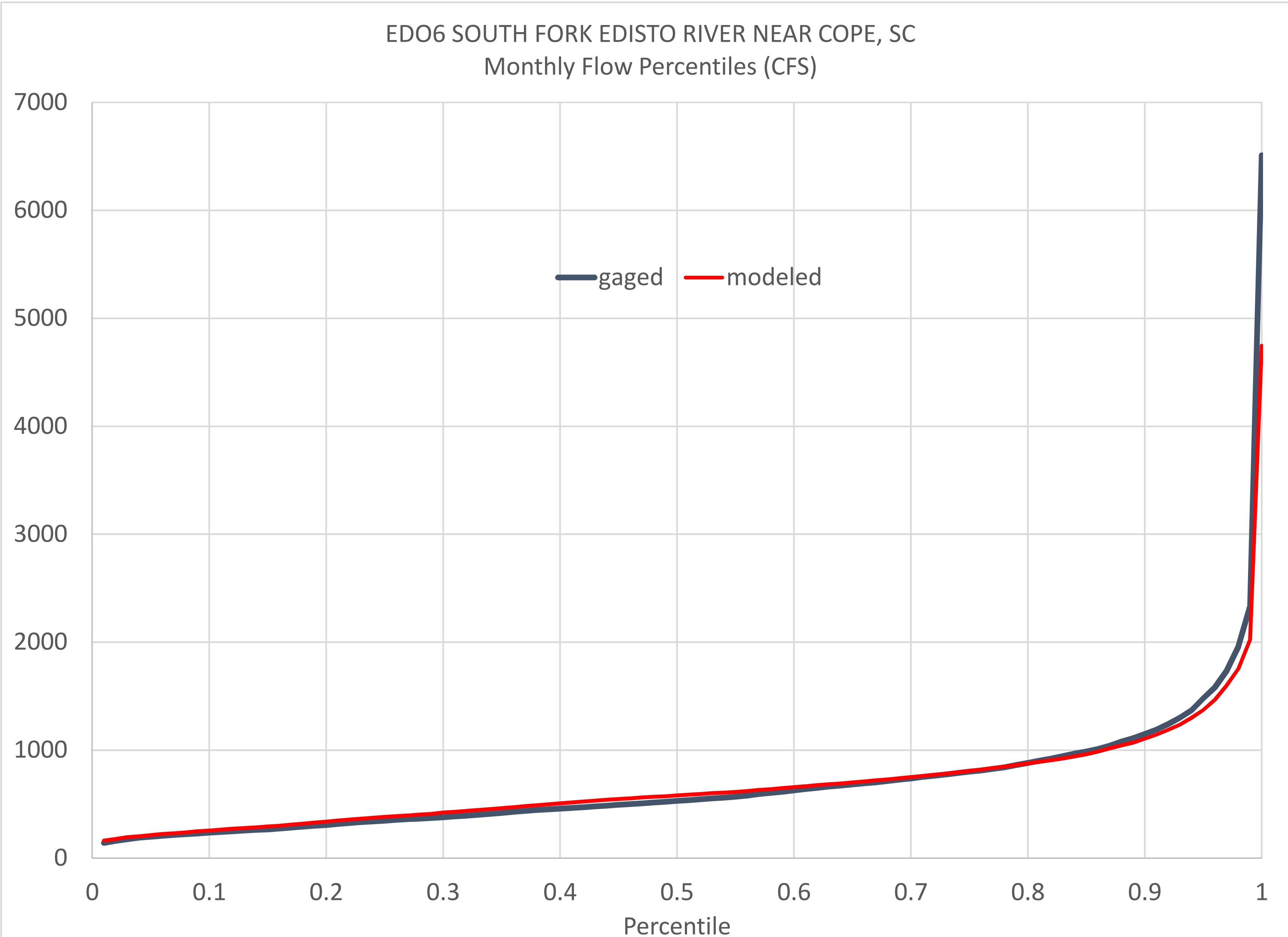

EDO4 DEAN SWAMP CREEK NR SALLEY, SC
Annual 7 Day Low Flow (CFS)
gaged
modeled
30.0
25.0
20.0
15.0
10.0
5.0
0.0
1980
1985
1990
1995
2000
2005
2010
2015
Year

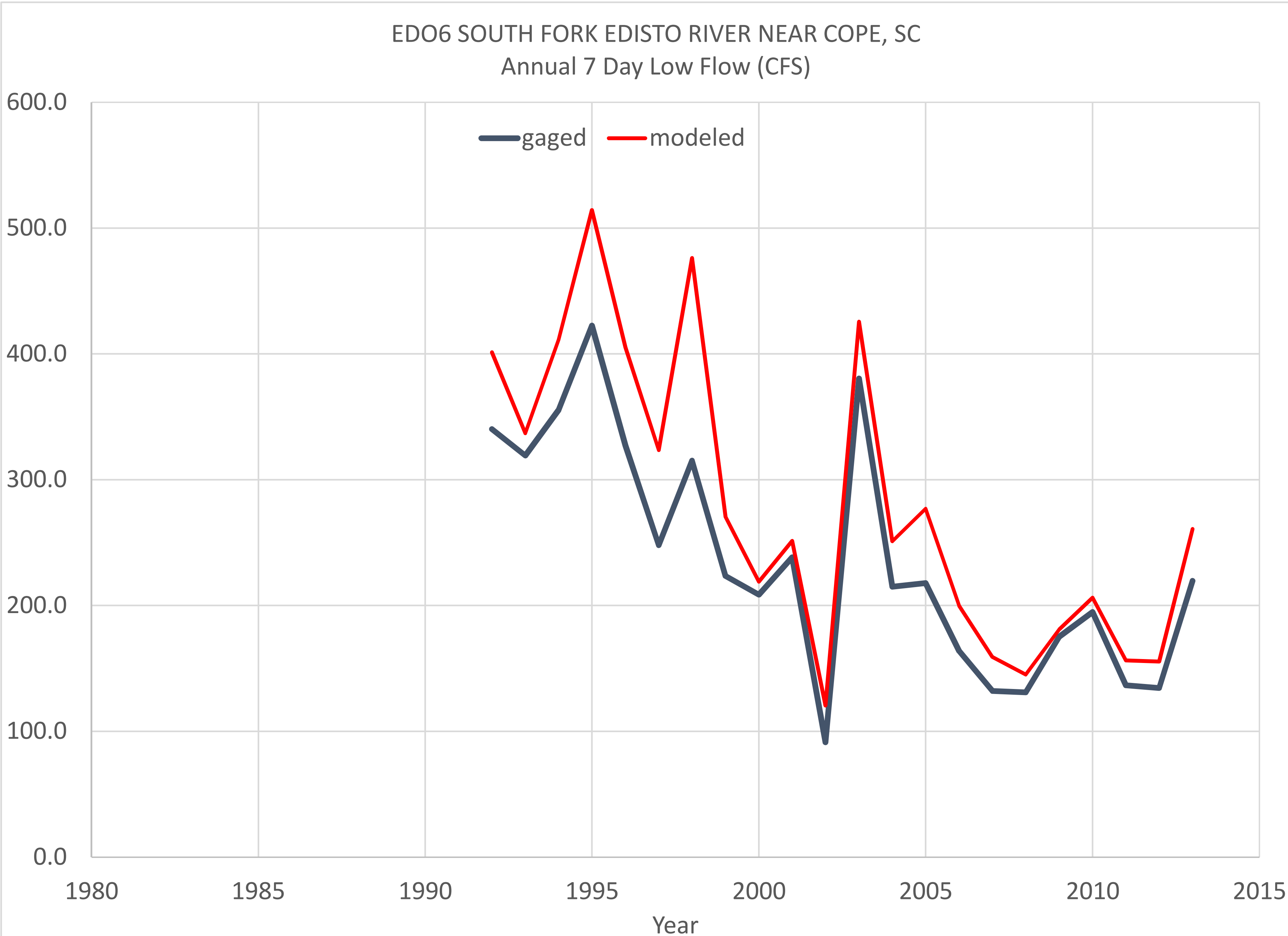

EDO5 SOUTH FORK EDISTO RIVER NEAR DENMARK, SC (CFS)
modeled
gaged
5,000
4,500
4,000
3,500
3,000
2,500
2,000
1,500
1,000
500
0
Jan-83
Jul-88
Dec-93
Jun-99
Dec-04
Jun-10


EDO5 SOUTH FORK EDISTO RIVER NEAR DENMARK, SC
Monthly Flow Percentiles (CFS)
gaged
modeled
5000
4500
4000
3500
3000
2500
2000
1500
1000
500
0
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
Percentile

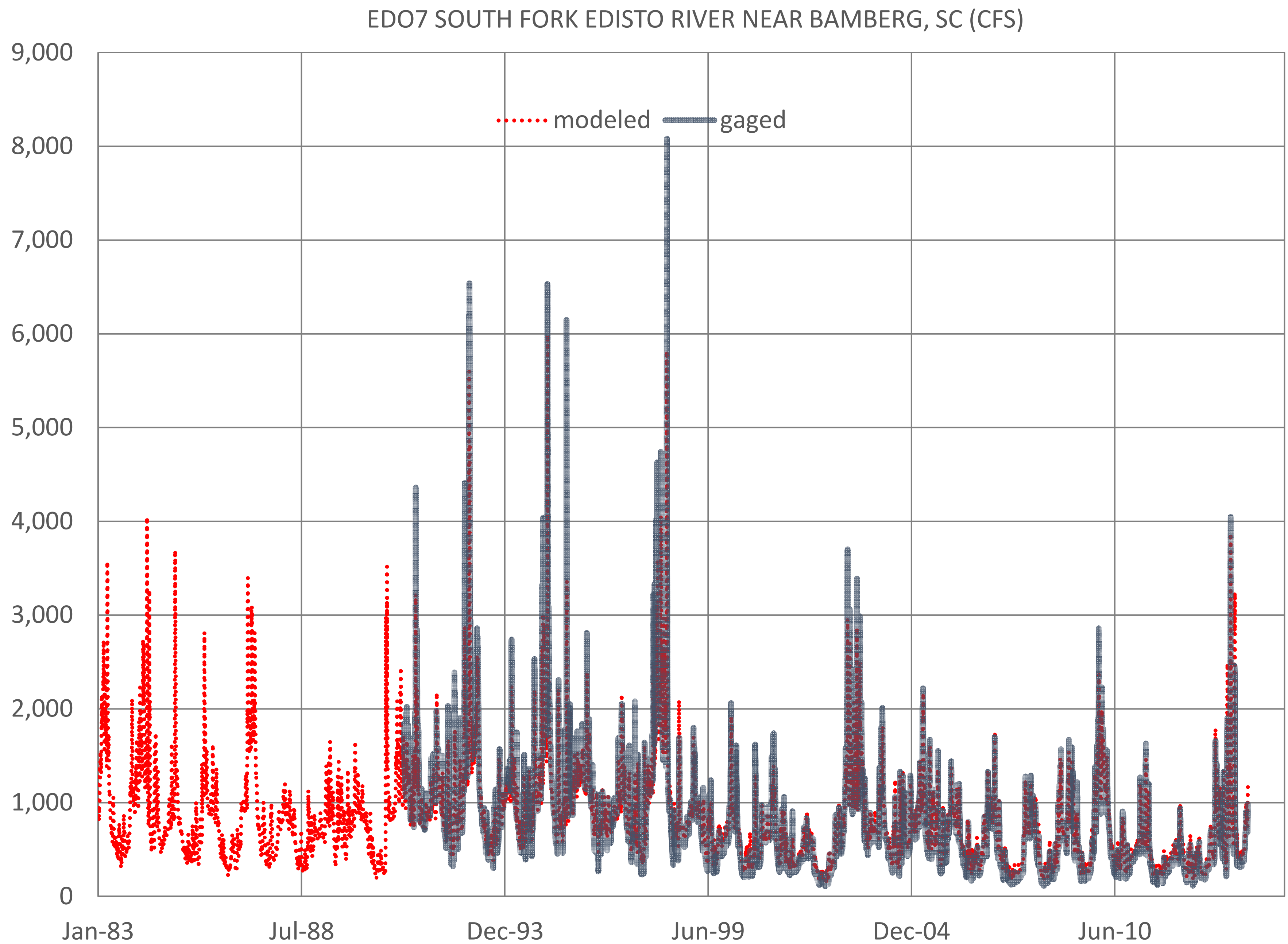

EDO5 SOUTH FORK EDISTO RIVER NEAR DENMARK, SC
Annual 7 Day Low Flow (CFS)
700.0
600.0
500.0
400.0
300.0
200.0
100.0
0.0
gaged
modeled
1980
1985
1990
1995
2000
2005
2010
2015
Year

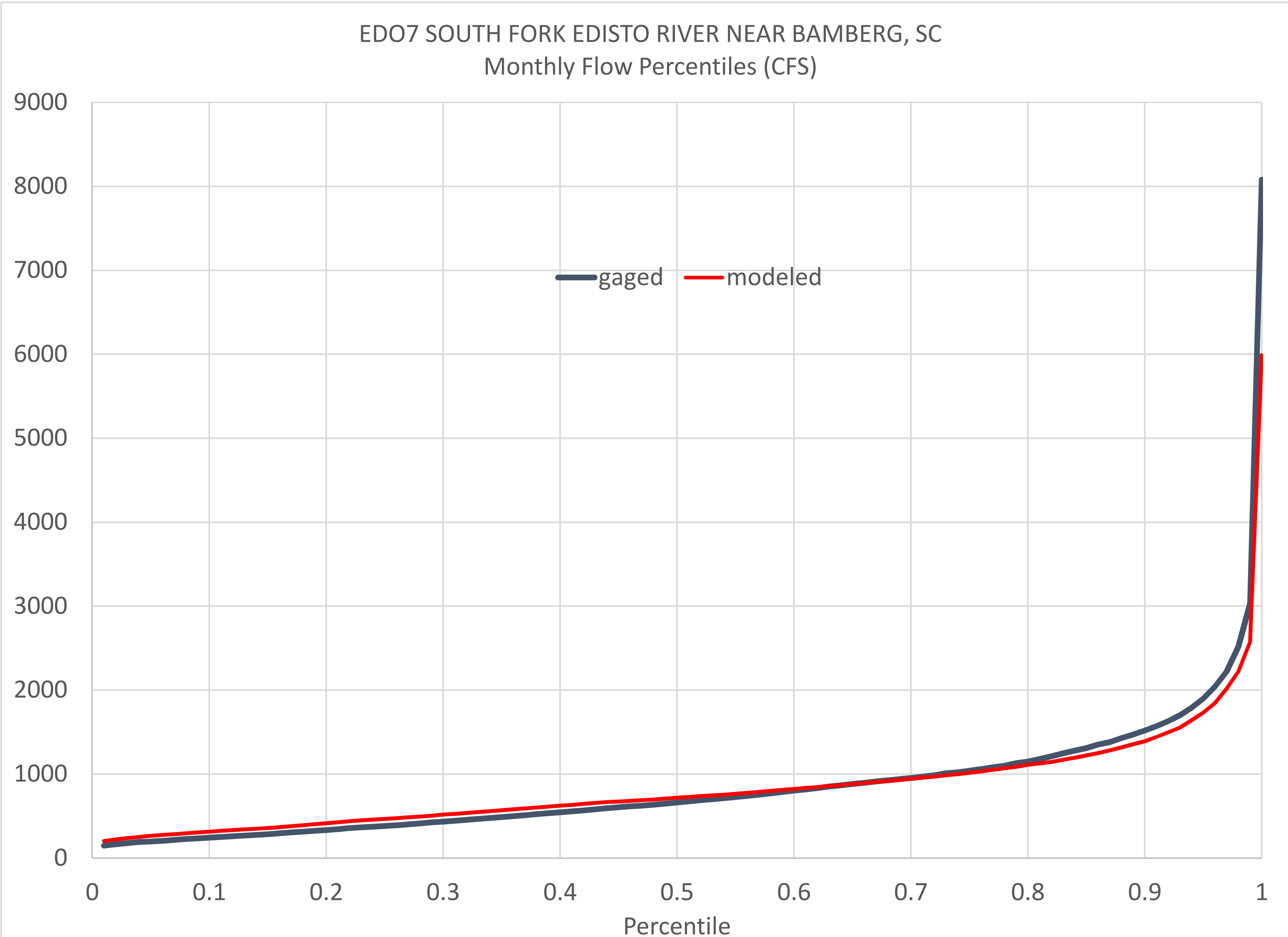

EDO6 SOUTH FORK EDISTO RIVER NEAR COPE, SC (CFS)
modeled
gaged
7,000
6,000
5,000
4,000
3,000
2,000
1,000
0
Jan-83
Jul-88
Dec-93
Jun-99
Dec-04
Jun-10


EDO6 SOUTH FORK EDISTO RIVER NEAR COPE, SC
Monthly Flow Percentiles (CFS)
gaged
modeled
7000
6000
5000
4000
3000
2000
1000
0
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
Percentile

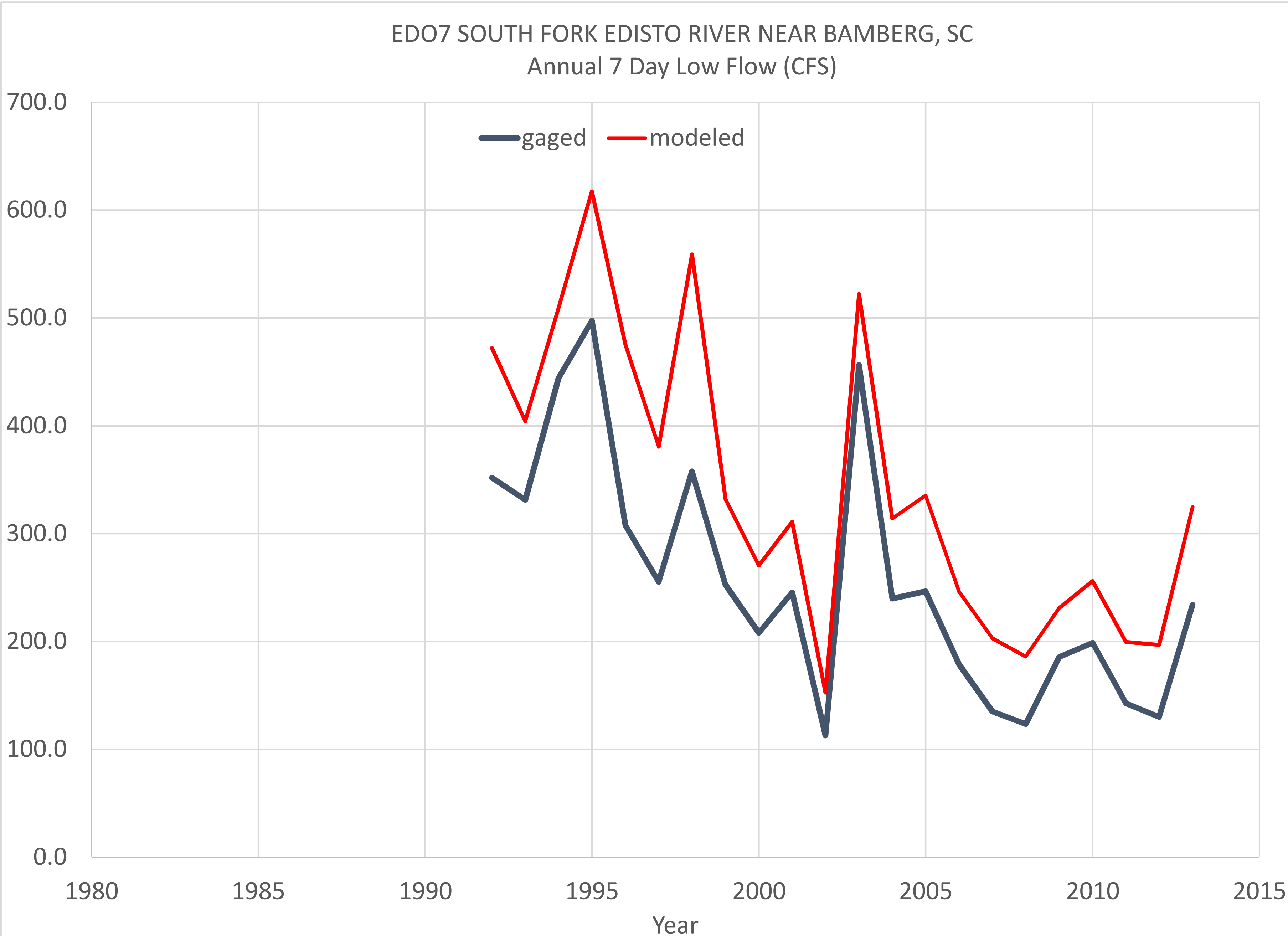


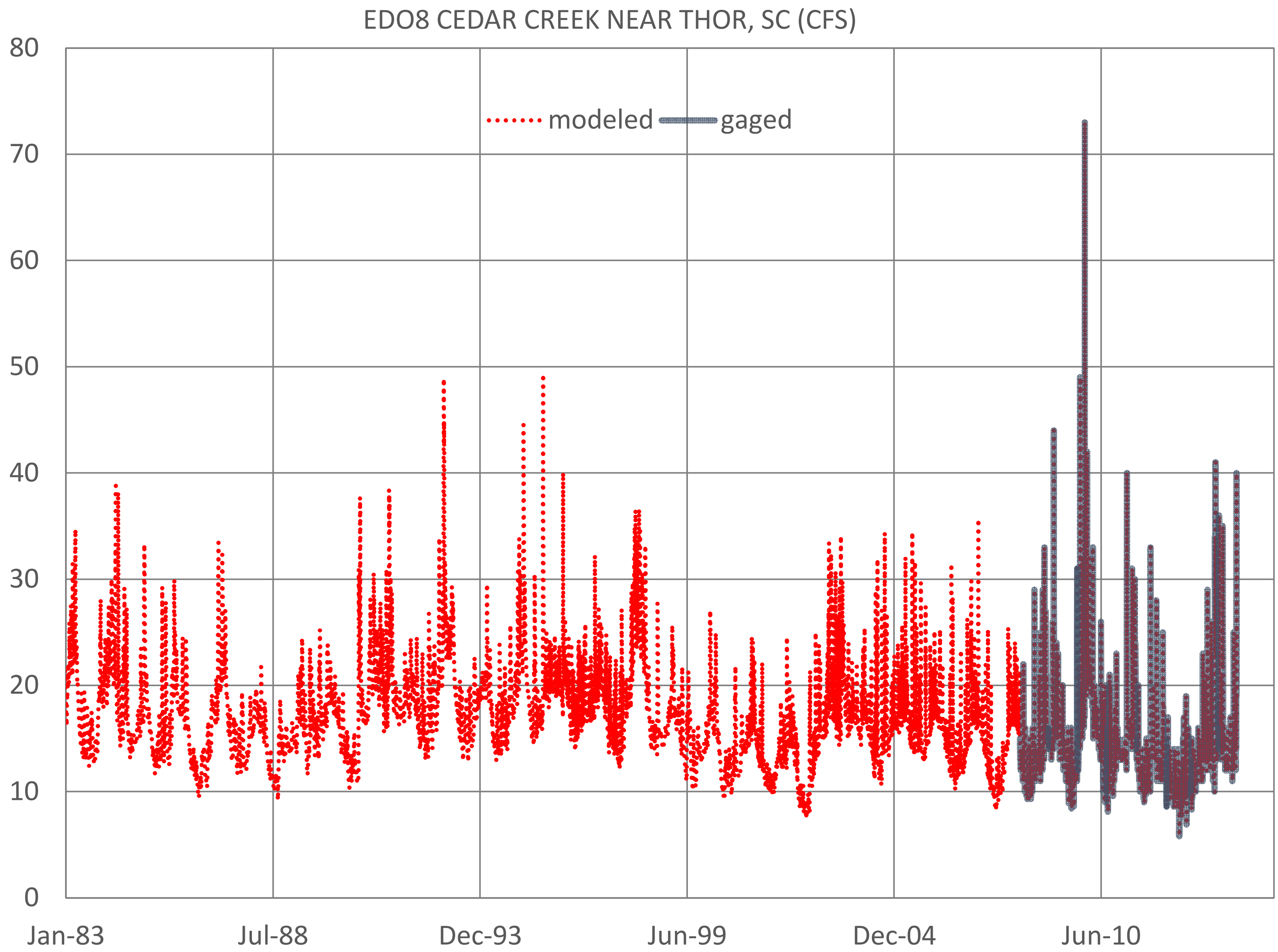
EDO6 SOUTH FORK EDISTO RIVER NEAR COPE, SC
Annual 7 Day Low Flow (CFS)
gaged
modeled
600.0
500.0
400.0
300.0
200.0
100.0
0.0
1980
1985
1990
1995
2000
2005
2010
2015
Year


EDO7 SOUTH FORK EDISTO RIVER NEAR BAMBERG, SC (CFS)
modeled
gaged
9,000
8,000
7,000
6,000
5,000
4,000
3,000
2,000
1,000
0
Jan-83
Jul-88
Dec-93
Jun-99
Dec-04
Jun-10

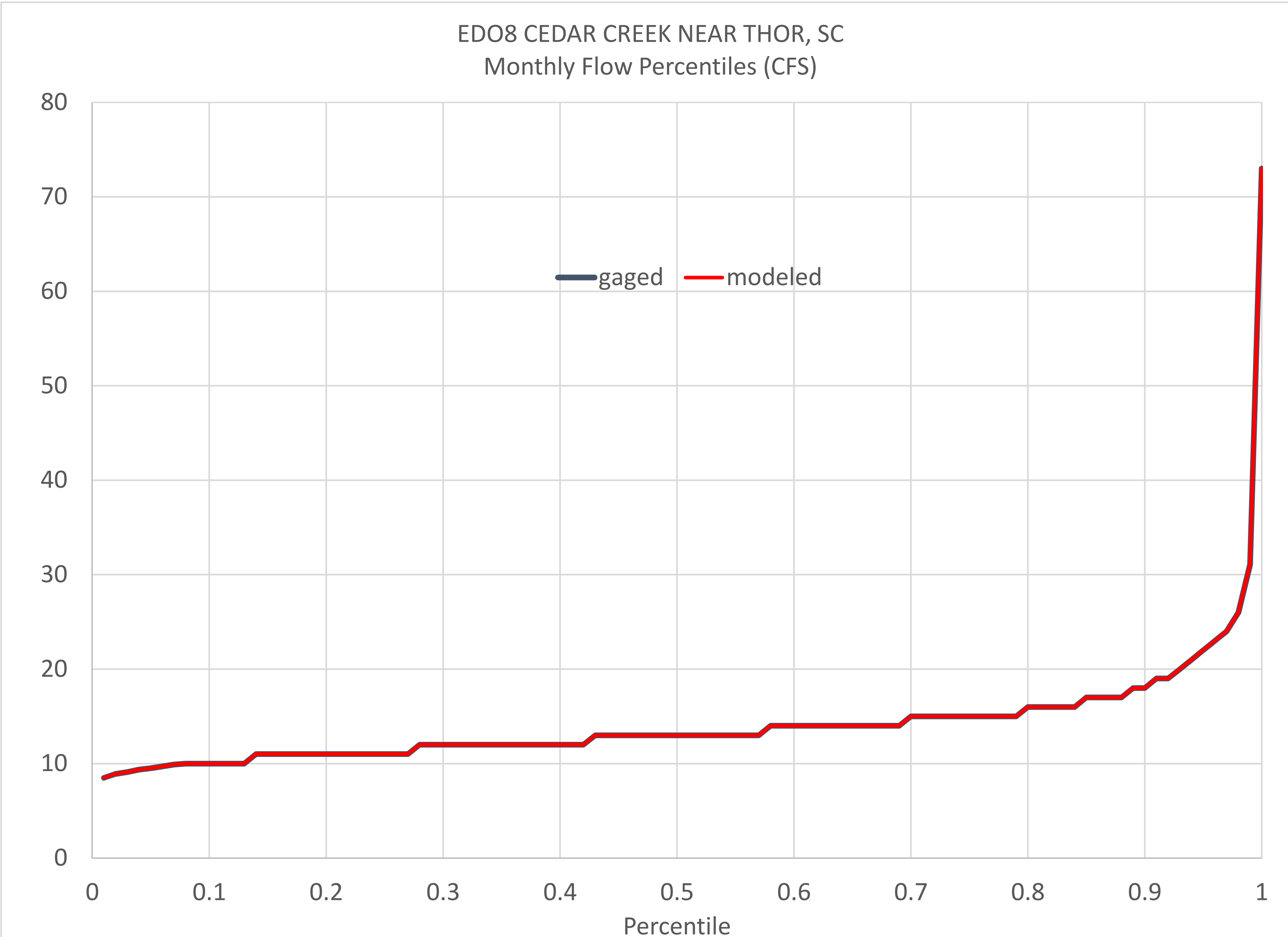


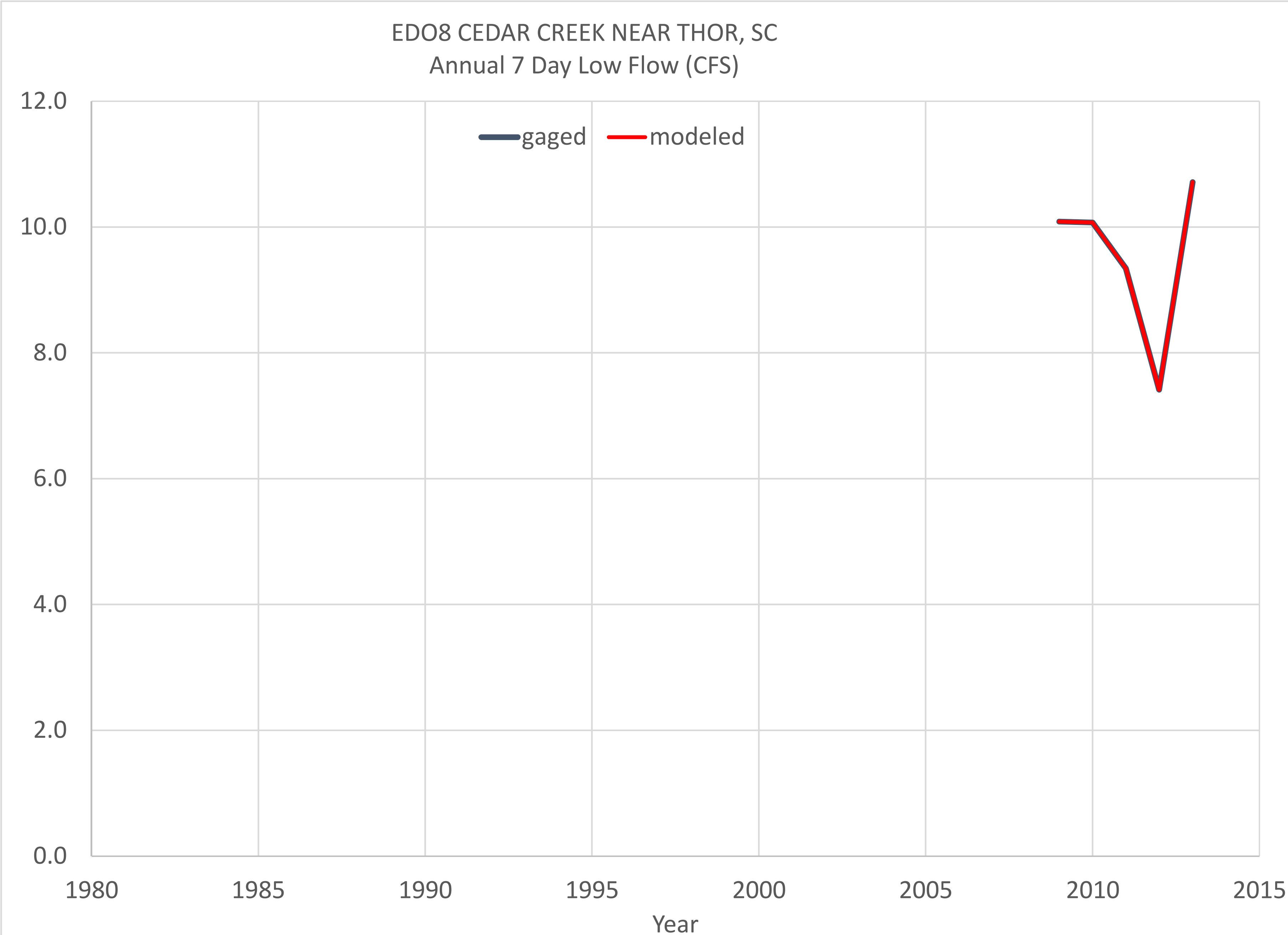
EDO7 SOUTH FORK EDISTO RIVER NEAR BAMBERG, SC
Monthly Flow Percentiles (CFS)
9000
8000
7000
6000
5000
4000
3000
2000
1000
0
gaged
modeled
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
Percentile

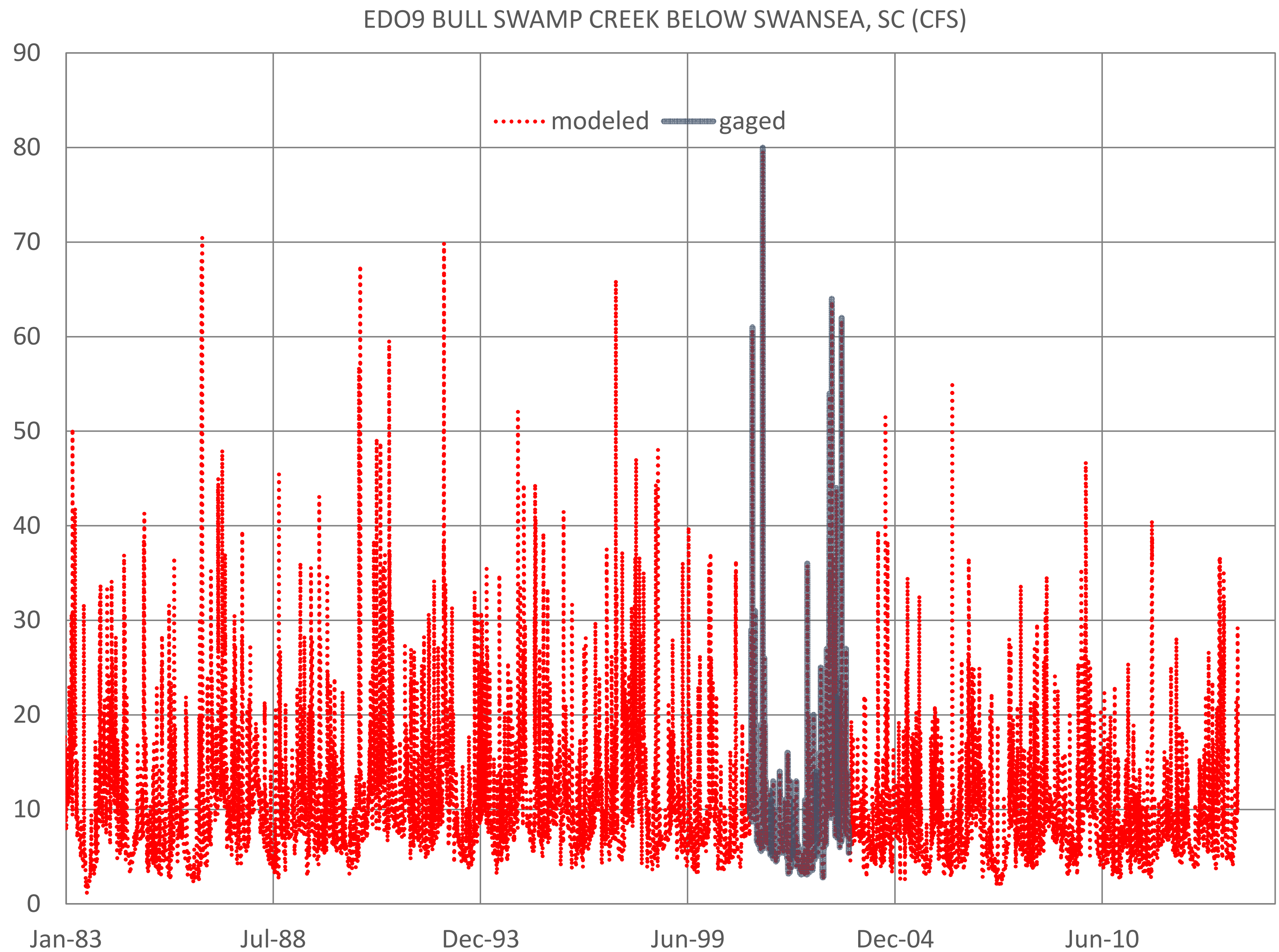

EDO7 SOUTH FORK EDISTO RIVER NEAR BAMBERG, SC
Annual 7 Day Low Flow (CFS)
gaged
modeled
700.0
600.0
500.0
400.0
300.0
200.0
100.0
0.0
1980
1985
1990
1995
2000
2005
2010
2015
Year

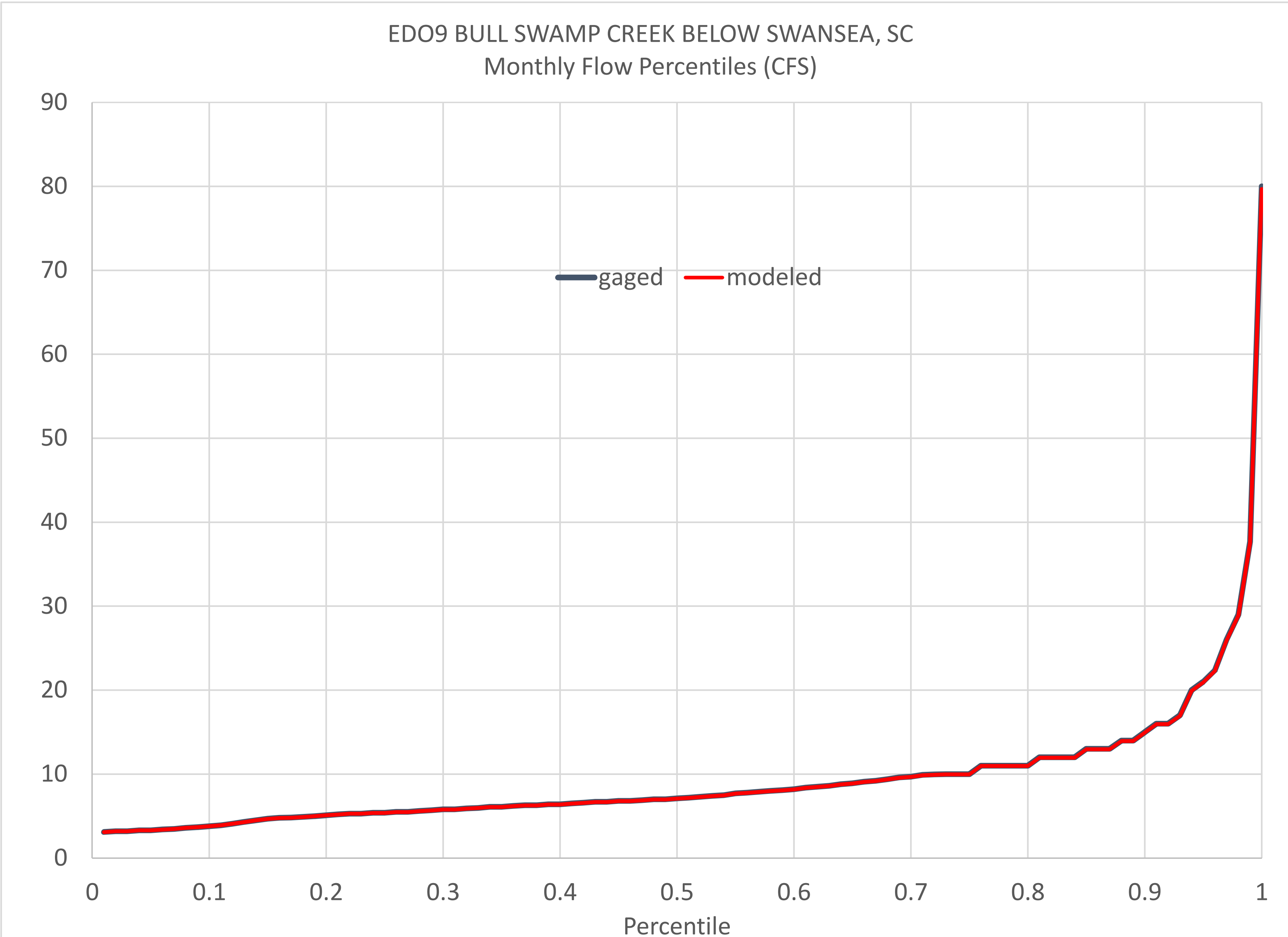


EDO8 CEDAR CREEK NEAR THOR, SC (CFS)
modeled
gaged
0
10
20
30
40
50
60
70
80
Jan-83
Jul-88
Dec-93
Jun-99
Dec-04
Jun-10

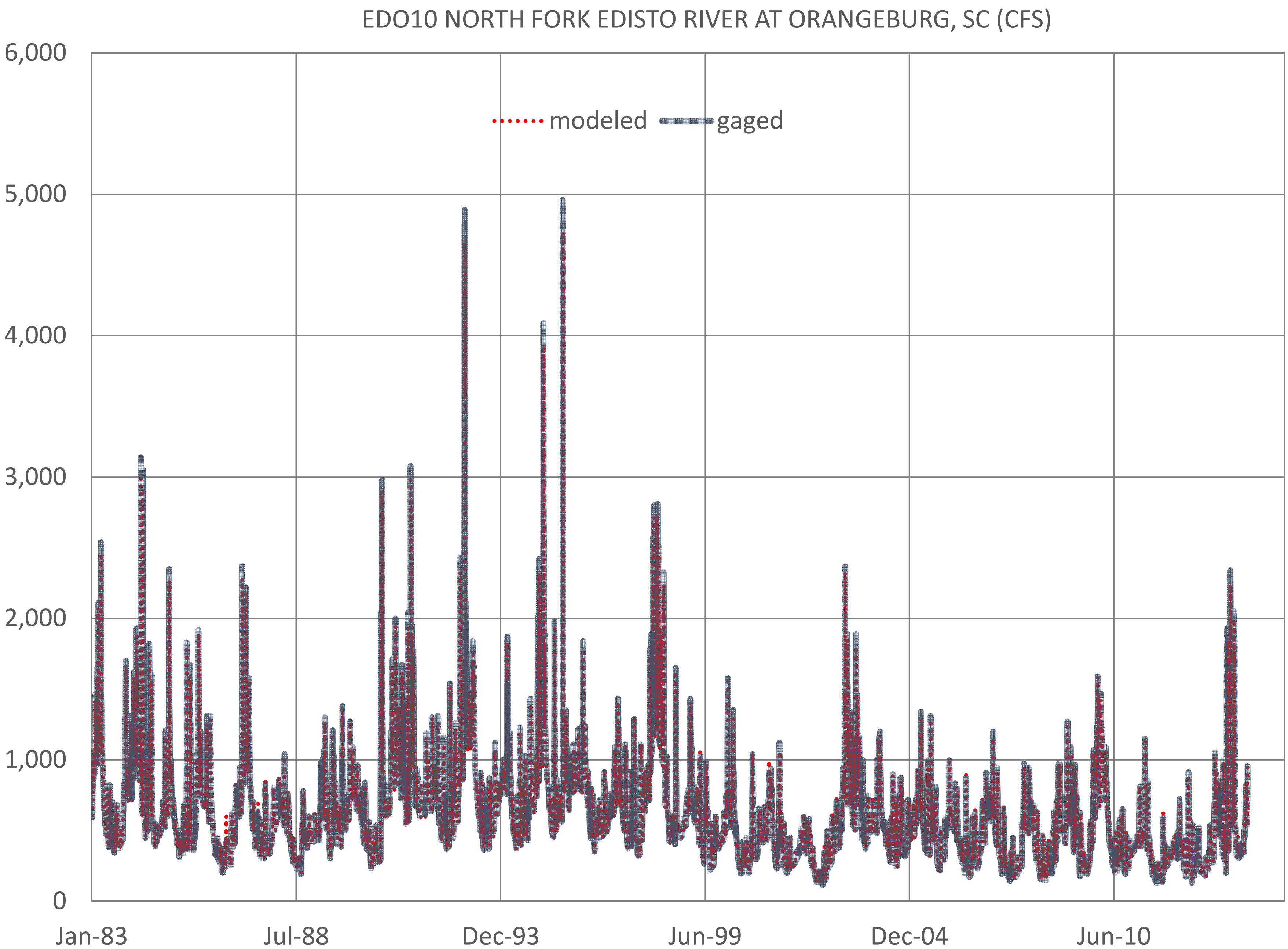

EDO8 CEDAR CREEK NEAR THOR, SC
Monthly Flow Percentiles (CFS)
gaged
modeled
80
70
60
50
40
30
20
10
0
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
Percentile


EDO8 CEDAR CREEK NEAR THOR, SC
Annual 7 Day Low Flow (CFS)
gaged
modeled
12.0
10.0
8.0
6.0
4.0
2.0
0.0
1980
1985
1990
1995
2000
2005
2010
2015
Year

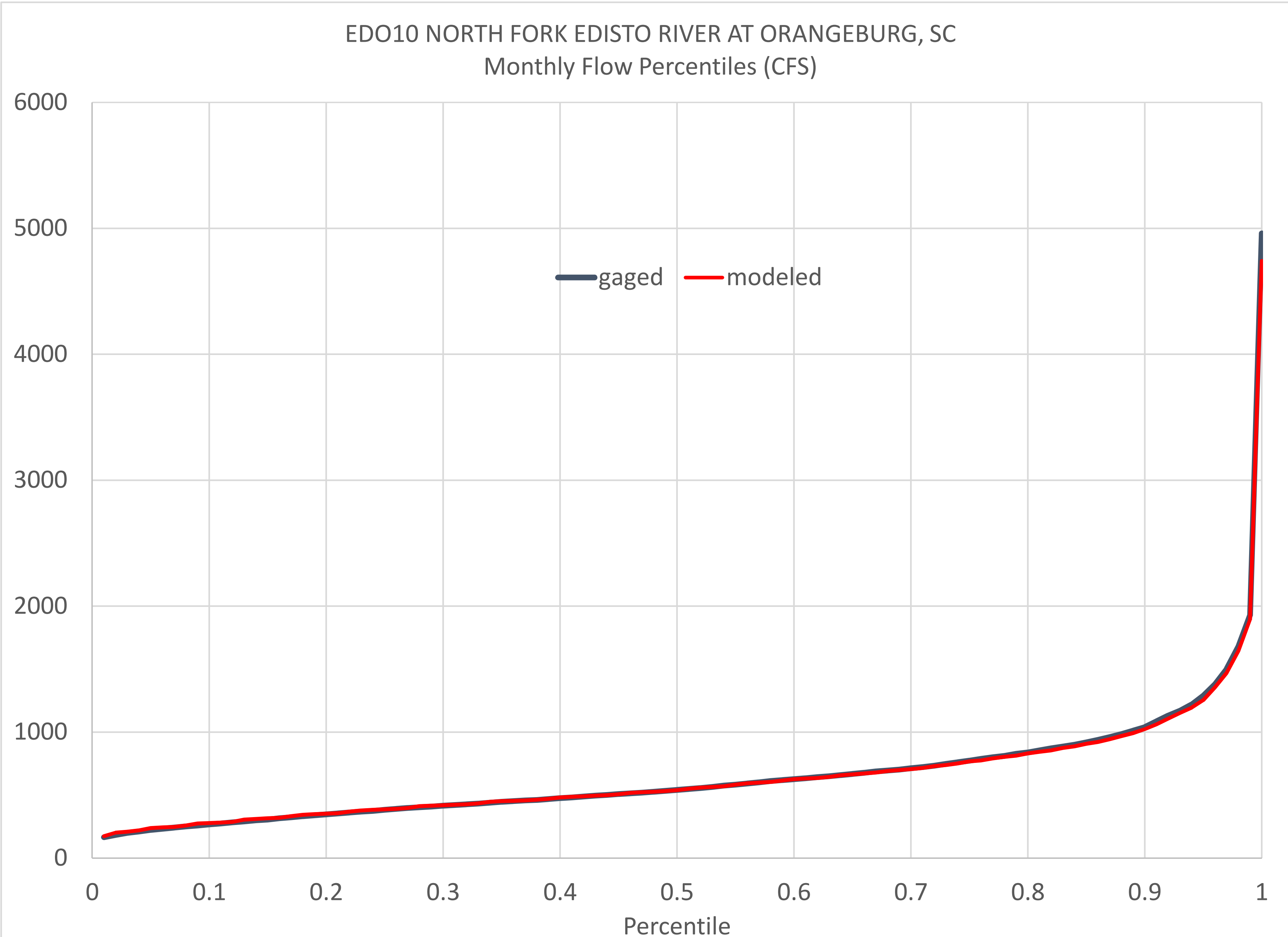

EDO9 BULL SWAMP CREEK BELOW SWANSEA, SC (CFS)
modeled
gaged
90
80
70
60
50
40
30
20
10
0
Jan-83
Jul-88
Dec-93
Jun-99
Dec-04
Jun-10

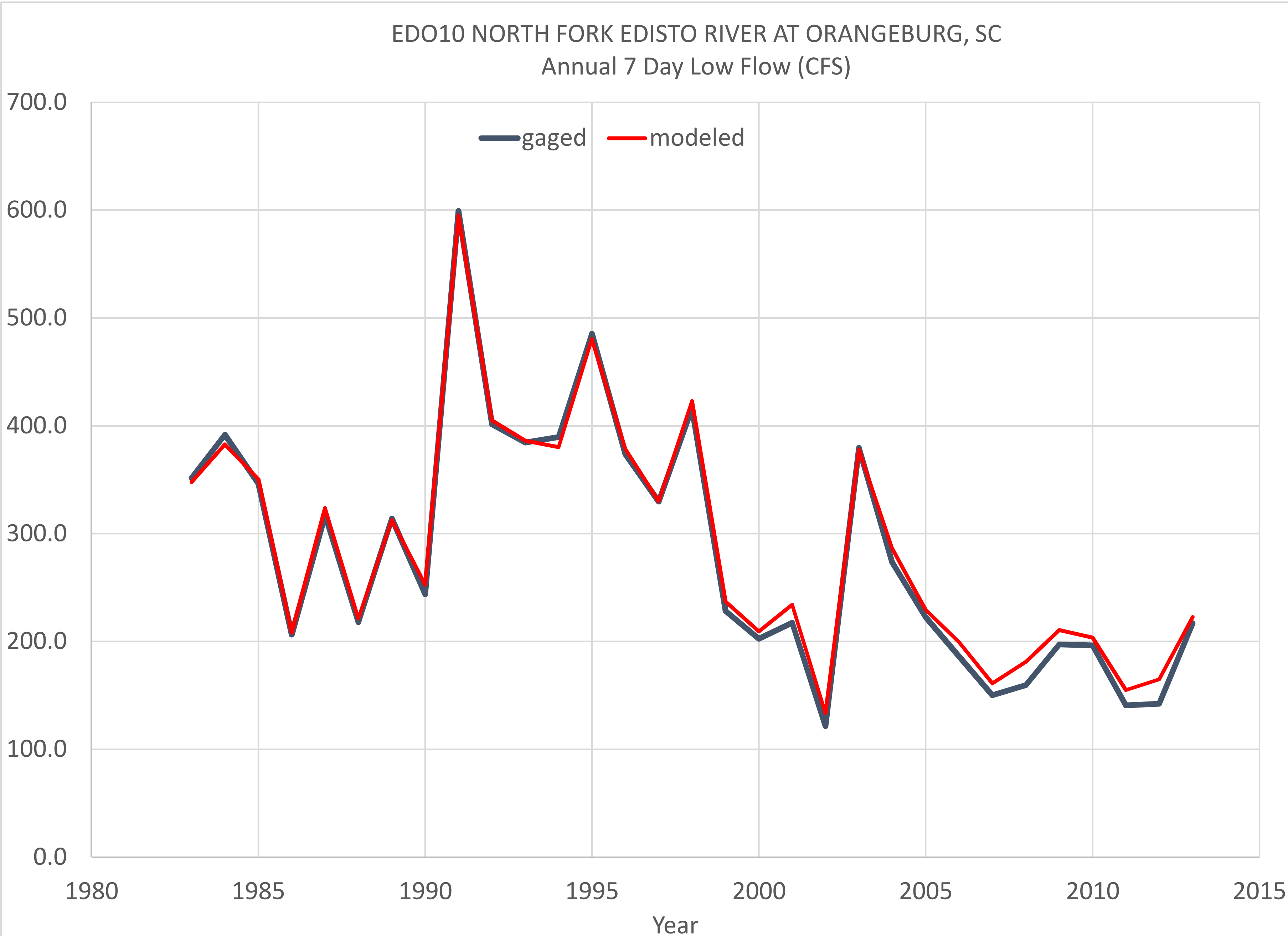


EDO9 BULL SWAMP CREEK BELOW SWANSEA, SC
Monthly Flow Percentiles (CFS)
90
80
70
60
50
40
30
20
10
0
gaged
modeled
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
Percentile

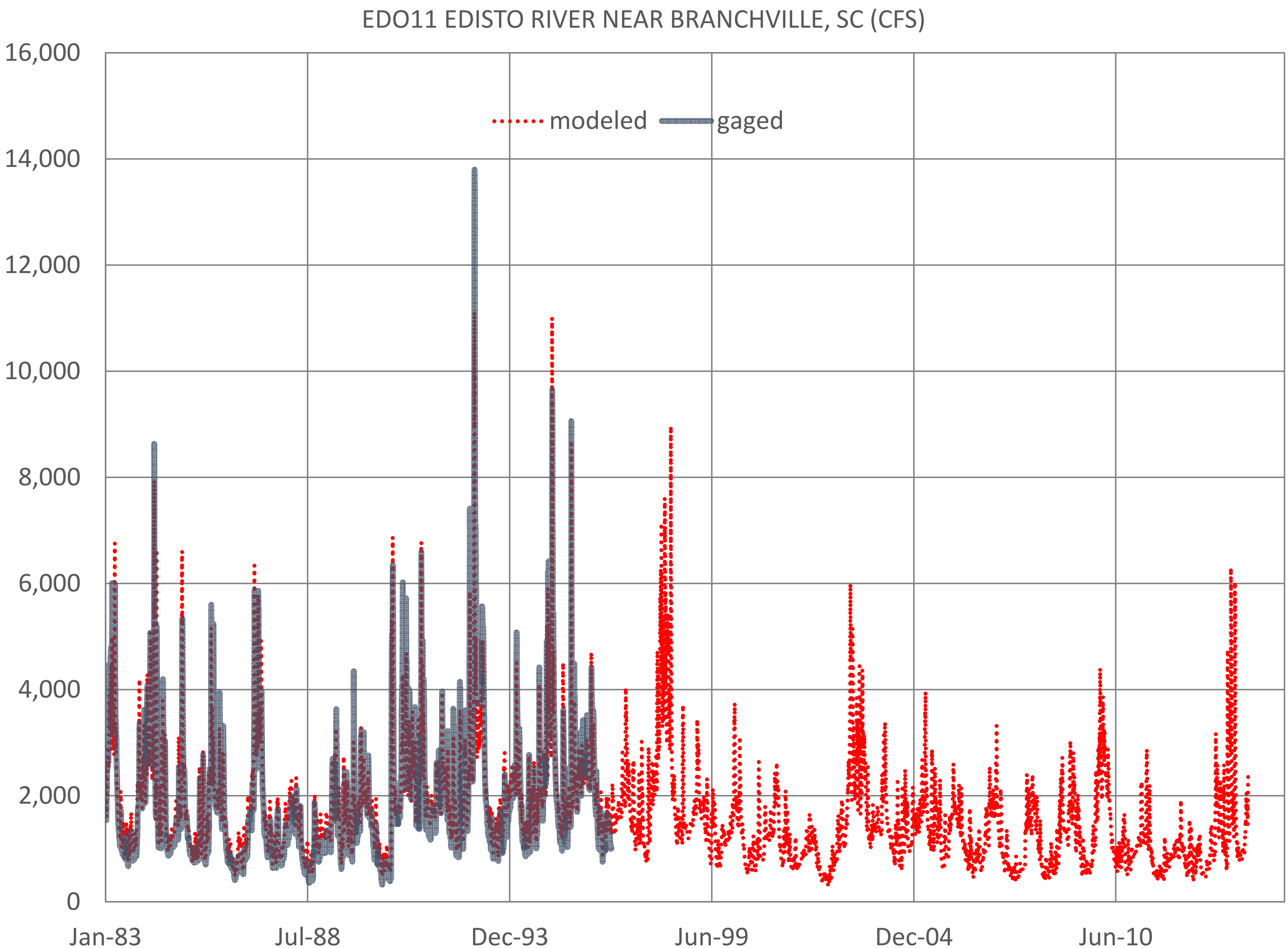


EDO10 NORTH FORK EDISTO RIVER AT ORANGEBURG, SC (CFS)
modeled
gaged
6,000
5,000
4,000
3,000
2,000
1,000
0
Jan-83
Jul-88
Dec-93
Jun-99
Dec-04
Jun-10

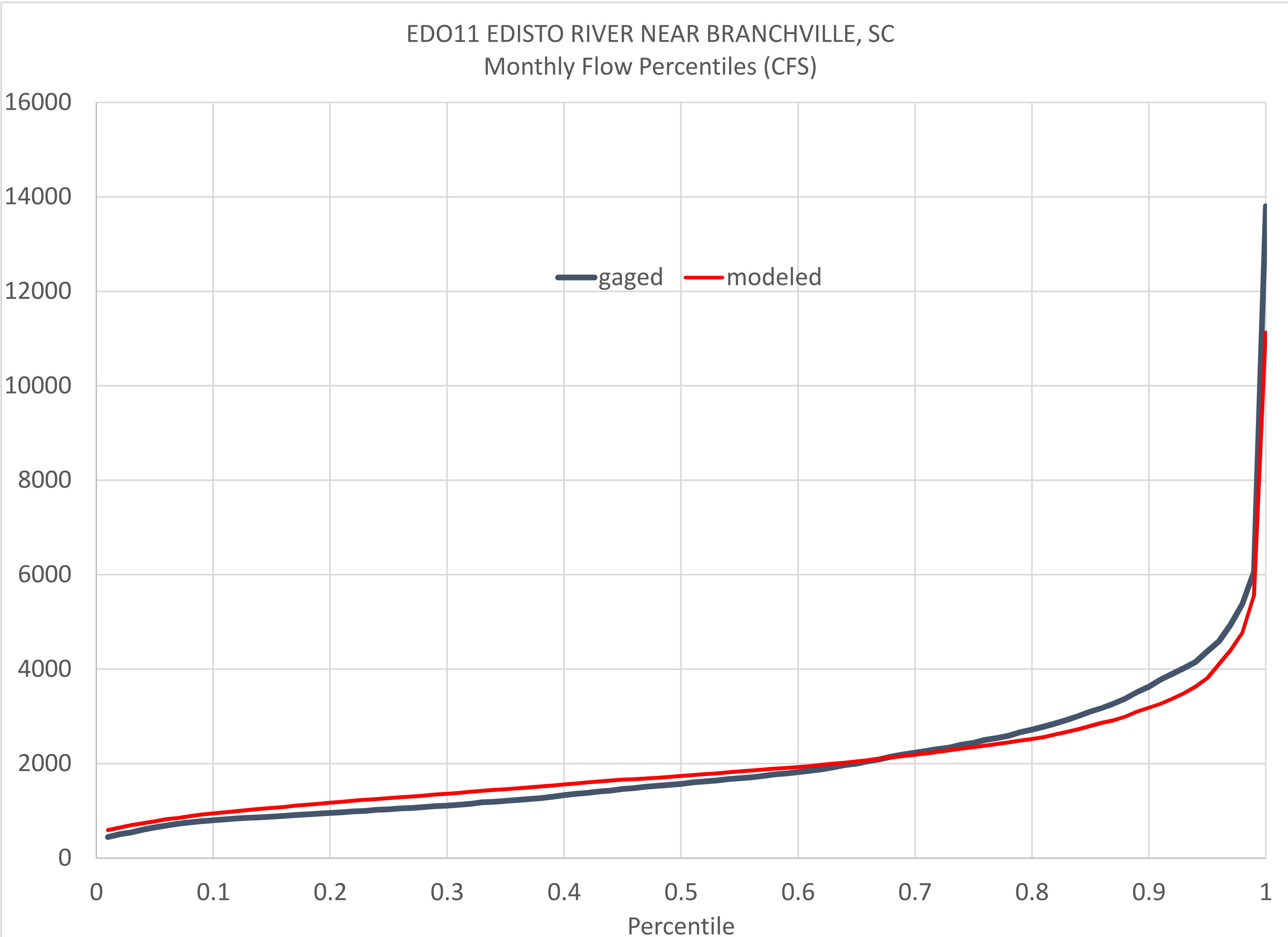

EDO10 NORTH FORK EDISTO RIVER AT ORANGEBURG, SC
Monthly Flow Percentiles (CFS)
gaged
modeled
6000
5000
4000
3000
2000
1000
0
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
Percentile



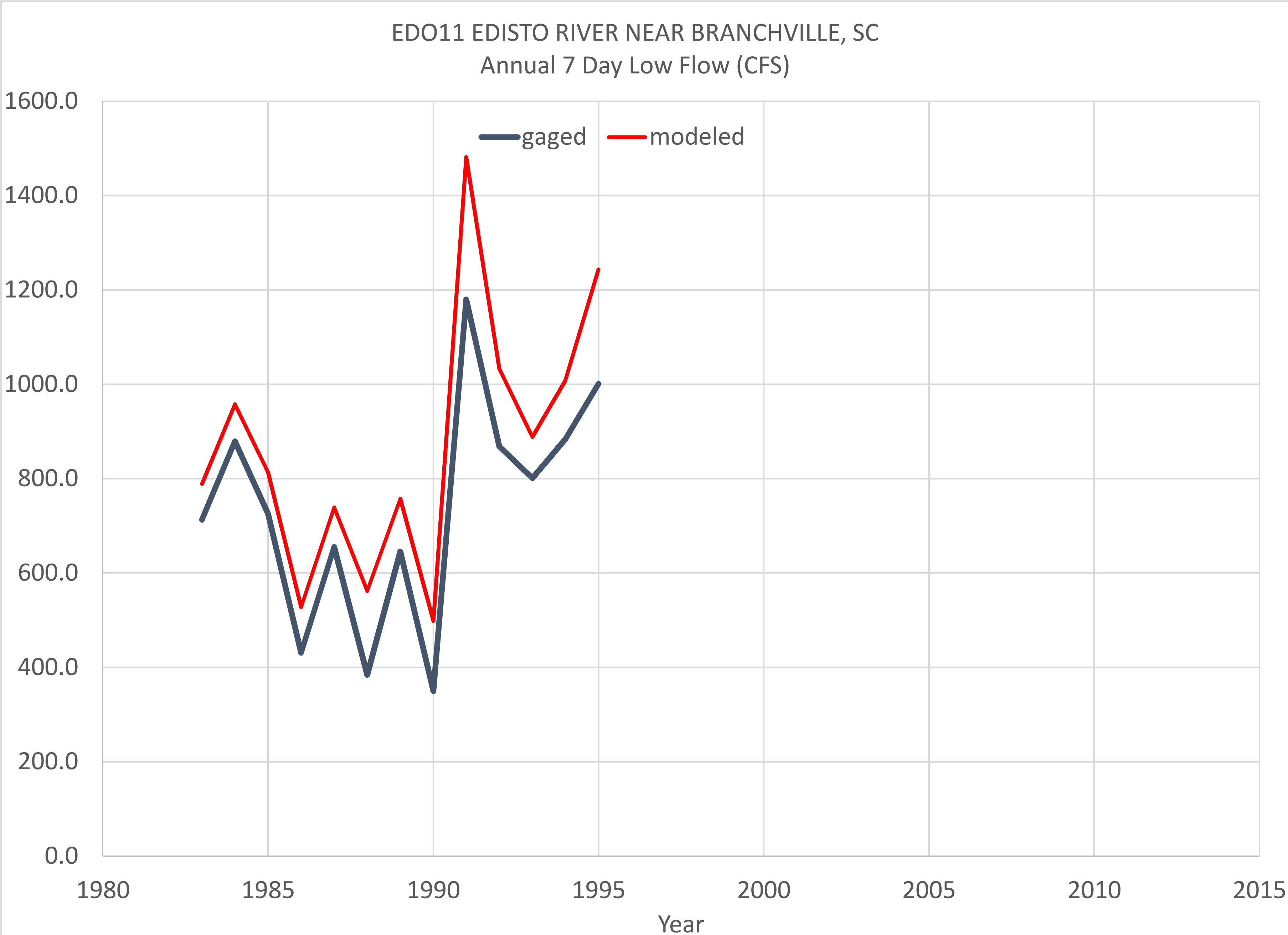
EDO10 NORTH FORK EDISTO RIVER AT ORANGEBURG, SC
Annual 7 Day Low Flow (CFS)
gaged
modeled
700.0
600.0
500.0
400.0
300.0
200.0
100.0
0.0
1980
1985
1990
1995
2000
2005
2010
2015
Year

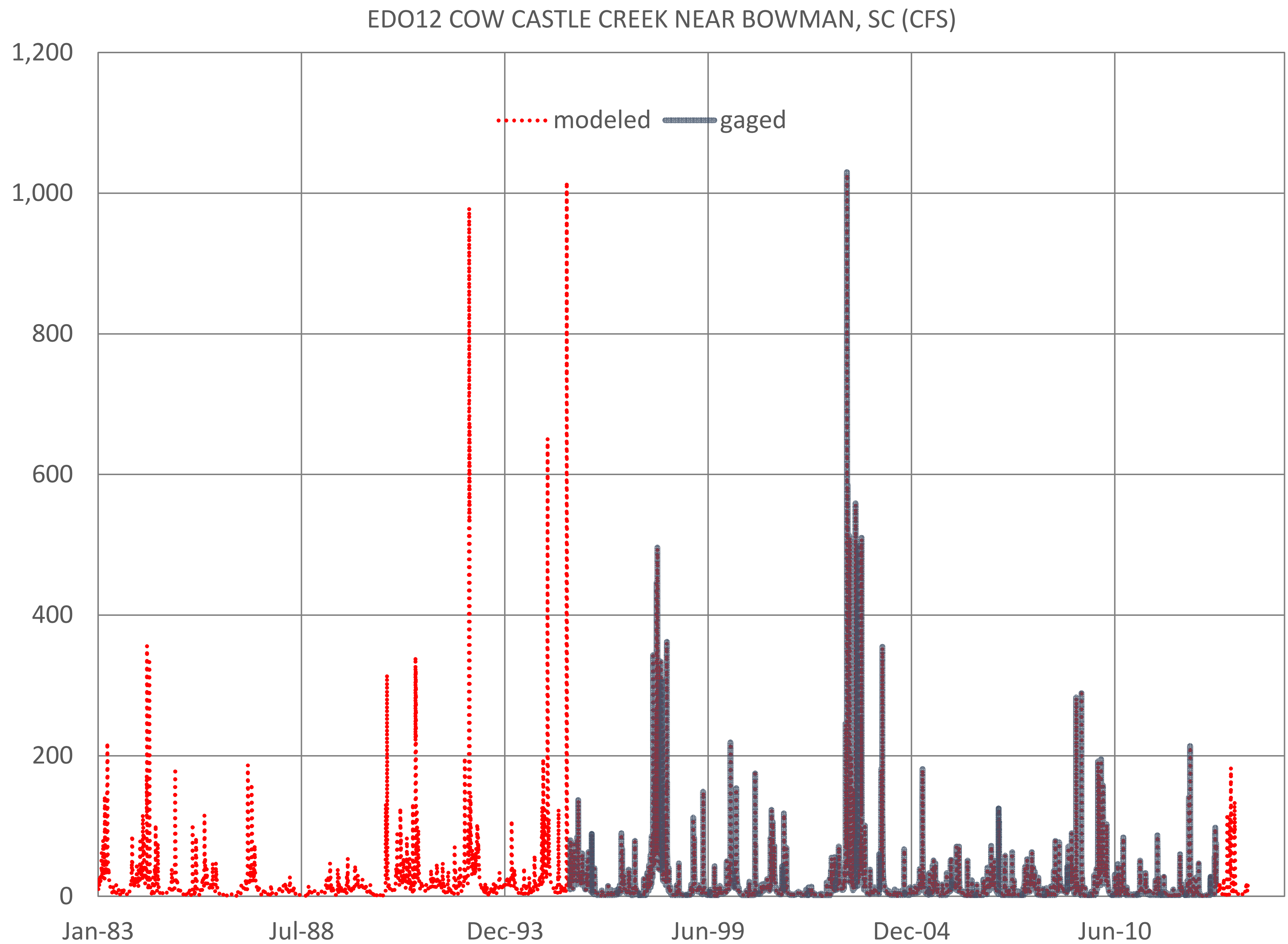


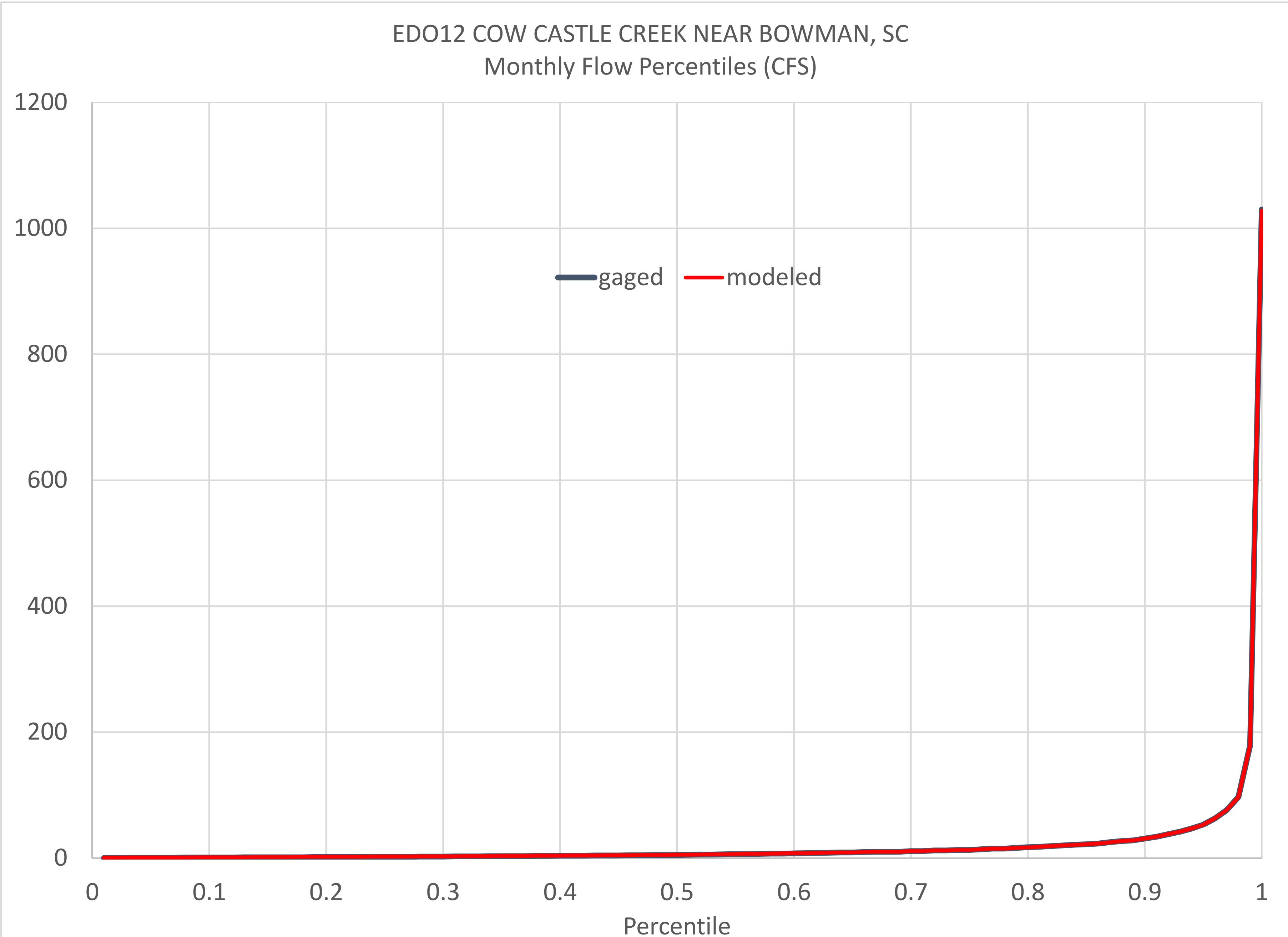
EDO11 EDISTO RIVER NEAR BRANCHVILLE, SC (CFS)
modeled
gaged
16,000
14,000
12,000
10,000
8,000
6,000
4,000
2,000
0
Jan-83
Jul-88
Dec-93
Jun-99
Dec-04
Jun-10

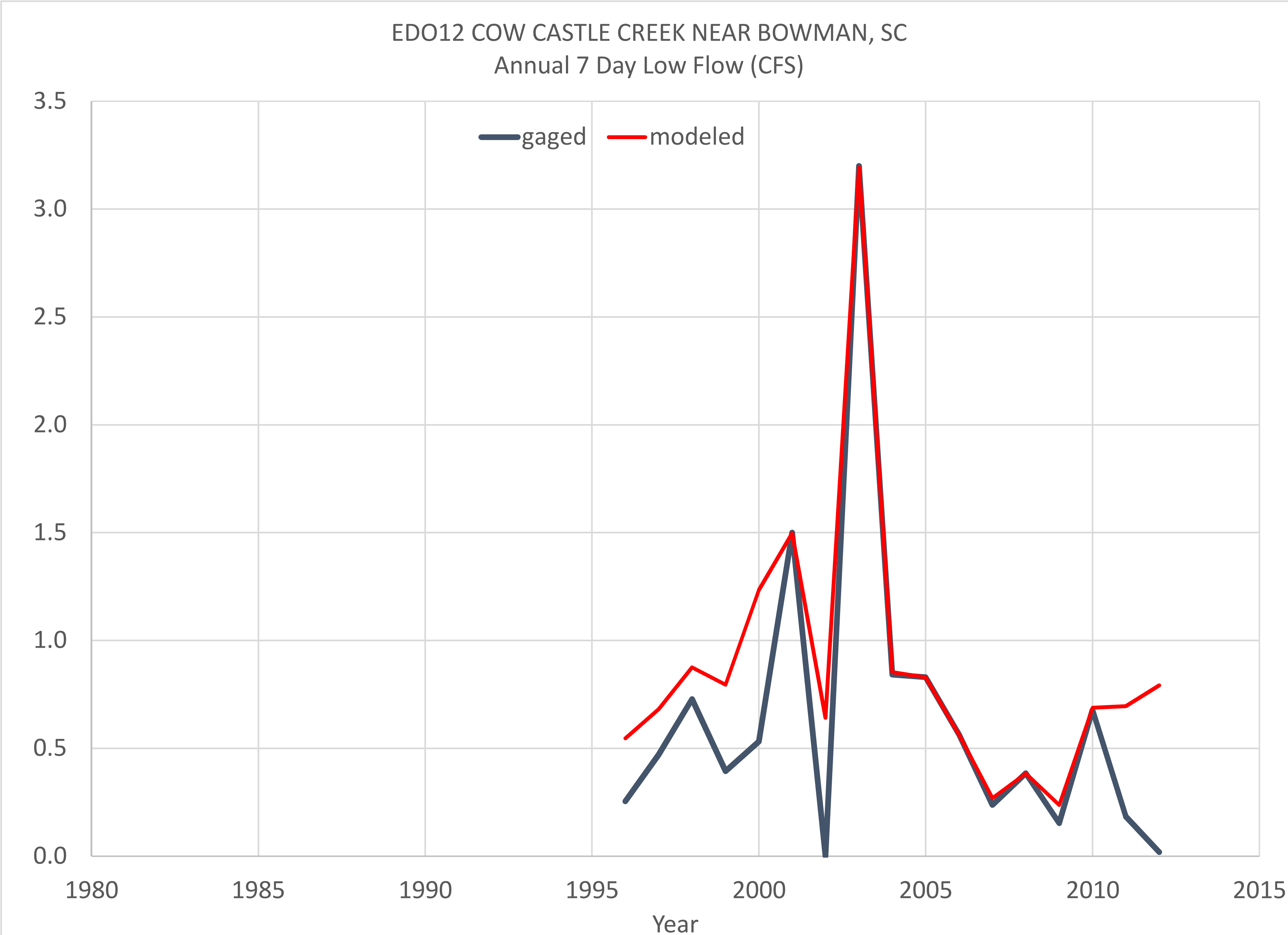


EDO11 EDISTO RIVER NEAR BRANCHVILLE, SC
Monthly Flow Percentiles (CFS)
16000
14000
12000
10000
8000
6000
4000
2000
0
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
Percentile
gaged
modeled

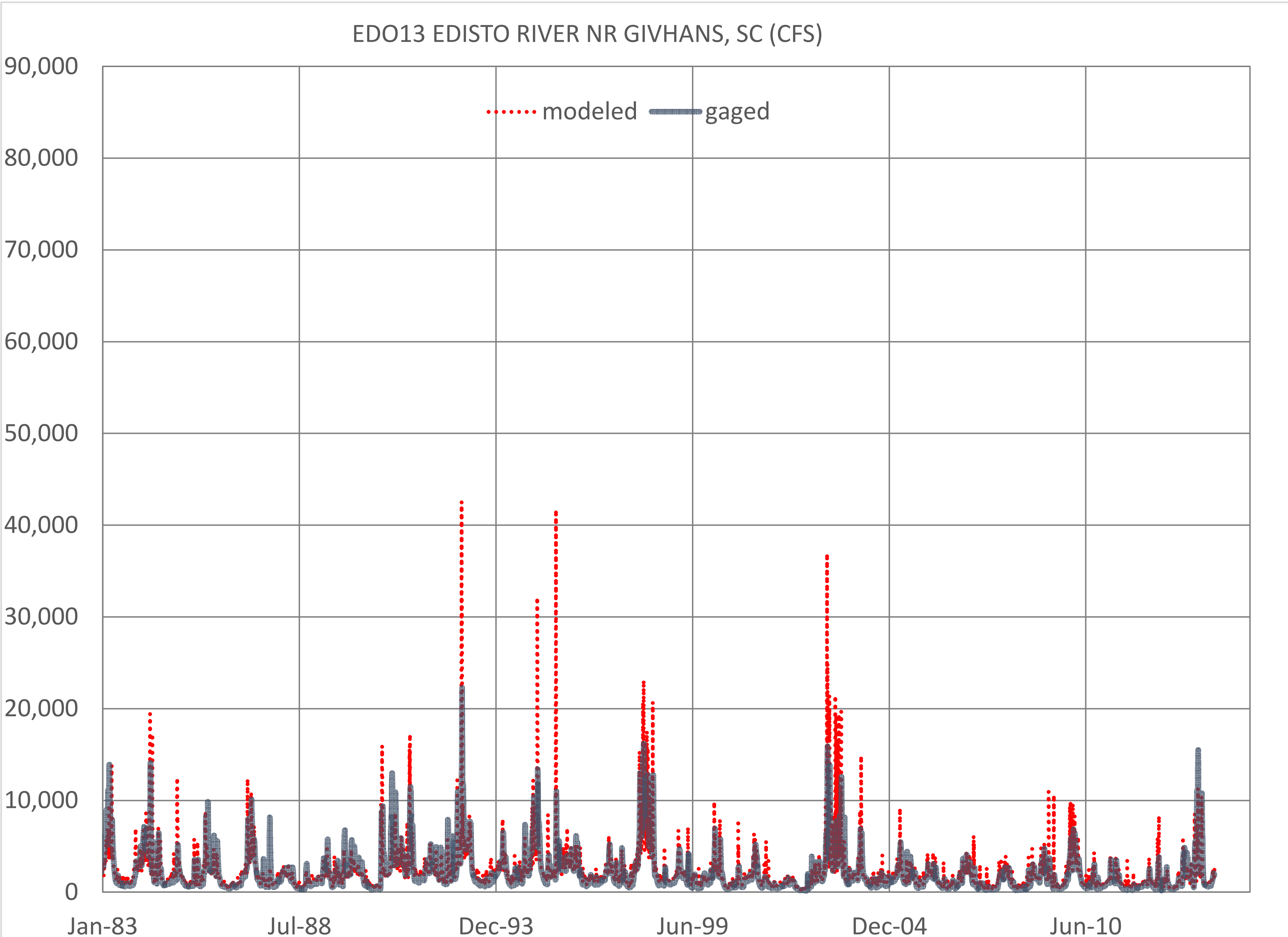

EDO11 EDISTO RIVER NEAR BRANCHVILLE, SC
Annual 7 Day Low Flow (CFS)
gaged
modeled
1600.0
1400.0
1200.0
1000.0
800.0
600.0
400.0
200.0
0.0
1980
1985
1990
1995
2000
2005
2010
2015
Year

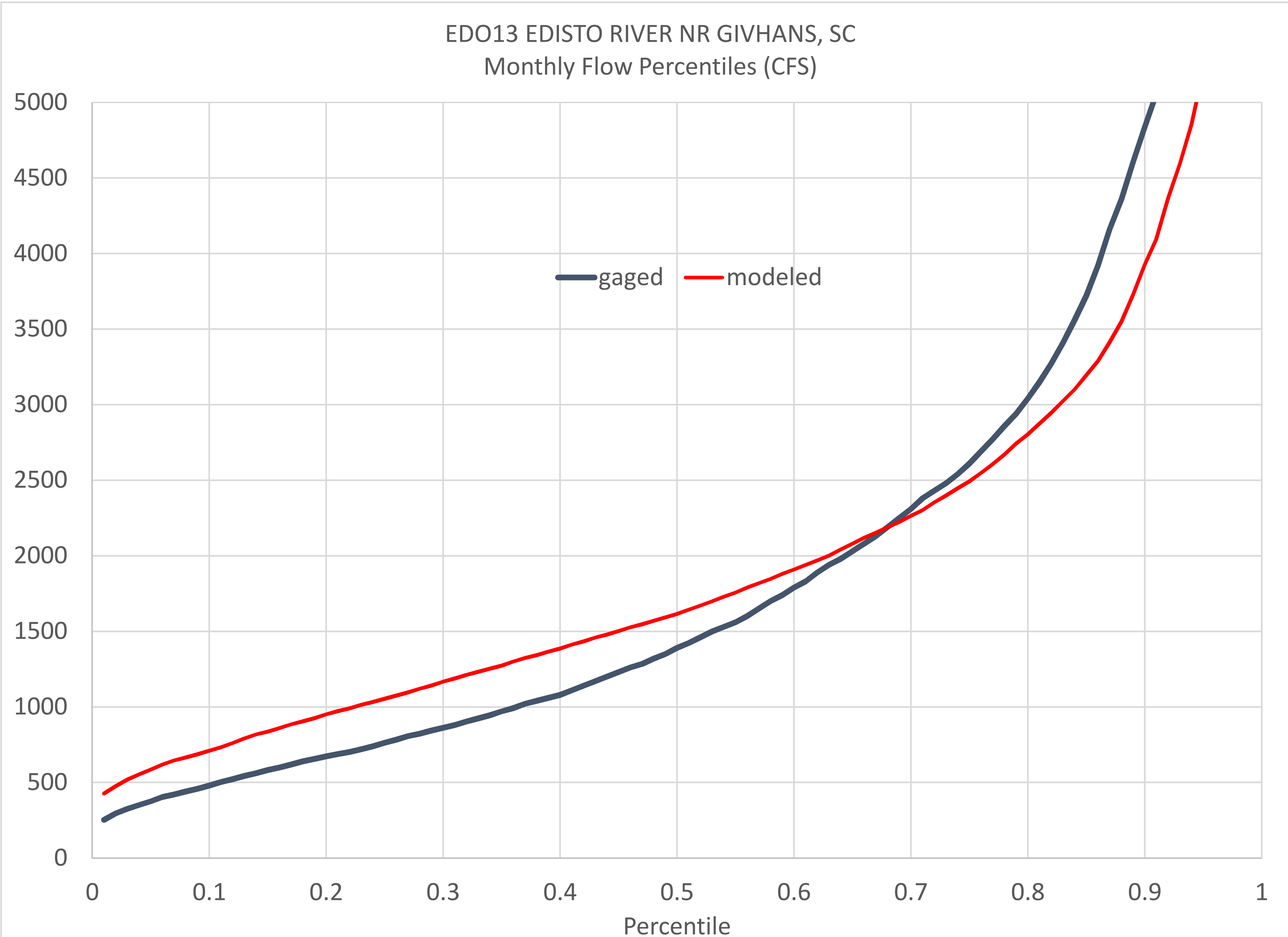

EDO12 COW CASTLE CREEK NEAR BOWMAN, SC (CFS)
modeled
gaged
1,200
1,000
800
600
400
200
0
Jan-83
Jul-88
Dec-93
Jun-99
Dec-04
Jun-10

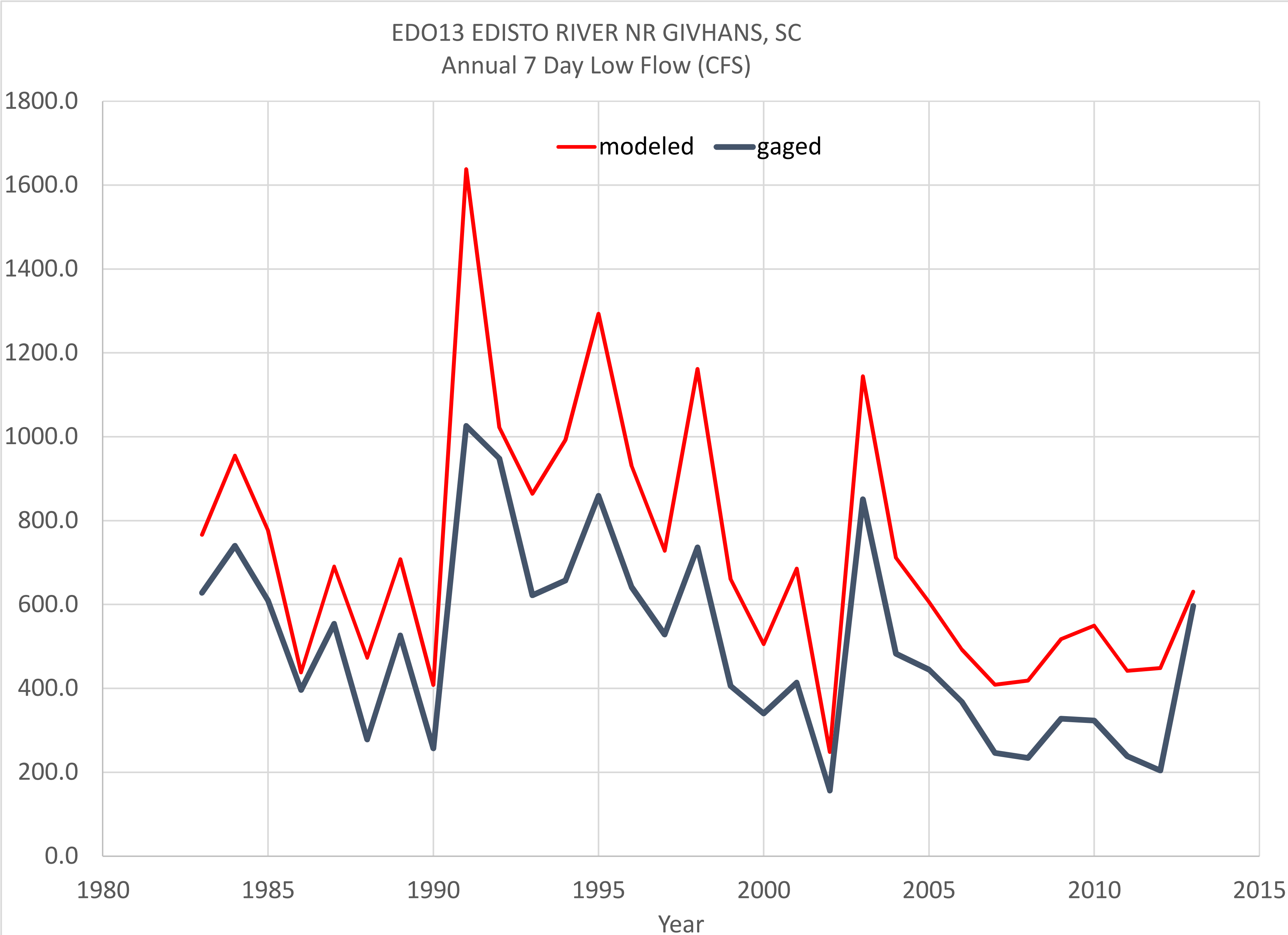

EDO12 COW CASTLE CREEK NEAR BOWMAN, SC
Monthly Flow Percentiles (CFS)
gaged
modeled
1200
1000
800
600
400
200
0
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
Percentile



EDO12 COW CASTLE CREEK NEAR BOWMAN, SC
Annual 7 Day Low Flow (CFS)
gaged
modeled
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
1980
1985
1990
1995
2000
2005
2010
2015
Year


EDO13 EDISTO RIVER NR GIVHANS, SC (CFS)
modeled
gaged
90,000
80,000
70,000
60,000
50,000
40,000
30,000
20,000
10,000
0
Jan-83
Jul-88
Dec-93
Jun-99
Dec-04
Jun-10


EDO13 EDISTO RIVER NR GIVHANS, SC
Monthly Flow Percentiles (CFS)
gaged
modeled
5000
4500
4000
3500
3000
2500
2000
1500
1000
500
0
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
Percentile



EDO13 EDISTO RIVER NR GIVHANS, SC
Annual 7 Day Low Flow (CFS)
modeled
gaged
1800.0
1600.0
1400.0
1200.0
1000.0
800.0
600.0
400.0
200.0
0.0
1980
1985
1990
1995
2000
2005
2010
2015
Year

Annual 7 day Low Flows: Modeled

Year	MCTIER CREEK (RD 209) NEAR MONETTA, SC (CFS)	MCTIER CREEK NEAR NEW HOLLAND, SC (CFS)	DEAN SWAMP CREEK NR SALLEY, SC (CFS)	SOUTH FORK EDISTO RIVER NEAR DENMARK, SC (CFS)	SOUTH FORK EDISTO RIVER NEAR COPE, SC (CFS)	SOUTH FORK EDISTO RIVER NEAR BAMBERG, SC (CFS)	CEDAR CREEK NEAR THOR, SC Flow (CFS)	BULL SWAMP CREEK BELOW SWANSEA, SC (CFS)	NORTH FORK EDISTO RIVER AT ORANGEBURG, SC (CFS)	EDISTO RIVER NEAR BRANCHVILLE, SC (CFS)	COW CASTLE CREEK NEAR BOWMAN, SC (CFS)	EDISTO RIVER NR GIVHANS, SC (CFS)
	EDO1	EDO2	EDO4	EDO5	EDO6	EDO7	EDO8	EDO9	EDO10	EDO11	EDO12	EDO13
1983			16.4	292.6					347.9	788.8		766.1
1984			17.0	374.1					382.8	957.7		955.0
1985			17.9	284.1					350.7	813.4		776.6
1986			15.9	195.7					208.3	527.8		437.9
1987				263.9					323.6	739.1		690.4
1988				209.5					221.4	562.2		473.0
1989			12.1	291.3					312.6	757.4		707.7
1990			12.3	159.1					252.6	498.4		407.9
1991			17.0	559.6					595.1	1481.7		1637.9
1992			20.0	385.2	401.3	472.2			405.1	1033.0		1022.3
1993			18.3	323.2	337.0	404.1			386.1	888.5		863.8
1994			20.1	394.7	411.4	509.0			380.2	1008.3		992.2
1995			24.3	494.1	514.4	617.3			480.8	1243.2		1293.4
1996	9.7		20.7	389.2	405.1	475.2			378.5		0.5	930.5
1997			18.9	311.2	323.5	380.7			330.0		0.7	728.1
1998			22.3	459.3	476.3	559.0			423.0		0.9	1161.7
1999			17.0	259.5	270.4	331.8			237.0		0.8	660.5
2000				209.8	218.9	270.4			209.4		1.2	505.5
2001				240.3	251.4	311.1			234.0		1.5	685.6
2002	1.5			115.3	120.5	152.5		3.1	133.4		0.6	248.1
2003	11.3			408.2	425.5	522.4			377.9		3.2	1144.4
2004	4.2			239.9	251.0	314.1			285.9		0.9	711.4
2005	7.4			265.9	276.9	335.4			229.4		0.8	605.6
2006	4.0			191.3	199.9	246.0			199.1		0.6	492.3
2007	2.0			151.0	159.1	203.0			161.0		0.3	408.8
2008	1.9	3.8		137.6	145.1	186.0			181.0		0.4	418.6
2009	2.6			171.8	181.0	231.1	10.1		210.5		0.2	517.5
2010	3.5			197.7	206.2	256.1	10.1		203.5		0.7	549.4
2011	2.1			149.2	156.4	199.7	9.3		154.9		0.7	441.8
2012	0.9			148.3	155.4	196.8	7.4		164.8		0.8	448.6
2013	4.0			248.6	260.8	324.7	10.7		222.7			630.6

Annual 7 day Low Flows: Measured

Year	MCTIER CREEK (RD 209) NEAR MONETTA, SC (CFS)	MCTIER CREEK NEAR NEW HOLLAND, SC (CFS)	DEAN SWAMP CREEK NR SALLEY, SC (CFS)	SOUTH FORK EDISTO RIVER NEAR DENMARK, SC (CFS)	SOUTH FORK EDISTO RIVER NEAR COPE, SC (CFS)	SOUTH FORK EDISTO RIVER NEAR BAMBERG, SC (CFS)	CEDAR CREEK NEAR THOR, SC Flow (CFS)	BULL SWAMP CREEK BELOW SWANSEA, SC (CFS)	NORTH FORK EDISTO RIVER AT ORANGEBURG, SC (CFS)	EDISTO RIVER NEAR BRANCHVILLE, SC (CFS)	COW CASTLE CREEK NEAR BOWMAN, SC (CFS)	EDISTO RIVER NR GIVHANS, SC (CFS)
	EDO1	EDO2	EDO4	EDO5	EDO6	EDO7	EDO8	EDO9	EDO10	EDO11	EDO12	EDO13
1983			16.4	235.9					351.6	713.0		627.7
1984			17.0	338.6					391.6	879.0		740.0
1985			17.9	255.1					346.3	725.9		609.3
1986			15.9	160.9					206.3	431.0		396.1
1987				241.4					317.1	655.6		554.1
1988				179.0					217.9	384.3		278.0
1989			12.1	262.3					314.0	645.6		526.3
1990			12.3	138.1					243.9	349.7		257.1
1991			17.0	550.0					599.3	1180.0		1025.7
1992			20.0	352.9	340.3	351.9			401.3	868.0		948.1
1993			18.3	291.9	319.3	331.3			384.4	800.7		621.7
1994			20.1	379.7	355.4	444.3			389.6	884.0		657.1
1995			24.3	431.7	422.6	497.4			485.4	1001.0		859.1
1996	9.7		20.7	353.6	327.1	307.6			373.6		0.3	641.7
1997			18.9	293.3	247.9	255.1			329.6		0.5	528.4
1998			22.3	396.7	315.1	357.7			416.4		0.7	736.3
1999			17.0	229.3	223.4	252.4			228.3		0.4	406.0
2000				182.3	208.6	208.0			202.4		0.5	340.1
2001				224.0	238.3	245.4			217.3		1.5	413.6
2002	1.5			113.0	91.3	112.7		3.2	121.4		0.0	156.3
2003	11.3			390.4	380.6	456.4			379.6		3.2	850.7
2004	4.2			220.1	215.0	239.9			273.3		0.8	482.7
2005	7.4			249.3	217.9	246.6			222.7		0.8	444.4
2006	4.0			186.0	163.7	178.6			186.0		0.6	367.9
2007	2.0			138.3	132.0	135.0			150.1		0.2	245.9
2008	1.9	3.7		126.9	131.0	123.4			159.4		0.4	233.9
2009	2.6			163.3	175.1	185.6	10.1		197.3		0.2	327.9
2010	3.5			190.1	194.9	198.7	10.1		196.4		0.7	323.4
2011	2.1			138.9	136.6	142.7	9.3		140.9		0.2	238.6
2012	0.9			143.1	134.4	130.0	7.4		142.1		0.0	204.4
2013	4.0			214.4	219.6	234.0	10.7		217.0			596.4

Approximate 7Q10 Comparison - Modeled vs. Gaged

Year	MCTIER CREEK (RD 209) NEAR MONETTA, SC (CFS)	MCTIER CREEK NEAR NEW HOLLAND, SC (CFS)	DEAN SWAMP CREEK NR SALLEY, SC (CFS)	SOUTH FORK EDISTO RIVER NEAR DENMARK, SC (CFS)	SOUTH FORK EDISTO RIVER NEAR COPE, SC (CFS)	SOUTH FORK EDISTO RIVER NEAR BAMBERG, SC (CFS)	CEDAR CREEK NEAR THOR, SC Flow (CFS)	BULL SWAMP CREEK BELOW SWANSEA, SC (CFS)	NORTH FORK EDISTO RIVER AT ORANGEBURG, SC (CFS)	EDISTO RIVER NEAR BRANCHVILLE, SC (CFS)	COW CASTLE CREEK NEAR BOWMAN, SC (CFS)	EDISTO RIVER NR GIVHANS, SC (CFS)
	EDO1	EDO2 *	EDO4	EDO5	EDO6	EDO7	EDO8 *	EDO9 *	EDO10	EDO11	EDO12	EDO13
Modeled:	1.56	3.82	13.71	149.22	155.55	197.12	8.19	3.15	164.81	534.67	0.34	418.65
Gaged:	1.56	3.73	13.71	138.29	132.24	130.50	8.19	3.16	150.14	393.63	0.10	238.57
%Diff:	0.0%	2.6%	0.0%	7.9%	17.6%	51.0%	0.0%	-0.3%	9.8%	35.8%	240.4%	75.5%

** Relatively few years (<10) available to make comparison*

Appendix C

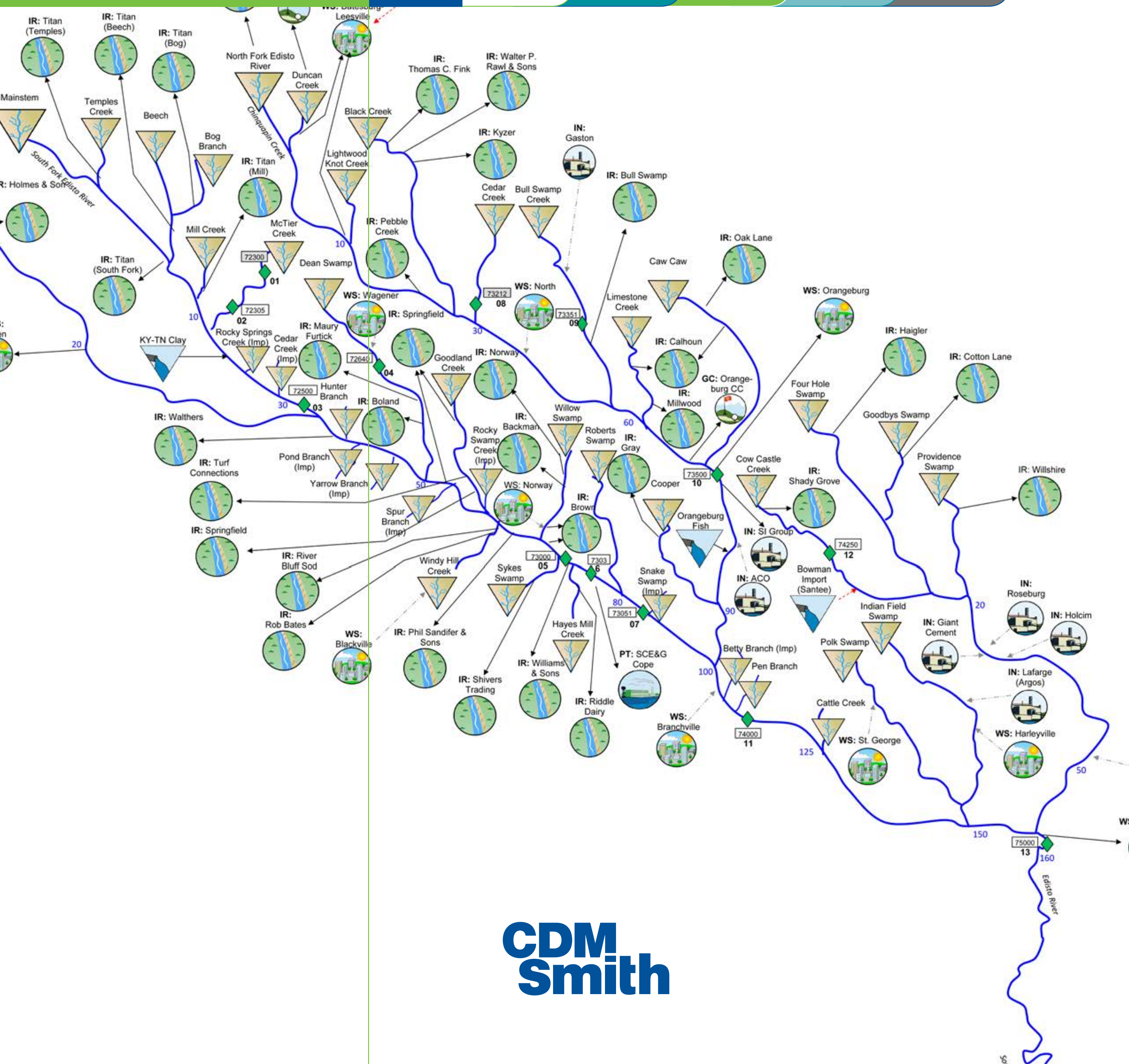
Guidelines for Representing Multi-Basin Water Users in SWAM

Appendix C
Guidelines for Representing Multi-Basin Water Users in SWAM

There are many examples in South Carolina of water users that access source waters in multiple river basins and/or discharge return flows to multiple basins. Since SWAM models for each major river basin are being developed, it is important to represent the multi-basin users concisely and clearly in the models. The following provides a recommended set of consistent guidelines to follow as each river basin model is developed. **In all cases, the constructs should be documented in the basin reports and described in the model itself using the Comment boxes.**

1. If a water user's primary source of supply and discharge locations are located with the given river basin, then this user should be explicitly included as a Water User object in that basin model.
    a. If secondary sources are from outside of the basin, then these should be included using the "transbasin import" option in SWAM.
    b. If a portion of the return flows are discharged to a different basin, then this should be incorporated by using the multiple return flow location option, with the exported portion represented by a specified location far downstream of the end of the basin mainstem (e.g. mile "999").
2. If only a water user's secondary source of supply (i.e., not the largest portion of overall supply) is located outside the river basin being modeled, then this should be represented as a water user with an "Export" identifier in the name (e.g. "Greenville Export") in the river basin model where the source is located.
    a. For this object, set the usage values based on only the amount sourced from inside the basin (i.e. only that portion of demand met by in-basin water).
    b. Set the return flow location for this use to a location outside of the basin (e.g. mainstem mile "999").
    c. For future demand projection simulations, the in-basin portion of overall demand will need to be disaggregated from the total demand projection, likely by assuming a uniform percent increase.
3. If a portion of a water user's return flow discharges to a different basin than the primary source basin, then this portion of return flow should be represented as a Discharge object (e.g. named "Greenville Import") in the appropriate basin model.
    a. Reported discharge data can be used to easily quantify this discharge for historical calibration simulations.
    b. For future demand projection simulations, this discharge can be easily quantified by analyzing the return flow output for the primary (source water basin). See 1b.

above. However, the user will need to manually make the changes to the prescribed Discharge object flows in the model.


IR: Titan (Temples)
IR: Titan (Beech)
IR: Titan (Bog)
North Fork Edisto River
Duncan Creek
WS: Batesburg-Leesville
Mainstem
Temples Creek
Beech
Bog Branch
Chinquapin Creek
South Fork Edisto River
IR: Holmes & Son
IR: Titan (Mill)
Mill Creek
McTier Creek
IR: Titan (South Fork)
72300
01
72305
02
Dean Swamp
Black Creek
Lightwood Knot Creek
IR: Thomas C. Fink
IR: Walter P. Rawl & Sons
IR: Kyzer
IN: Gaston
IR: Bull Swamp
Cedar Creek
Bull Swamp Creek
IR: Pebble Creek
73212
08
WS: North
73351
09
WS: Wagener
IR: Springfield
KY-TN Clay
Rocky Springs Creek (Imp)
Cedar Creek (Imp)
IR: Maury Furtick
72640
04
Goodland Creek
IR: Norway
Limestone Creek
Caw Caw
IR: Oak Lane
WS: Orangeburg
IR: Calhoun
GC: Orangeburg CC
IR: Millwood
72500
03
Hunter Branch
IR: Boland
IR: Walthers
Pond Branch (Imp)
Yarrow Branch (Imp)
IR: Turf Connections
Rocky Swamp Creek (Imp)
IR: Backman
Willow Swamp
Roberts Swamp
IR: Gray
Cooper
73500
10
Cow Castle Creek
IR: Shady Grove
IR: Haigler
Four Hole Swamp
IR: Cotton Lane
Goodbys Swamp
Providence Swamp
IR: Willshire
WS: Norway
IR: Brown
Spur Branch (Imp)
IR: Springfield
IR: River Bluff Sod
IR: Rob Bates
Windy Hill Creek
Sykes Swamp
73000
05
7303
06
Orangeburg Fish
IN: SI Group
74250
12
IN: ACO
Snake Swamp (Imp)
73051
07
Bowman Import (Santee)
Indian Field Swamp
IN: Roseburg
IN: Holcim
IN: Giant Cement
WS: Blackville
IR: Phil Sandifer & Sons
Hayes Mill Creek
PT: SCE&G Cope
Betty Branch (Imp)
Pen Branch
Polk Swamp
IN: Lafarge (Argos)
IR: Shivers Trading
IR: Williams & Sons
IR: Riddle Dairy
WS: Branchville
74000
11
Cattle Creek
WS: St. George
WS: Harleyville
75000
13
Edisto River
10
20
30
50
60
80
90
100
125
150
160

CDM Smith