SOUTH CAROLINA SURFACE WATER QUANTITY MODELS SAVANNAH RIVER BASIN MODEL

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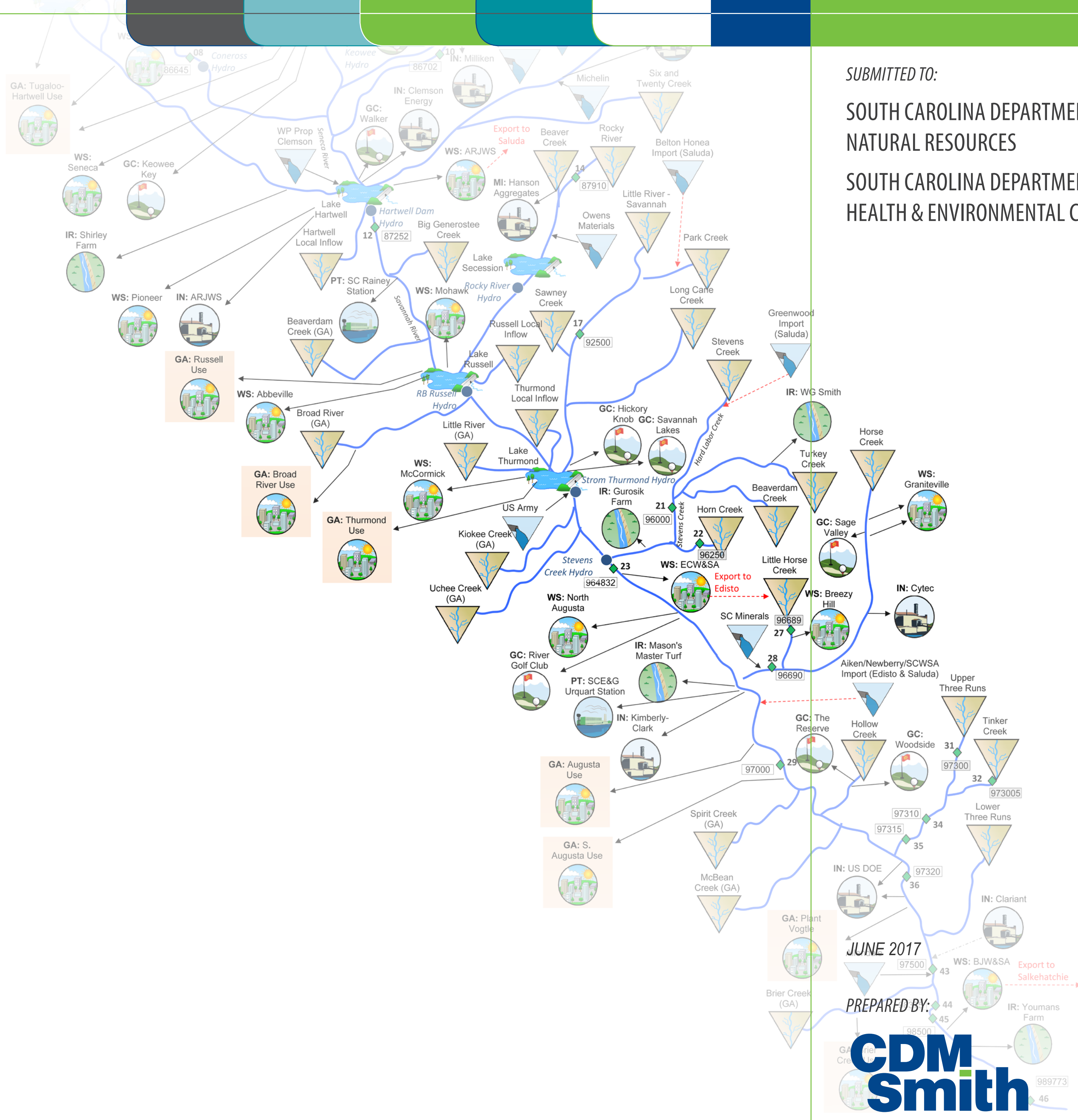

SUBMITTED TO:

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Section 1

Purpose

This document, the Savannah 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 Savannah 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 Savannah River Basin Model is provided in the *Simplified Water Allocation Model (SWAM) User's Manual Version 4.0* (CDM Smith, 2016).

Additionally, this document is intended to help disseminate the information about how the model represents the South Carolina portion of the Savannah 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 Savannah 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 Savannah 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 1939 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 flow recommendations.

Lastly, the model is intended to support a large user base, including staff at DNR and DHEC along with stakeholders throughout the South Carolina portion of the Savannah 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 Savannah River Basin Model. Where appropriate, additional discussion has been included in this report, to elaborate on specific aspects covered in the Modeling Plan. In certain instances, the procedures and guidelines detailed in the plan were modified and/or enhanced during development of the pilot model developed for the Saluda River Basin and the subsequent models developed for the Broad, Edisto, Pee Dee, Catawba-Wateree, Santee, and Salkehatchie river basins. The enhanced procedures and guidelines, and the "lessons learned" were applied to the Savannah River Basin – especially, with regard to model calibration and validation.

Section 4

Savannah Model Framework

The initial Savannah River Basin SWAM Model Framework was developed in collaboration with South Carolina DNR and DHEC, and was presented in the memorandum *Savannah Basin SWAM Model Framework* (CDM Smith, August 2016). The proposed framework was developed as a starting point for representing the South Carolina portion of the Savannah Basin river network and its significant water withdrawals and discharges. The guiding principles in determining what elements of the Savannah 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 Savannah 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 Savannah, 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. Withdraws may include both water used directly by that water user and water sold to other water users who may or may not be included as separate objects in the model. Since water withdrawals are associated with the permit holder rather than the ultimate water user, the Water User objects reflect the withdrawals associated with their permit.

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 Savannah 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 and municipal discharges – Pickens Roper, Pickens Middle, Pickens Eighteen, Owens Materials, WP Prop Clemson, Key Utility, Michelin, SC Minerals, Allendale, US Army, were deemed significant enough to include in the model; however, the industry/municipality either purchases water from another permit holder or withdraws (or supplements) using groundwater. They do not have their own surface water withdrawal permit.
- Water withdrawn by Belton-Honea in the Saluda River Basin, and then discharged in the Savannah Basin to Park Creek is represented by a Discharge object.
- Water withdrawn by Greenwood in the Saluda River Basin, and then discharged in the Savannah Basin to Stevens Creek is represented by a Discharge object.
- Water withdrawn by Easley in the Saluda River Basin, and then discharged in the Savannah Basin to Golden Creek is represented by a Discharge object.
- Water withdrawn by multiple municipalities in both the Edisto (City of Aiken) and Saluda (Newberry and SCWSA) have a combined associated discharge facility on the Savannah River and is represented by one Discharge object.

4.3 Representation of Hydropower Facilities

Nine hydropower facilities are located on the Savannah River or a tributary located in the South Carolina. Three of these facilities essentially operate as run-of-river facilities where inflow equal outflow on a daily basis. Since these run-of-river hydropower facilities do not substantially impact the water balance (limited or no storage) nor have associated minimum flow requirements or consumption, they are not explicitly included in the model, but are still shown on the model's visual framework. These facilities include Coneross Hydro, Rocky River Hydro and Stevens Creek Hydro.

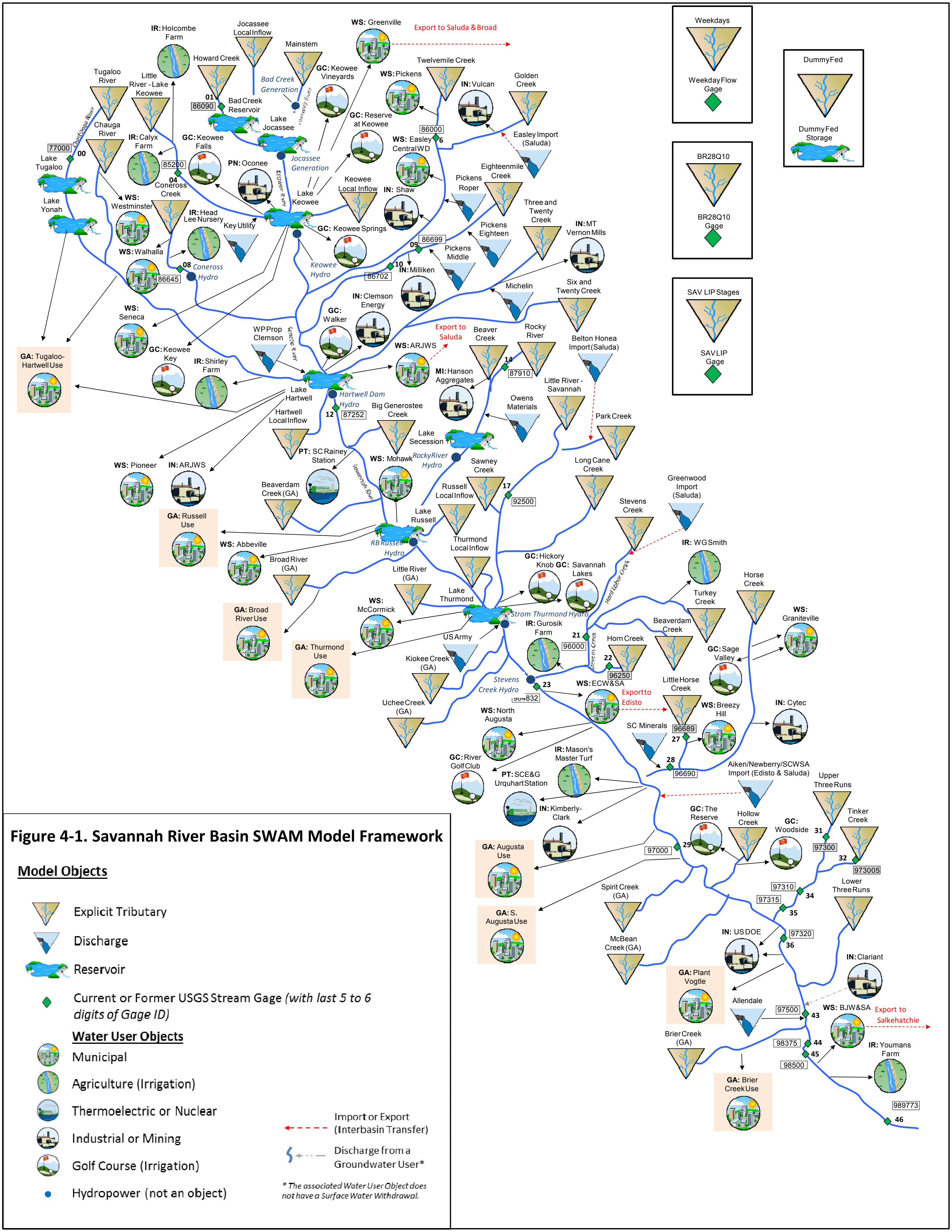


Figure 4-1. Savannah River Basin SWAM Model Framework

The other Savannah River Basin hydropower facilities operate as conventional hydropower facilities and/or pumped storage facilities. These facilities have minimum flow requirements and unique release/operating rules which are specified in the associated Reservoir object. These are detailed in Section 6.

The facilities which operate in a pumped storage mode include Bad Creek and Jocassee. The 300-acre Bad Creek Reservoir serves as the upper reservoir and the 7,980-acre Lake Jocassee serves as the lower reservoir of this Duke Energy development. The Bad Creek Reservoir is operated as needed for generation, with reservoir elevations fluctuating over an approximately 20-foot range. The Bad Creek facility includes four reversible motor-pump/turbine-generator units.

Duke Energy's other development in the Savannah River Basin, which is located on Lake Keowee, operates as a conventional hydropower facility with two turbine-generator units. Operations are conducted to maintain reservoir elevations within a 3 to 4-foot range, and in coordination with the downstream U.S. Army Corps of Engineers (USACE) reservoirs. Drawdown is limited to 794.6 ft AMSL to maintain the lake surface above Duke Energy's Oconee Nuclear Generating Station intake.

The three downstream USACE reservoirs include Hartwell, Richard B. Russell (Russell) and J. Strom Thurmond (Thurmond). All three reservoirs provide flood storage. Hartwell follows a seasonal guide curve which varies by 4 feet and provides additional flood control during winter/spring. The Russell development includes a pumped storage facility and conventional turbines for hydropower. Russel is operated with a consistent guide curve with no seasonal drawdown. Thurmond, the most downstream development, contains seven conventional turbine-generators units. Like Hartwell, Thurmond follows a seasonal guide curve which varies by 4 feet and provides additional flood control during winter/spring

4.4 Groundwater Users and Associated Discharge

Although the Savannah 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 Savannah River Basin, only one significant industrial groundwater withdrawal was identified – Clariant, which had a corresponding, significant discharge to surface water. It is represented by a Water User object.

4.5 Georgia-Side Tributary Objects

At certain locations along the main stem of the Savannah River, new tributary objects were added to capture drainage for Georgia-side tributaries. These tributaries serve a similar function as implicit tributaries in other basins as they represent confluence flows. However, unlike implicit tributaries they provide a location for point inputs of aggregated Georgia usage and return flows. The list of Georgia-side tributaries included in the Savannah Model is provided in Section 6.

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 and reservoir operations data to best reflect past conditions in the basin. These data include time-varying river and reservoir withdrawals and consumptive use estimates and historical reservoir release and operational rules. 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 1939, the start of the hydrologic record for the Savannah 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) for most users, on a monthly basis. These monthly demands are repeated in the baseline model for each simulation year. Similarly, reservoir operations defined in the baseline model are based on current rules, guidelines, and minimum release requirements. In certain instances, future rules that are not yet in effect, can be included (and can be toggled on or off in the model). 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 primarily presents the inputs used in the baseline Savannah River Basin model, but also summarizes the major differences between the baseline and calibration 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 Savannah River Basin baseline model. 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

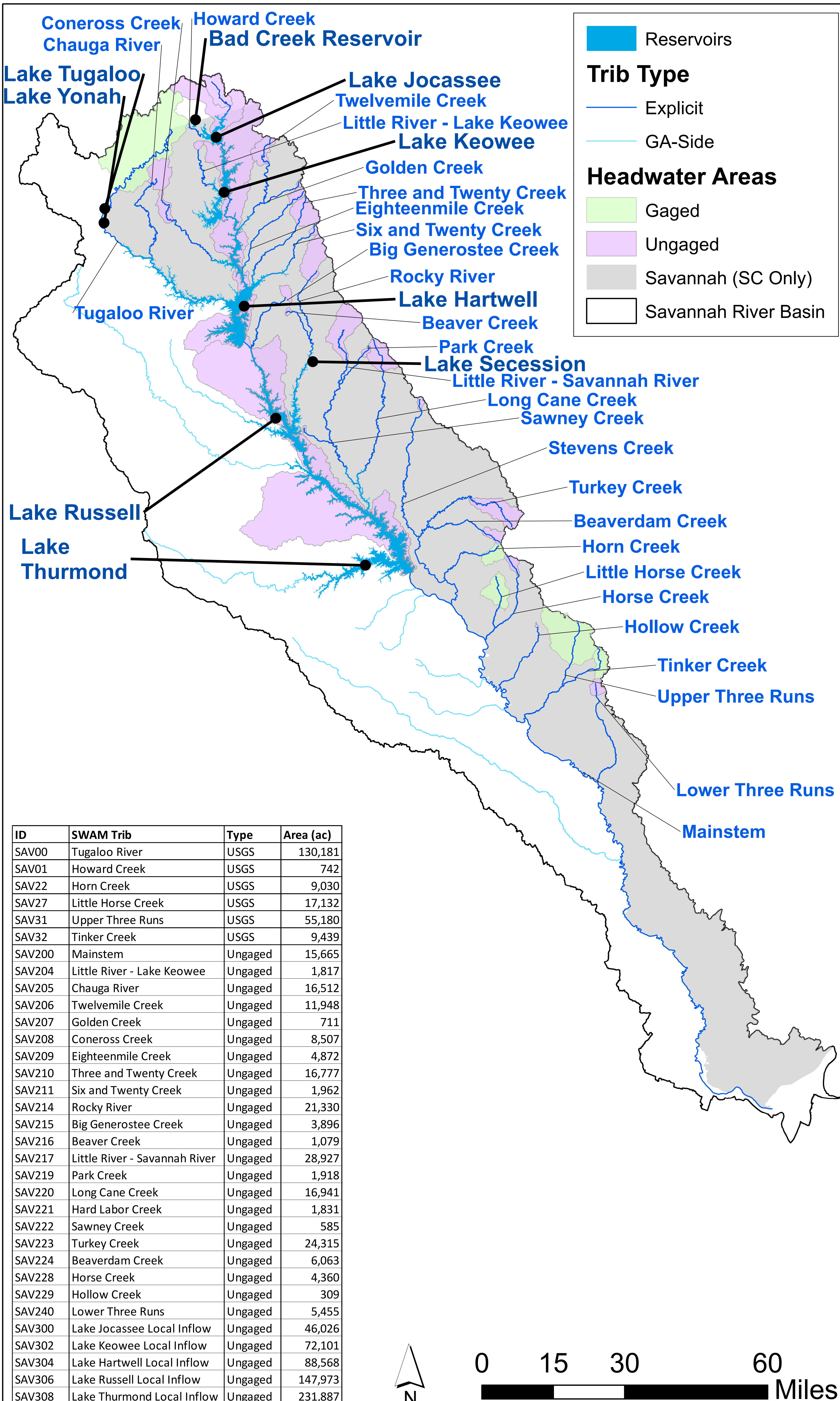
Explicit tributary objects in SWAM are tributaries that include any number of Water User objects and/or reservoir objects with operations and water use explicitly simulated in the model. Conversely, implicit tributary objects (discussed below) are treated as simple point inflows to receiving streams 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, area-prorated from calculated UIFs elsewhere in the basin, or output flows from existing models.

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.

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
SAV205	Ungaged		Chauga River	SAV00	02177000	Chattooga River
SAV200	Ungaged		Mainstem			
SAV204	Ungaged		Little River - Lake Keowee	SAV04	02185200	Little River
SAV207	Ungaged		Golden Creek	SAV06	02186000	Twelvemile Creek
SAV206	Ungaged		Twelvemile Creek			
SAV302	Ungaged		Lake Keowee Local Inflow			
SAV304	Ungaged		Lake Hartwell Local Inflow			
SAV208	Ungaged		Coneross Creek	SAV08	02186645	Coneross Creek
SAV211	Ungaged		Six and Twenty Creek	SAV09	02186699	Eighteenmile Creek
SAV210	Ungaged		Three and Twenty Creek			
SAV209	Ungaged		Eighteenmile Creek			
SAV216	Ungaged		Beaver Creek	SAV14	02187910	Rocky River
SAV215	Ungaged		Big Generostee Creek			
SAV214	Ungaged		Rocky River			
SAV222	Ungaged		Sawney Creek	SAV17	02192500	Little River
SAV220	Ungaged		Long Cane Creek			
SAV219	Ungaged		Park Creek			
SAV217	Ungaged		Little River - Savannah River			
SAV306	Ungaged		Lake Russell Local Inflow			
SAV224	Ungaged		Beaverdam Creek	SAV21	02196000	Stevens Creek
SAV223	Ungaged		Turkey Creek			
SAV221	Ungaged		Hard Labor Creek			
SAV308	Ungaged		Lake Thurmond Local Inflow			
SAV228	Ungaged		Horse Creek	SAV28	02196690	Horse Creek
SAV229	Ungaged		Hollow Creek	SAV31	02197300	Upper Three Runs
SAV240	Ungaged		Lower Three Runs	SAV32	021973005	Tinker Creek
SAV00	Gaged	02177000	Tugaloo River	-	-	-
SAV01	Gaged	02184475	Howard Creek	-	-	-
SAV22	Gaged	02196250	Horn Creek	-	-	-
SAV27	Gaged	02196689	Little Horse Creek	-	-	-
SAV31	Gaged	02197300	Upper Three Runs	-	-	-
SAV32	Gaged	021973005	Tinker Creek	-	-	-



ID	SWAM Trib	Type	Area (ac)
SAV00	Tugaloo River	USGS	130,181
SAV01	Howard Creek	USGS	742
SAV22	Horn Creek	USGS	9,030
SAV27	Little Horse Creek	USGS	17,132
SAV31	Upper Three Runs	USGS	55,180
SAV32	Tinker Creek	USGS	9,439
SAV200	Mainstem	Ungaged	15,665
SAV204	Little River - Lake Keowee	Ungaged	1,817
SAV205	Chauga River	Ungaged	16,512
SAV206	Twelvemile Creek	Ungaged	11,948
SAV207	Golden Creek	Ungaged	711
SAV208	Coneross Creek	Ungaged	8,507
SAV209	Eighteenmile Creek	Ungaged	4,872
SAV210	Three and Twenty Creek	Ungaged	16,777
SAV211	Six and Twenty Creek	Ungaged	1,962
SAV214	Rocky River	Ungaged	21,330
SAV215	Big Generostee Creek	Ungaged	3,896
SAV216	Beaver Creek	Ungaged	1,079
SAV217	Little River - Savannah River	Ungaged	28,927
SAV219	Park Creek	Ungaged	1,918
SAV220	Long Cane Creek	Ungaged	16,941
SAV221	Hard Labor Creek	Ungaged	1,831
SAV222	Sawney Creek	Ungaged	585
SAV223	Turkey Creek	Ungaged	24,315
SAV224	Beaverdam Creek	Ungaged	6,063
SAV228	Horse Creek	Ungaged	4,360
SAV229	Hollow Creek	Ungaged	309
SAV240	Lower Three Runs	Ungaged	5,455
SAV300	Lake Jocassee Local Inflow	Ungaged	46,026
SAV302	Lake Keowee Local Inflow	Ungaged	72,101
SAV304	Lake Hartwell Local Inflow	Ungaged	88,568
SAV306	Lake Russell Local Inflow	Ungaged	147,973
SAV308	Lake Thurmond Local Inflow	Ungaged	231,887

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

6.1.2 Georgia-Side Tributary Objects: Confluence Flows

Implicit tributaries are input confluence flows estimated from reference UIFs. The Savannah River Basin Model has eight tributaries which serve a similar function—confluence flows for tributaries from Georgia. While confluence flows, they are not strictly implicit as they provide a location for point inputs of aggregated Georgia usage and return flows (see Section 6.3.1). **Table 6-2** lists which unimpaired USGS gage was used as a reference gage for calculating flows for each GA-side tributary object. **Figure 6-2** shows drainage areas for the eight tributaries and the inset table provides the corresponding drainage area in acres.

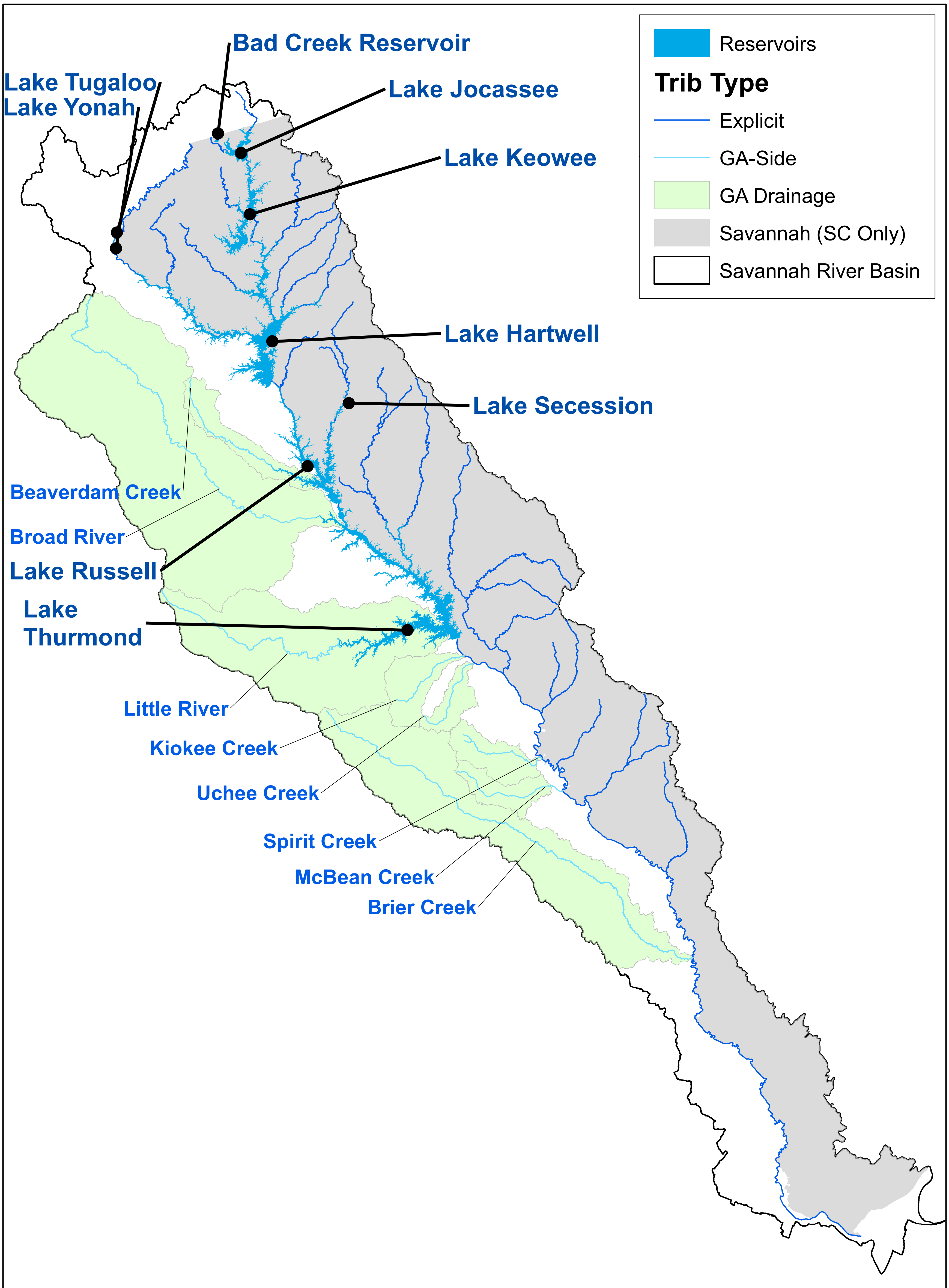
Table 6-2. Reference Gages Used for Confluence Flows on GA-Side Tributaries

	Ungaged Basin	USGS Reference Gage (Unimpaired)		
Project ID	**SWAM Tributary**	**Project Gage ID**	**USGS Number**	**Stream**
SAV402	Beaverdam Creek	SAV14	02187910	Rocky River
SAV404	Broad River	SAV17	02192500	Little River
SAV416	Brier Creek	SAV21	02196000	Stevens Creek
SAV408	Kiokee Creek			
SAV412	Spirit Creek			
SAV410	Uchee Creek			
SAV414	McBean Creek			
SAV406	Little River			

6.1.3 Reach Gains and Losses

In SWAM, mainstem gain/loss factors and tributary subbasin 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 subbasin 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, subbasin 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 subbasin 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-



ID	NAME	Area (ac)
SAV402	Beaverdam Creek	78,843
SAV404	Broad River	961,919
SAV406	Little River	491,353
SAV408	Kiokee Creek	70,936
SAV410	Uchee Creek	41,250
SAV412	Spirit Creek	66,999
SAV414	McBean Creek	55,103
SAV416	Brier Creek	543,037

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Figure 6-2
GA-Side Tributaries
in the Savannah River Basin

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 subbasin 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 highly 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 subbasin 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 subbasin 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 Reservoirs

Nine reservoirs are represented in the Savannah River Basin Model. Duke Energy owns and operates Bad Creek Reservoir, Lake Jocassee and Lake Keowee; the USACE owns and operates Lake Hartwell, Lake Russell, and Lake Thurmond; and Georgia Power owns Lake Tugaloo and Lake Yonah. Lake Secession was constructed by the City of Abbeville. **Table 6-4** provides a summary of model inputs and other information used to characterize each reservoir. Additional details and explanation for reservoir inputs are summarized in Tables 6-4. Area-capacity relationships are provided in **Table 6-5**. Reservoir operating rules are summarized in Section 6.2.4 and **Table 6-6**.

6.2.1 Evaporation

In SWAM, evaporative losses can be specified using monthly-varying seasonal rates (inches per day or percent volume) or with a user-specified timeseries of monthly or daily evaporative losses (inches per month or inches per day). In both the calibration and baseline models, evaporative losses are specified using a timeseries developed during the UIF process. Evaporation was computed using the Hargreaves method from daily temperature data and latitude, and further adjusted by pan evaporation data compiled by Purvis (undated). Temperature stations for were chosen based on proximity to pan evaporation sites. Temperature and evaporation stations used in developing evaporative loss estimated are listed in Table 6-4**.**

6.2.2 Direct Precipitation

Typically, large reservoirs in SWAM release to an explicit tributary object and have an additional tributary representing local inflow and direct precipitation. Four reservoirs, Lake Keowee, Lake Hartwell, Lake Russell, and Lake Thurmond, have direct precipitation to their surfaces that is included as part of their local inflow tributary object. The local runoff aspect of these tributary objects was estimated via area proration of an appropriate unimpaired flow.

Direct precipitation to the other six, much smaller reservoirs was considered negligible, and not explicitly included in the model. However, precipitation rates were factored into the calculation of non-negative net evaporation rates for these smaller reservoirs. In other words, when evaporation was equal to or exceeded precipitation, precipitation was subtracted from the gross evaporation rate to calculate net rates. For timesteps where precipitation exceeded evaporation, net evaporation rates were set to zero.

Table 6-3. Model Tributary Inputs

SWAM Tributary Object	Tributary Type	Confluence Stream	Confluence Location (mile)	Area (ac)	Headwater ID	End Mile	Original Drainage Ratio	Subbasin Flow Factor (unitless)
Savannah River (Mainstem)	Explicit	None	None	7,042,300	SAV200	24.0	-	0*
						65.0	-	0*
						94.0	-	0.1*
						131.5	-	0.1*
						500	-	0.1*
Beaver Creek	Explicit	Rocky River	16	10,814	SAV216	9.1	10.0	10.0
Beaverdam Creek	Explicit	Turkey Creek	17.2	27,939	SAV224	20.9	4.6	4.6
Big Generostee Creek	Explicit	Mainstem	67.2	53,042	SAV215	18.9	13.6	13.6
Chauga River	Explicit	Tugaloo River	26.1	32,623	SAV205	10	2.0	2.0
				70,760		31.4	4.3	4.3
Coneross Creek	Explicit	Mainstem	44.3	41,844	SAV208	9.8	4.9	4.9
				68,113		29.8	8.0	8.0
Eighteenmile Creek	Explicit	Mainstem	47.4	22,162	SAV209	8.6	4.5	4.5
				29,942		13.2	6.1	6.1
				38,105		25.8	7.8	7.8
Golden Creek	Explicit	Twelvemile Creek	13.9	10,243	SAV207	10	14.4	14.4
Hartwell Local Inflow	Explicit	Mainstem	64	88,568	SAV304	1	1.0	1.0
Hollow Creek	Explicit		176.2	71,317	SAV229	18.3	230.5	230.5
Horn Creek	Explicit	Stevens Creek	54.4	50,201	SAV22	19.1	5.6	5.6
Horse Creek	Explicit	Mainstem	1628.4	57,265	SAV228	11.4	13.1	13.1
				103,423		25	23.7	20.0
Howard Creek	Explicit	Mainstem	9.6	32,279	SAV01	9.7	43.5	43.5
Keowee Local Inflow	Explicit	Mainstem	23	72,101	SAV302	1	1.0	1.0
Little Horse Creek	Explicit	Horse Creek	15	29,515	SAV27	13.3	1.7	1.7
Little River - Lake Keowee	Explicit	Mainstem	23.8	46,176	SAV204	11.5	25.4	25.4
				104,996		20.2	57.8	57.8
Little River - Savannah River	Explicit	Mainstem	115	137,319	SAV217	25.6	4.3	4.3
				207,196		37.2	6.4	6.4
				382,813		61.7	7.4	7.4
Long Cane Creek	Explicit	Mainstem	45.4	146,017	SAV220	42.9	8.6	8.6
Lower Three Runs	Explicit	Mainstem	220.9	110,829	SAV240	27.9	20.3	20.3
Park Creek	Explicit	Little River - Savannah River	7.2	13,515	SAV219	11.9	7.0	7.0
Rocky River	Explicit	Mainstem	88.2	71,148	SAV214	15.6	3.3	3.3
				125,326		28.4	5.4	5.4
				178,188		50	7.8	7.8
Russell Local Inflow	Explicit	Mainstem	93	147,973	SAV306	1	1.0	1.0
Sawney Creek	Explicit	Little River - Savannah River	27.3	8,231	SAV222	8.2	14.1	14.1

SWAM Tributary Object	Tributary Type	Confluence Stream	Confluence Location (mile)	Area (ac)	Headwater ID	End Mile	Original Drainage Ratio	Subbasin Flow Factor (unitless)
Six and Twenty Creek	Explicit	Three and Twenty Creek	20.8	19,129	SAV211	9.5	9.7	9.7
				44,441		22.5	22.6	22.6
Stevens Creek	Explicit	Mainstem	144.4	159,302	SAV221	38.8	87.0	87.0
				473,486		65.7	116.1	116.1
Three and Twenty Creek	Explicit	Six and Twenty Creek	57.4	29,763	SAV210	7.2	1.8	1.8
				59,029		20.7	3.5	3.5
				105,751		31.1	3.7	3.7
Thurmond Local Inflow	Explicit	Mainstem	131	231,887	SAV308	1	1.0	1.0
Tinker Creek	Explicit	Upper Three Runs	5.1	33,657	SAV32	15	3.6	3.6
Tugaloo River	Explicit	Mainstem	56.9	178,677	SAV00	9.9	1.4	1.1
				453,959		26	3.2	1.5
				633,290		86.7	4.3	2.3
Turkey Creek	Explicit	Stevens Creek	38.8	182,705	SAV223	37.5	6.4	6.4
Twelvemile Creek	Explicit	Mainstem	35.5	66,661	SAV206	11.5	5.6	5.6
				98,972		32.9	7.4	7.4
Upper Three Runs	Explicit	Mainstem	193.1	122,486	SAV31	10.1	1.6	1.1
				157,568		29.1	2.2	2.0
Beaverdam Creek (GA)	GA-Side	Mainstem	89	78,843	SAV402	1	1.0	1.0
Brier Creek (GA)	GA-Side	Mainstem	249.5	543,037	SAV416	1	1.0	1.0
Broad River (GA)	GA-Side	Mainstem	99.5	961,919	SAV404	1	1.0	1.0
Kiokee Creek (GA)	GA-Side	Mainstem	135.3	70,936	SAV408	1	1.0	1.0
Little River (GA)	GA-Side	Mainstem	128.5	491,353	SAV406	1	1.0	1.0
McBean Creek (GA)	GA-Side	Mainstem	186.3	55,103	SAV414	1	1.0	1.0
Spirit Creek (GA)	GA-Side	Mainstem	169.6	66,999	SAV412	1	1.0	1.0
Uchee Creek (GA)	GA-Side	Mainstem	137.8	41,250	SAV410	1	1.0	1.0

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

Table 6-4. Reservoir Inputs

Reservoir	Purpose	Receiving Stream	Temperature Station for Evaporation	Evaporation Station	Precipitation Station	Release Location (mi)	Storage Capacity (MG)	Dead Pool (MG)	Operating Rules
Bad Creek Reservoir	Power	Howard Creek	Clemson USC00381770	Clemson USC00381770	Salem 5 Nine USC00387589/ Walhalla USC00388887	0.2	11,578	0	Advanced
Lake Jocassee	Power, recreation, and water supply	Mainstem	Clemson USC00381770	Clemson USC00381770	Salem 5 Nine USC00387589/ Walhalla USC00388887	10.8	406,368	0	Advanced
Lake Keowee	Power, recreation, and water supply	Mainstem	Clemson USC00381770	Clemson USC00381770	Salem 5 Nine USC00387589/ Walhalla USC00388887	24	312,578	0	Advanced
Lake Tugaloo	Power and recreation	Tugaloo River	Clemson USC00381770	Clemson USC00381770	Long Creek USC00385278/ Walhalla USC00388887	10	5,865	0	Simple
Lake Yonah	Power and recreation	Tugaloo River	Clemson USC00381770	Clemson USC00381770	Long Creek USC00385278/ Walhalla USC00388887	13	2,085	0	Advanced
Lake Hartwell	Power, recreation, and water supply	Mainstem	Clemson USC00381770	Clemson USC00381770	Clemson Univ USC00381770	65	1,237,597	369,548	Advanced
Lake Secession	Power, recreation, and water supply	Rocky River	Calhoun Falls USC00381277	Clark Hills USC00381726	Anderson USC00380165	28.4	6,308	0	Simple
Lake Russell	Power, recreation, flood control, and water supply	Mainstem	Calhoun Falls USC00381277	Clark Hills USC00381727	Calhoun Falls USC00381277	94	542,478	0	Advanced
Lake Thurmond	Power, recreation, flood control, and water supply	Mainstem	Calhoun Falls USC00381277	Clark Hills USC00381728	Calhoun Falls USC00381277	131.5	1,343,920	477,372	Advanced

Note: For all reservoirs, the "Simple" area-capacity relationship table was used.

6.2.3 Area-Capacity Relationships and Flood Control Outflow

Area-capacity relationships for the nine reservoirs are summarized in Table 6-5. The area-capacity relationships are represented in SWAM with 12 points or less, which in some cases is a simplified representation of the full tabular relationship. SWAM treats flood flows (when reservoirs are at capacity) simply as bypass flow. Generally, flood control outflow relationships are not needed, and not assigned.

Table 6-5. Reservoir Area-Capacity Relationship

Reservoir	Volume (MG)	Area (Acres)
Bad Creek Reservoir	0	0
	1,008	50
	1,880	70
	3,077	109
	5,340	181
	6,862	225
	8,677	271
	11,578	346
Lake Jocassee	10	11
	5,391	660
	18,815	1,426
	60,026	2,871
	104,499	3,951
	162,655	4,986
	275,528	6,538
	319,793	7,038
	406,368	8,138
Lake Keowee	0	1
	1,275	542
	9,465	2,020
	28,483	3,879
	42,898	4,989
	84,115	7,750
	111,974	9,382
	145,418	11,165
	184,870	13,057
	230,575	15,025
	312,578	19,465
Lake Hartwell	0	0
	146,633	10,000
	369,548	27,650
	416,959	30,500
	469,487	34,000
	527,782	37,500
	592,593	41,750
	664,444	46,000
	743,723	50,975
	830,791	55,940
	962,298	61,400
	1,237,597	77,813
Lake Russell	0	0
	114,048	8,000
	173,861	10,000
	255,733	20,000
	293,064	23,380
	334,403	25,653
	379,997	29,340
	389,648	30,555
	394,541	30,739
	421,792	31,770
	483,538	35,150
	542,478	39,451
Lake Thurmond	0	0
	146,633	15,000
	356,004	36,200
	381,246	39,000
	462,709	43,750
	521,362	49,500
	606,084	57,000
	703,839	64,250
	817,887	70,250
	944,969	78,500
	1,007,533	85,570
	1,343,920	111,065
Lake Tugaloo	0	0
	5,865	300
Lake Yonah	0	0
	2,085	200
Lake Secession	0	0
	6,308	880

6.2.4 Releases and Operating Rules

Reservoir release locations are assigned in the model based on best available information for dam and outflow locations. Actual modeled releases are calculated in the model based on prescribed operating rules and release targets (see SWAM User's Manual). Enhancements to SWAM reservoir rules now include three types of advanced operations: minimum releases, storage curves, and instream flow targets. The Savannah River Basin reservoirs operated by Duke Energy and the USACE have these advanced rules. Table 6-6 summarizes which of these three types of rules apply to each reservoir, the rule set priority, and the corresponding dates and conditions. While SWAM performs reservoir calculations in terms of volume, elevations are also displayed for ease of comparison to existing rules. Unless otherwise noted, these elevations are in the NGVD29 datum.

A "dummy" tributary object ("Weekdays") with a corresponding "dummy" flow gage ("Weekday Flow Gage") is used in the daily model to differentiate weekdays from weekend days. Rules associated with Lake Hartwell differentiate daily releases based on whether it is a weekday or weekend day. The model prevents releases from Hartwell on weekend days, which is consistent Hartwell's historical weekend operations.

6.2.5 Low Inflow Protocol

The Low Inflow Protocol (LIP) was incorporated as part of the Relicensing Agreement (RA) for the Keowee-Toxaway Project reservoirs, Jocassee and Keowee. The LIP has five stages (0 through 4) which specify how the reservoirs will be operated during drought conditions. The five stages are triggered by (1) remaining usable storage; (2) USACE Drought Plan levels; (3) composite average streamflow in three streams located in South Carolina, Georgia, and North Carolina; and (4) the US Drought Monitor. The storage index is based on remaining useable storage in Bad Creek, Jocassee, and Keowee. Because composite streamflow and the US Drought Monitor are not modeled parameters, a predetermined historical LIP timeseries based solely on the composite average streamflow in the three streams is used in the SWAM model, consistent with the modeled period of hydrology. The LIP timeseries is input as a "dummy" tributary object ("SAV LIP Stages") with a corresponding "dummy" flow gage ("SAV LIP Gage").

In the model, operating rules were added to generally mimic the effect of the LIP's specified minimum reservoir elevations (maximum drawdowns) for Jocassee and Keowee, and the maximum weekly releases from Keowee under each LIP stage. These are incorporated into the model's operating rules as summarized in Table 6-6. Note that the changes to operating rules are not conditioned upon the SAV LIP Gage, but instead on storage in the USACE reservoirs.

The LIP-specified actions that pertain to certain Water User objects include reductions in water usage. These apply to public water supply intakes (WS objects. Under Stage 1, the goal is to reduce water usage by 3-5% (or more) from the amount that otherwise would be expected. Similarly, stages 2, 3 and 4 call for 5-10%, 10-20%, and 20-30% reductions, respectively. These reductions are incorporated in SWAM using the Conservation feature, and setting Advanced Conservation Rules. An average percent reduction associated with the appropriate LIP stage is included, and is conditioned upon the SAV LIP Gage, which reads the LIP timeseries contained in the LIP tributary object.

6.2.6 Savannah River Basin Drought Management Plan

The Savannah River Basin Drought Management Plan (or DP, for short) has evolved from the initial Drought Contingency Plan established in 1989 to the current version which includes a number of modifications made primarily as a result of the droughts of 1998-2002 and 2007-2009. The DP trigger.

Table 6-6. Advanced Reservoir Rules for the Baseline Model

Reservoir	Priority	Type	Target	Months	Conditioned On:	Description
Dummy Fed Storage	1	Storage Curve (MG)	1,983,081	Jan 1 - Apr 1	None	Representative object which tracks 100% usable storage values seasonally for Russell, Thurmond, and Hartwell.
			1,983,081	Apr 2 - Oct 15	None	
			1,821,524	Oct 16 - Dec 15	None	
			1,821,524	Dec 16 - Dec 31	None	
Bad Creek Reservoir	1	Storage Curve (MG)	1,205 (2157')	Jan - Dec	Lake Keowee Storage >231,630 (90')	Storage targets set so that % usable storage mirrors that in Lake Keowee (i.e., reservoir fluctuations follow Keowee fluctuations).
			1,599 (2170')	Jan - Dec	Lake Keowee Storage >233,738 (90.5')	
			1,993 (2183')	Jan - Dec	Lake Keowee Storage >235,847 (91')	
			2,486 (2185')	Jan - Dec	Lake Keowee Storage >238,483 (91.5')	
			3,471 (2217')	Jan - Dec	Lake Keowee Storage >243,754 (92.5')	
			4456 (2234')	Jan - Dec	Lake Keowee Storage >249,025 (93.5')	
			5,441 (2251')	Jan - Dec	Lake Keowee Storage >254,297 (94.5')	
			6,426 (2264')	Jan - Dec	Lake Keowee Storage >259,568 (95.5')	
			7,411 (2276')	Jan - Dec	Lake Keowee Storage >264,840 (96.5')	
			8,396 (2287')	Jan - Dec	Lake Keowee Storage >270,111 (97.5')	
			9,381 (2296')	Jan - Dec	Lake Keowee Storage >275,382 (98.5')	
			10,366 (2305')	Jan - Dec	Lake Keowee Storage >280,654 (99.5')	
Lake Jocassee	1	Minimum Release (cfs)	47	Jan - Dec	USACE Res. Storage <0.65*	If USACE Res. usable storage is < 12%, then release replacement water for hydro seepage and leakage.
	2	Storage Curve (MG)	338,154 (78')	Jan - Dec	USACE Res. Storage <0.7*	Low storage value. Storage target set so that % storage equals USACE Res. % storage.
	3	Storage Curve (MG)	374,876 (93')	Jan - Dec	USACE Res. Storage <0.9*	Medium storage value. Storage target set so that % storage equals USACE Res. % storage.
			367,531 (90')	Jan - Dec	USACE Res. Storage <0.86*	
			360,187 (87')	Jan - Dec	USACE Res. Storage <0.82*	
			352,843 (84')	Jan - Dec	USACE Res. Storage <0.78*	
			345,498 (81')	Jan - Dec	USACE Res. Storage <0.74*	
	4	Storage Curve (MG)	389,564 (99')	Jan - Dec	USACE Res. Storage <2*	High storage value. Storage target set so that % storage equals USACE Res. % storage.
			385,892 (97')	Jan - Dec	USACE Res. Storage <0.98*	
			382,220 996')	Jan - Dec	USACE Res. Storage <0.94*	
			378,548 (94')	Jan - Dec	USACE Res. Storage <0.92*	
Lake Keowee	1	Minimum Release (cfs)	47	Jan - Dec	USACE Res. Storage <0.65*	If USACE Res. usable storage is < 12%, then release replacement water for hydro seepage and leakage.
	2	Storage Curve (MG)	243,754 (92.5')	Jan - Dec	USACE Res. Storage <0.7*	Low storage value. Storage target set so that % storage equals USACE Res. % storage.
	3	Storage Curve (MG)	270,111 (97.5')	Jan - Dec	USACE Res. Storage <0.9*	Medium storage value. Storage target set so that % storage equals USACE Res. % storage.
			264,840 (96.5')	Jan - Dec	USACE Res. Storage <0.86*	
			259,568 (95.5')	Jan - Dec	USACE Res. Storage <0.82*	
			254,297 (94.5')	Jan - Dec	USACE Res. Storage <0.78*	
			249,025 (93.5')	Jan - Dec	USACE Res. Storage <0.74*	
	4	Storage Curve (MG)	283,289 (100')	Jan - Dec	USACE Res. Storage <2*	High storage value. Storage target set so that % storage equals USACE Res. % storage.
			280,654 (99.5')	Jan - Dec	USACE Res. Storage <0.98*	
			275,382 (99')	Jan - Dec	USACE Res. Storage <0.94*	
			272,747 (98')	Jan - Dec	USACE Res. Storage <0.92*	
Lake Hartwell	1	Minimum Release (cfs)	2,000	Jan - Dec	Ratio of Hartwell & Thurmond and day of week	Matching Thurmond fluctuations through reservoir releases, triggered by relative comparison of Hartwell vs. Thurmond storage. If Hartwell is greater than 90% of Thurmond storage, release to maintain storage balance. Release target and moving trigger factor adjusted as part of model validation process. For monthly model only.
	2	Storage Curve (MG)	369,548 (625')	Jan - Dec	Thurmond Storage <477,372 (312') and day of week	Matching Thurmond fluctuations during time of drought. First 15 feet of drawdown, matching Thurmond foot for foot. Then based on %usable storage. Also, on weekends don't release anything. Subject to max release of 20,000 cfs. For daily
			1,237,597 (679')	Jan - Dec	Day of week	
	3	Storage Curve (MG)	634,824 (648')	Apr 2 - Oct 15	Thurmond Storage <572,195 (318') & day of w	Matching Thurmond fluctuations during time of drought. First 15 feet of drawdown, matching Thurmond foot for foot. Then based on %usable storage. Subject to max release of 20,000 cfs. For daily timestep only.
			540,196 (641')	Oct 16 - Dec 15	Thurmond Storage <506,699 (314') & day of w	
			540,196 (641')	Dec 16 - Dec 31	Thurmond Storage <506,699 (314') & day of w	
			634,824 (648')	Jan 1 - Apr 1	Thurmond Storage <572,195 (318') & day of w	
			606,377 (646')	Apr 2 - Oct 15	Thurmond Storage <538,307 (316') & day of w	
			369,548 (625')	Oct 16 - Dec 15	Thurmond Storage <477,372 (312') & day of w	
			369,548 (625')	Dec 16 - Dec 31	Thurmond Storage <477,372 (312') & day of w	
			606,377 (646')	Jan 1 - Apr 1	Thurmond Storage <538,307 (316') & day of w	
			407,086 (629')	Apr 2 - Oct 15	Thurmond Storage <506,699 (314') & day of w	
			369,548 (625')	Oct 16 - Dec 15	Thurmond Storage <477,372 (312') & day of w	
			369,548 (625')	Dec 16 - Dec 31	Thurmond Storage <477,372 (312') & day of w	
			407,086 (629')	Jan 1 - Apr 1	Thurmond Storage <506,699 (314') & day of w	

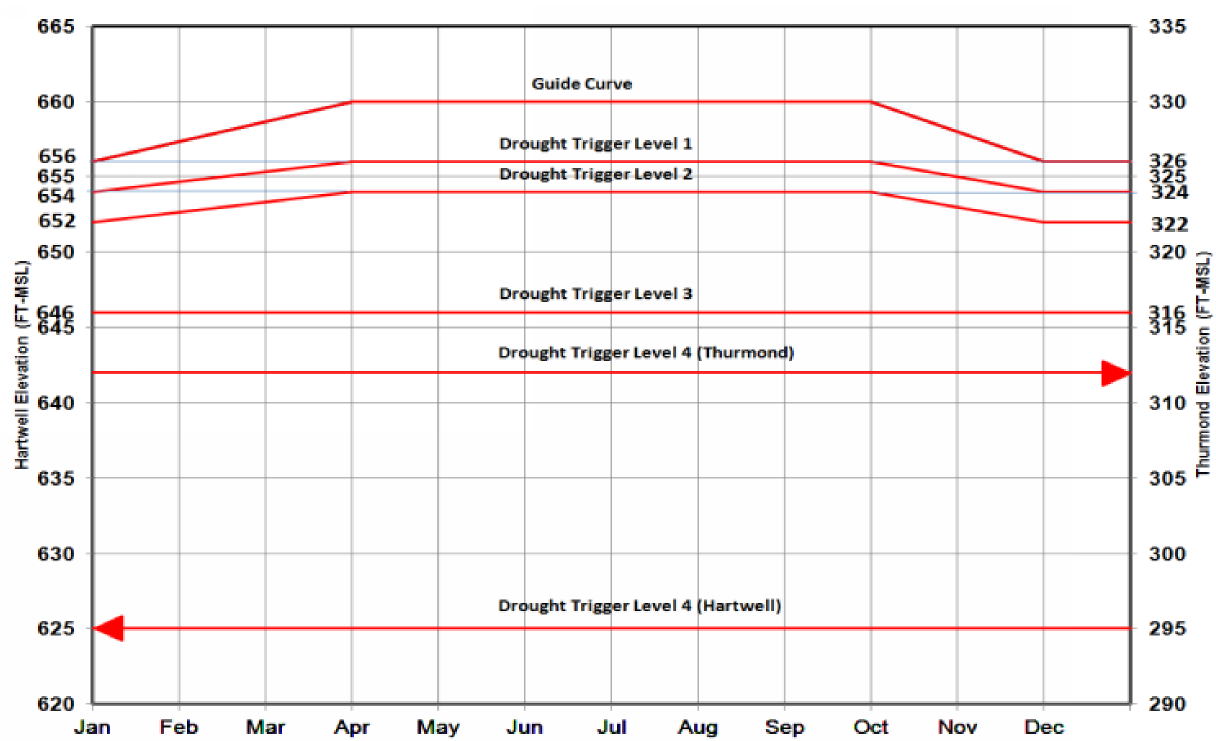
Table 6-6. Advanced Reservoir Rules for the Baseline Model (continued)

Reservoir	Priority	Type	Target	Months	Conditioned On:	Description
Lake Hartwell (continued)	4	Storage Curve (MG)	727,235 (654')	Apr 2 - Oct 15	Thurmond Storage <684,288 (324') & day of w	Matching Thurmond fluctuations during time of drought. First 15 feet of drawdown, matching Thurmond foot for foot. Then based on %usable storage. Subject to max release of 20,000 cfs. For daily timestep only.
			664,444 (650')	Oct 16 - Dec 15	Thurmond Storage <606,084 (320') & day of w	
			664,444 (650')	Dec 16 - Dec 31	Thurmond Storage <606,084 (320') & day of w	
			727,235 (654')	Jan 1 - Apr 1	Thurmond Storage <684,288 (324') & day of w	
			695,237 (652')	Apr 2 - Oct 15	Thurmond Storage <645,186 (322') & day of w	
			634,824 (648')	Oct 16 - Dec 15	Thurmond Storage <572,195 (318') & day of w	
			634,824 (648')	Dec 16 - Dec 31	Thurmond Storage <572,195 (318') & day of w	
			695,237 (652')	Jan 1 - Apr 1	Thurmond Storage <645,186 (322') & day of w	
			664,444 (650')	Apr 2 - Oct 15	Thurmond Storage <606,084 (320') & day of w	
			606,377 (646')	Oct 16 - Dec 15	Thurmond Storage <538,307 (316') & day of w	
			606,377 (646')	Dec 16 - Dec 31	Thurmond Storage <538,307 (316') & day of w	
			664,444 (650')	Jan 1 - Apr 1	Thurmond Storage <606,084 (320') & day of w	
	5	Storage Curve (MG)	830,791 (660')	Apr 2 - Oct 15	None	Normal operating guide curve. Plus conditional drawdown rules based on drawdown at Thurmond. Matching Thurmond fluctuations during time of drought. First 15 feet of drawdown, matching Thurmond foot for foot. Then based on %usable storage. Subject to max release of 20,000 cfs. For daily timestep only.
			760,472 (656')	Oct 16 - Dec 15	None	
			760,472 (656')	Dec 16 - Dec 31	None	
			830,791 (660')	Jan 1 - Apr 1	None	
			794,980 (658')	Apr 2 - Oct 15	Thurmond Storage <772,268 (328') & day of w	
			727,235 (654')	Oct 16 - Dec 15	Thurmond Storage <684,288 (324') & day of w	
			727,235 (654')	Dec 16 - Dec 31	Thurmond Storage <684,288 (324') & day of w	
			794,980 (658')	Jan 1 - Apr 1	Thurmond Storage <772,268 (328') & day of w	
			760,472 (656')	Apr 2 - Oct 15	Thurmond Storage <726,649 (326') & day of w	
			695,237 (652')	Oct 16 - Dec 15	Thurmond Storage <645,186 (322') & day of w	
			695,237 (652')	Dec 16 - Dec 31	Thurmond Storage <645,186 (322') & day of w	
			760,472 (656')	Jan 1 - Apr 1	Thurmond Storage <726,649 (326') & day of w	
Lake Russell	1	Minimum Release (cfs)	4,200	Jan - Dec	Thurmond Storage <477,372 (312')	Depletes Russell Storage and replenishes Thurmond storage, when Thurmond drops below Level 4.
	2	Storage Curve (MG)	334,403 (475')	Jan - Dec	None	Normal operating storage curve
Lake Thurmond	1	Minimum Release (cfs)	3,100	Nov 1 - Jan 31	Thurmond Storage >477,372 (312')	Minimum releases during Level 3 & 4 drought conditions. First row = Level 3 & 4, early winter, drought conditions. Second row = Level 3, rest of year, drought conditions. Third row = Level 4, rest of year, drought condition.
			3,800	Feb 1 - Oct 31	Thurmond Storage >477,372 (312')	
			3,600	Feb 1 - Oct 31	Thurmond Storage >0	
	2	Minimum Release (cfs)	4,200	Apr 2 - Oct 15	Thurm. Storage >726,649 (326') & BR28=0	Minimum releases during drought conditions. First 4 rows = normal operations. Second 4 rows = Level 1 + <BR28 drought condition. Third 3 rows = Level 2 drought condition.
			4,200	Oct 16 - Dec 15	Thurm. Storage >684,288 (324') & BR28=0	
			4,200	Dec 16 - Dec 31	Thurm. Storage >684,288 (324') & BR28=0	
			4,200	Jan 1 - Apr 1	Thurm. Storage >726,649 (326') & BR28=0	
			4,000	Apr 2 - Oct 15	Thurm. Storage >684,288 (324') & BR28=1	
			4,000	Oct 16 - Dec 15	Thurm. Storage >645,186 (322') & BR28=1	
			4,000	Dec 16 - Dec 31	Thurm. Storage >645,186 (322') & BR28=1	
			4,000	Jan 1 - Apr 1	Thurm. Storage >684,288 (324') & BR28=1	
			4,000	Feb 1 - Oct 31	Thurm. Storage >538,307 (316') & BR28=0	
			3,800	Feb 1 - Oct 31	Thurm. Storage >538,307 (316') & BR28=1	
			3,600	Nov 1 - Jan 31	Thurmond Storage >538,307 (316')	
	3	Storage Curve (MG)	817,887 (330')	Apr 2 - Oct 15	None	Normal operating storage curve, subject to max release of 30,000 cfs.
			726,649 (326')	Oct 16 - Dec 15	None	
			726,649 (326')	Dec 16 - Dec 31	None	
			817,887 (330')	Jan 1 - Apr 1	None	

** Moving trigger of fraction of total usable storage, represented by Dummy Fed storage object*

action levels and definitions are provided in **Figure 6-3**. The DP is implemented when either Hartwell or Thurmond pool elevations drop below the corresponding trigger level 1 elevation. On a rising pool, flow restrictions are lessened only after both Hartwell and Thurmond elevations are 2 feet above the trigger elevation. In the SWAM model, these rules are simplified slightly as only Thurmond elevations are used as a trigger and the same trigger level is used when the pool is rising.

In Drought Levels 1 and 2, the 28-day running average streamflow measured at the USGS Broad River gage is used to further define the weekly average release from Thurmond. The 28-day running average is compared to the 10th percentile of the historical 28-day running average for the particular day of the year. The 10th percentile is used as the breakpoint which delineates between normal and moderate drought. In the model, a timeseries is included as a "dummy" tributary object ("BR28Q10") with a corresponding "dummy" flow gage ("BR28Q10 Gage"). The time series consists of "0"s and "1"s, which specifies whether, on each day of the historical hydrologic period of record, the BR28 was above or below the 10th percentile. The reservoir rules for Thurmond read this timeseries, and set the appropriate release, when in Drought Levels 1 and 2.



Trigger Level	Time of Year	Drought Response
1	Jan 1 - Dec 31	IF BR28 > BR28Q10, Target 4200 cfs (weekly average) release at Thurmond Dam IF BR28 < BR28Q10, Target 4000 cfs (weekly average) release at Thurmond Dam
2	Feb 1 - Oct 31	IF BR28 > BR28Q10, Target 4000 cfs (weekly average) release at Thurmond Dam IF BR28 < BR28Q10, Target 3800 cfs (daily average) release at Thurmond Dam
	Nov 1 - Jan 31	Target 3600 cfs (daily average) release at Thurmond Dam
3	Feb 1 - Oct 31	Target 3800 cfs (daily average) release at Thurmond Dam
	Nov 1 - Jan 31 (Feb 1 – Feb 28 w/NMFS approval)	Target 3100 cfs (daily average) release at Thurmond Dam
4	Feb 1 - Oct 31	Target 3600 cfs (daily average) release at Thurmond Dam
	Nov 1 - Jan 31 (Feb 1 – Feb 28 w/NMFS approval)	Target 3100 cfs (daily average) release at Thurmond Dam

Figure 6-3. USACE Savannah Reservoir's Drought Trigger Action Levels and Definitions (USACE, 2012)

6.3 Water Users

6.3.1 Sources of Supply

Table 6-7 summarizes the sources of supply for all Water User objects included in the model. This information includes withdrawal tributaries (or reservoirs), diversion locations, and permit limits. All Water User objects appear in both the calibration and baseline models, with no changes in sources of supply. No users withdraw both surface water and groundwater to an extent significant enough to be included. **IN: Clariant** is sourced entirely from groundwater and appears in **Table 6-9.** Several out-of-basin sources are represented as Discharge objects (discussed below) and therefore do not appear in Table 6-7. The Georgia Environmental Protection Division (GAEPD) supplied permit information for users and return flows, which have been condensed into eight objects representing users from the Georgia portion of the Savannah River Basin. Two objects contain users aggregated by demand and to a single withdrawal point on a representative Georgia tributary, **GA: Brier Creek Use** and **GA: Broad River Use**. Similarly, **GA: Russell Use** and **GA: Thurmond Use** are aggregated Georgia users for each respective reservoir. **GA: Tugaloo-Hartwell Use** contains several users aggregated by total demand, but withdraw from several sources as Lake Yonah, Lake Hartwell, and the Tugaloo River are explicit model objects. **GA: Augusta Use** and **GA: S. Augusta Use** are on the mainstem, partitioned by relative location of calibration gages. **GA: Plant Vogtle** is a Georgia Power facility and is the only GA-side user with non-aggregated intakes or return locations. The full list of permitted users and return flow locations is listed in **Appendix H**.

6.3.2 Demands

Table 6-8 presents the monthly demand for Municipal (WS), Industrial (IN), Mining (MI), Nuclear (PN), and Thermoelectric (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 6-9**. 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 for most users, with several exceptions. **IN: Cytec** stopped withdrawing in 1994 but still has an active permit, therefore has zeroes for baseline demand. **WS: Breezy Hill**, **WS: Graniteville**, and **IN: ARJWS** did not start withdrawing until 2013, therefore only 2013 values form the baseline demands. **IN: US DOE** underwent a change in demand patterns in 2012 and as a result its baseline demands are defined by 2013 only as well. Per correspondence and recommendation from GA EPD, **GA: Plant Vogtle** has its demand represented as a net consumptive loss of 43 MGD. **WS: Pioneer**, **GC: Hickory Knob**, and **IR: Mason's Master Turf** were included in the framework but have no reported values from which baseline demands could be estimated.

In the calibration model, demands for the calibration period were input as a timeseries of monthly values based on monthly withdrawals reported to DHEC or GA EPD.

6.3.3 Transbasin Imports and Exports

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 G – Guidelines for Representing Multi-Basin Water Users in SWAM**. In the Savannah River Basin Model, several water users import water from outside the basin and exist only as a Discharge object as their water is sourced from either the Edisto or Saluda River Basins. These are **Aiken/Newberry/SCWSA Import**, **Belton Honea**, **Greenwood Import**, and **Easley Import**.

Table 6-7. Water User Objects and Sources of Supply Included in the Savannah River Basin Model

Model Object ID	Facility Name	Source of Supply	Intake ID	Diversion Location (mi)	Permit Limit (MGM)	Note
WS: Abbeville	City of Abbeville	Lake Russell/Mainstem	01WS002S01	94.0	315	1
WS: Mohawk	Mohawk Ind - Rocky River Plant	Lake Russell/Mainstem	01WS004S01	94.0	160	1
GC: Woodside	Woodside Plantation	Hollow Creek	02GC007S01	1.1	94	1
			02GC007S02		94	
GC: River Golf Club	River Golf Club - North Augusta	Mainstem	02GC008S01	152.6	30	1
GC: Sage Valley	Sage Valley Golf Club	Horse Creek	02GC012S01	4.6	NA	1
GC: The Reserve	The Reserve Club	Hollow Creek	02GC052S01	1.6	12	1
			02GC052S02		10	
IN: Kimberly-Clark	Kimberly-Clark Beech Island Mill	Mainstem	02IN003S01	157.1	1,607	1
IN: Cytec	Cytec Industries - Langley Plant	Horse Creek	02IN008S01	11.4	147	1
IN: US DOE	US DOE - Savannah River Site	Mainstem	02IN010S01	195.0	3,285	1
			02IN010S02		10,950	
			02IN010S03		10,950	
IR: Mason's Master Turf	Mason's Master Turf	Mainstem	02IR014S01	156.2	15	1,2
PT: SCE&G Urquart Station	SCE&G Urquart Station	Mainstem	02PT001S01	157.2	6,600	1
WS: Breezy Hill	Breezy Hill WTP	Little Horse Creek	02WS005S01	4.9	1,674	1
WS: North Augusta	City of North Augusta WTP	Mainstem	02WS007S01	150.4	583	1
			02WS007S02		1,302	
WS: Graniteville	Graniteville Water Treatment Facility	Horse Creek	02WS029S01	7.1	620	1
	WG Development LLC	Horse Creek	02WS030S01	3.5	122	1
IN: MT Vernon Mills	MT Vernon Mills La France	Three and Twenty Creek	04IN017S01	12.1	21	1
MI: Hanson Aggregates	Hanson Aggregates - Anderson Facility	Beaver Creek	04MI002S01	3.1	29	1
PT: SC Rainey Station	Santee Cooper Rainey Generating Station	Mainstem	04PT002S01	68.0	509	1
IN: ARJWS	South Anderson Water Supply Intake	Lake Hartwell/Mainstem	04IN051S01	65.0	806	1
WS: ARJWS	Anderson Regional JWS	Lake Hartwell/Mainstem	04WS006S01	65.0	NA	1
WS: BJW&SA	Beaufort Jasper Water & Sewer Authority	Mainstem	07WS005S01	308.8	4,836	1
IR: WG Smith	WG Smith III	Turkey Creek	19IR012S01	5.4	8	1,2
IR: Gurosik Farm	Gurosik Farm	Stevens Creek	19IR055S01	56.9	23	1,2
			19IR055S02		2	1,2
			19IR055S03		13	1,2
			19IR055S04		18	1,2
WS: ECW&SA	Edgefield County W&S Authority	Mainstem	19WS001S01	144.9	698	1
GC: Keowee Falls	Cliffs Club At Keowee Falls	Lake Keowee/Mainstem	23GC015S01	24.0	30	1
WS: Greenville	Greenville Water System Adkins Treatment Plant	Lake Keowee/Mainstem	23WS007S01	24.0	4,650	1
IR: Youmans Farm	Youmans Alex Farm	Mainstem	25IR022S01	285.5	NA	1,2
			25IR022S02		NA	1,2
GC: Hickory Knob	Hickory Knob State Park	Lake Thurmond/Mainstem	35GC002S01	131.5	NA	1
GC: Savannah Lakes	Savannah Lakes Village POA	Lake Thurmond/Mainstem	35GC003S01	131.5	54	1

Model Object ID	Facility Name	Source of Supply	Intake ID	Diversion Location (mi)	Permit Limit (MGM)	Note
			35GC003S02		54	1
WS: McCormick	McCormick Water Treatment Plant	Lake Thurmond/Mainstem	35WS001S01	131.5	89	1
GC: Keowee Key	Keowee Key Golf Club	Lake Keowee/Mainstem	37GC001S01	24.0	45	1
IR: Holcombe Farm	Holcombe Farm	Little River - Lake Keowee	37IR005S01	1.5	10	1,2
IR: Head Lee Nursery	Head Lee Nursery	Coneross Creek	37IR011S02	7.5	282	1,2
IR: Shirley Farm	Shirley Farm	Tugaloo River	37IR057S01	49.5	NA	1,2
IR: Calyx Farm	Calyx Farm	Little River - Lake Keowee	37IR058S01	11.0	29	1,2
PN: Oconee	Oconee Nuclear Station	Lake Keowee/Mainstem	37PN001S01	24.0	94,817	1
			37PN001S02		68	1
WS: Pioneer	Pioneer Rural Water - WTP	Lake Hartwell/Mainstem	37WS001S01	65.0	233	1
WS: Walhalla	City of Walhalla WTP	Coneross Creek	37WS002S01	0.1	93	1
			37WS002S02		24	1
WS: Westminster	City of Westminster WTP	Chauga River	37WS003S01	18.7	124	1
WS: Seneca	City of Seneca WTP	Lake Keowee/Mainstem	37WS004S01	24.0	930	1
GC: Keowee Springs	Cliffs Club At Keowee Springs	Lake Keowee/Mainstem	39GC007S01	24.0	17	1
GC: Walker	Walker Course at Clemson University	Lake Hartwell/Mainstem	39GC008S01	65.0	36	1
			39GC008S02		12	1
GC: Keowee Vineyards	Cliffs Club At Keowee Vineyards	Lake Keowee/Mainstem	39GC009S01	24.0	-	1
GC: Reserve at Keowee	The Reserve At Lake Keowee	Lake Keowee/Mainstem	39GC010S01	24.0	62	1
IN: Vulcan	Vulcan Contruction Materials	Golden Creek	39IN007S01	2.1	63	1
IN: Milliken	Milliken Pendleton Plant	Eighteenmile Creek	39IN008S01	13.3	78	1
IN: Clemson Energy	Clemson University Central Energy Plant	Lake Hartwell/Mainstem	39IN010S01	65.0	563	1
IN: Shaw	Shaw Industries Group	Twelvemile Creek	39IN013S01	17.2	103	1
WS: Easley Central WD	Easley Central Water District	Twelvemile Creek	39WS003S01	15.3	93	1
WS: Pickens	City of Pickens WTP	Twelvemile Creek	39WS005S01	0.1	159	1
			39WS005S02		60	1
GA: Brier Creek Use	Multiple	Brier Creek	Multiple	0.5	289	1,3
GA: Broad River Use	Multiple	Broad River	Multiple	0.5	205	1,3
GA: Tugaloo-Hartwell Use	Multiple	Lake Yonah/Tugaloo River	Multiple	13	304	1,3
		Lake Hartwell/Mainstem	Multiple	65	213	1,3
		Tugaloo River	Multiple	26	608	1,3
GA: Augusta Use	Multiple	Mainstem	Multiple	165	3934	1,3
GA: S. Augusta Use	International Paper Corporation - Augusta Mill	Mainstem	121-0191-02	169	2189	1,3
GA: Plant Vogtle	Georgia Power Co - Plant Vogtle	Mainstem	017-0191-05	199	2584	1,3
GA: Russell Use	Multiple	Lake Russell/Mainstem	Multiple	94	164	1,3
GA: Thurmond Use	Multiple	Lake Thurmond/Mainstem	Multiple	131.5	482	1,3

Note 1 indicates the withdrawal is currently active, and was included in both the baseline and calibration model.

Note 2 indicates registered limit for irrigation.

Note 3 indicates a GA-Side object of aggregated GA water use

Aiken/Newberry/SCWSA Import represents transbasin flows from multiple users in both the Edisto and Saluda River Basins sent to a single treatment facility at Horse Creek WWTF (SC0024457-001).

There are also exports of water from the Savannah River Basin to the Saluda, Broad, Edisto and Salkehatchie river basins. These include **WS: Greenville**, which exports water to the Saluda and Broad; **WS: ARJWS**, which exports water to the Saluda; **WS: ECW&SA**, which exports to the Edisto; and **WS: BJW&SA**, which exports to the Salkehatchie. The model specifies return flow locations for this exported water to the mainstem, at node locations below the last object in the model.

6.3.4 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 (calculated return flows) or specified within a Discharge object (prescribed discharges). **Table 6-10** 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., all pipes for **PN: Oconee** returns were combined). No returns are assumed for golf course and agricultural irrigation (i.e., 100% consumptive use).

Table 6-11 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 or GA EPD-reported withdrawals and discharges over the baseline period (2004 through 2013). Multiple users share common associated wastewater treatment facilities, which in each case reported discharge was split accordingly amongst the users to account for respective consumptive use. For example, **WS: Seneca**, **WS: Westminster**, and **WS: Walhalla** all have return flows at Coneross Creek WWTF (SC0033553-001).

Multiple users have a general use discharge permit (e.g., **IN: Vulcan**), which have flows that do not require reporting to DHEC. Instead, returns for these water users are defined by the estimated percent of return flow indicated in its surface water withdrawal permit.

Table 6-12 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). **Aiken/Newberry/SCWSA Import** does not reflect the raw averages from Horse Creek WWTF, but the remaining discharge after accounting for consumptive use from the in-basin users **WS: North Augusta**, **WS: Breezy Hill**, and **WS: ECW&SA**.

6.5 Summary

This section has presented the form and numerical values of data that are input into the Savannah 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 Savannah River Basin model, these calibration inputs only included reach hydrologic gain/loss factors and, to a very limited extent, reservoir operating rule targets.

Table 6-8. Baseline Model Average Monthly Demand for IN, MI, PT, PN, and WS Water Users

Baseline Model Average Monthly Demand (MGD)													
Water User	Permit Limit (MGD)	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
WS: Abbeville	10.4	1.9	1.9	1.9	2.0	2.2	2.3	2.3	2.4	2.3	2.2	2.0	1.8
WS: Mohawk	5.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.2	0.2
IN: Kimberly-Clark	52.9	7.3	7.7	7.3	6.8	7.7	7.4	7.9	8.1	8.7	8.7	7.2	8.1
IN: Cytec	4.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
IN: US DOE	828.5	9.6	9.9	9.9	9.9	9.7	9.8	9.8	10.3	10.0	9.7	9.8	10.0
PT: SCE&G Urquart Station	217.1	155.6	135.7	115.1	137.9	145.8	189.7	208.5	217.3	174.8	136.8	124.7	117.3
WS: Breezy Hill	55.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0	0.8	0.8	0.8	0.6
WS: North Augusta	62.0	3.0	3.0	3.3	4.3	5.4	5.8	5.7	5.4	5.2	4.4	3.5	3.0
WS: Graniteville	24.4	9.9	9.5	9.8	8.3	10.0	10.0	10.0	10.0	10.0	10.0	10.3	10.0
IN: MT Vernon Mills	0.7	0.1	0.2	0.2	0.1	0.1	0.2	0.1	0.2	0.2	0.2	0.1	0.1
MI: Hanson Aggregates	1.0	0.0	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.0	0.0	0.0
PT: SC Rainey Station	16.7	0.6	0.6	0.8	0.9	1.3	1.8	1.9	2.1	1.8	1.3	0.9	0.8
IN: ARJWS	26.5	0.2	0.4	0.5	2.0	1.8	3.9	3.8	3.6	3.9	3.8	3.6	5.7
WS: ARJWS	NA	16.4	16.7	16.6	18.1	19.7	21.3	21.5	21.3	20.4	18.6	18.8	16.1
WS: BJW&SA	159.1	19.2	19.7	18.4	22.2	27.5	28.9	29.4	27.0	27.9	25.3	23.2	20.7
WS: ECW&SA	22.9	3.5	3.5	3.7	4.5	5.2	5.5	5.4	5.3	5.0	4.5	4.0	3.5
WS: Greenville	153.0	21.6	21.4	21.1	24.1	26.7	29.8	28.6	27.9	27.2	25.7	24.0	22.5
WS: McCormick	2.9	1.0	1.0	1.0	1.1	1.2	1.3	1.3	1.3	1.2	1.1	1.0	1.0
PN: Oconee	3121.2	2329	2150	1973	2056	2239	2696	3013	3045	3038	2583	2187	2535
WS: Pioneer	7.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
WS: Walhalla	3.8	1.6	1.6	1.5	1.6	1.7	1.8	1.8	1.8	1.7	1.7	1.6	1.6
WS: Westminster	4.1	1.8	1.7	1.8	2.0	2.2	2.4	2.5	2.4	2.2	2.0	1.7	1.8
WS: Seneca	30.6	5.8	5.7	5.5	6.0	6.6	7.3	7.6	7.5	7.0	6.4	6.0	5.7
IN: Vulcan	2.1	0.0	0.0	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.0	0.0
IN: Milliken	2.6	1.0	1.1	1.0	1.1	1.1	1.2	1.0	1.1	1.1	1.1	1.1	1.0
IN: Clemson Energy	18.5	0.5	0.2	0.4	3.3	7.3	10.4	9.8	9.6	8.7	6.5	2.7	0.8
IN: Shaw	3.4	0.3	0.3	0.3	0.3	0.3	0.4	0.4	0.3	0.4	0.3	0.3	0.3
WS: Easley	0.0	1.1	1.0	1.0	1.1	1.2	1.3	1.3	1.3	1.3	1.3	1.2	1.1
WS: Pickens	7.2	1.7	1.7	1.7	1.7	1.7	1.8	1.9	1.8	1.7	1.5	1.6	1.6
IN: Clariant	NA	2.1	1.8	2.1	1.8	2.1	2.1	2.2	2.2	2.1	2.0	1.9	1.8
GA: Brier Creek Use	9.5	5.2	5.3	5.2	5.1	4.5	4.2	4.0	4.5	4.3	4.1	4.4	5.1
GA: Broad River Use	6.7	2.5	2.6	2.5	2.6	2.9	3.1	3.1	3.0	2.9	2.7	2.6	2.5
GA: Tugaloo-Hartwell Use	37.0	7.6	6.8	7.2	7.5	8.0	8.8	9.4	9.4	8.7	7.7	7.3	7.0
GA: Augusta Use	129.4	49.1	49.0	51.4	58.9	66.1	66.5	67.4	66.1	64.8	59.6	55.3	50.8
GA: S. Augusta Use	72.0	52.8	52.9	52.3	51.8	53.5	54.0	54.6	55.8	54.6	53.5	54.1	52.4
GA: Plant Vogtle	85.0	43.0	43.0	43.0	43.0	43.0	43.0	43.0	43.0	43.0	43.0	43.0	43.0
GA: Russell Use	5.4	1.4	1.5	1.5	1.5	1.6	1.7	1.7	1.7	1.6	1.6	1.5	1.4
GA: Thurmond Use	15.9	4.4	4.6	5.0	5.3	6.4	7.0	7.3	7.0	6.7	5.7	5.1	4.7

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

Table 6-9. Baseline Model Average Monthly Demand for GC and IR Water Users

Baseline Model Average Monthly Demand (MGD)												
Water User	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**
IR: Mason's Master Turf	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
IR: WG Smith	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
IR: Gurosik Farm	0.05	0.05	0.14	0.21	0.12	0.14	0.08	0.06	0.05	0.21	0.03	0.04
IR: Youmans Farm	0.00	0.00	0.00	0.00	0.00	0.03	0.06	0.08	0.11	0.32	0.34	0.07
IR: Holcombe Farm	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
IR: Head Lee Nursery	0.20	0.23	0.31	0.56	0.58	0.64	0.62	0.62	0.61	0.59	0.53	0.29
IR: Shirley Farm	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.01	0.00	0.00	0.00	0.00
IR: Calyx Farm	0.01	0.01	0.01	0.02	0.02	0.03	0.03	0.03	0.03	0.02	0.02	0.01
GC: Woodside	0.00	0.03	0.08	0.16	0.47	0.61	0.57	0.50	0.39	0.22	0.11	0.02
GC: River Golf Club	0.01	0.01	0.04	0.09	0.15	0.11	0.13	0.11	0.13	0.11	0.05	0.01
GC: Sage Valley	0.01	0.04	0.14	0.24	0.27	0.31	0.32	0.22	0.26	0.20	0.09	0.02
GC: The Reserve	0.10	0.18	0.22	0.26	0.41	0.50	0.51	0.50	0.58	0.55	0.17	0.07
GC: Keowee Falls	0.01	0.03	0.07	0.14	0.27	0.46	0.35	0.34	0.30	0.12	0.05	0.02
GC: Hickory Knob	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
GC: Savannah Lakes	0.01	0.02	0.05	0.10	0.21	0.24	0.25	0.27	0.21	0.08	0.03	0.01
GC: Keowee Key	0.00	0.00	0.02	0.06	0.10	0.13	0.14	0.14	0.11	0.08	0.02	0.00
GC: Keowee Springs	0.01	0.02	0.09	0.16	0.22	0.24	0.22	0.23	0.24	0.12	0.03	0.01
GC: Walker	0.00	0.01	0.05	0.13	0.23	0.25	0.28	0.26	0.24	0.10	0.03	0.00
GC: Keowee Vineyards	0.01	0.02	0.04	0.08	0.16	0.24	0.31	0.24	0.20	0.11	0.04	0.01
GC: Reserve at Keowee	0.00	0.15	0.19	0.31	0.47	0.60	0.51	0.51	0.50	0.21	0.07	0.03

Table 6-10. Returns and Associated Model Objects

Model Object ID	Facility Name	NPDES Pipe ID	Associated Water Permit	Discharge Tributary	Model River Mile	% of Return Flow
Returns Represented Within Water User Objects						
WS: Abbeville	Sage Auto Interiors/Abbeville Plant	SC0000353-001	01WS002	Long Cane Creek	15.3	76
	Abbeville/Long Cane Creek	SC0040614-001				
	Calhoun Falls, Town Of	SC0025721-001		Sawney Creek	0.1	24
WS: Mohawk	Mohawk Ind/Rocky River Plant	SC0000299-001	01WS004	Rocky River	43.2	100
IN: Kimberly-Clark	Kimberly-Clark/Beech Island	SC0000582-001	02IN003	Mainstem	158.8	100
IN: Cytec	Cytec Industries Inc	SC0039730-001	02IN008	Horse Creek	11.5	100
IN: US DOE	US DOE/Savannah River Site	SC0000175-A01, A11, A1A, H02, M05	02IN010	Upper Three Runs	10.0	5
	US DOE/Savannah River Site	SC0000175-TH1, TH2		Upper Three Runs	10.7	0.2
	Ameresco SRS Biomass Cogeneration Facility	SC0049107-G05				
	US DOE/Savannah River Site	SC0000175-X08		Mainstem	195.8	72
	US DOE/SRS/D-Area Powerhouse	SC0047431-01D, D06, 01C, D01				
	US DOE/Savannah River Site	SC0000175-F08, H12, K18, L07		Mainstem	200.0	22.8
PT: SCE&G Urquart Station	SCE&G/Urquhart Steam Station	SC0000574	02PT001	Mainstem	157.3	100
IN: MT Vernon Mills	Mount Vernon Mills/LaFrance	SC0000485-001	04IN017	Three and Twenty Creek	12.9	100
IN: ARJWS	First Quality Tissue SE LLC	SC0049115-001	04IN051	Big Generostee Creek	5.2	100
MI: Hanson Aggregates	Hanson Aggregates-Anderson Facility	SCG730222	04MI002	Beaver Creek	3.2	100
PT: Santee Cooper - Rainey	SCPSA/John Rainey Gen Station	SC0048135-001	04PT002	Mainstem	68.1	100
WS: ARJWS	Clemson/Cochran Road WWTP	SC0020010-001	04WS006	Twelvemile Creek	21.4	8
	Pickens CO PSC/Central-North	SC0024996-001				
	Anderson/Generostee Creek	SC0023752-001		Big Generostee Creek	4.1	39
	Anderson/Rocky River	SC0023744-001		Rocky River	7.6	36
	Clemson University WWTF	SC0034843-001		Mainstem	37.7	7
	Pendleton-Clemson Reg. WWTF	SC0035700-001		Eighteenmile Creek	14.8	10
WS: BJW&SA	BJW&SA/Hardeeville Church Road	SC0034584-001	07WS005	Mainstem	314	51
	BJW&SA/Cherry Point WWTP	SC0047279				
	BJW&SA/Port Royal Wtr Recl Fac	SC0048348-001		**Out of Basin (Salkehatchie)**	**1000**	49
	US Marine Corps Air Station	SC0000825-001				
WS: North Augusta/ WS: Breezy Hill/ WS: ECW&SA	Aiken PSA/Horse Creek WWTF	SC0024457-001	02WS007/ 02WS005/ 19WS001	Mainstem	155.6	100/ 100/ 58
WS: ECW&SA	ECW&SA/Brooks Street WWTP	SC0025330-001	19WS001	Beaverdam Creek	0.2	18
	ECW&SA/Johnston #1 Plant	SC0025691-001		**Out of Basin (Edisto)**	**1001**	24
WS: Greenville	Witty Adkins WTP	SCG646049	23WS007	Mainstem	21.9	7
	ReWa/Mauldin Road	SC0041211-001		**Out of Basin (Saluda/Broad)**	**1002**	93
	ReWa/Lower Reedy River Plant	SC0002461-001				
	ReWa/Georges Creek	SC0047309-001				

Model Object ID	Facility Name	NPDES Pipe ID	Associated Water Permit	Discharge Tributary	Model River Mile	% of Return Flow
	ReWa/Durbin Creek	SC0040002-001				
	ReWa/Gilder Creek	SC0040525-001				
	ReWa/Pelham WWTF	SC0033804-001				
WS: McCormick	Town of McCormick WTP	SCG646029	35WS001	Stevens Creek	27	100
	McCormick/Rocky Creek WWTF	SC0030783-001				
PN: Oconee	Duke Energy/Oconee Nuclear	SC0000515	37PN001	Little River- Lake Keowee	19.6	100
WS: Pioneer	Lake Hartwell WTP	SCG646068	37WS001	Tugaloo River	44.5	100
WS: Walhalla	Coneross Creek Water Treatment Facility	SCG641004	37WS002	Coneross Creek	0.2	2
WS: Walhalla/ WS: Seneca/ WS: Westminster	Oconee CO/Coneross Creek WWTF	SC0033553-001	37WS002/ 37WS004/ 37WS003	Coneross Creek	9.8	98/ 100/ 100
IN: Vulcan	Vulcan Materials Liberty Quarry	SCG730065	39IN007	Golden Creek	2.8	100
IN: Milliken	Milliken/Pendleton Plant	SC0000477-001	39IN008	Eighteenmile Creek	13.4	100
IN: Clemson Energy	Clemson Univ/Central Energy	SC0022004-001	39IN010	Mainstem	36.9	100
IN: Shaw	Shaw Industries Group/Clemson	SC0000302	39IN013	Twelvemile Creek	17.8	100
WS: Pickens	Pickens/12 Mile Rv & Wolf Crk	SC0047716-001	39WS005	Twelvemile Creek	5.1	100
IN: Clariant	Clariant Corp/Martin Plant	SC0042803	03IN001G	Mainstem	224.0	100
Transbasin Imports Represented by Discharge Objects						
Aiken/Newberry/ SCWSA Import	Aiken PSA/Horse Creek WWTF	SC0024457-001	02WS002	Mainstem	155.9	-
			36WS001			-
			41WS003			-
Belton Honea Import	Due West WWTF	SC0022403-001	04WS005	Park Creek	0.2	-
Greenwood Import	Greenwood/West Alexander WWTF	SC0022870-001	24WS001	Stevens Creek	0.2	-
Easley Import	Easley/Golden Creek Lagoon	SC0023035-001	39WS001	Golden Creek	0.4	-
In-basin Returns Represented by Individual or Aggregated Discharge Objects						
Pickens Roper	Pickens CO-Liberty/Roper	SC0026191-001	-	Twelvemile Creek	5.2	-
Pickens Middle	Pickens CO/Middle Reg. WWTF	SC0047856-001	-	Eighteenmile Creek	10.2	-
Pickens Eighteen	Pickens CO/Eighteen Mile Crk	SC0042994-001	-	Eighteenmile Creek	2.1	-
Owens Materials	Owens Corning Composite Materials/Anderson	SC0000400-001	-	Beaver Creek	0.1	-
WP Prop Clemson	WP Prop Clemson/Clemson Fin Pl	SC0000591-001	-	Mainstem	40.0	-
Key Utility	Keowee Key Utility Systems Inc	SC0022322-001	-	Mainstem	17.0	-
Michelin	Michelin N America/Sandy Sprgs	SC0026701-001	-	Three and Twenty Creek	13.1	-
SC Minerals	SC Minerals Inc/N Augusta Mine	SC0027529-001	-	Horse Creek	16.4	-
Allendale	Allendale WWTF	SC0039918-001	-	Mainstem	231.0	-
US Army	US Army/J Strom Thurmond PWRPL	SC0047317-001	-	Mainstem	131.6	-

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

Table 6-11. Baseline Model Monthly Consumptive Use Percentage

Baseline Model Average Monthly Consumptive Use (%)												
Water User	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**
WS: Abbeville	22.1	20.8	23.2	31.9	40.2	45.4	43.8	47.6	47.2	46.0	39.1	27.2
WS: Mohawk	29.0	23.5	28.7	40.9	51.7	53.8	56.4	56.2	48.6	44.3	33.9	35.0
IN: Kimberly-Clark	11.2	11.9	9.2	7.9	7.3	12.4	13.8	6.9	5.8	6.6	10.8	16.3
IN: Cytec	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	90.0
IN: US DOE	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
PT: SCE&G Urquart Station	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
WS: Breezy Hill	0.0	0.0	0.0	0.0	0.0	0.0	0.0	80.8	80.8	80.8	80.8	80.8
WS: North Augusta	44.0	44.0	44.0	44.0	44.0	44.0	44.0	44.0	44.0	44.0	44.0	44.0
WS: Graniteville	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
IN: MT Vernon Mills	62.7	62.2	58.6	58.8	59.0	63.1	65.7	62.4	59.6	52.9	61.5	65.1
MI: Hanson Aggregates	15.0	15.0	15.0	15.0	15.0	15.0	15.0	15.0	15.0	15.0	15.0	15.0
PT: SC Rainey Station	60.1	52.1	60.8	70.9	74.8	86.4	86.3	86.2	86.0	76.6	71.6	63.7
IN: ARJWS	0.0	0.0	0.0	31.5	12.1	64.6	64.3	59.1	58.9	57.7	47.9	62.0
WS: ARJWS	45.1	44.9	42.9	51.6	60.0	61.2	60.3	60.7	59.7	58.5	58.3	44.0
WS: BJW&SA	67.9	67.7	66.2	69.6	73.2	73.7	73.7	72.2	73.2	71.7	70.8	67.8
WS: ECW&SA	66.6	64.6	62.7	66.9	71.2	73.2	72.3	72.3	73.6	73.2	71.9	68.8
WS: Greenville	42.0	42.0	42.0	42.0	42.0	42.0	42.0	42.0	42.0	42.0	42.0	42.0
WS: McCormick	29.5	20.1	21.8	34.4	46.8	50.6	46.8	46.5	48.5	41.6	34.1	29.0
PN: Oconee	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
WS: Pioneer	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
WS: Walhalla	76.5	76.5	76.5	76.5	76.5	76.5	76.5	76.5	76.5	76.5	76.5	76.5
WS: Westminster	87.0	87.0	87.0	87.0	87.0	87.0	87.0	87.0	87.0	87.0	87.0	87.0
WS: Seneca	60.1	60.9	57.3	67.1	73.2	74.6	73.7	74.7	72.0	71.5	67.4	59.1
IN: Vulcan	90.0	90.0	90.0	90.0	90.0	90.0	90.0	90.0	90.0	90.0	90.0	90.0
IN: Milliken	36.1	31.5	30.7	31.9	31.8	31.4	31.3	36.6	33.5	37.9	42.2	42.9
IN: Clemson Energy	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
IN: Shaw	59.1	57.2	55.3	62.6	54.0	55.4	59.0	51.1	59.6	62.8	57.2	54.6
WS: Easley	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
WS: Pickens	81.4	82.9	80.0	83.0	83.7	85.0	85.2	84.5	81.9	83.8	82.9	78.7
IN: Clariant	10.9	9.7	6.2	8.7	9.3	7.1	14.7	13.5	6.2	7.0	7.9	7.1
GA: Brier Creek Use	42.7	31.7	21.8	34.5	38.0	25.5	30.8	34.9	27.5	47.6	48.0	32.1
GA: Broad River Use	36.1	34.0	33.9	45.9	55.5	57.8	58.4	54.8	53.8	50.6	57.7	43.7
GA: Tugaloo-Hartwell Use	74.2	72.6	73.1	74.6	77.7	78.7	80.4	79.9	77.0	79.9	77.1	72.6
GA: Augusta Use	8.6	4.4	6.3	23.3	36.0	29.9	32.9	30.6	31.9	31.1	25.2	12.6
GA: S. Augusta Use	10.0	8.3	8.5	9.1	15.6	11.0	10.3	10.4	10.5	20.2	11.8	10.1
GA: Plant Vogtle	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
GA: Russell Use	26.5	26.3	25.3	20.3	16.1	14.6	14.7	14.2	17.2	19.1	20.8	26.7
GA: Thurmond Use	61.5	73.9	54.7	63.9	85.1	81.0	71.9	80.6	76.6	66.2	77.0	67.2

Table 6-12. Baseline Model Monthly Return Flows for Discharge Objects

Monthly Return Flow (MGD)							
Month	Pickens Roper	Pickens Middle	Pickens Eighteen	Owens Materials	WP Prop Clemson	Key Utility	Michelin
Jan	0.2	0.3	0.3	0.1	0.0	0.2	0.2
Feb	0.2	0.3	0.3	0.1	0.0	0.2	0.2
Mar	0.2	0.3	0.3	0.1	0.0	0.2	0.2
Apr	0.2	0.3	0.3	0.1	0.1	0.2	0.2
May	0.2	0.3	0.2	0.1	0.0	0.2	0.2
Jun	0.2	0.3	0.3	0.1	0.0	0.2	0.2
Jul	0.2	0.3	0.2	0.1	0.0	0.2	0.2
Aug	0.2	0.3	0.3	0.1	0.0	0.2	0.2
Sep	0.2	0.4	0.2	0.1	0.0	0.2	0.2
Oct	0.2	0.3	0.2	0.1	0.0	0.2	0.2
Nov	0.2	0.3	0.2	0.1	0.0	0.2	0.2
Dec	0.2	0.3	0.3	0.1	0.0	0.2	0.2
Month	SC Minerals	Allendale	US Army	Aiken/ Newberry/ SCWSA Import	Belton Honea Import	Greenwood Import	Easley Import
Jan	0.3	1.3	0.5	7.7	0.1	1.2	0.2
Feb	0.3	1.8	0.5	8.3	0.1	1.3	0.1
Mar	0.3	1.8	0.5	8.2	0.1	1.3	0.1
Apr	0.3	1.6	0.5	7.0	0.1	1.2	0.1
May	0.3	1.2	0.6	5.7	0.1	1.2	0.1
Jun	0.3	1.2	0.6	6.2	0.1	1.2	0.1
Jul	0.3	1.1	0.6	5.9	0.1	1.2	0.1
Aug	0.3	1.3	0.6	6.0	0.1	1.2	0.1
Sep	0.2	1.1	0.6	5.8	0.1	1.1	0.1
Oct	0.2	0.9	0.6	6.1	0.1	1.1	0.1
Nov	0.3	0.9	0.5	6.6	0.1	1.1	0.1
Dec	0.3	1.1	0.5	7.4	0.1	1.2	0.2

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, 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 primary objective in the SWAM calibration process is to verify that the model accurately represents water availability throughout the basin by testing (individually and collectively) the ungaged flow estimates, the combination of flows, and the simulated water uses and management strategies. 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: reservoir operational rules, 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, and reservoir operating rules. 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 subbasin 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 reservoir operating rules, consumptive use rates, and flow estimates in ungaged headwater basins. It is important to note that reservoir operating rules are simulated in the verification of the model in lieu of actual historic data on reservoir usage (which is built into the UIF datasets). This is to help ensure that the model has predictive strength for simulating the continuation of prescribed rules into the future, by demonstrating that the rules adequately reproduce historic reservoir dynamics.

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 enlargement 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

Model calibration in the Savannah River Basin was performed using historical hydrology for the period 1983 – 2013. As described in Sections 5 and 6, the calibration model includes input data representative of past conditions, rather than current conditions in the basin. The specific calibration 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.

While there are known changes in reservoir operating rules and strategies within the calibration period, these changes appear to have been subtle and are unlikely to have had a significant impact on downstream flow regimes. For example, the original ACOE drought management operational policy was instituted in 1989 via the Savannah River Drought Contingency Plan. In 2006, this plan was modified to better, and more proactively, respond to severe droughts. Minimum release requirements were adjusted as part of this update. Similar modifications were made in the years following, including

2007, 2009, and then most recently in 2012. These changes are all well documented in the 2012 ACOE Savannah River Basin Drought Management Plan. While it is not possible to explicitly simulate these changes within a single calibration model, the general operational strategies for the majority of the calibration period are captured in the model rules – based on pre-2012 documented rules and operations implied by measured storage and flow data. Further, as described below, simulated reservoir operations were eliminated as a complicating factor by prescribing (rather than predicting) major reservoir outflows within a focused model validation exercise.

As noted above, the operating rules included in SWAM for the calibration period generally reflect previous Duke Energy and ACOE reservoirs agreements, storage targets, and release requirements, prior to the latest updates in 2012 - 2014. These rules include a combination of storage targets and simplified minimum release requirements and differ from those included in the baseline model (described in Section 6). These rules are summarized in **Table 7-1**. Additionally, explicit consumptive withdrawal reduction rules, conditioned on LIP stages, were not included in the calibration model (but were included in the basin baseline model). Any conservation measures that occurred during the calibration period are implicitly captured in the prescribed water usage values in the calibration model.

Table 7-1. Advanced Reservoir Rules for the Calibration Model

Reservoir	Priority	Type	Target	Months	Conditioned On:	Description
Bad Creek Reservoir	1	Storage Curve (MG)	8,677	Jan - Dec	None	Steady storage target.
Lake Jocassee	1	Minimum Release (cfs)	350	Jan - Dec	None	Steady minimum release, set as part of the calibration process.
	2	Storage Curve (MG)	391,949	Jan 2 - Oct 15	None	Normal operating storage targets.
			382,933	Oct 16 - Jan 1	None	
Lake Keowee	1	Minimum Release (cfs)	600	Jan - Dec	None	Steady minimum release, set as part of the calibration process.
	2	Storage Curve (MG)	277,819	Jan 2 - Oct 15	None	Normal operating storage targets.
			261,410	Oct 16 - Jan 1	None	
Lake Hartwell	1	Storage Curve (MG)	830,791	Apr 2 - Oct 15	Day of week	Weekend storage curve with a reduced maximum release of 120 cfs. Max release set as part of calibration process.
			760,472	Oct 16 - Dec 15	Day of week	
			760,472	Dec 16 - Dec 31	Day of week	
			830,791	Jan 1 - Apr 1	Day of week	
	2	Minimum Release (cfs)	3,000	Jan - Dec	Day of week	First two rules ensures smaller releases on weekends (daily model only). Last rule is monthly average (monthly model only). Values set as part of the calibration process.
			100	Jan - Dec	Day of week	
			2,200	Jan - Dec	Day of week	
	3	Storage Curve (MG)	830,791	Apr 2 - Oct 15	Day of week	Weekday storage curve subject to maximum release of 20,000 cfs. Max release set as part of calibration process.
			760,472	Oct 16 - Dec 15	Day of week	
			760,472	Dec 16 - Dec 31	Day of week	
			830,791	Jan 1 - Apr 1	Day of week	
Lake Russell	1	Storage Curve (MG)	313,217	Jan - Dec	None	Normal operating storage curve
Lake Thurmond	1	Minimum Release (cfs)	4,200	Jan -Dec	None	Minimum release, year-round.
	2	Storage Curve (MG)	817,887	Apr 2 - Oct 15	None	Normal operating storage curve, subject to max release of 30,000 cfs.
			726,649	Oct 16 - Dec 15	None	
			726,649	Dec 16 - Dec 31	None	
			817,887	Jan 1 - Apr 1	None	

7.2.1 Calibration Steps

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. Intermediary subbasin flow factors were adjusted for tributary objects to achieve adequate modeled vs. measured comparisons at selected tributary flow gage targets, based on monthly timestep modeling.
3. 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.
4. Simulated reservoir operating rules were reviewed and refined based on a combination of monthly and daily reservoir level modeled vs. measured comparisons.
5. Daily timestep streamflow simulations were verified by reviewing daily output following the monthly model calibration.
6. 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.

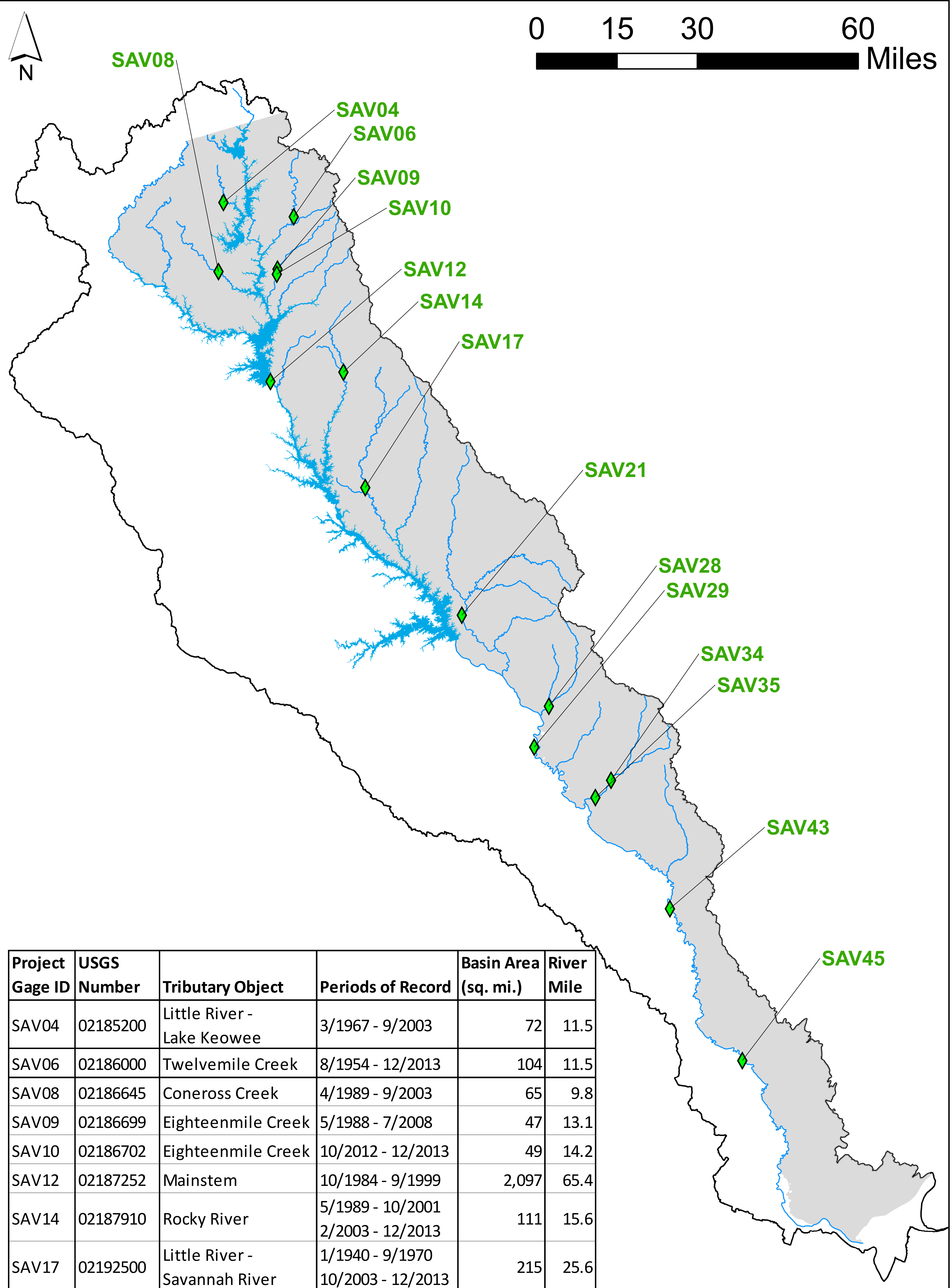
All USGS flow gages at downstream locations in the basin with reasonable records within the targeted calibration period were used to assess model performance and guide the model calibration steps described above. The gages used for calibration are shown in **Figure 7-1**. Note that, to minimize the uncertainty in the calibration targets, only gaged (i.e. measured) flow records, with adequate periods of record, 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.

Note that USGS gage 02197320 (Savannah River near Jackson) was eliminated as a calibration target after concerns were raised about the quality of high flow data at this gage.

7.2.2 Reservoir Levels and Storage

In addition to the flow gages, reported historical reservoir levels and storage (where available) were also used as calibration/verification targets to a certain extent. In the Savannah River Basin, several factors complicate the use of reservoir levels and storage as calibration targets, as described below:

- The model uses a static set of reservoir operating rules throughout the calibration period. In reality, reservoir level and storage fluctuations outside of predefined ranges often occur due to



Project Gage ID	USGS Number	Tributary Object	Periods of Record	Basin Area (sq. mi.)	River Mile
SAV04	02185200	Little River - Lake Keowee	3/1967 - 9/2003	72	11.5
SAV06	02186000	Twelvemile Creek	8/1954 - 12/2013	104	11.5
SAV08	02186645	Coneross Creek	4/1989 - 9/2003	65	9.8
SAV09	02186699	Eighteenmile Creek	5/1988 - 7/2008	47	13.1
SAV10	02186702	Eighteenmile Creek	10/2012 - 12/2013	49	14.2
SAV12	02187252	Mainstem	10/1984 - 9/1999	2,097	65.4
SAV14	02187910	Rocky River	5/1989 - 10/2001 2/2003 - 12/2013	111	15.6
SAV17	02192500	Little River - Savannah River	1/1940 - 9/1970 10/2003 - 12/2013	215	25.6
SAV21	02196000	Stevens Creek	11/1929 - 9/1931 2/1940 - 9/1978 11/1983 - 12/2013	544	42.8
SAV28	02196690	Horse Creek	4/2005 - 12/2013	149	16.2
SAV29	02197000	Mainstem	1/1925 - 12/2013	7,510	165.4
SAV34	02197310	Upper Three Runs	6/1974 - 9/2002	191	10.1
SAV35	02197315	Upper Three Runs	6/1974 - 9/2002	201	15.6
SAV43	02197500	Mainstem	10/1939 - 9/1970 10/2003 - 12/2013	8,584	230.9
SAV45	02198500	Mainstem	10/1929 - 9/1933 10/1937 - 12/2013	9,855	285.3

Figure 7-1
USGS Streamflow Gages
Used in Calibration

subtle changes in operational strategies and/or operator decisions that are not consistent with normal operating rules.

- In the Savannah Basin, historical reservoir operating rules and strategies are not well defined or documented. There is also ambiguity with respect to the timing of changes of operating rules during the calibration period.
- The model also uses a static set of (current) reservoir characteristics throughout the calibration period (e.g., dam height). Modifications to dams, hydropower plants, bypass reaches, and spillways during the calibration period are not accounted for.

7.2.3 Calibration Parameters and Performance Metrics

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 small group of inputs with relatively high associated uncertainty. In general, these might include any of the following: mainstem hydrologic gain/loss factors, tributary subbasin flow factors, reservoir operational rules, 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 reach gain/loss factors. Adjustments to other parameters are secondary and often not required. For the Savannah Basin model calibration, only reach gain/loss and subbasin flow factors and, to a limited extent, advanced reservoir operating rule parameters (for some reservoirs) were adjusted as part of the calibration process. The final model reach gains/losses are presented in Section 6, **Table 6-3**.

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 both river flow and reservoir levels, 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 storage data 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 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 (10^{th} 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. 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.

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). Record quality of specific streamflow gages are discussed below.[1] Seasonal and annual patterns in both flow and reservoir storage 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. Modeled vs. measured cumulative flow over the entire calibration period was compared at select sites to confirm that there was not an overall bias toward too high or too low of flows. Using the monthly timestep, the comparisons indicate that, where there is at least ten years of gage records, the modeled cumulative flows are within 5% of cumulative measured flows, indicating that the model is not significantly over-or under-predicting flows. The spatial and temporal availability of gage records is more limited compared to other basins (such as the Broad River Basin) however.

Table 7-2 contains modeled and measured averages over the full period of record, along with the available number of years for comparison. For all gages included as calibration targets, model simulated average flows are within 5% of measured mean flows. This indicates that the overall water balance is very well represented 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 5 - 15% with no clear bias one way or the other.

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[1] Gage quality reports from 2006 to 2013 can be found at http://wdr.water.usgs.gov/allsearch.php and 1999 to 2004 can be found at http://pubs.usgs.gov/wdr/wdr_sc/scAARindex.html.

Table 7-2. Annual Flow Statistics

Project ID	Station	Years of Record	Measured Average	Predictive Modeled Average	Predictive % Diff Average	Prescribed Modeled Average	Prescribed % Diff Average
SAV12*	SAVANNAH RIVER BELOW HARTWELL LK NR HARTWELL, GA	16	3,303	3,316	0.4%	3,426	3.7%
SAV29*	SAVANNAH RIVER AT AUGUSTA, GA	31	8,048	8,099	0.6%	7,969	-1.0%
SAV43*	SAVANNAH R AT BURTONS FERRY BR NR MILLHAVEN, GA	31	9,323	9,425	1.1%	9,287	-0.4%
SAV45*	SAVANNAH RIVER NEAR CLYO, GA	31	10,229	10,356	1.2%	10,226	0.0%
SAV04	LITTLE RIVER NEAR WALHALLA, SC	21	164	164	-0.1%		
SAV06	TWELVEMILE CREEK NEAR LIBERTY, SC	23	177	178	0.4%		
SAV08	CONEROSS CK NR SENECA, SC	15	116	115	-0.4%		
SAV09	EIGHTEENMILE CREEK ABOVE PENDLETON, SC	11	55	54	-1.6%		
SAV10	EIGHTEENMILE CREEK BELOW PENDLETON,SC	2	70	73	3.7%		
SAV14	ROCKY RIVER NR STARR, SC	24	122	121	-1.0%		
SAV17	LITTLE RIVER NEAR MT. CARMEL, SC	25	163	163	0.2%		
SAV21	STEVENS CREEK NEAR MODOC, SC	31	332	335	0.7%		
SAV34	UPPER THREE RUNS ABOVE ROAD C (SRS), SC	18	203	200	-1.9%		
SAV35	UPPER THREE RUNS AT ROAD A (SRS), SC	18	219	226	3.3%		
SAV28	HORSE CREEK AT CLEARWATER, SC	9	166	169	1.5%		

** Mainstem Gage*

Monthly reservoir storage and level comparisons, while clearly simplified due to the static assumptions (rules) incorporated into the model, were aimed at assessing the model's ability to generally reproduce historical reservoir storage and releases using the rule sets available in the software. As noted above, historical reservoir operations in the basin were typically simulated with a combination of seasonal storage targets and, higher priority, minimum release requirements. For the latter, minimum release targets were not well defined in any available documentation for the historical calibration period. However, minimum releases were clearly implied in the measured downstream flow data for many of the reservoirs, and specific minimum release targets were quantified as part of the calibration process. Reservoirs that fall into this category include: Lake Jocassee, Lake Keowee, and Lake Hartwell. Minimum release targets were well documented for Lake Thurmond and were included in the calibration model without modification. Given these simplifications and uncertainties associated with major reservoir operations in the basin, the model does a very good job of reproducing long term reservoir fluctuations in both the daily and monthly timestep simulations.

In terms of daily timestep simulations, daily flow fluctuations are generally well captured by the model, despite the noted uncertainty associated with upstream reservoir operations. Modeled daily percentile plots exhibit adequate agreement with measured data (within 5 – 30%) for all mainstem and tributary locations. As expected, those gages closest to the downstream end of reservoirs (e.g. SAV12 immediately downstream of Lake Hartwell) exhibit the largest deviations in modeled vs. measured daily flow data, due to uncertainties in reservoir operations. SAV12 especially has limits as a calibration point—when Lake Russell downstream exceeds around 476 ft in mean-daily elevation, this gage can be affected by backwater. Beyond reservoir operations, other sources of error, particularly in the daily simulations, include the lack of reach routing and overall simplified representation of hydrologic processes in the model, common to all water allocation models. However, these secondary sources of error appear to be dwarfed by reservoir operational uncertainty in this basin. For this reason, a supplemental model validation run (Section 7.4) was performed whereby this source of error was eliminated from the simulation. discrepancies are generally within 20% of gaged flows and deemed acceptable for the daily model.

Modeled regulatory low flow values (7Q10) are within 10% of measured values at all downstream mainstem (Savannah River) gages, except SAV12. Further, annual 7-day low flow variability is very accurately simulated by the model for these gages. The exception, SAV12, is very sensitive to operational simulation error associated with Lake Hartwell and backwater effects as discussed above. This issue is rectified in the supplemental validation exercise described in Section 7.4, which demonstrates the model's ability to accurate simulate daily low flows at this location given accurate and well-defined reservoir operational rules.

A table comparing model and measured 7Q10 flows is provided at the end of Appendix B. It is important to realize that low flows in the model are highly sensitive to modeled basin water use and operations. Small errors in estimated (or reported) withdrawals or modeled reservoir releases 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 fit are generally not justified.

Additionally, the model adequately hindcasts delivered water supply for each of the water users in the model. Simulated supply roughly equals simulated demand for all users, with no significant shortfalls.

7.4 Downstream Hydrology Validation Exercise

To support the validation of model hydrologic calibration parameters, model performance was further analyzed for a limited spatial domain. Published historical reservoir discharge data was used to redefine model upstream boundary conditions for the modeled reach downstream of Lake Hartwell (Lake Hartwell to SAV45). This downstream reach was further sub-divided into two sections: Lake Hartwell outlet to Lake Thurmond inlet and Lake Thurmond outlet to the SAV45 flow gage. Reservoir discharge boundary conditions were prescribed for the top of each sub-reach (Lake Hartwell outflows and Lake Thurmond outflows, respectively). To achieve this, predictive ("Advanced") reservoir operations in the model were turned off, and new "dummy" water user objects were used to withdraw water from the two reservoirs at rates equal to the historical reported outflow rates. The water user withdrawals were prescribed as 100% consumptive. New "dummy" tributary objects were then used to add the same amount of water back into the system, just downstream of each reservoir.

Model simulations were then performed to assess model hydrologic representation within these isolated reaches, without the confounding impacts of upstream operational uncertainty. Specifically, this exercise was performed to validate model reach gain/loss and flow augmentation factors for this portion of the model domain. Simulations were performed for both monthly and daily timesteps, for the full calibration period (1983 – 2013).

Results of this exercise are presented in **Appendices C and D**. As can be seen, across all sites and all performance metrics, a very close fit is achieved with the model compared to measured data. Included here are modeled 7Q10 values that are within 6% of measured values for all targeted gages. This confirms that the hydrology of the river below Lake Hartwell is accurately represented in the model.

Going forward, these results imply a strong predictive power of the model given well-defined reservoir operations.

7.5 Baseline Model Reservoir Operations Validation Exercise

As noted above, operational rules for the major reservoirs in the basin changed significantly over the past few years compared to historical operations. This includes operational rules for the Duke Power reservoirs (Lakes Jocassee and Keowee) and the downstream ACOE reservoirs (Lakes Hartwell, Russell, and Thurmond). For the former, these changes appear to be governed by a 2014 operating agreement between the Duke reservoirs and the ACOE reservoirs (October 2014). For the latter, recent changes were implemented as part of ACOE drought management plan (2012). The new rules, as implemented in the baseline model, are described and tabulated in Section 6. To increase user confidence in the model's representation of these rules in the baseline model, a second validation exercise was performed focused on ACOE reservoir operations. Based on our understanding of the rule changes, two years in the model simulation period include current ACOE reservoir operating rules: 2012 and 2013. These simulation years were the focus of this exercise. There are no years in the model simulation period that include current Duke reservoir operational rules. Therefore, the Duke reservoirs were not included in this validation exercise.

For this exercise, inflows to Lake Hartwell and Lake Thurmond were prescribed based on published data (Jan 1, 2012 – Dec 31, 2013). All other upstream flows were removed from the model. Since the published reservoir inflows are defined as "net inflows", and were presumably calculated as a function of measured storage and discharge, evaporative losses are assumed to be implicitly represented in these flow values. Therefore, reservoir evaporation rates were set to zero in the model, to avoid double counting. By isolating the ACOE reservoirs and prescribing inflows with published data, this exercise allows for the direct assessment of the model's ability to simulate reservoir operations using simple rules and its subsequent calculation of discharge and storage.

Results of this exercise are provided in **Appendices E and F**. As can be seen, an excellent agreement between modeled and measured reservoir storage levels and discharge was achieved for both Lake Hartwell and Lake Thurmond and both monthly and daily timesteps. Note that results include both rising and falling storage limbs for the two reservoirs and deviations from normal storage targets due to limited flow availability. These results lend confidence to the model's representation of current ACOE reservoir operating rules and to the use of the model for predictive purposes in the future.

It is recommended that additional validation of the baseline model operating rules in this basin be undertaken in the future. As data continues to be collected in this basin, future "auditing" of the model's ability to simulate complex reservoir operations will either increase user confidence in current model parameterization and/or highlight the need for refinement. The Duke reservoirs should be included in any future validation exercises.

Section 8

User Guidelines for the Baseline Model

The baseline Savannah 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. Current plans are for training to be offered to stakeholders once the models for all eight river basins are completed.

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 1939 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 the Savannah River Basin, it may be useful to examine flows with either managed or unimpaired flows coming from Georgia tributaries into the Savannah River. It may also 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 reservoir drops below a certain pool elevation. Results indicate that under current demand patterns, the reservoir will drop below this threshold in one month out of the ten years. Under future demand projections (modified by the user), the results indicate that the reservoir will drop below this threshold 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 Version 4.0* (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, November 2014. *South Carolina Surface Water Quantity Models – Modeling Plan.*

CDM Smith, July 2016. *Santee River Basin SWAM Model Framework.*

CDM Smith, 2016. *Simplified Water Allocation Model (SWAM) User's Manual, Version 4.0.*

Federal Energy Regulatory Commission (FERC), 2014. *Operating Agreement executed by the United States of America acting by and through the Savannah District, U.S. Army Corps of Engineers and the Southeastern Power Administration and Duke Energy Carolinas, LLC*

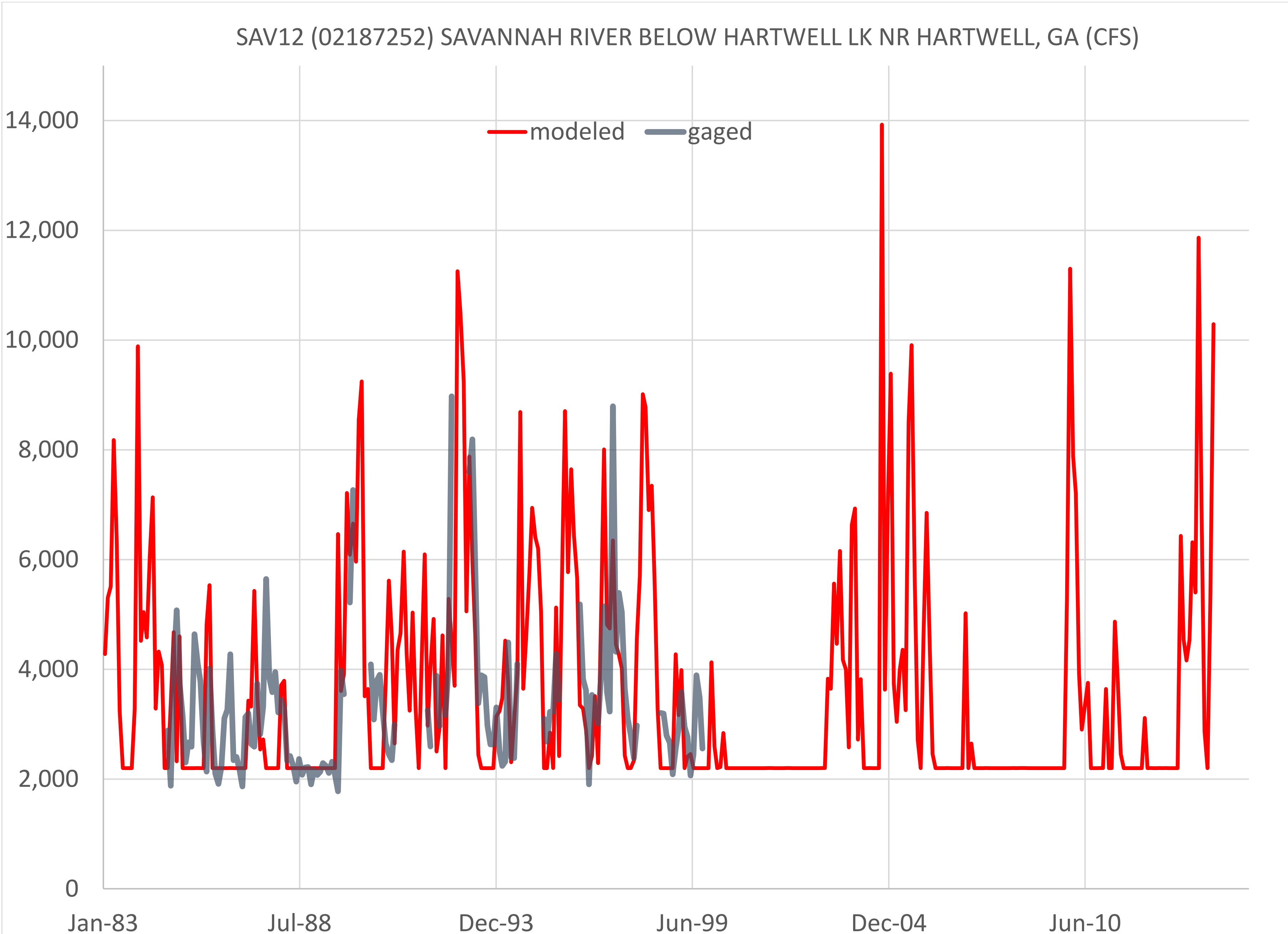
Purvis, John C., undated. *Pan Evaporation Records for the South Carolina Area, Southeast Regional Climate Center Columbia, SC* http://dnr.sc.gov/climate/sco/Publications/pan_evap_records.php

U.S. Army Corps of Civil Engineers (USACE), 2012. *Savannah River Basin Drought Management Plan.*

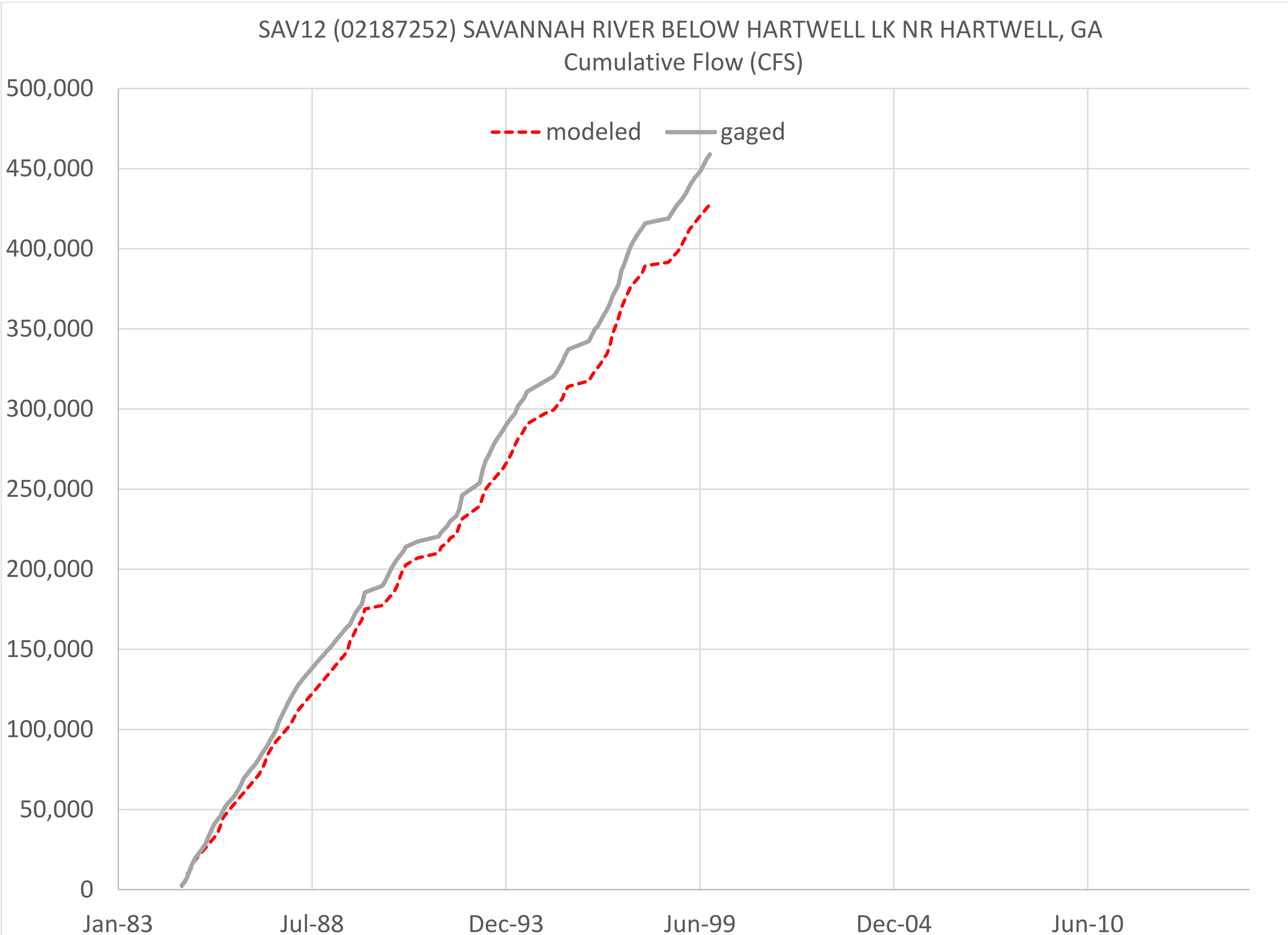
Appendix A

Savannah River Basin Model Monthly Calibration Results

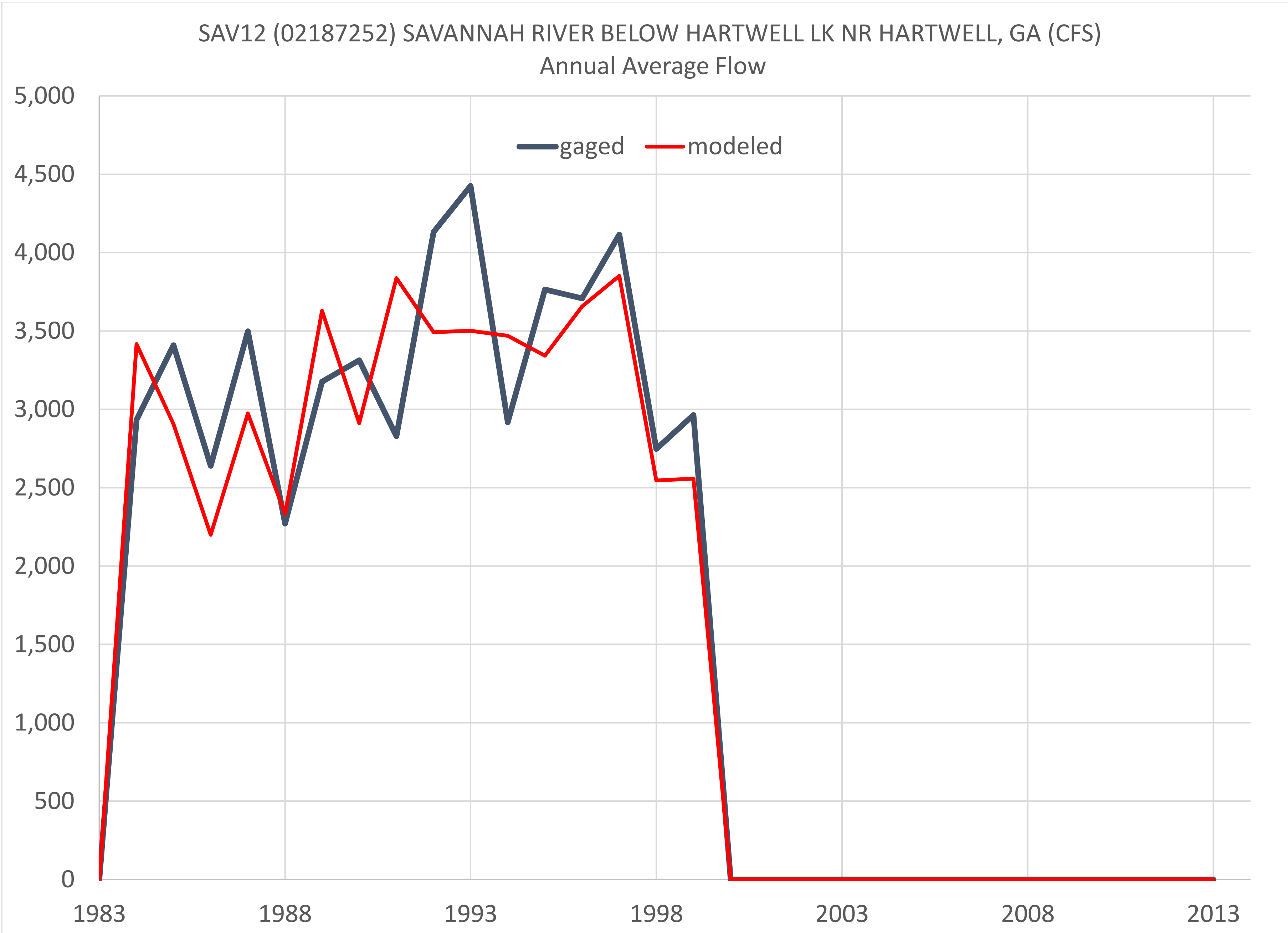
CDM Smith



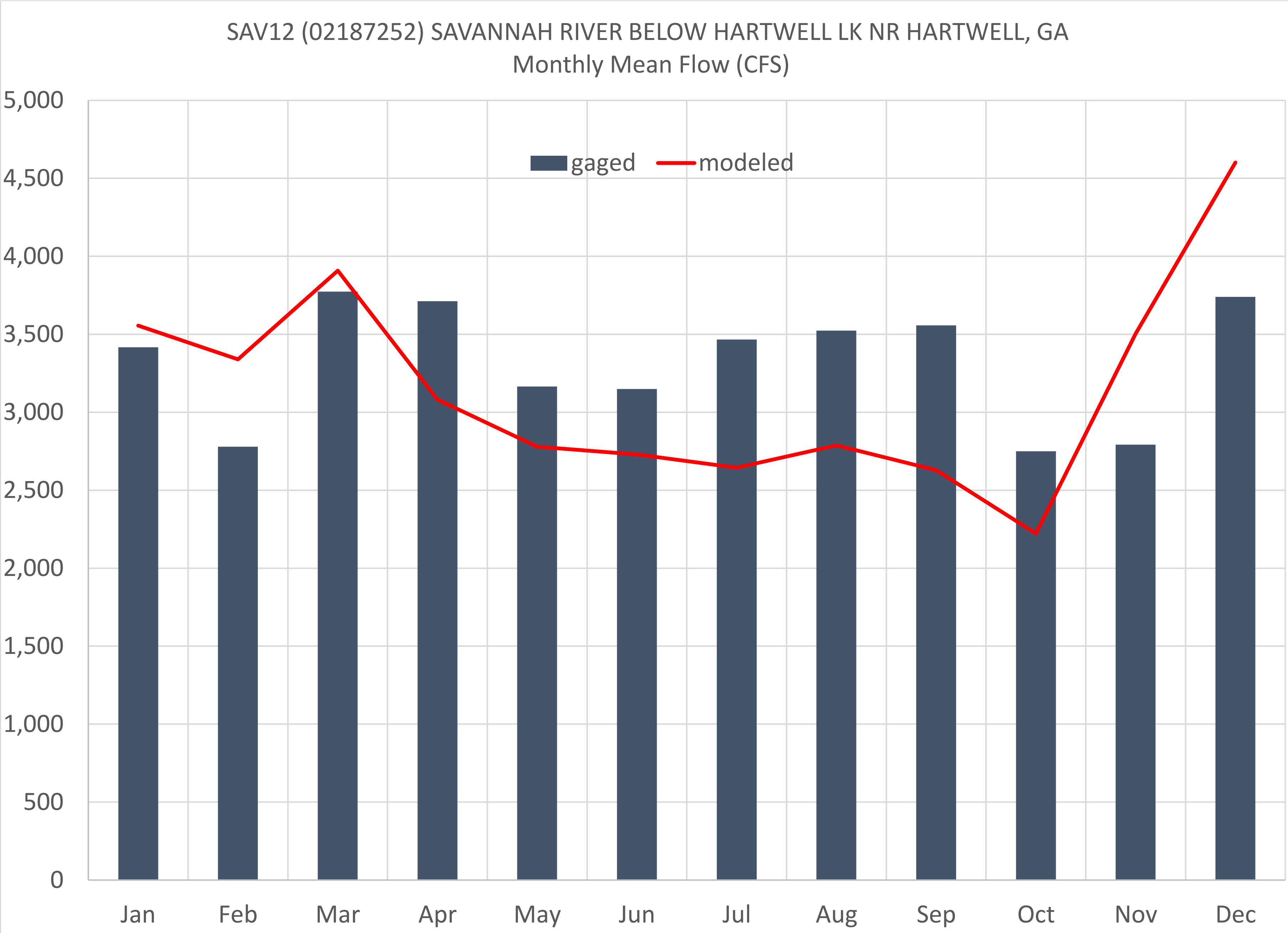
SAV12 (02187252) SAVANNAH RIVER BELOW HARTWELL LK NR HARTWELL, GA (CFS)
modeled
gaged
14,000
12,000
10,000
8,000
6,000
4,000
2,000
0
Jan-83
Jul-88
Dec-93
Jun-99
Dec-04
Jun-10

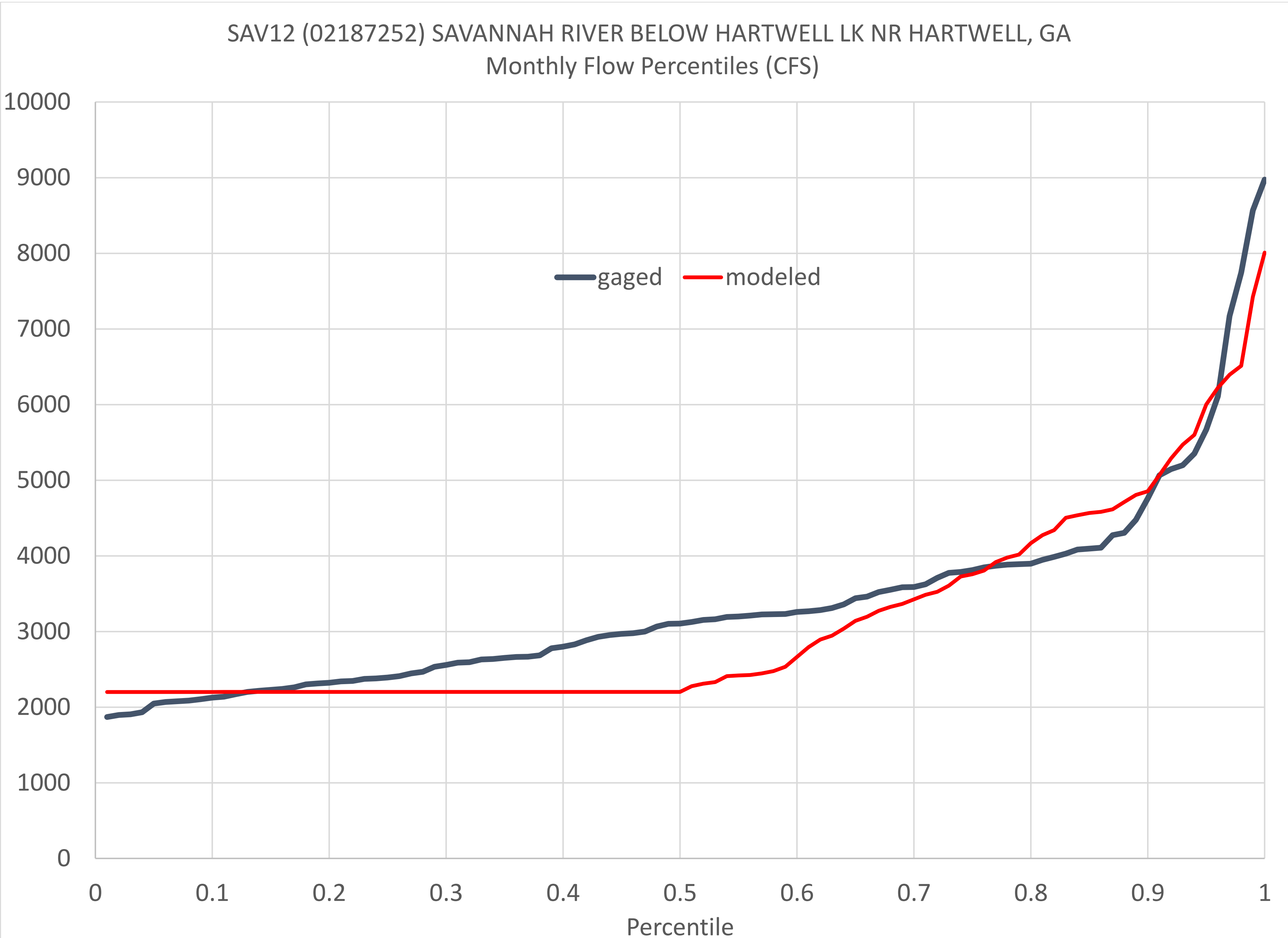


SAV12 (02187252) SAVANNAH RIVER BELOW HARTWELL LK NR HARTWELL, GA
Cumulative Flow (CFS)
modeled
gaged
500,000
450,000
400,000
350,000
300,000
250,000
200,000
150,000
100,000
50,000
0
Jan-83
Jul-88
Dec-93
Jun-99
Dec-04
Jun-10

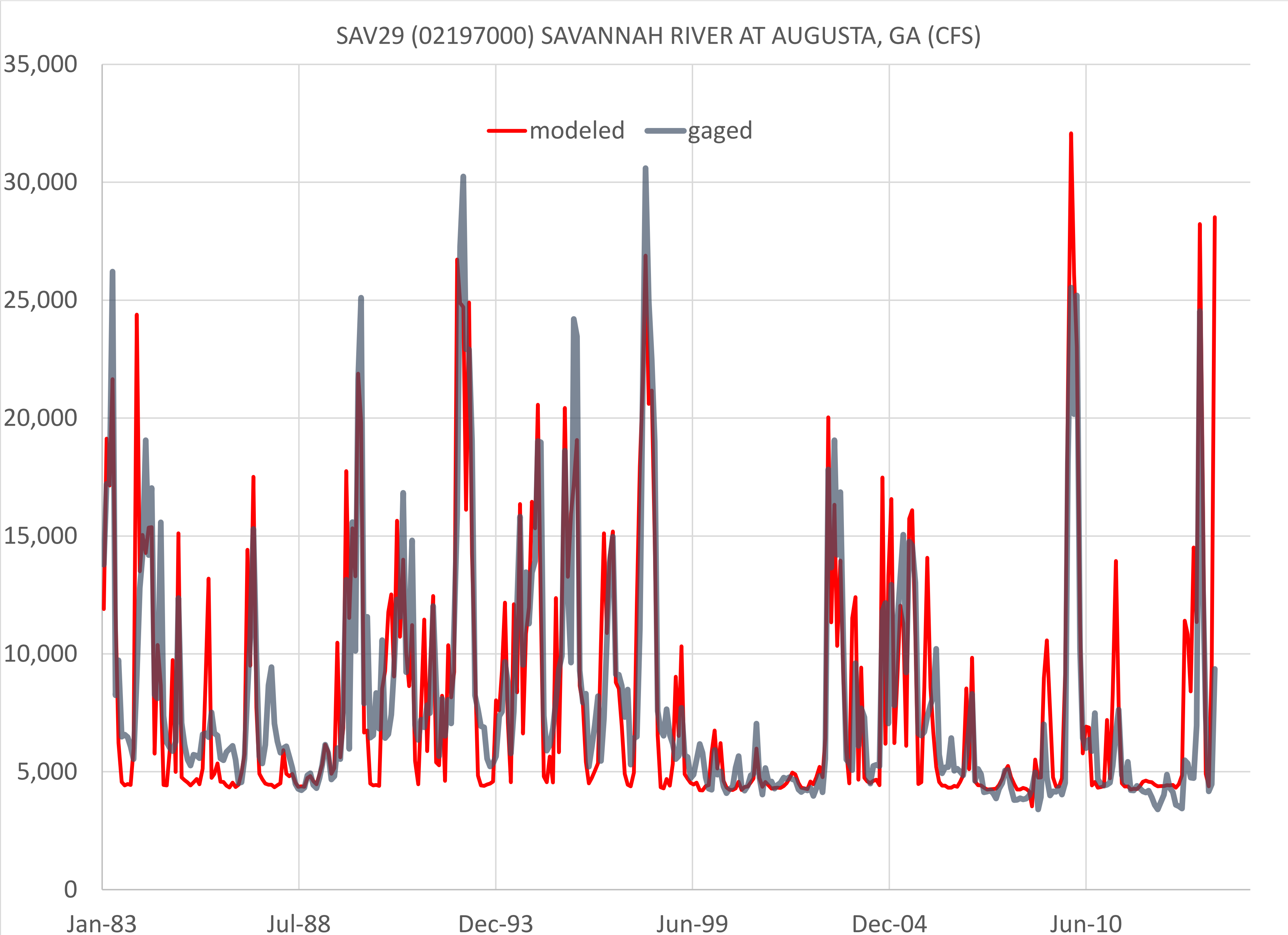


SAV12 (02187252) SAVANNAH RIVER BELOW HARTWELL LK NR HARTWELL, GA (CFS)
Annual Average Flow
gaged
modeled
5,000
4,500
4,000
3,500
3,000
2,500
2,000
1,500
1,000
500
0
1983
1988
1993
1998
2003
2008
2013

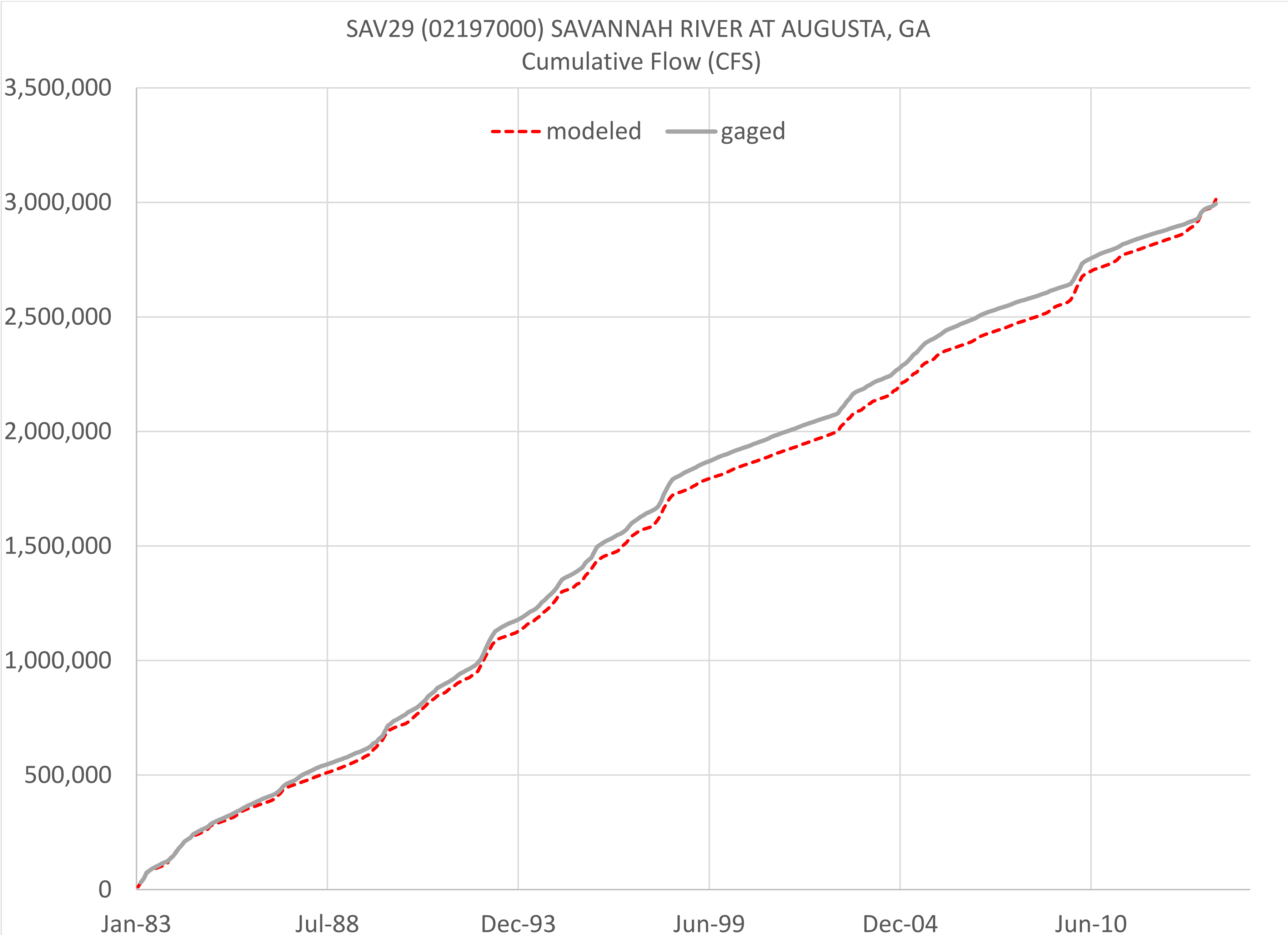

SAV12 (02187252) SAVANNAH RIVER BELOW HARTWELL LK NR HARTWELL, GA
Monthly Mean Flow (CFS)
gaged
modeled
5,000
4,500
4,000
3,500
3,000
2,500
2,000
1,500
1,000
500
0
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec

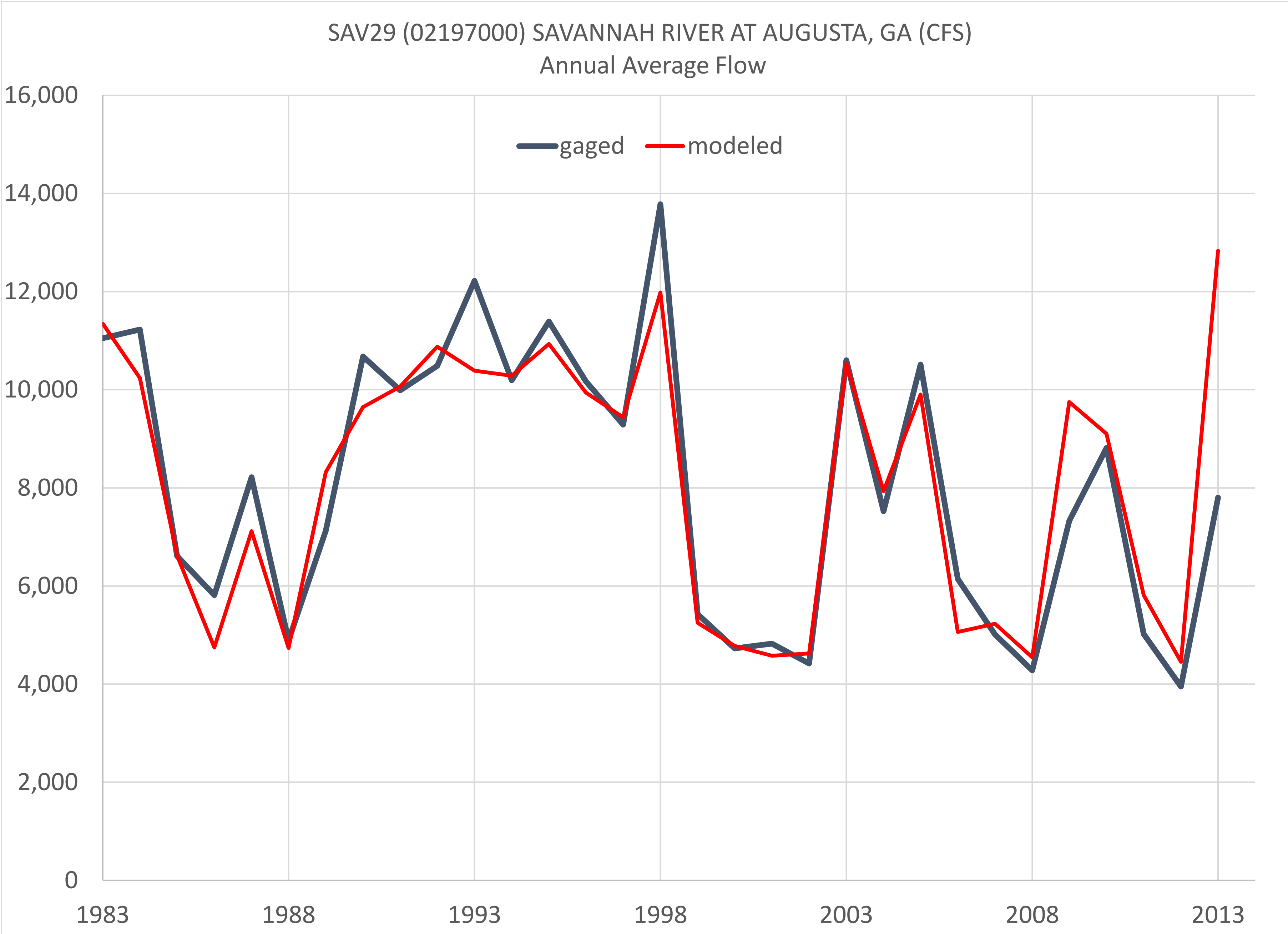


SAV12 (02187252) SAVANNAH RIVER BELOW HARTWELL LK NR HARTWELL, GA
Monthly Flow Percentiles (CFS)
gaged
modeled
10000
9000
8000
7000
6000
5000
4000
3000
2000
1000
0
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
Percentile



SAV29 (02197000) SAVANNAH RIVER AT AUGUSTA, GA (CFS)
modeled
gaged
35,000
30,000
25,000
20,000
15,000
10,000
5,000
0
Jan-83
Jul-88
Dec-93
Jun-99
Dec-04
Jun-10


SAV29 (02197000) SAVANNAH RIVER AT AUGUSTA, GA
Cumulative Flow (CFS)
modeled
gaged
3,500,000
3,000,000
2,500,000
2,000,000
1,500,000
1,000,000
500,000
0
Jan-83
Jul-88
Dec-93
Jun-99
Dec-04
Jun-10


SAV29 (02197000) SAVANNAH RIVER AT AUGUSTA, GA (CFS)
Annual Average Flow
gaged
modeled
16,000
14,000
12,000
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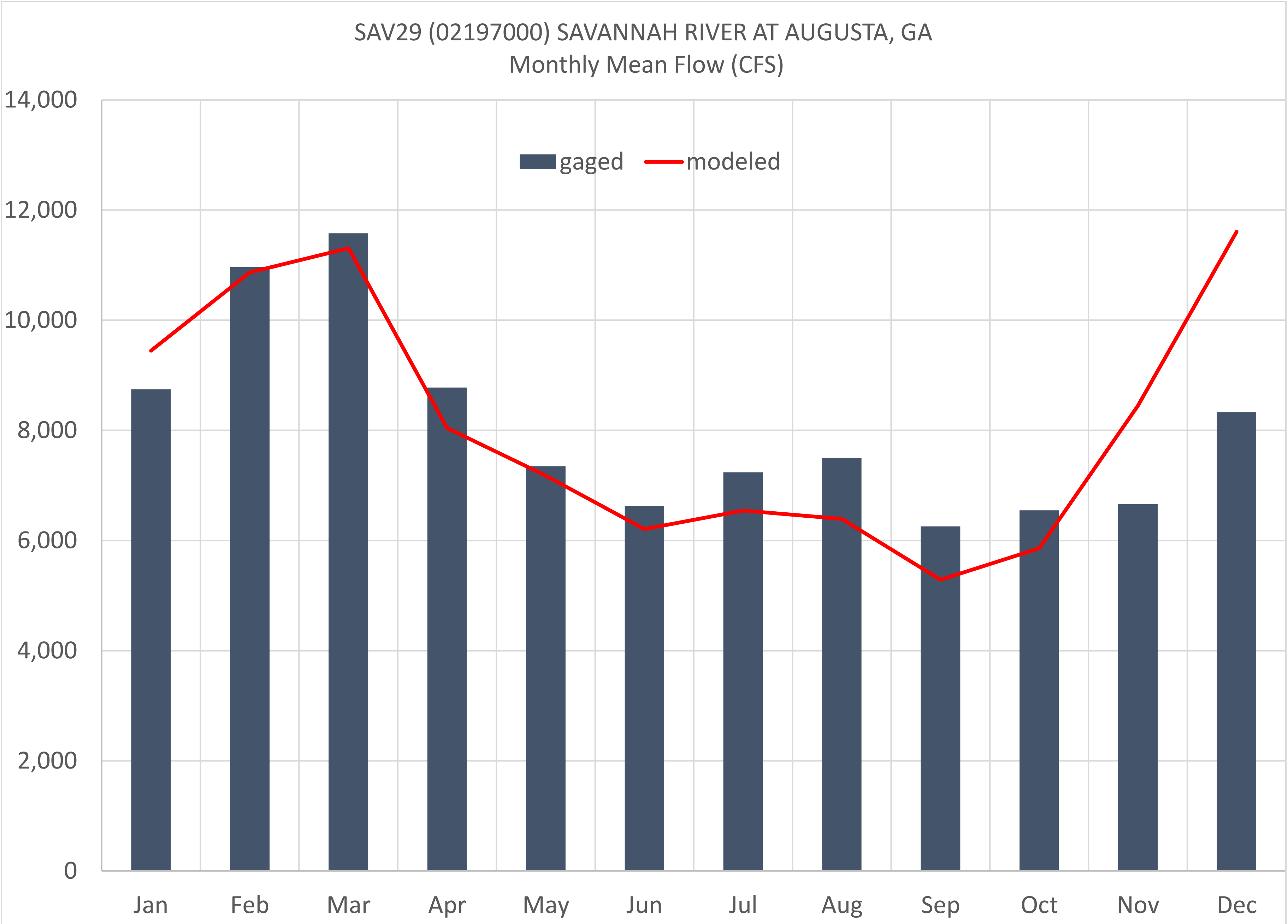
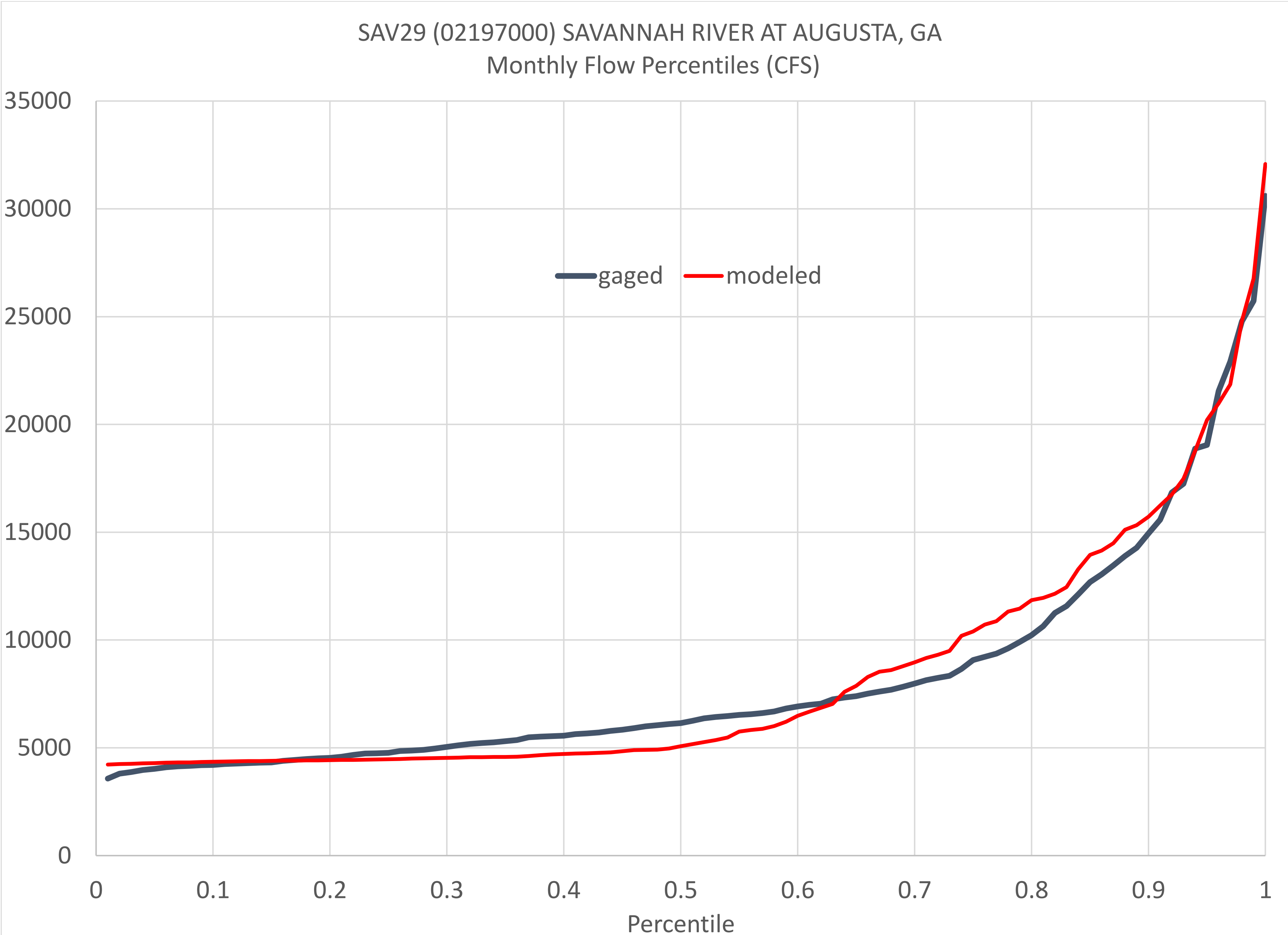
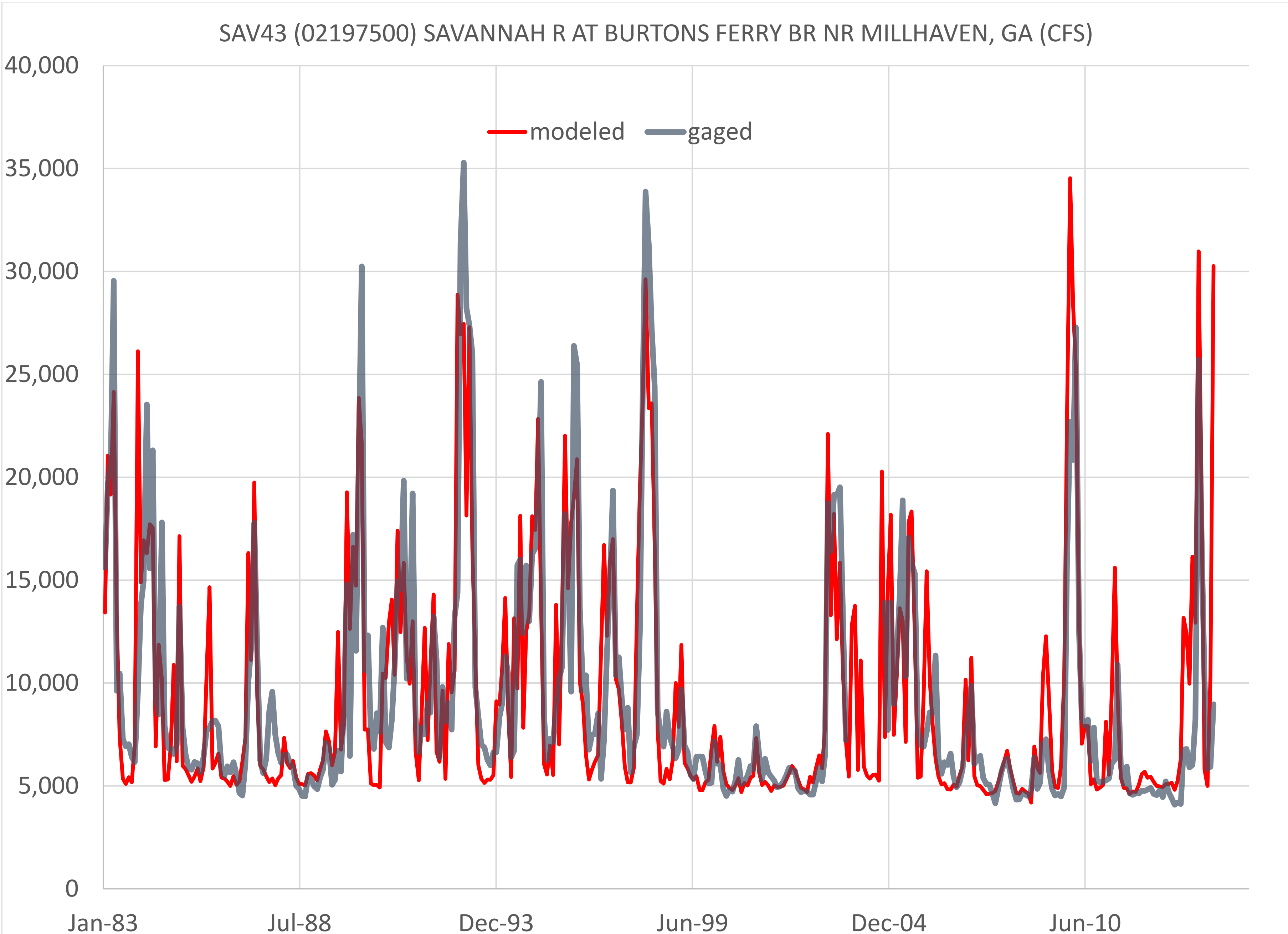
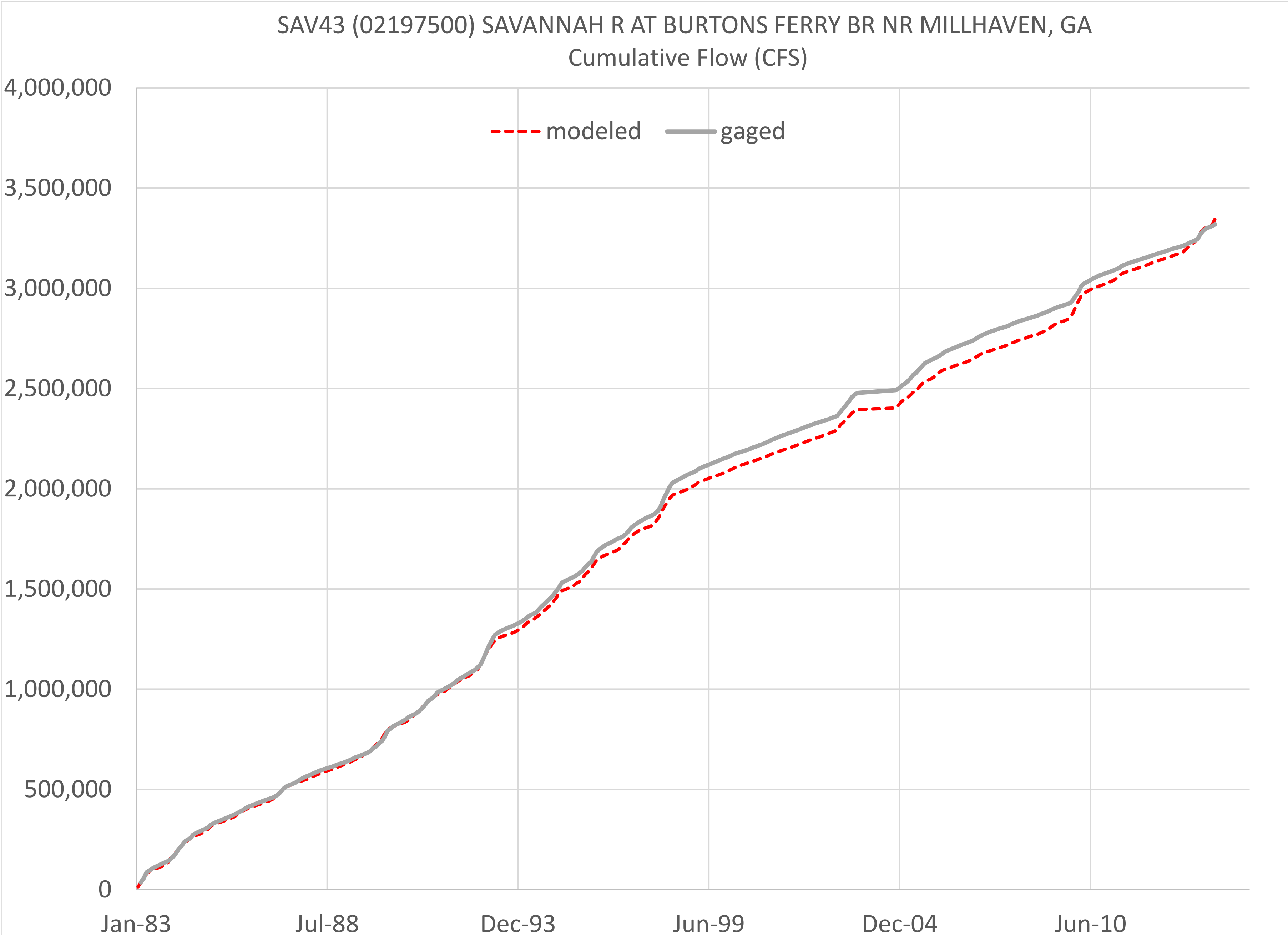
8,000
6,000
4,000
2,000
0
1983
1988
1993
1998
2003
2008
2013

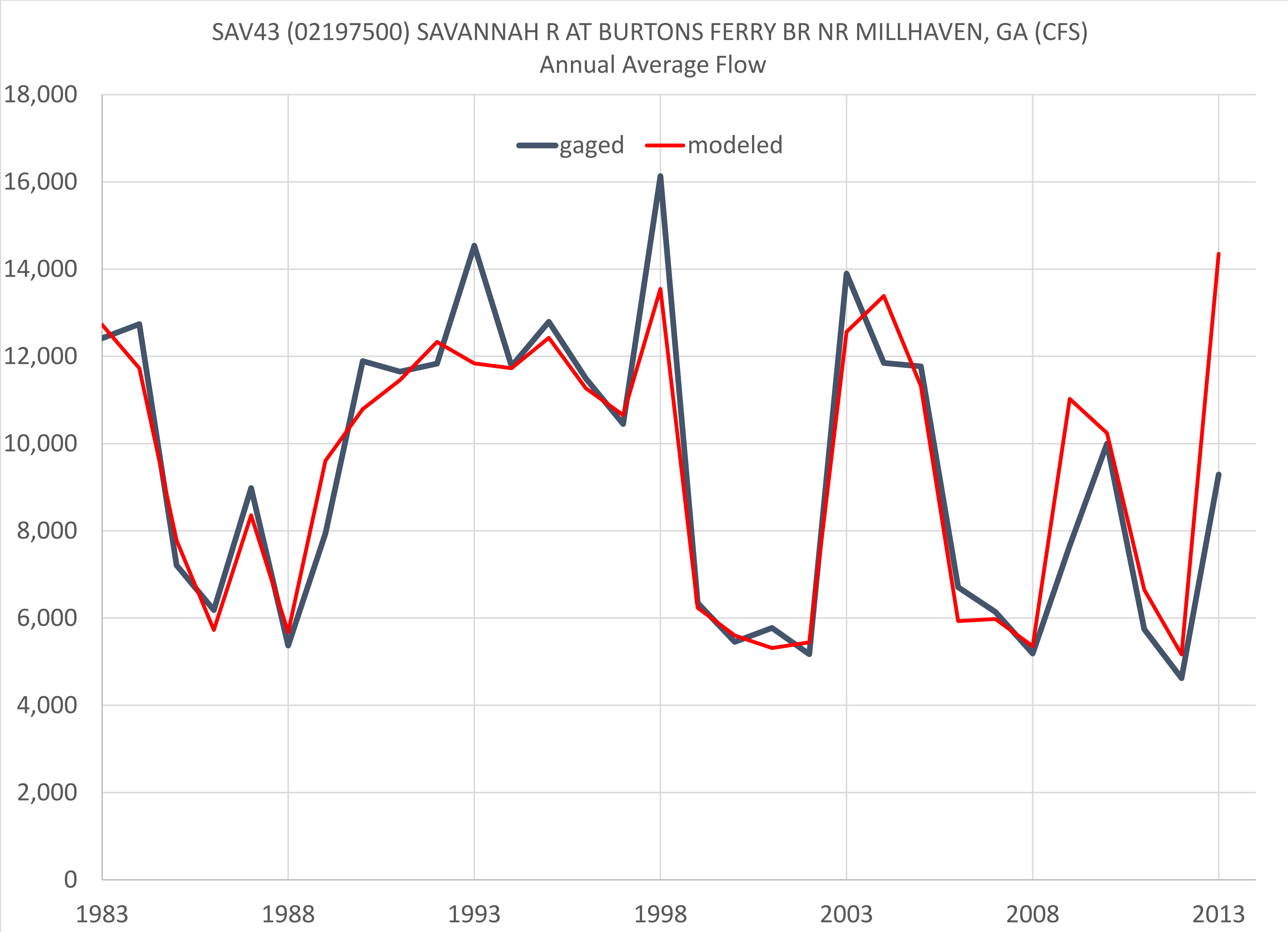

SAV29 (02197000) SAVANNAH RIVER AT AUGUSTA, GA
Monthly Mean Flow (CFS)
gaged
modeled
14,000
12,000
10,000
8,000
6,000
4,000
2,000
0
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec

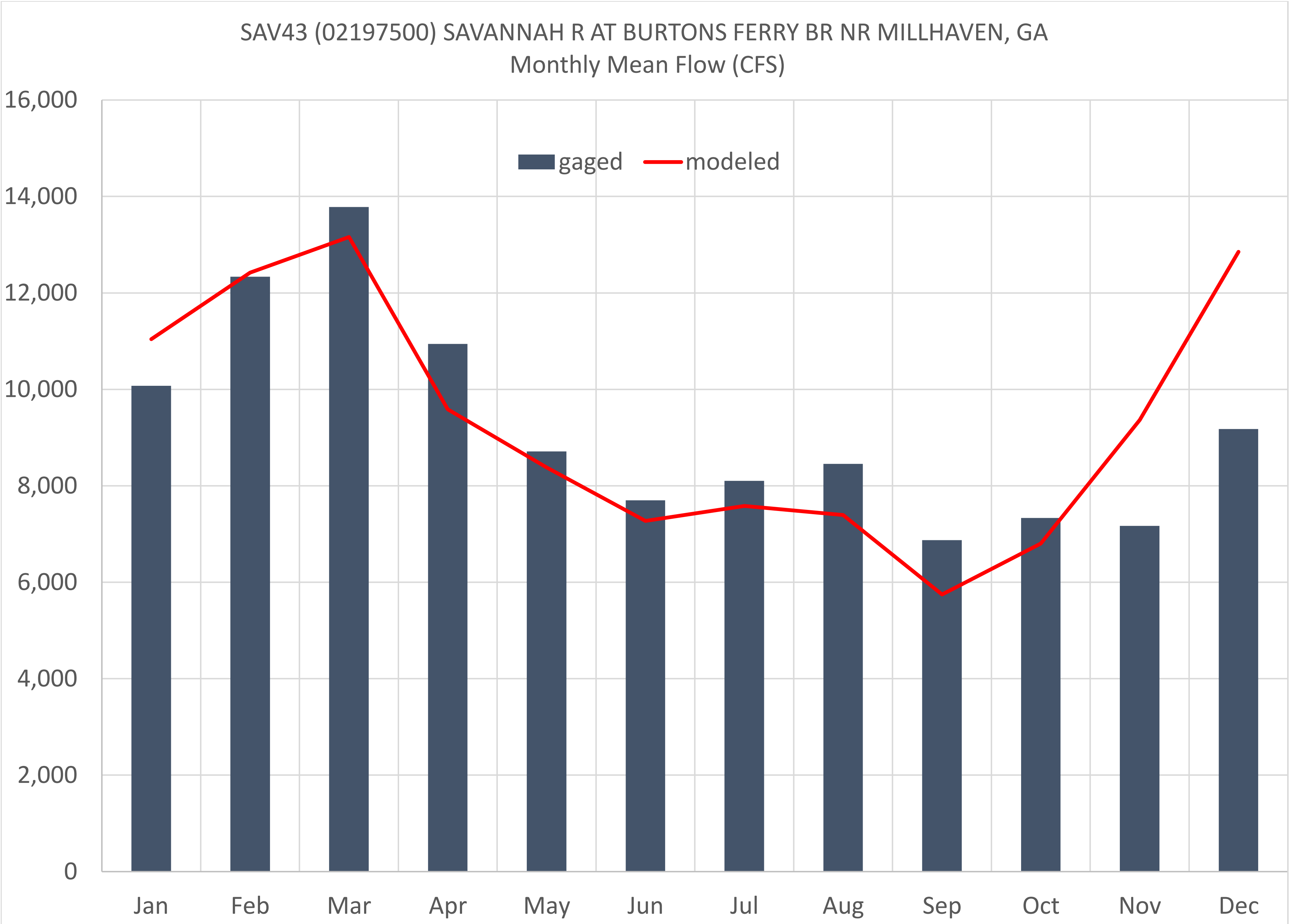


SAV29 (02197000) SAVANNAH RIVER AT AUGUSTA, GA
Monthly Flow Percentiles (CFS)
gaged
modeled
35000
30000
25000
20000
15000
10000
5000
0
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
Percentile

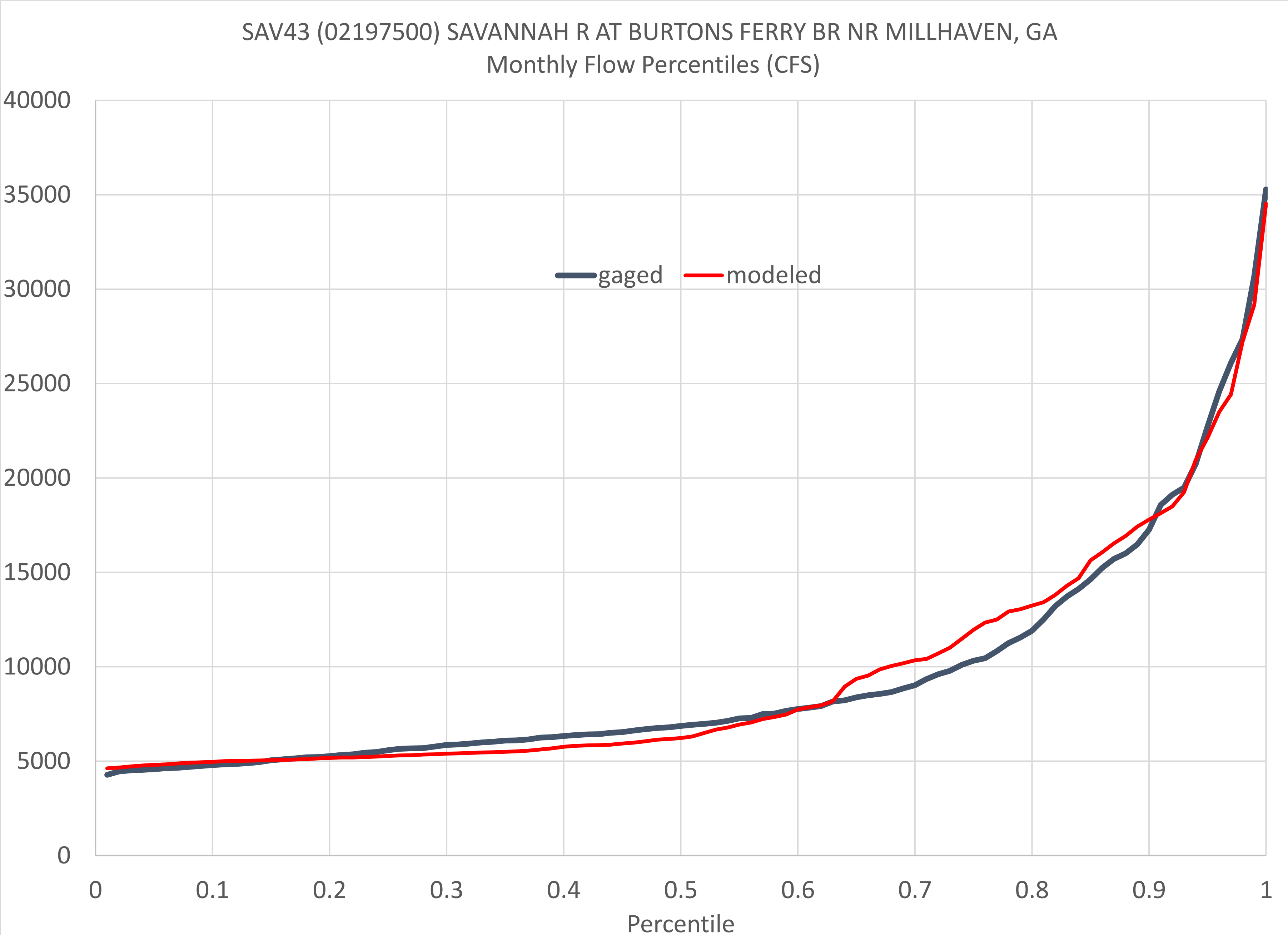

SAV43 (02197500) SAVANNAH R AT BURTONS FERRY BR NR MILLHAVEN, GA (CFS)
modeled
gaged
40,000
35,000
30,000
25,000
20,000
15,000
10,000
5,000
0
Jan-83
Jul-88
Dec-93
Jun-99
Dec-04
Jun-10


SAV43 (02197500) SAVANNAH R AT BURTONS FERRY BR NR MILLHAVEN, GA
Cumulative Flow (CFS)
modeled
gaged
4,000,000
3,500,000
3,000,000
2,500,000
2,000,000
1,500,000
1,000,000
500,000
0
Jan-83
Jul-88
Dec-93
Jun-99
Dec-04
Jun-10

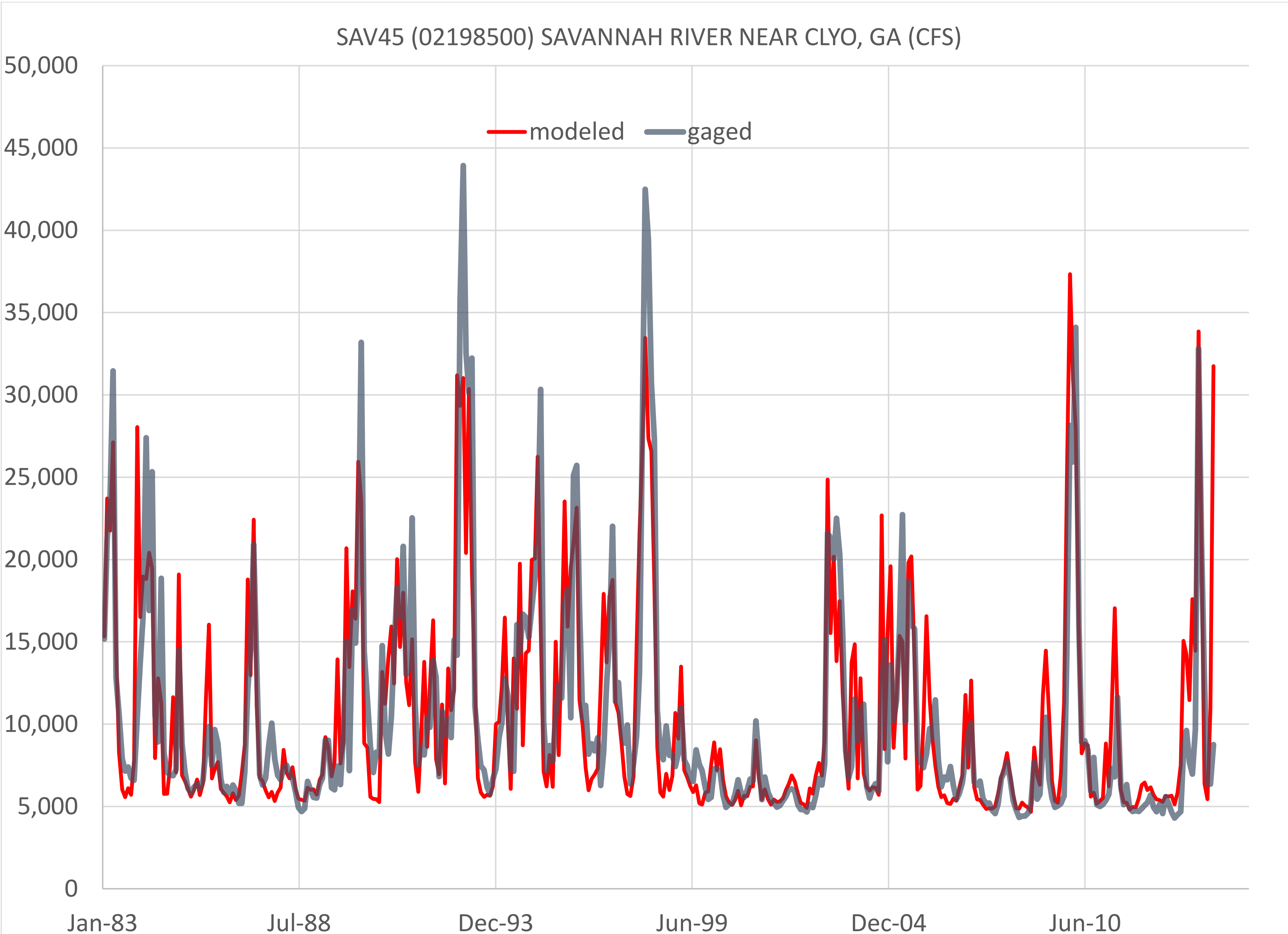

SAV43 (02197500) SAVANNAH R AT BURTONS FERRY BR NR MILLHAVEN, GA (CFS)
Annual Average Flow
gaged
modeled
18,000
16,000
14,000
12,000
10,000
8,000
6,000
4,000
2,000
0
1983
1988
1993
1998
2003
2008
2013

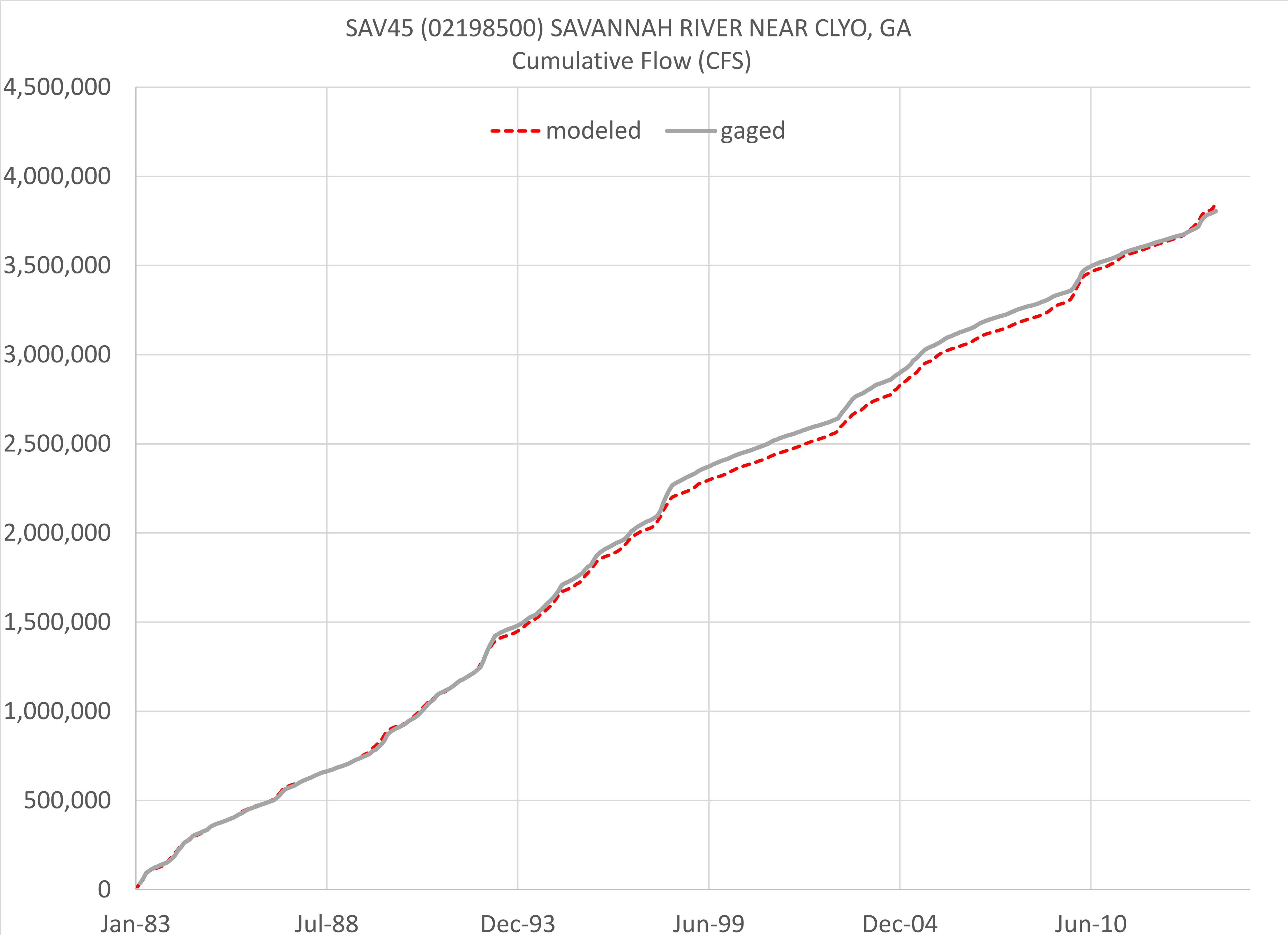


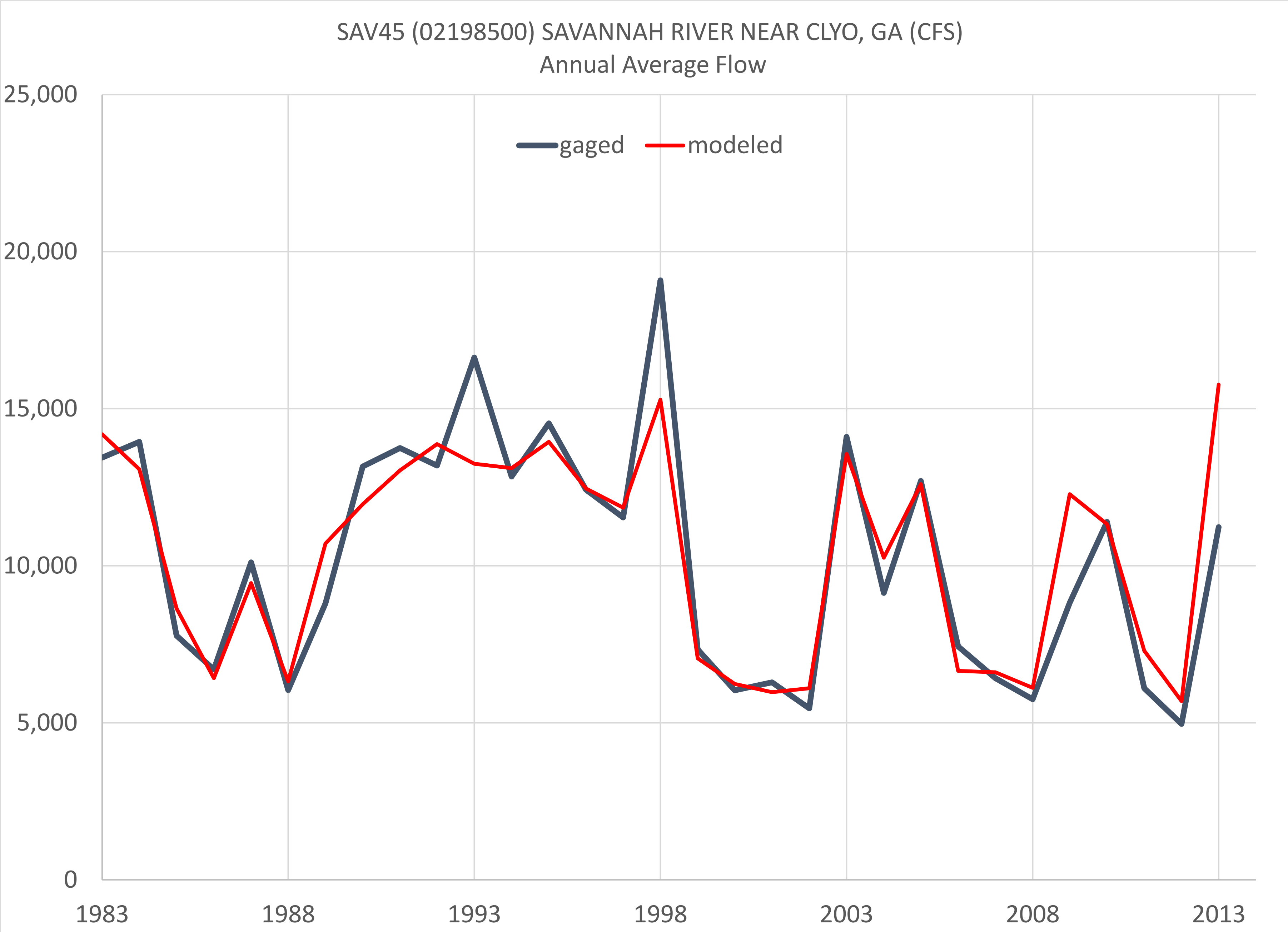
SAV43 (02197500) SAVANNAH R AT BURTONS FERRY BR NR MILLHAVEN, GA
Monthly Mean Flow (CFS)
gaged
modeled
16,000
14,000
12,000
10,000
8,000
6,000
4,000
2,000
0
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec

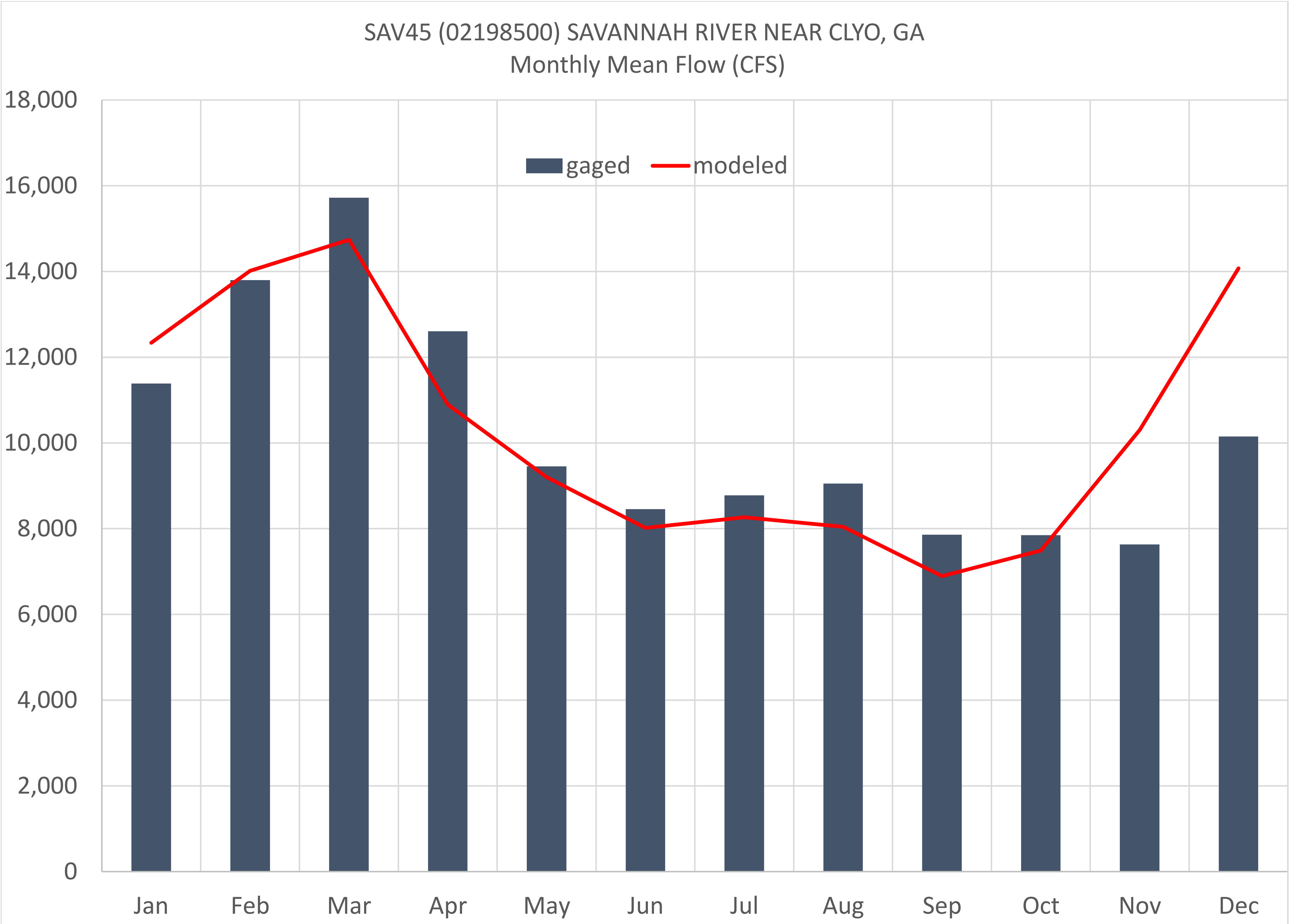


SAV43 (02197500) SAVANNAH R AT BURTONS FERRY BR NR MILLHAVEN, GA
Monthly Flow Percentiles (CFS)
gaged
modeled
40000
35000
30000
25000
20000
15000
10000
5000
0
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
Percentile

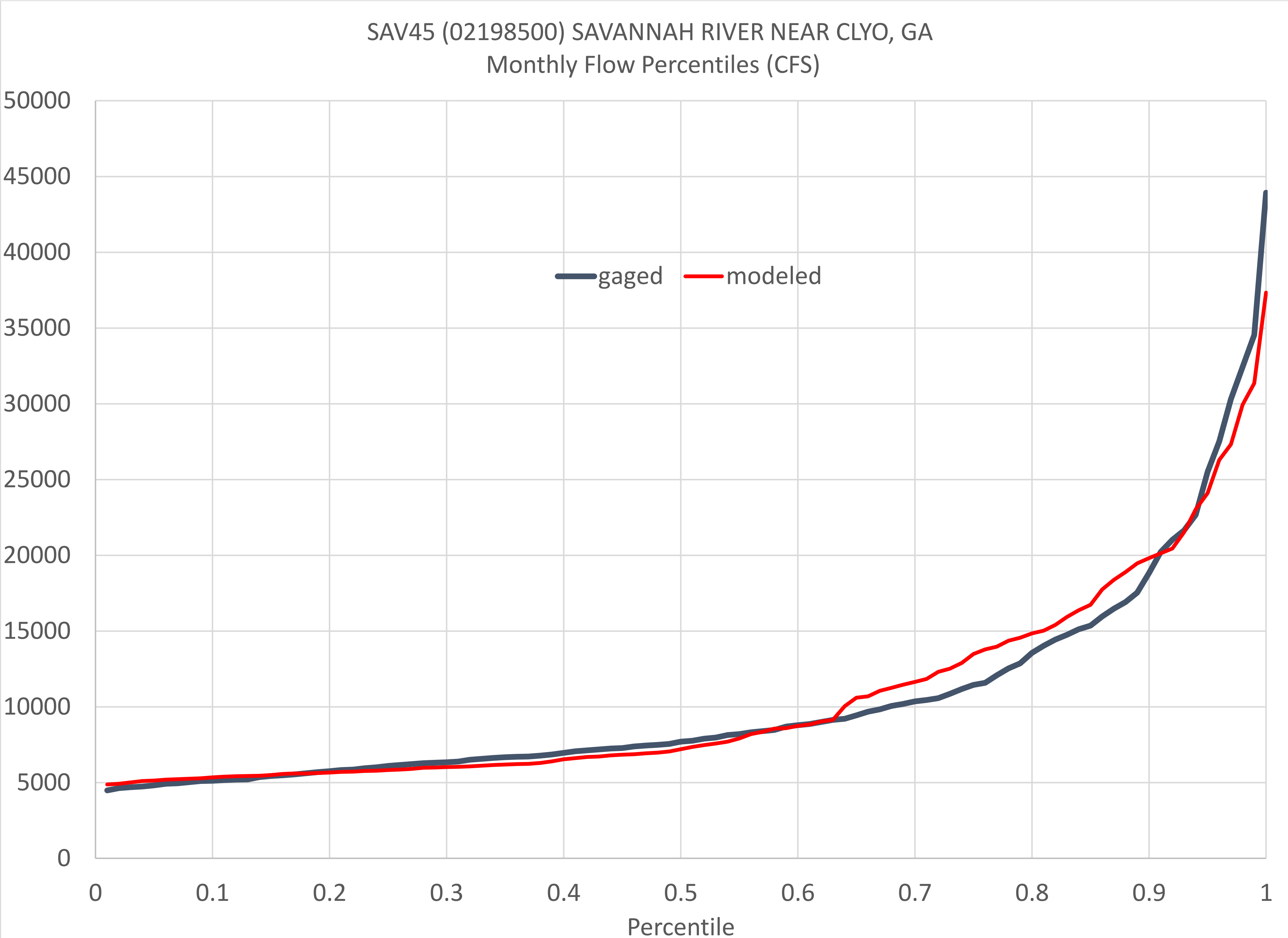

SAV45 (02198500) SAVANNAH RIVER NEAR CLYO, GA (CFS)
modeled
gaged
50,000
45,000
40,000
35,000
30,000
25,000
20,000
15,000
10,000
5,000
0
Jan-83
Jul-88
Dec-93
Jun-99
Dec-04
Jun-10

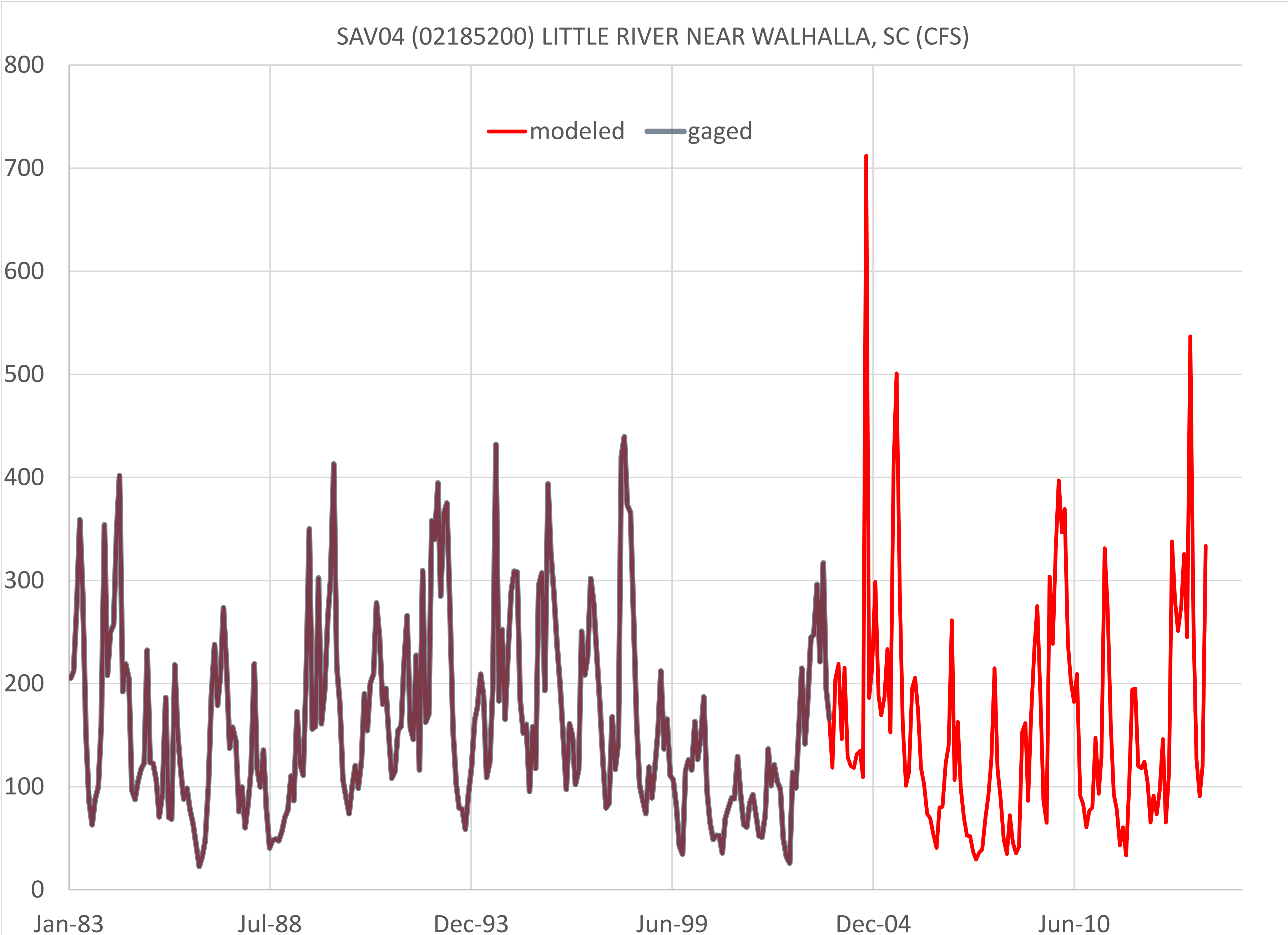

SAV45 (02198500) SAVANNAH RIVER NEAR CLYO, GA
Cumulative Flow (CFS)
modeled
gaged
4,500,000
4,000,000
3,500,000
3,000,000
2,500,000
2,000,000
1,500,000
1,000,000
500,000
0
Jan-83
Jul-88
Dec-93
Jun-99
Dec-04
Jun-10

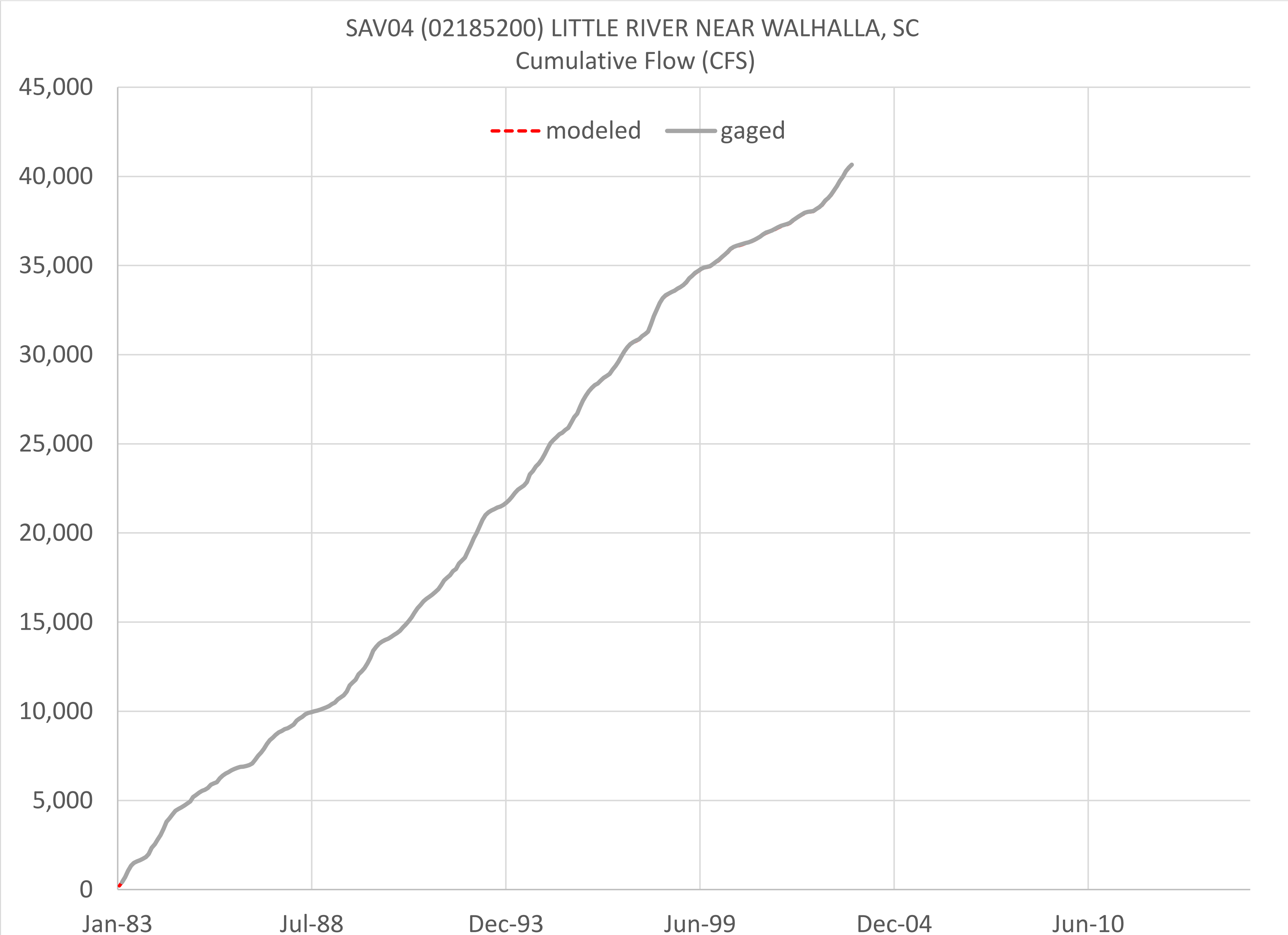

SAV45 (02198500) SAVANNAH RIVER NEAR CLYO, GA (CFS)
Annual Average Flow
gaged
modeled
25,000
20,000
15,000
10,000
5,000
0
1983
1988
1993
1998
2003
2008
2013

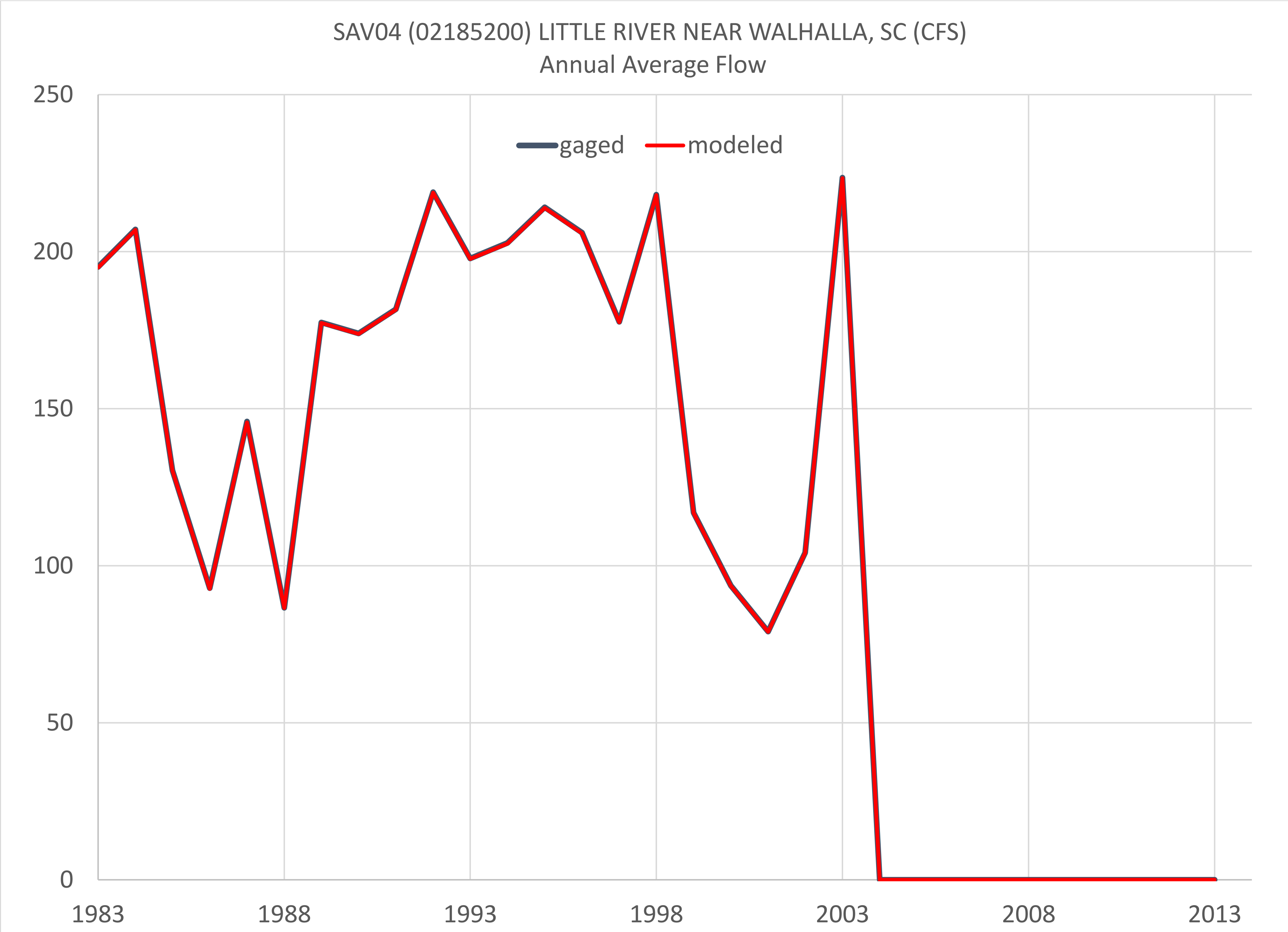


SAV45 (02198500) SAVANNAH RIVER NEAR CLYO, GA
Monthly Mean Flow (CFS)
gaged
modeled
18,000
16,000
14,000
12,000
10,000
8,000
6,000
4,000
2,000
0
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec

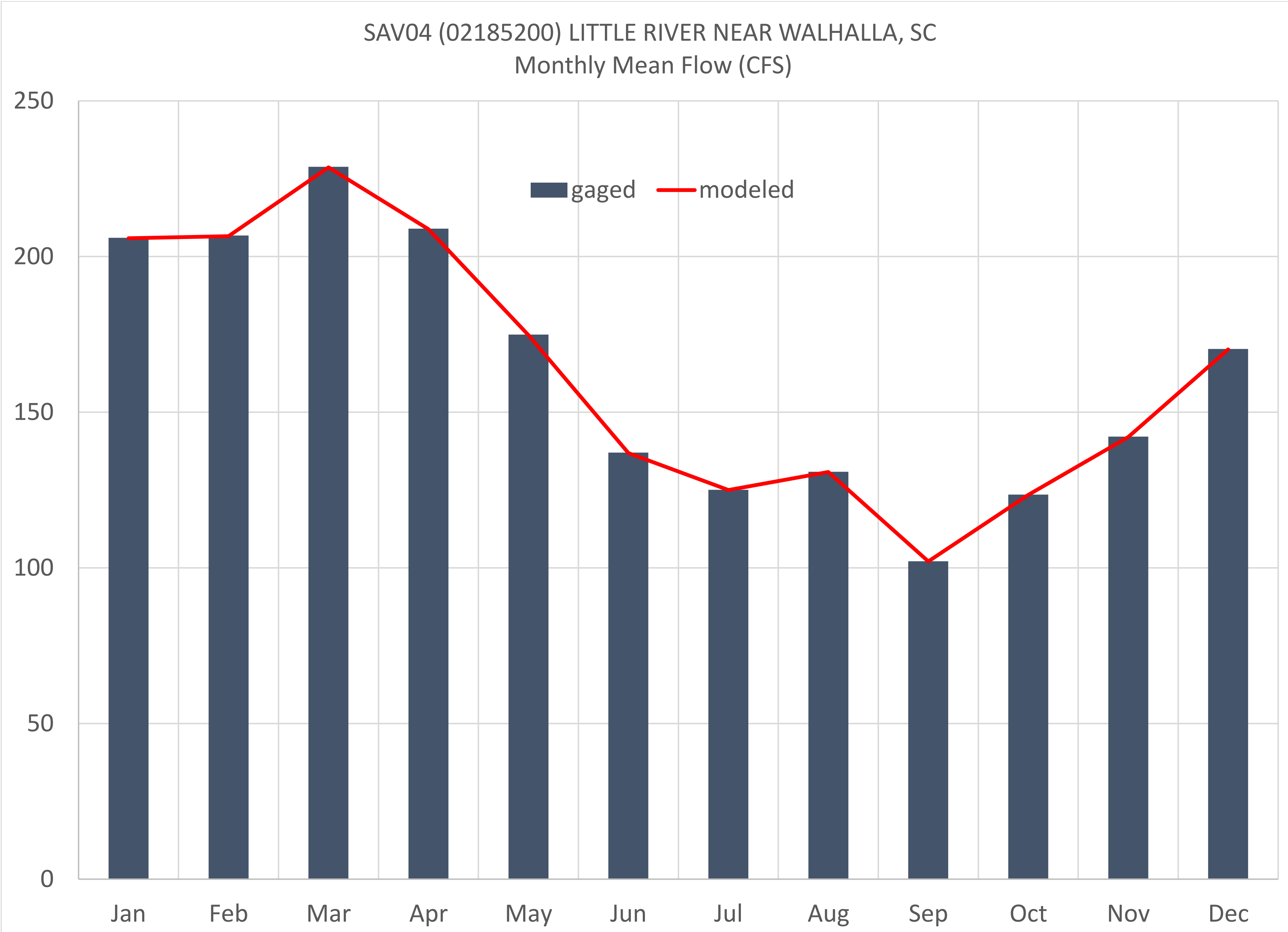

SAV45 (02198500) SAVANNAH RIVER NEAR CLYO, GA
Monthly Flow Percentiles (CFS)
gaged
modeled
50000
45000
40000
35000
30000
25000
20000
15000
10000
5000
0
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
Percentile

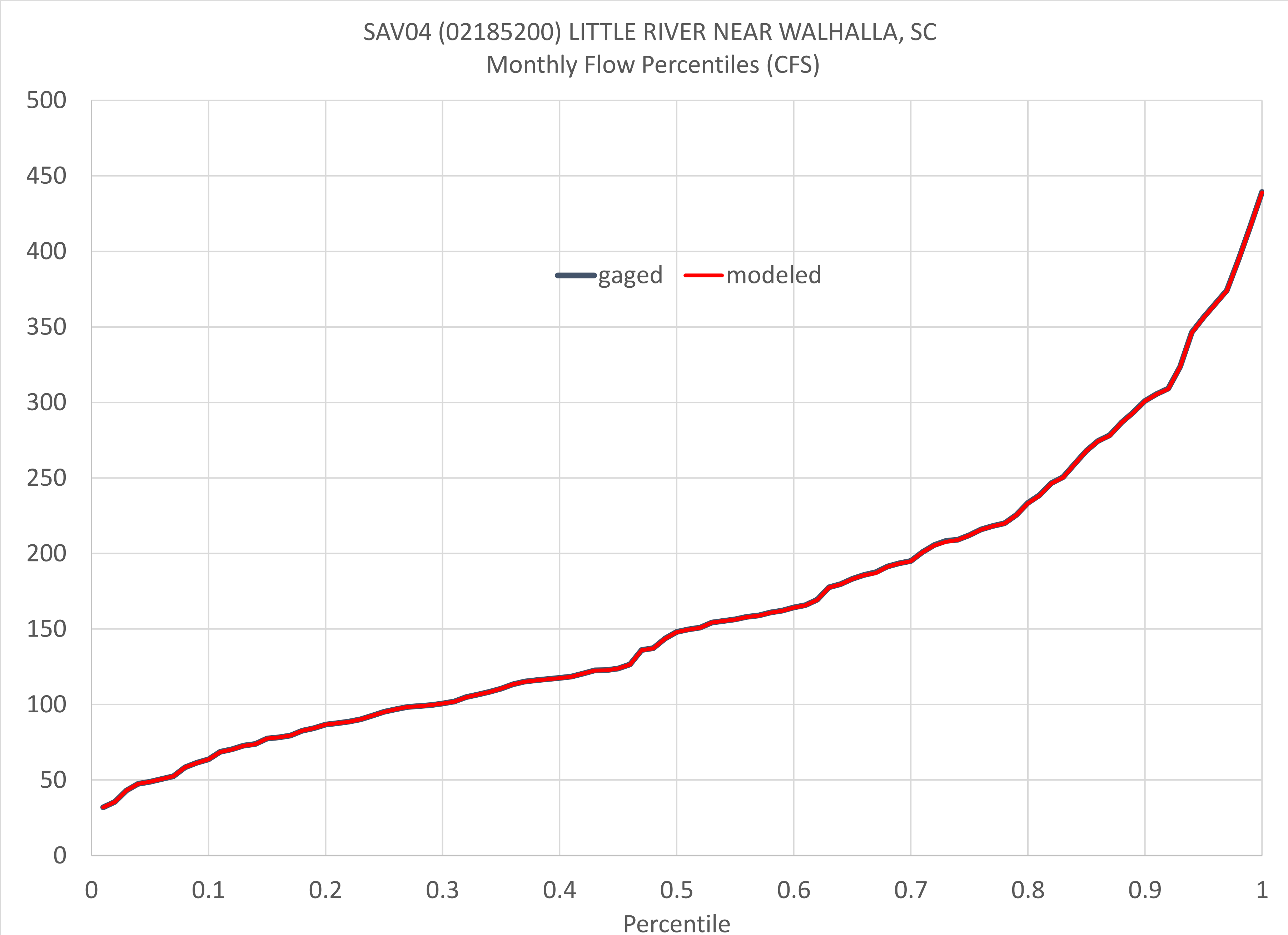

SAV04 (02185200) LITTLE RIVER NEAR WALHALLA, SC (CFS)
modeled
gaged
800
700
600
500
400
300
200
100
0
Jan-83
Jul-88
Dec-93
Jun-99
Dec-04
Jun-10

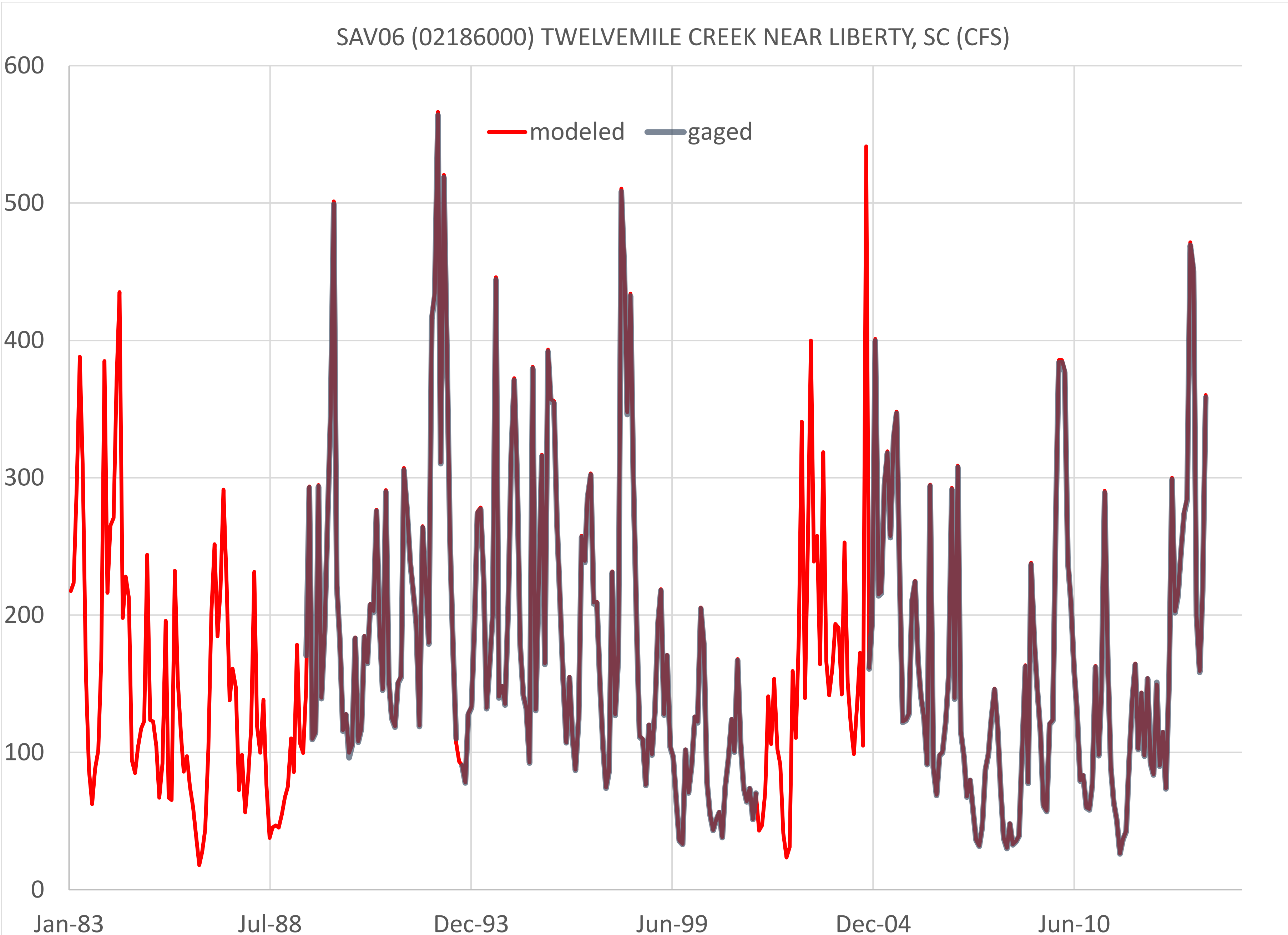

SAV04 (02185200) LITTLE RIVER NEAR WALHALLA, SC
Cumulative Flow (CFS)
modeled
gaged
45,000
40,000
35,000
30,000
25,000
20,000
15,000
10,000
5,000
0
Jan-83
Jul-88
Dec-93
Jun-99
Dec-04
Jun-10

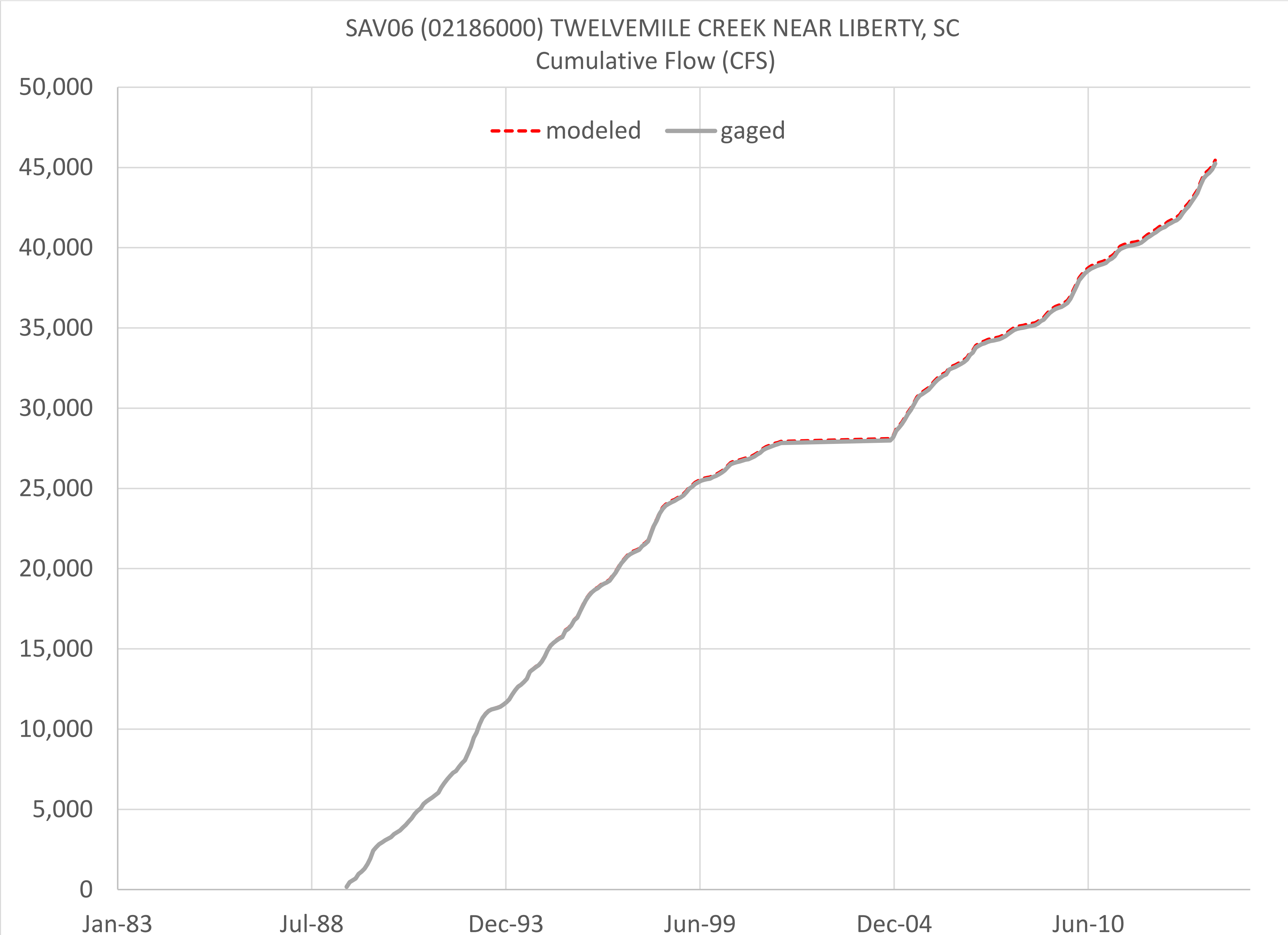


SAV04 (02185200) LITTLE RIVER NEAR WALHALLA, SC (CFS)
Annual Average Flow
gaged
modeled
250
200
150
100
50
0
1983
1988
1993
1998
2003
2008
2013

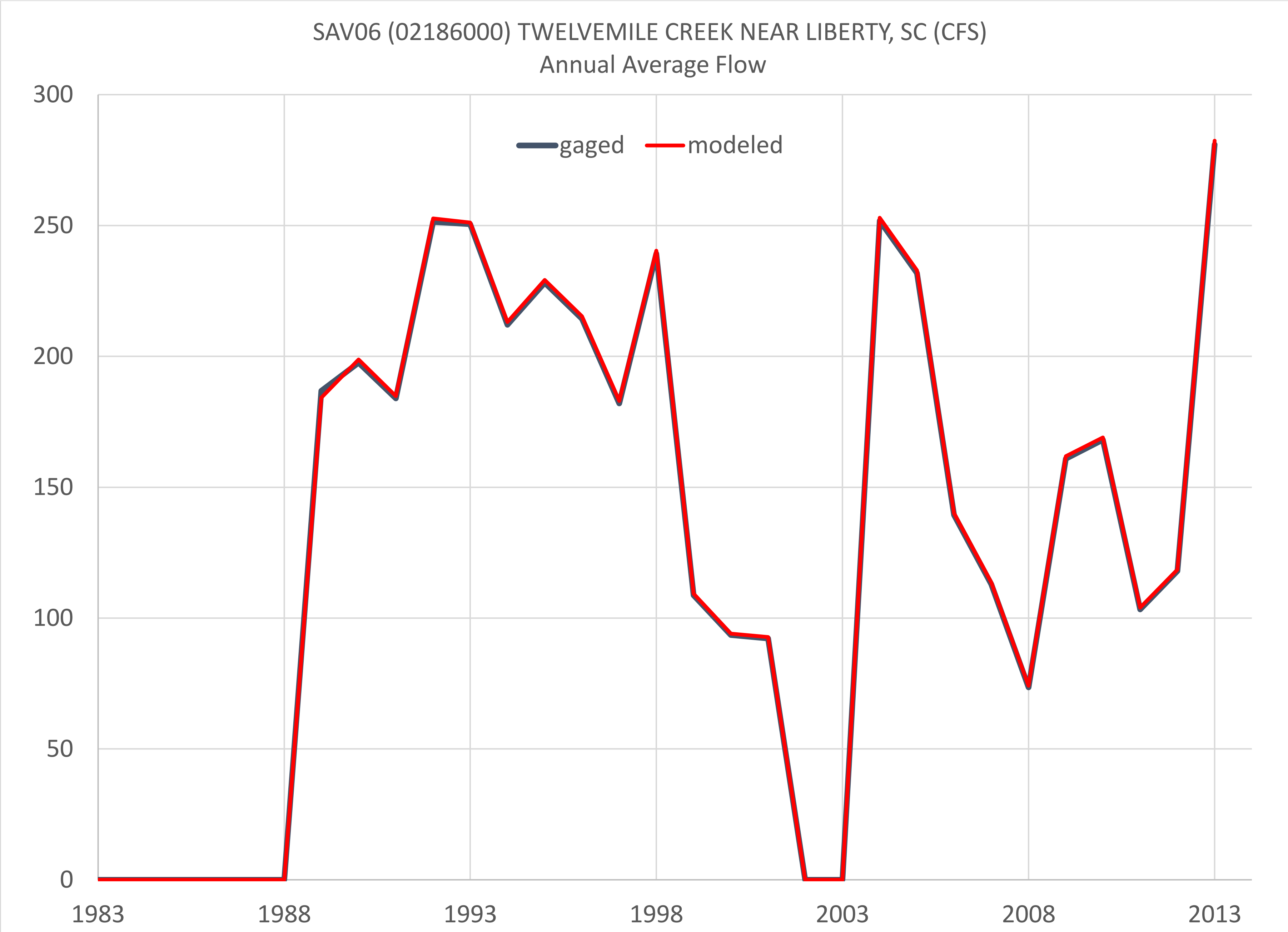

SAV04 (02185200) LITTLE RIVER NEAR WALHALLA, SC
Monthly Mean Flow (CFS)
250
200
150
100
50
0
gaged
modeled
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec


SAV04 (02185200) LITTLE RIVER NEAR WALHALLA, SC
Monthly Flow Percentiles (CFS)
500
450
400
350
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
gaged
modeled

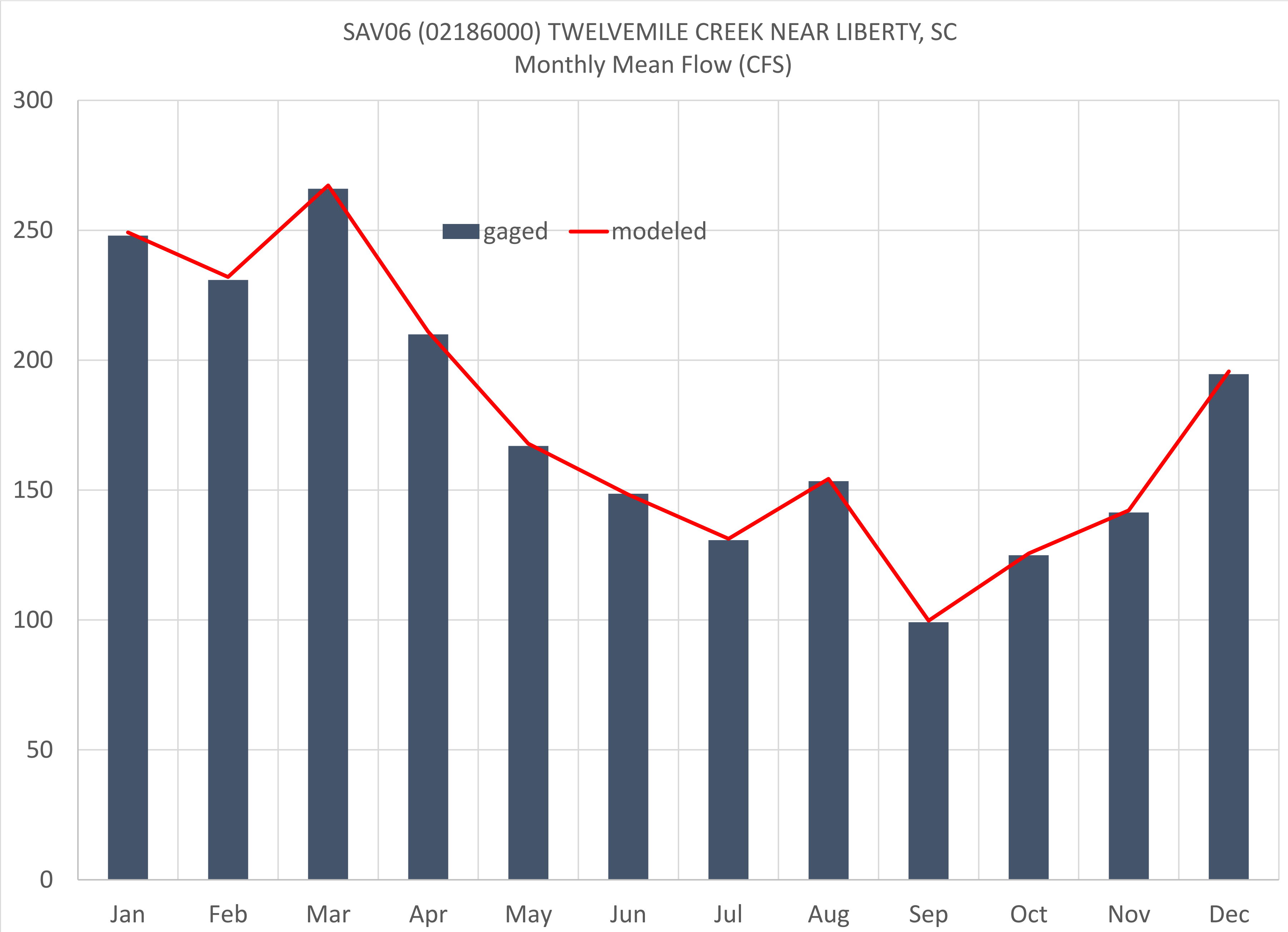

SAV06 (02186000) TWELVEMILE CREEK NEAR LIBERTY, SC (CFS)
modeled
gaged
600
500
400
300
200
100
0
Jan-83
Jul-88
Dec-93
Jun-99
Dec-04
Jun-10

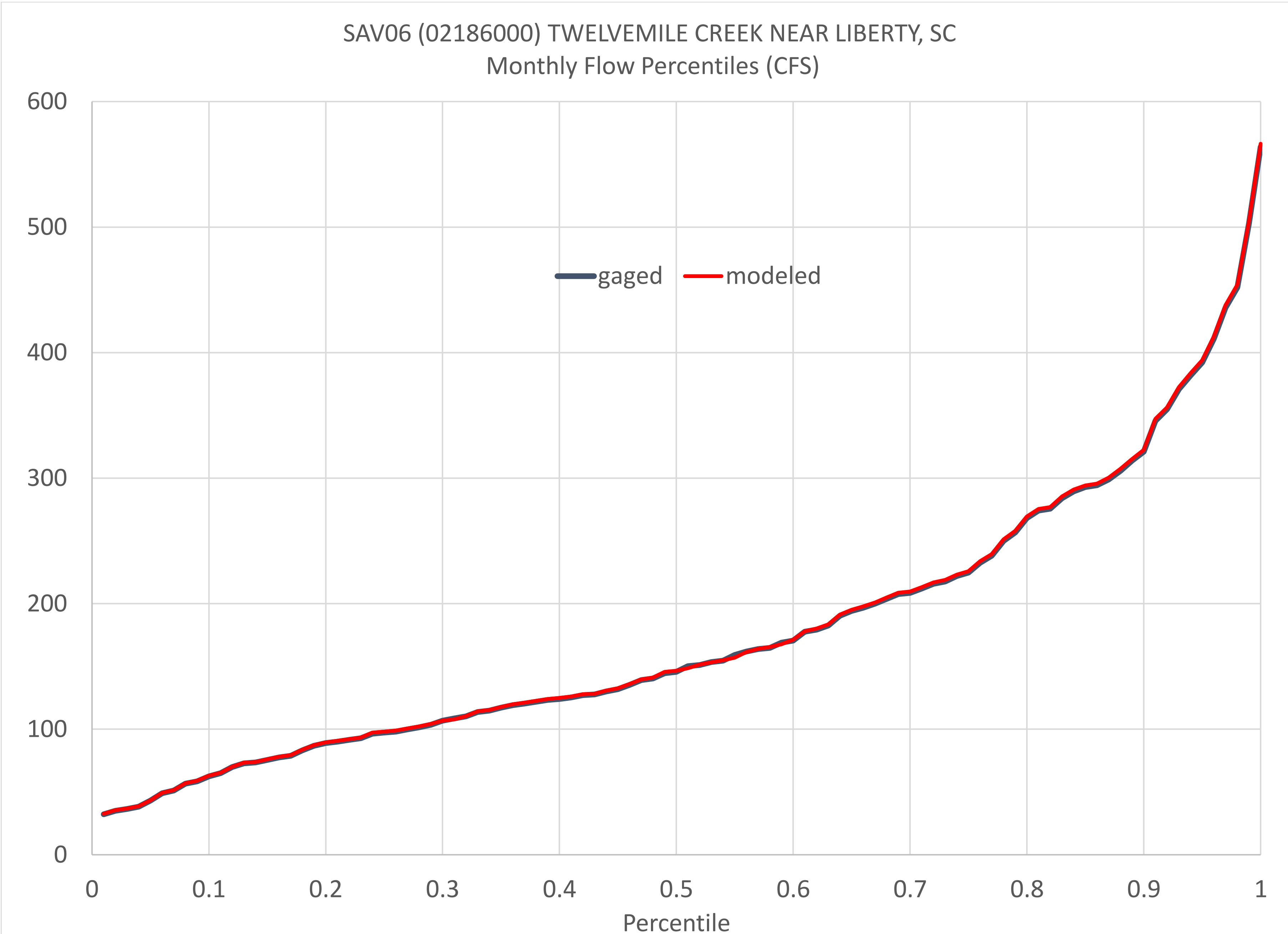


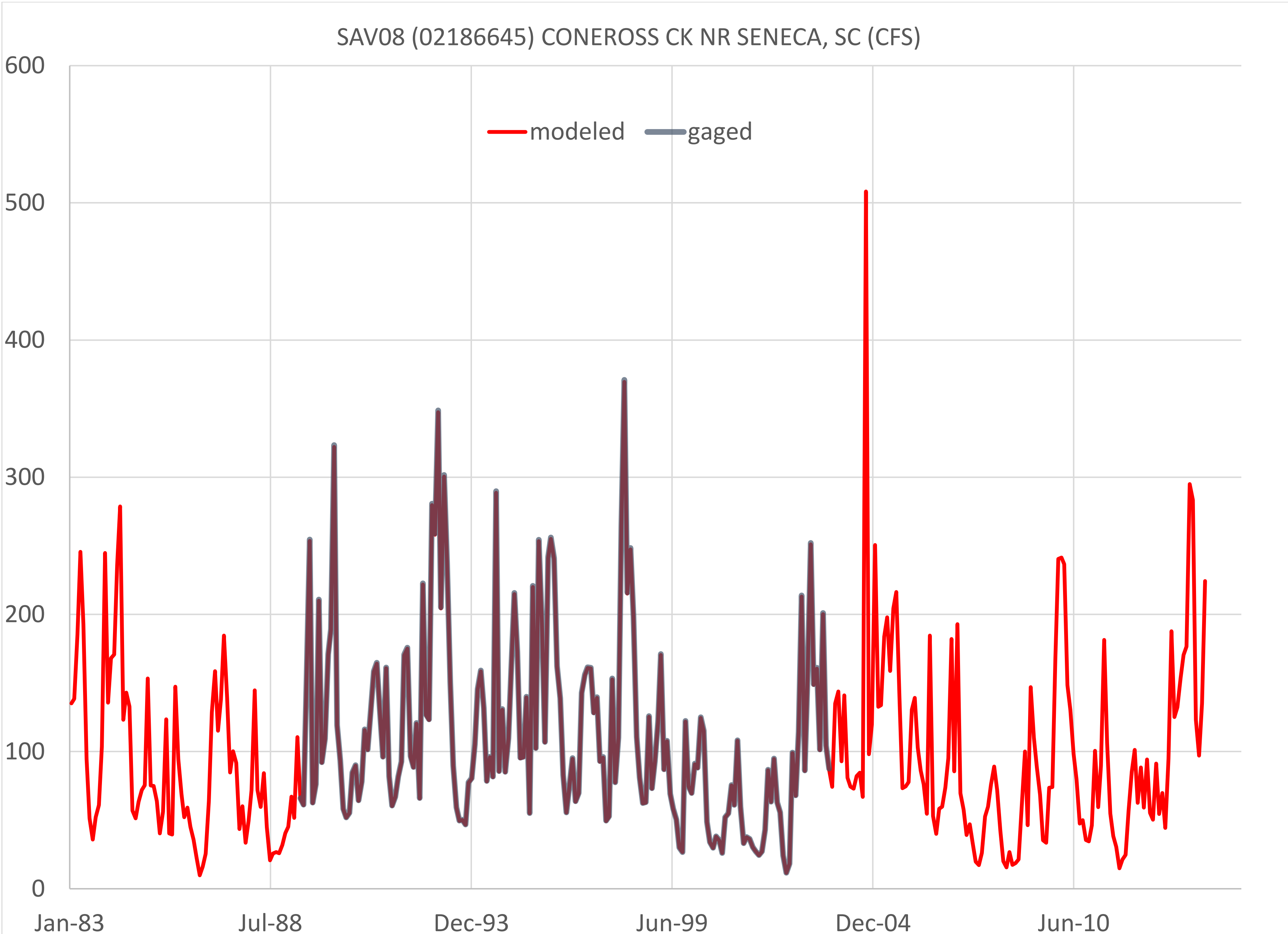
SAV06 (02186000) TWELVEMILE CREEK NEAR LIBERTY, SC
Cumulative Flow (CFS)
modeled
gaged
50,000
45,000
40,000
35,000
30,000
25,000
20,000
15,000
10,000
5,000
0
Jan-83
Jul-88
Dec-93
Jun-99
Dec-04
Jun-10

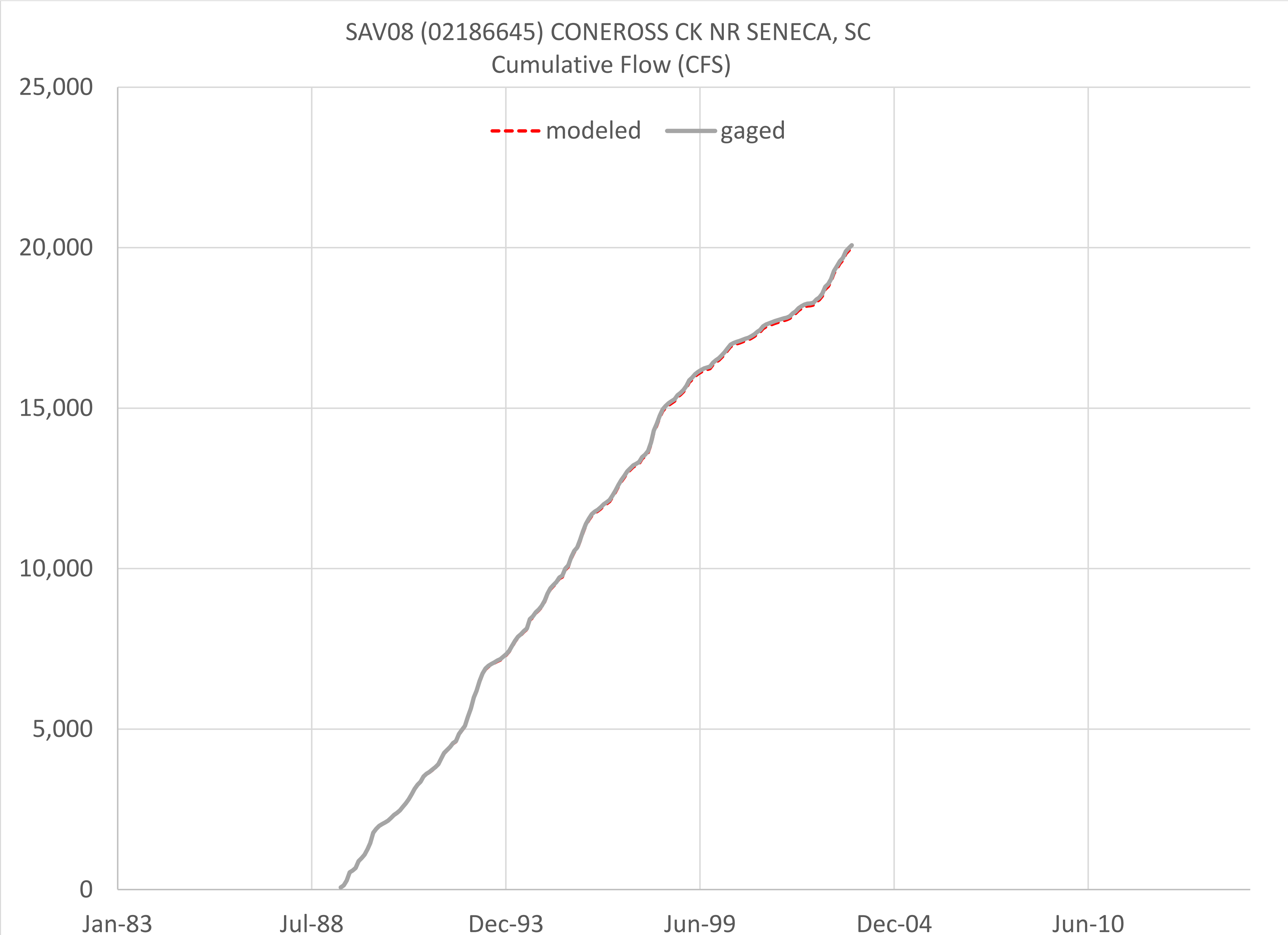


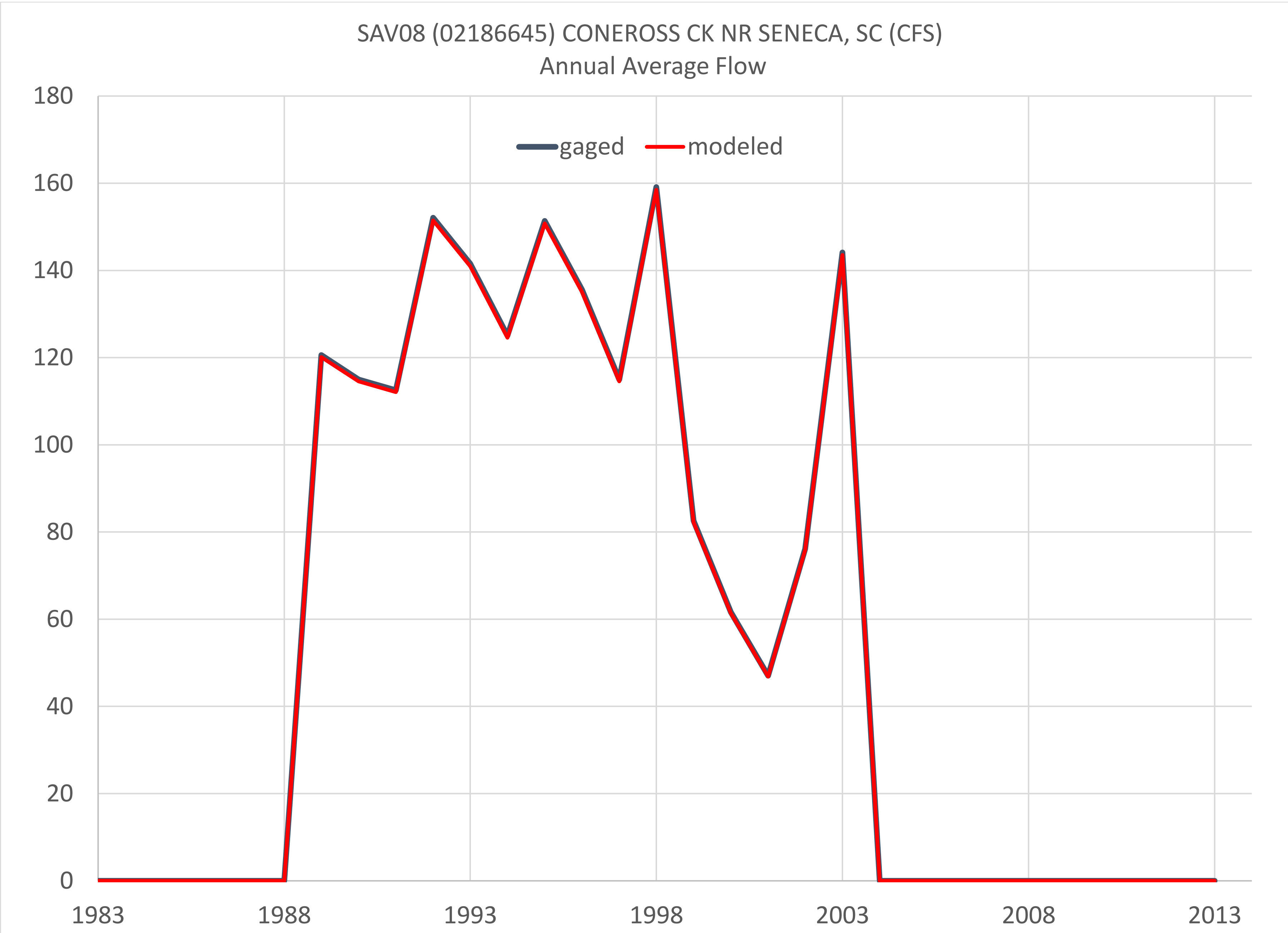
SAV06 (02186000) TWELVEMILE CREEK NEAR LIBERTY, SC (CFS)
Annual Average Flow
gaged
modeled
300
250
200
150
100
50
0
1983
1988
1993
1998
2003
2008
2013


SAV06 (02186000) TWELVEMILE CREEK NEAR LIBERTY, SC
Monthly Mean Flow (CFS)
300
250
200
150
100
50
0
gaged
modeled
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec

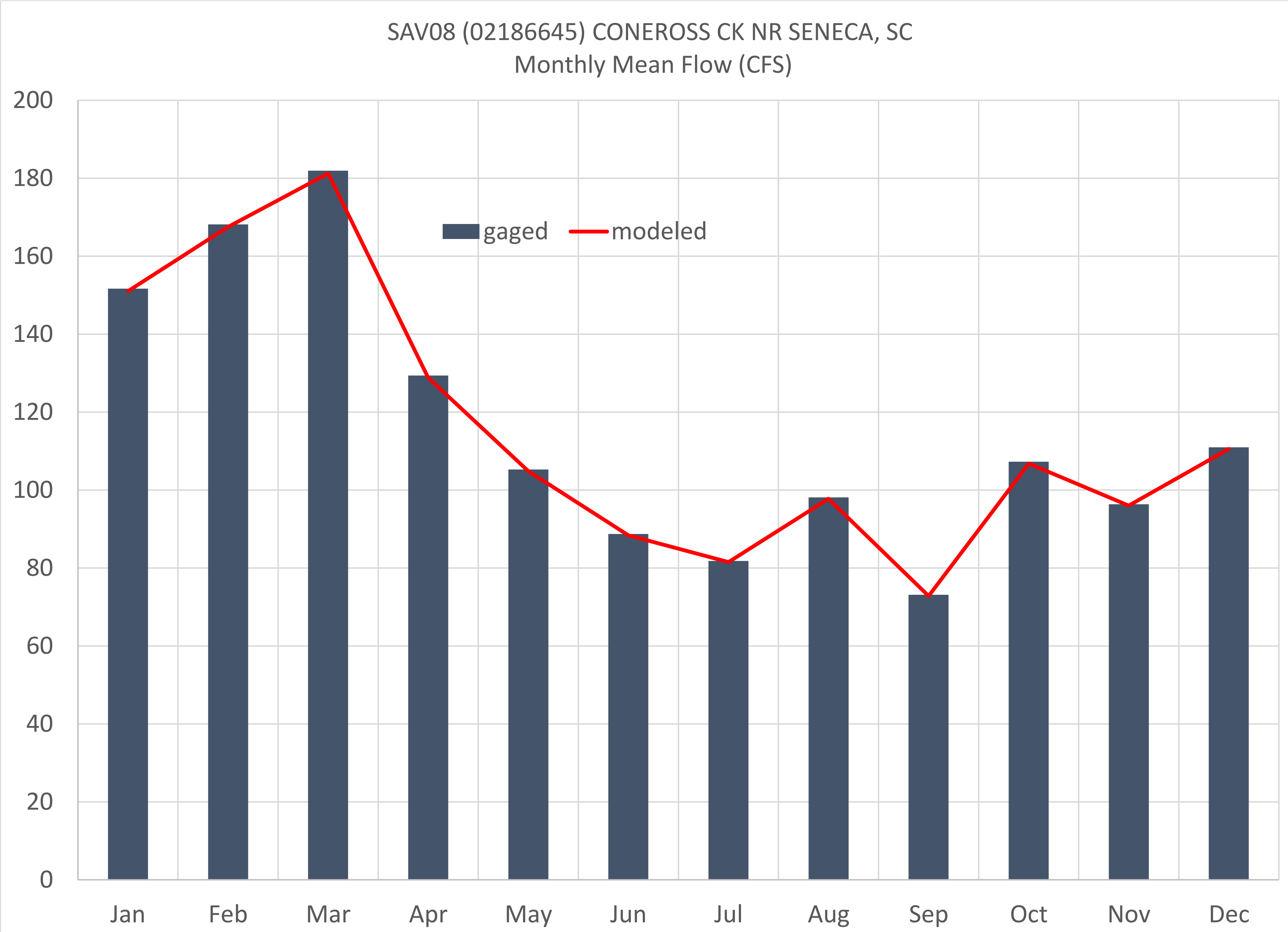

SAV06 (02186000) TWELVEMILE CREEK NEAR LIBERTY, SC
Monthly Flow Percentiles (CFS)
gaged
modeled
600
500
400
300
200
100
0
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
Percentile


SAV08 (02186645) CONEROSS CK NR SENECA, SC (CFS)
modeled
gaged
600
500
400
300
200
100
0
Jan-83
Jul-88
Dec-93
Jun-99
Dec-04
Jun-10

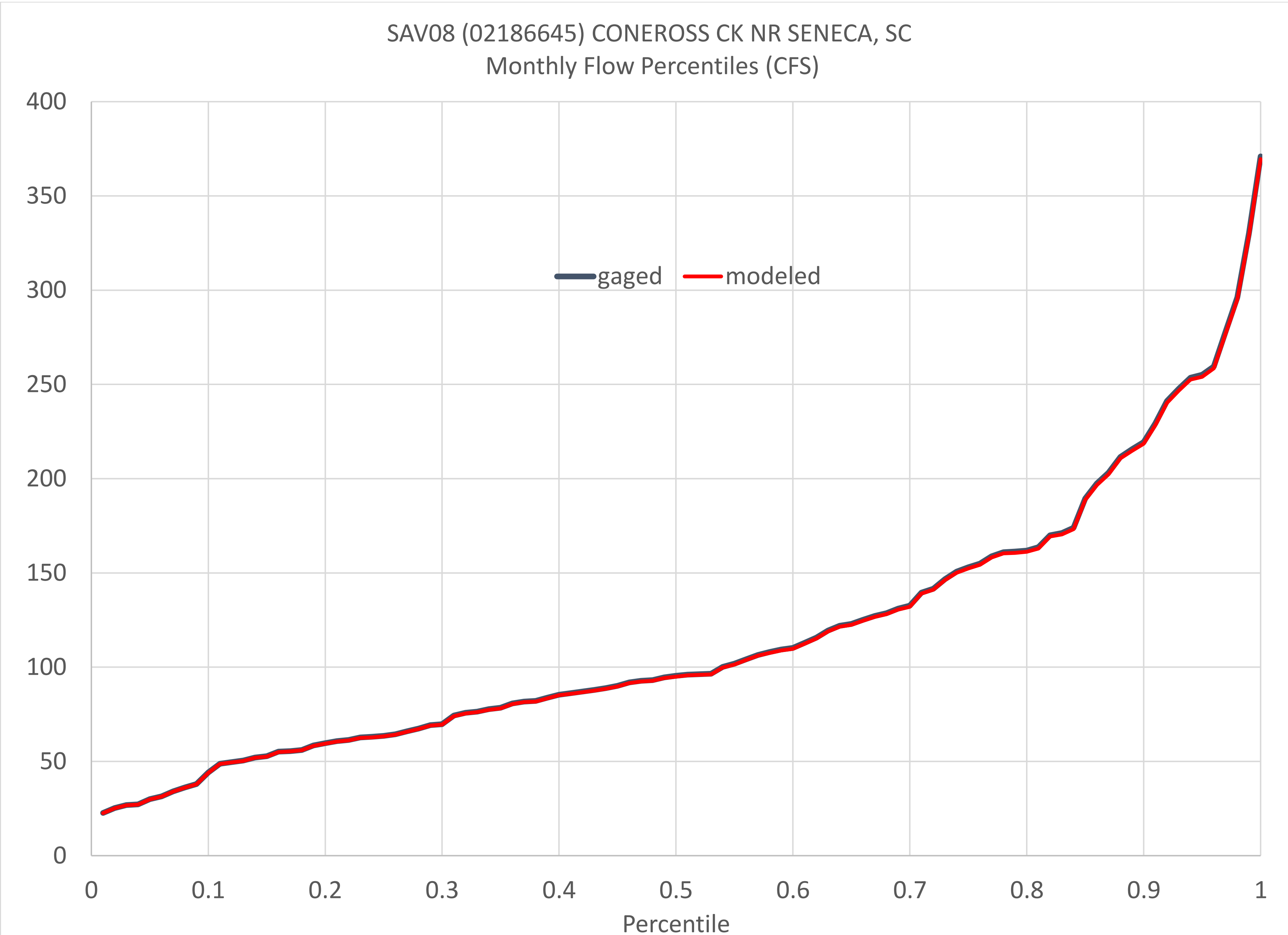

SAV08 (02186645) CONEROSS CK NR SENECA, SC
Cumulative Flow (CFS)
modeled
gaged
25,000
20,000
15,000
10,000
5,000
0
Jan-83
Jul-88
Dec-93
Jun-99
Dec-04
Jun-10

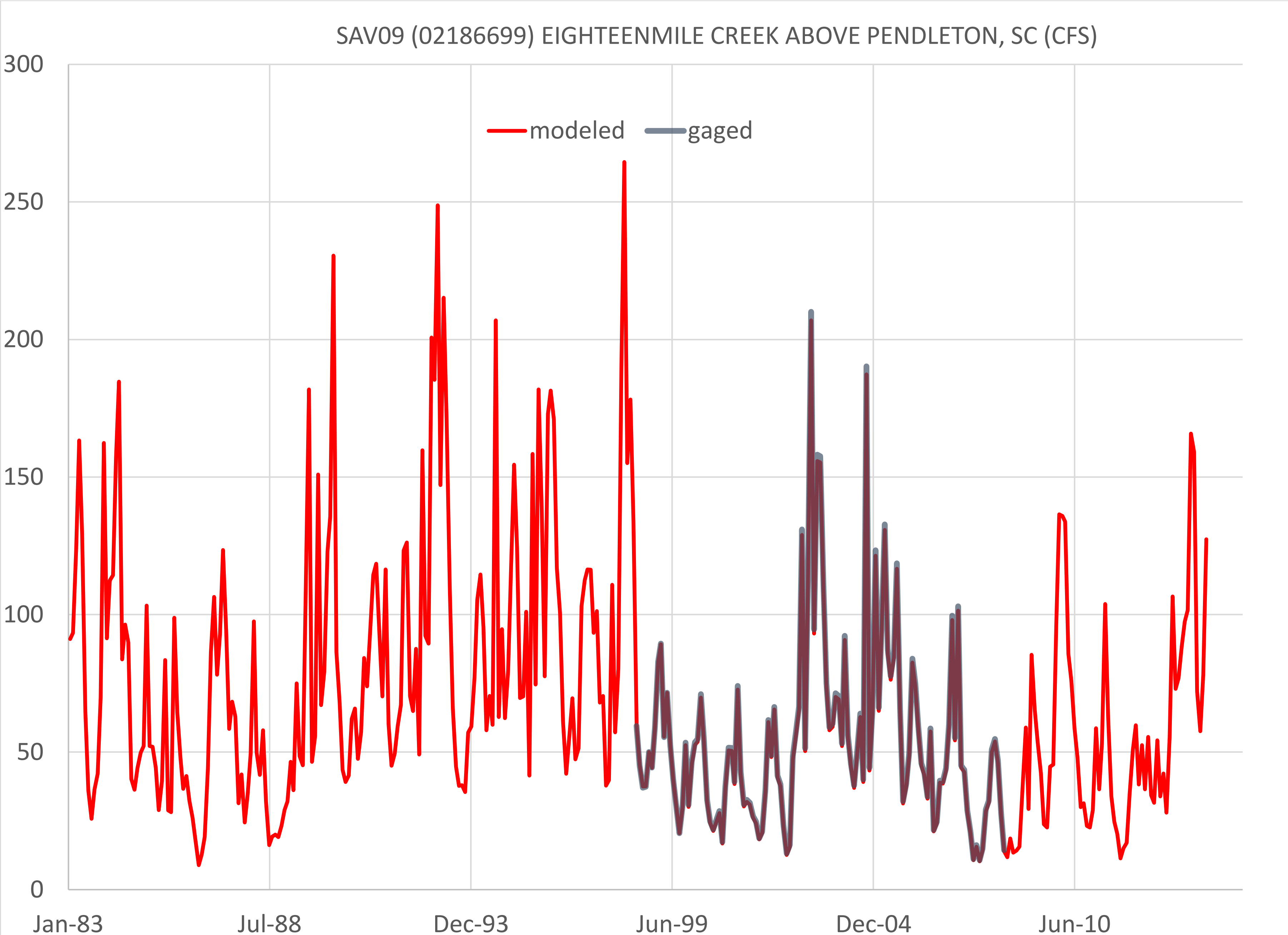


SAV08 (02186645) CONEROSS CK NR SENECA, SC (CFS)
Annual Average Flow
gaged
modeled
180
160
140
120
100
80
60
40
20
0
1983
1988
1993
1998
2003
2008
2013

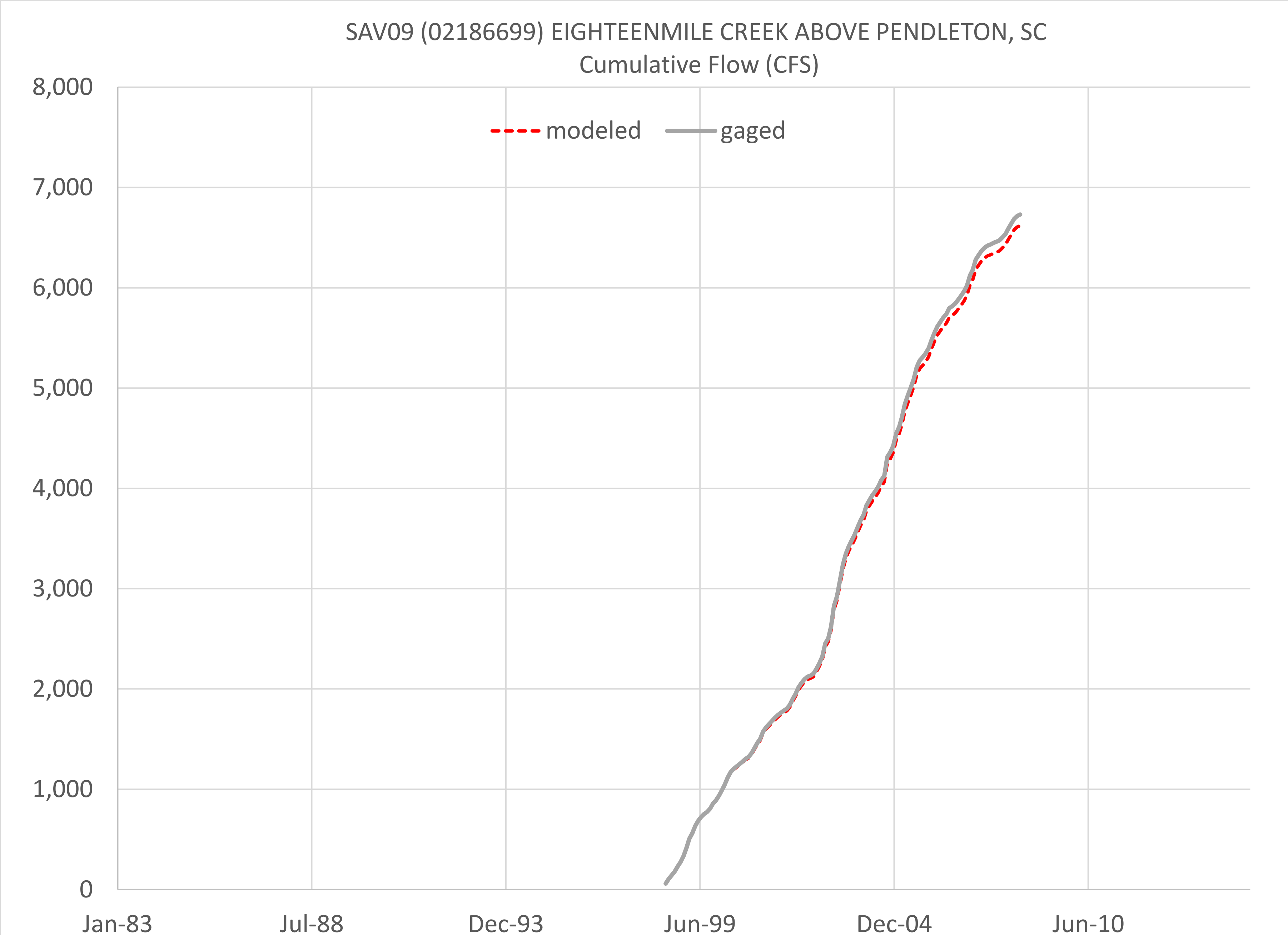


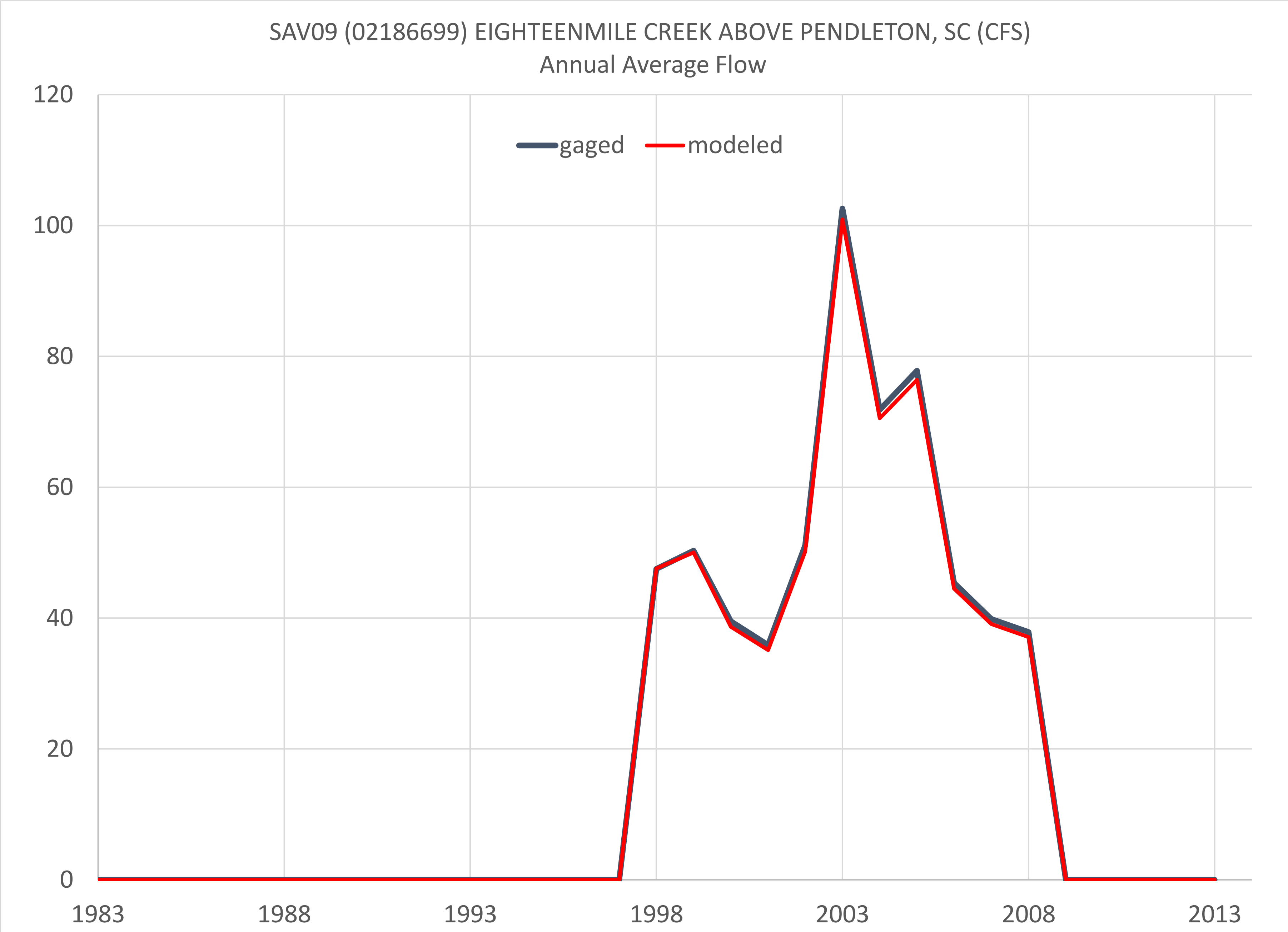
SAV08 (02186645) CONEROSS CK NR SENECA, SC
Monthly Mean Flow (CFS)
gaged
modeled
200
180
160
140
120
100
80
60
40
20
0
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec

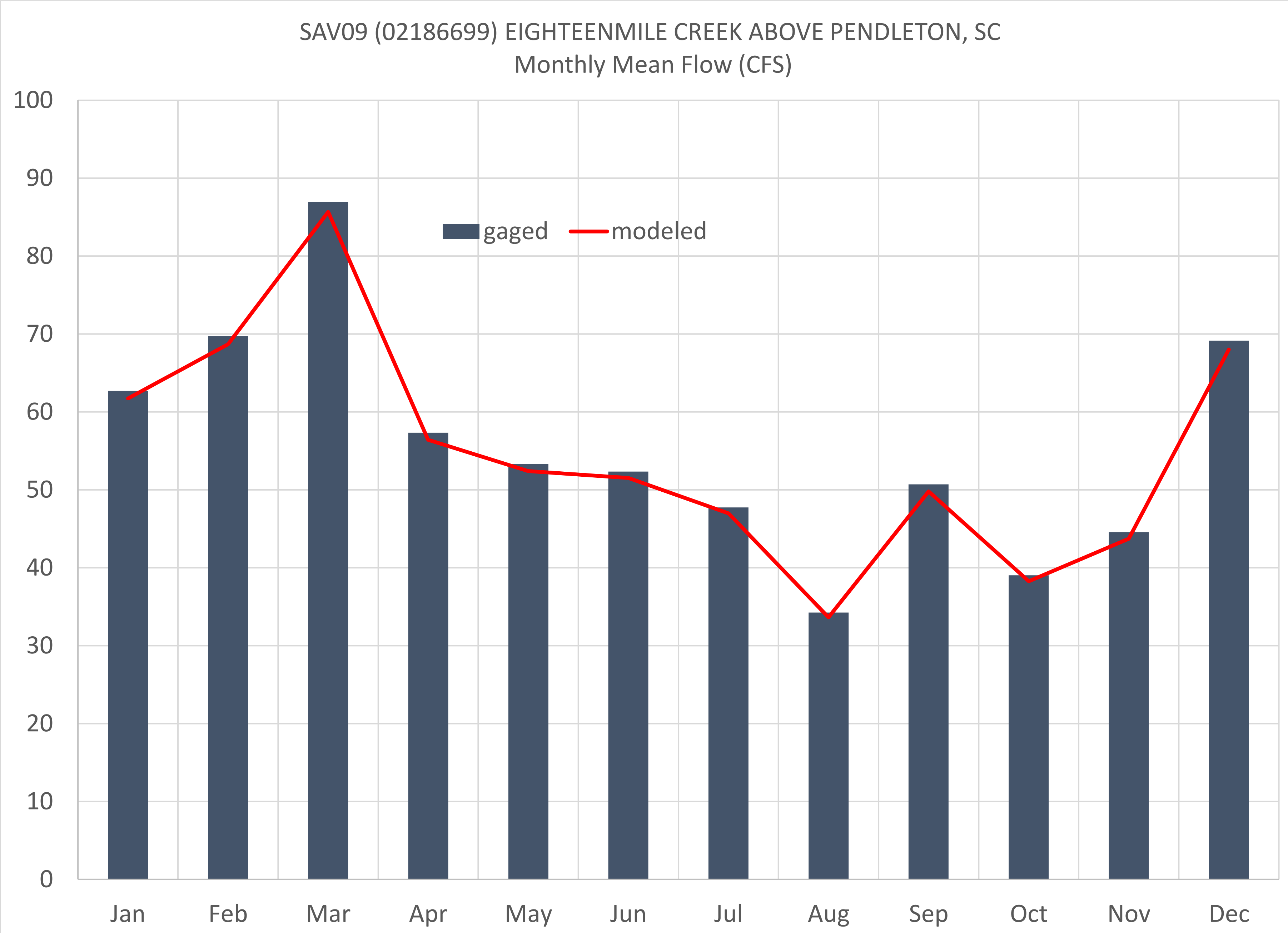

SAV08 (02186645) CONEROSS CK NR SENECA, SC
Monthly Flow Percentiles (CFS)
gaged
modeled
400
350
300
250
200
150
100
50
0
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
Percentile



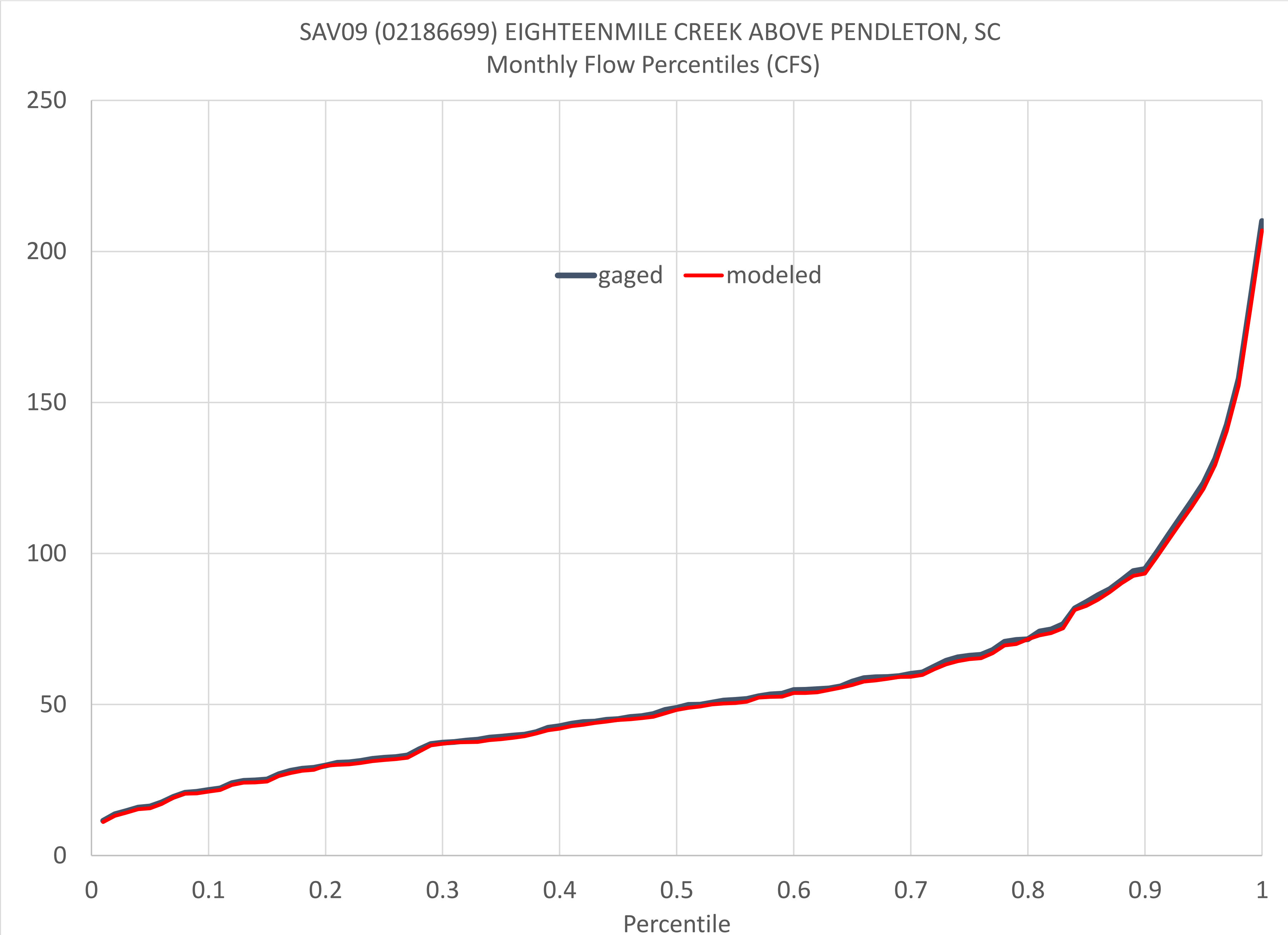
SAV09 (02186699) EIGHTEENMILE CREEK ABOVE PENDLETON, SC (CFS)
modeled
gaged
300
250
200
150
100
50
0
Jan-83
Jul-88
Dec-93
Jun-99
Dec-04
Jun-10

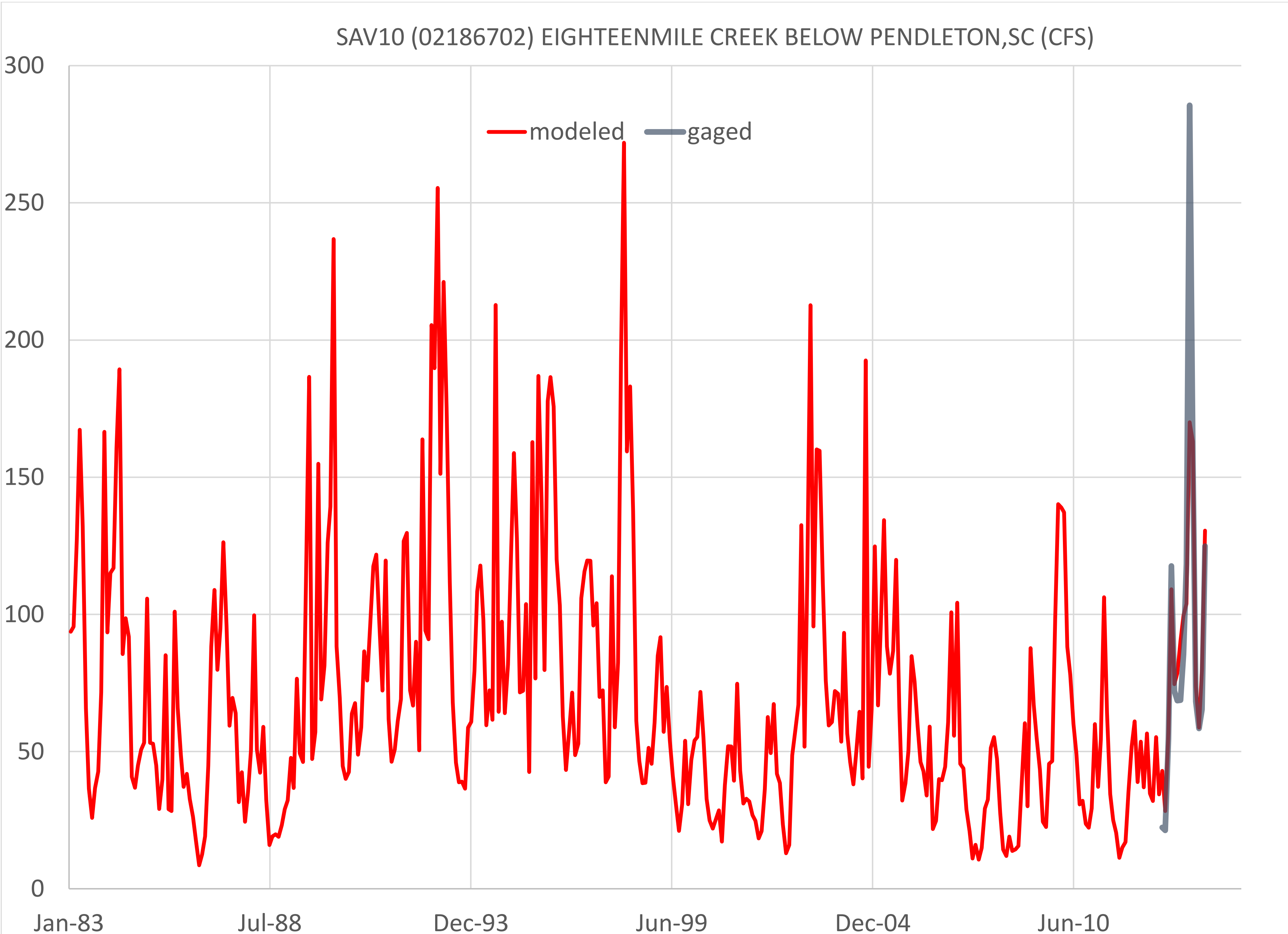

SAV09 (02186699) EIGHTEENMILE CREEK ABOVE PENDLETON, SC
Cumulative Flow (CFS)
modeled
gaged
8,000
7,000
6,000
5,000
4,000
3,000
2,000
1,000
0
Jan-83
Jul-88
Dec-93
Jun-99
Dec-04
Jun-10


SAV09 (02186699) EIGHTEENMILE CREEK ABOVE PENDLETON, SC (CFS)
Annual Average Flow
gaged
modeled
120
100
80
60
40
20
0
1983
1988
1993
1998
2003
2008
2013

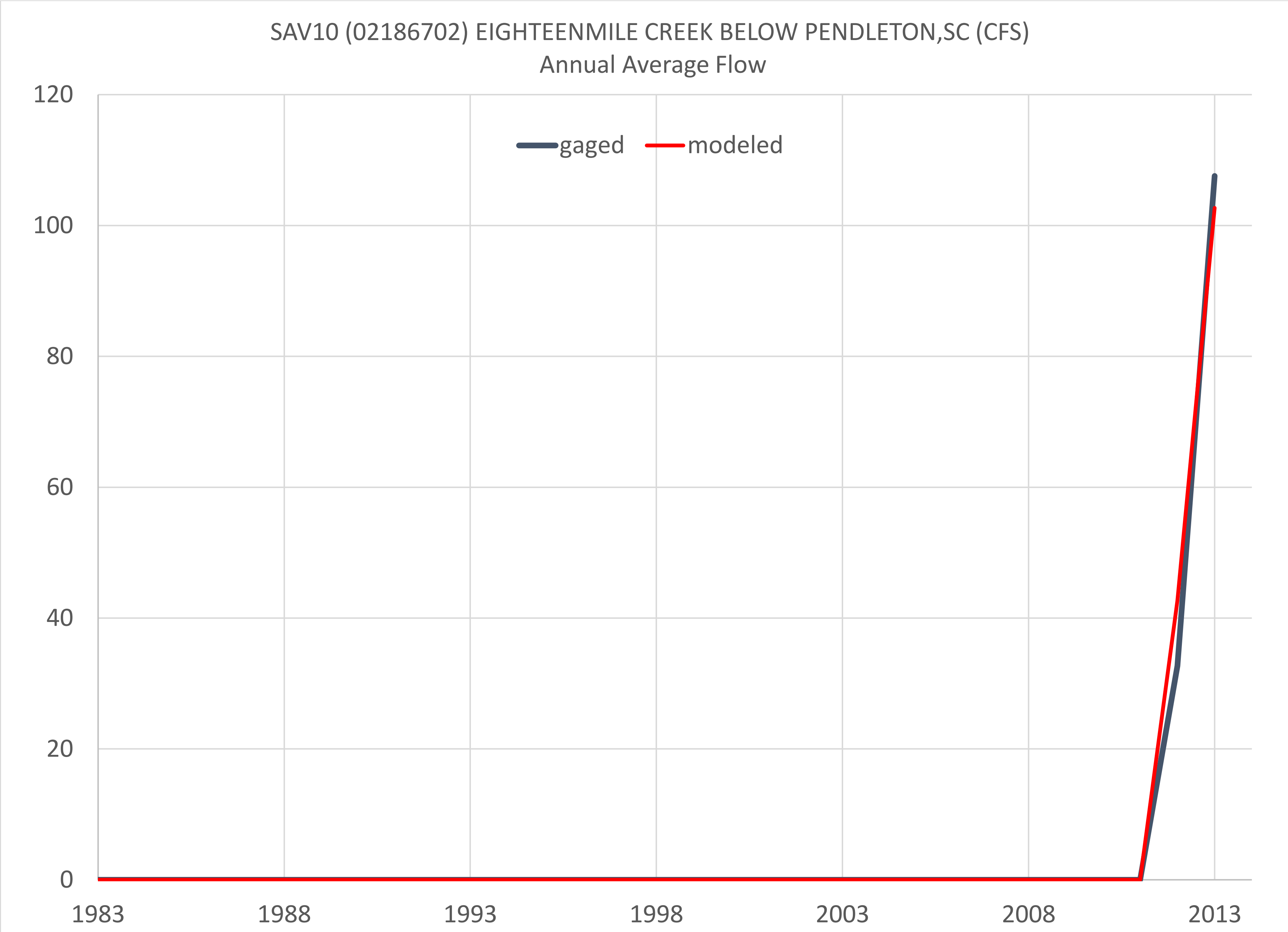


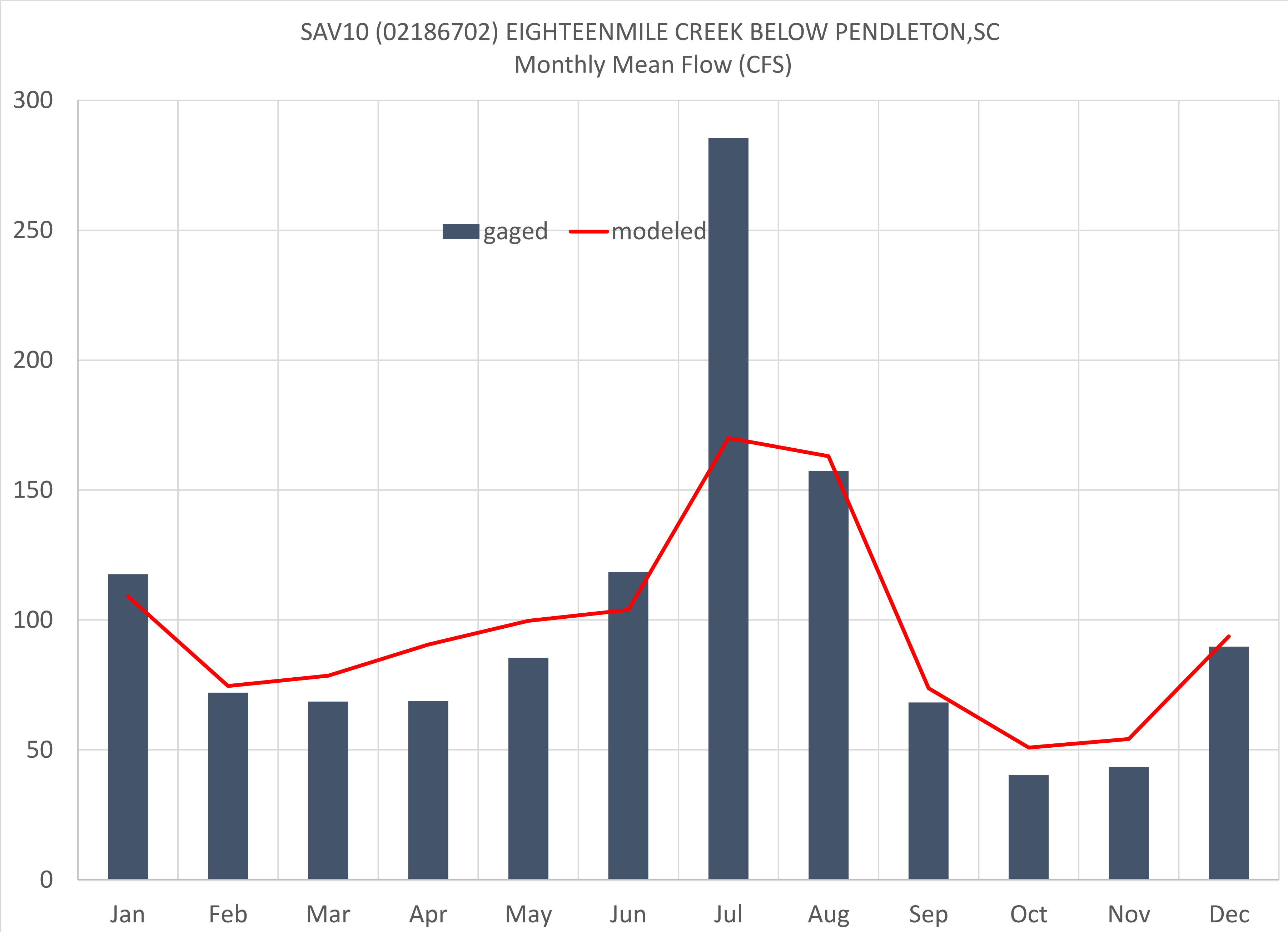
SAV09 (02186699) EIGHTEENMILE CREEK ABOVE PENDLETON, SC
Monthly Mean Flow (CFS)
gaged
modeled
100
90
80
70
60
50
40
30
20
10
0
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec

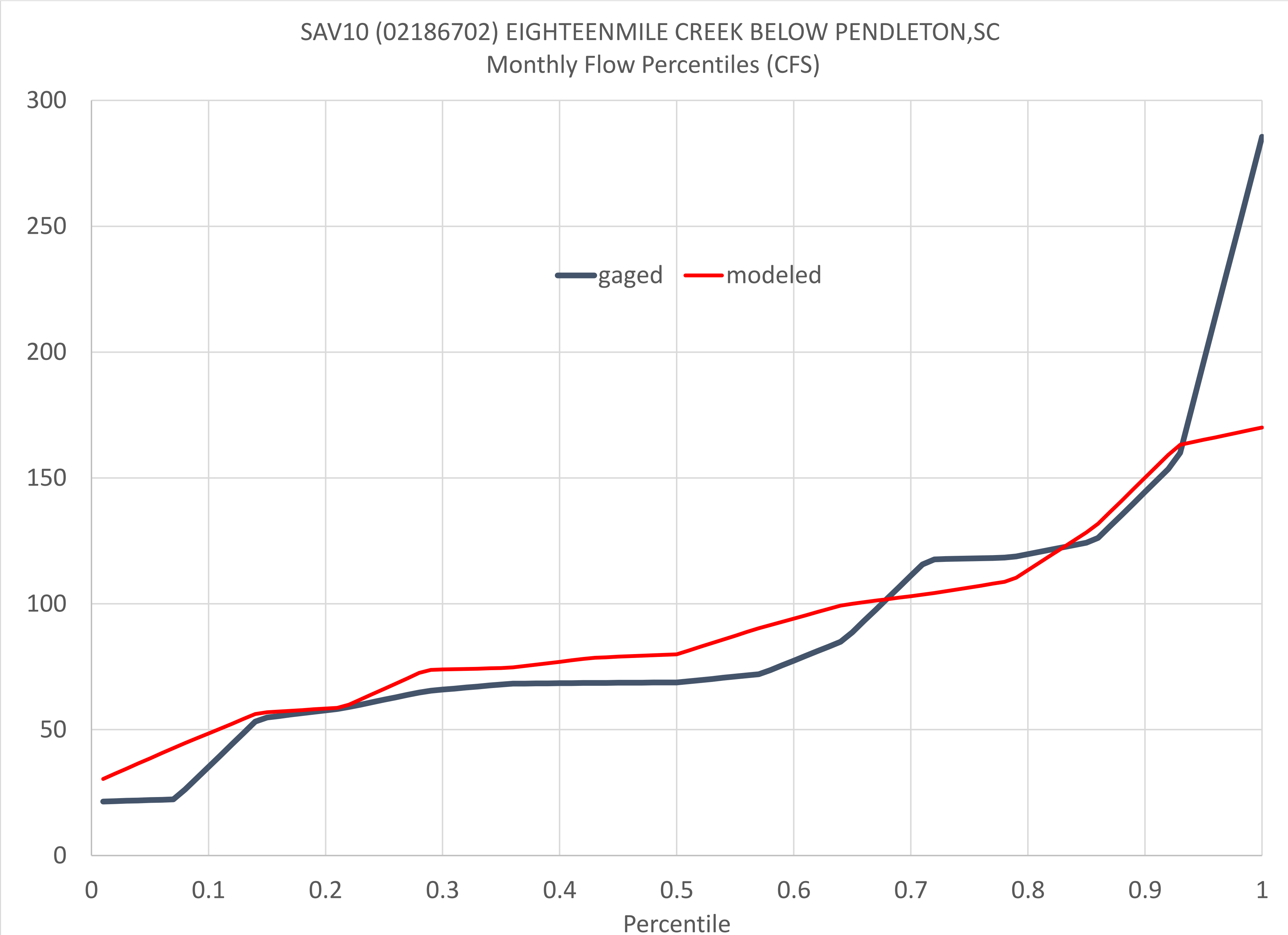

SAV09 (02186699) EIGHTEENMILE CREEK ABOVE PENDLETON, SC
Monthly Flow Percentiles (CFS)
250
200
150
100
50
0
gaged
modeled
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
Percentile

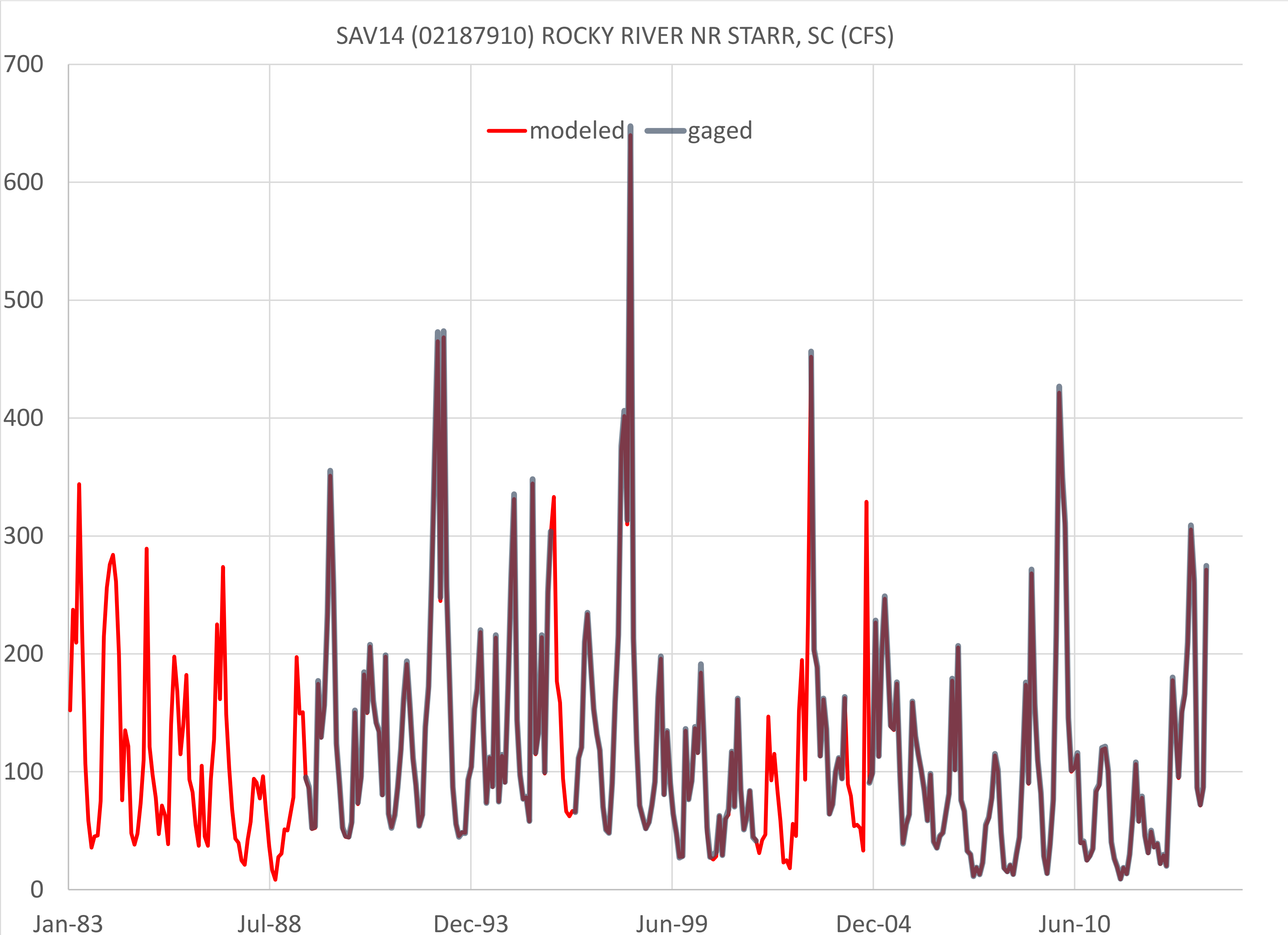

SAV10 (02186702) EIGHTEENMILE CREEK BELOW PENDLETON,SC (CFS)
modeled
gaged
300
250
200
150
100
50
0
Jan-83
Jul-88
Dec-93
Jun-99
Dec-04
Jun-10


SAV10 (02186702) EIGHTEENMILE CREEK BELOW PENDLETON,SC
Cumulative Flow (CFS)
modeled
gaged
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

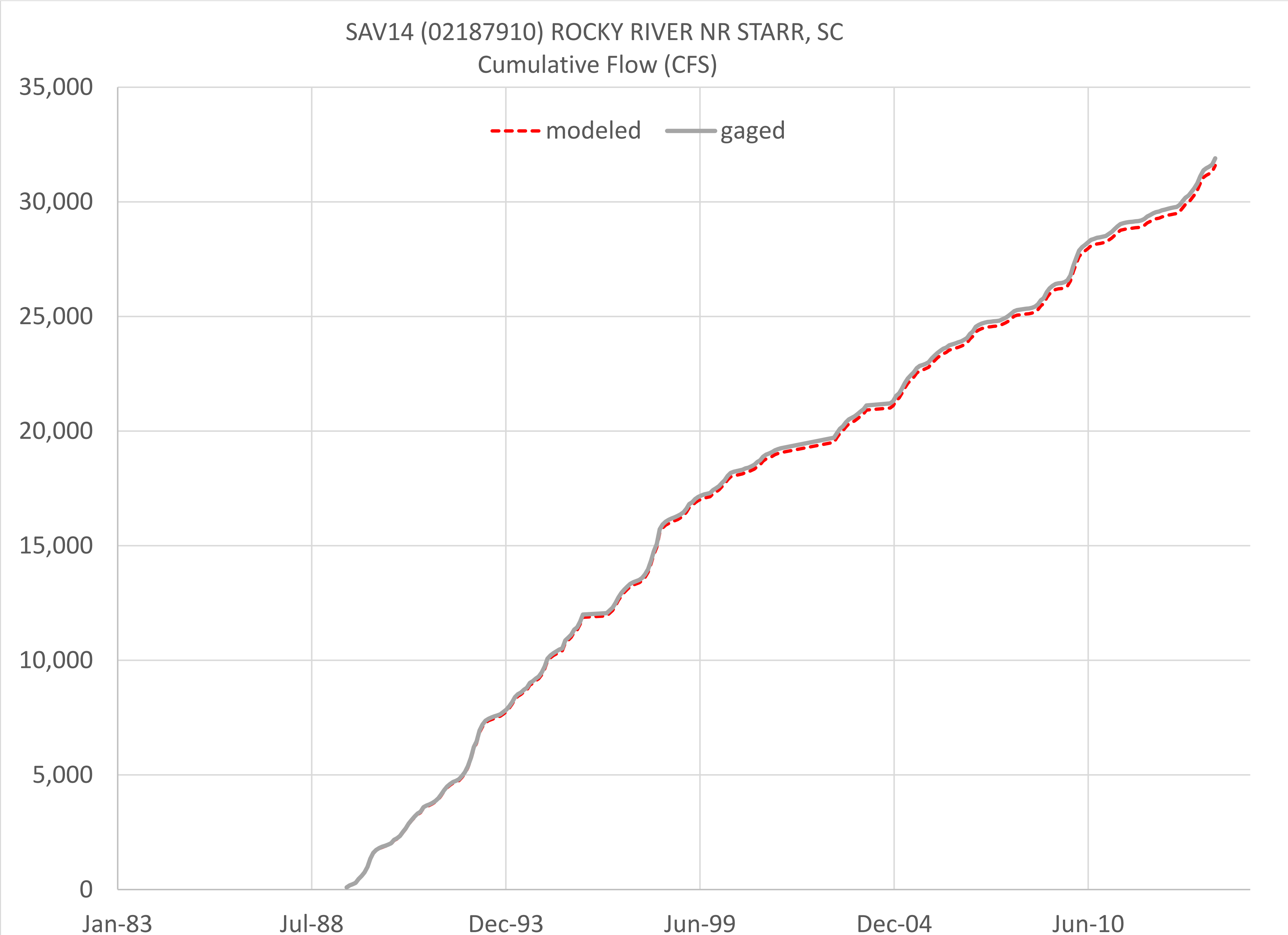

SAV10 (02186702) EIGHTEENMILE CREEK BELOW PENDLETON,SC (CFS)
Annual Average Flow
gaged
modeled
120
100
80
60
40
20
0
1983
1988
1993
1998
2003
2008
2013


SAV10 (02186702) EIGHTEENMILE CREEK BELOW PENDLETON,SC
Monthly Mean Flow (CFS)
300
250
200
150
100
50
0
gaged
modeled
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec

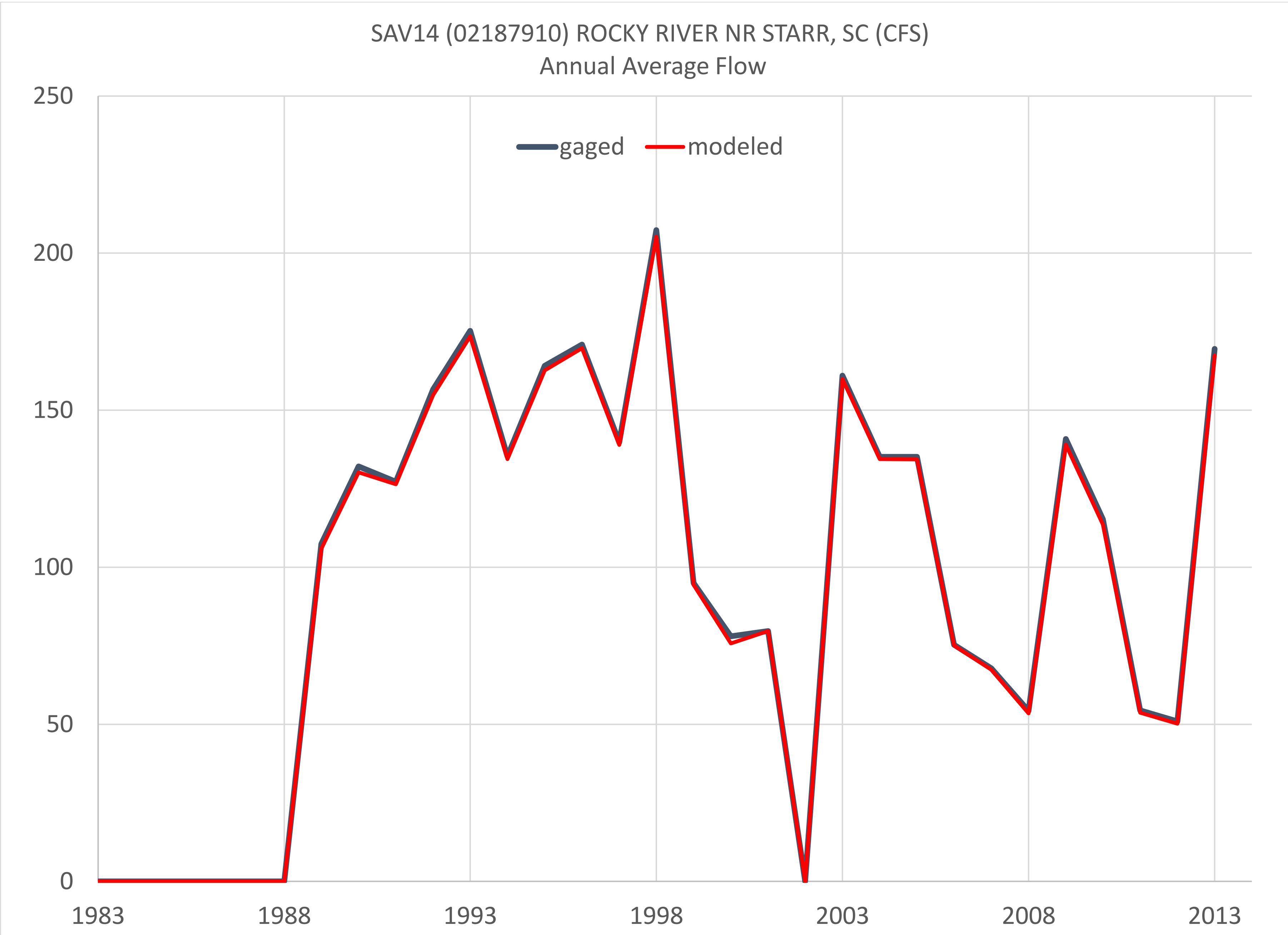

SAV10 (02186702) EIGHTEENMILE CREEK BELOW PENDLETON,SC
Monthly Flow Percentiles (CFS)
300
250
200
150
100
50
0
gaged
modeled
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
Percentile

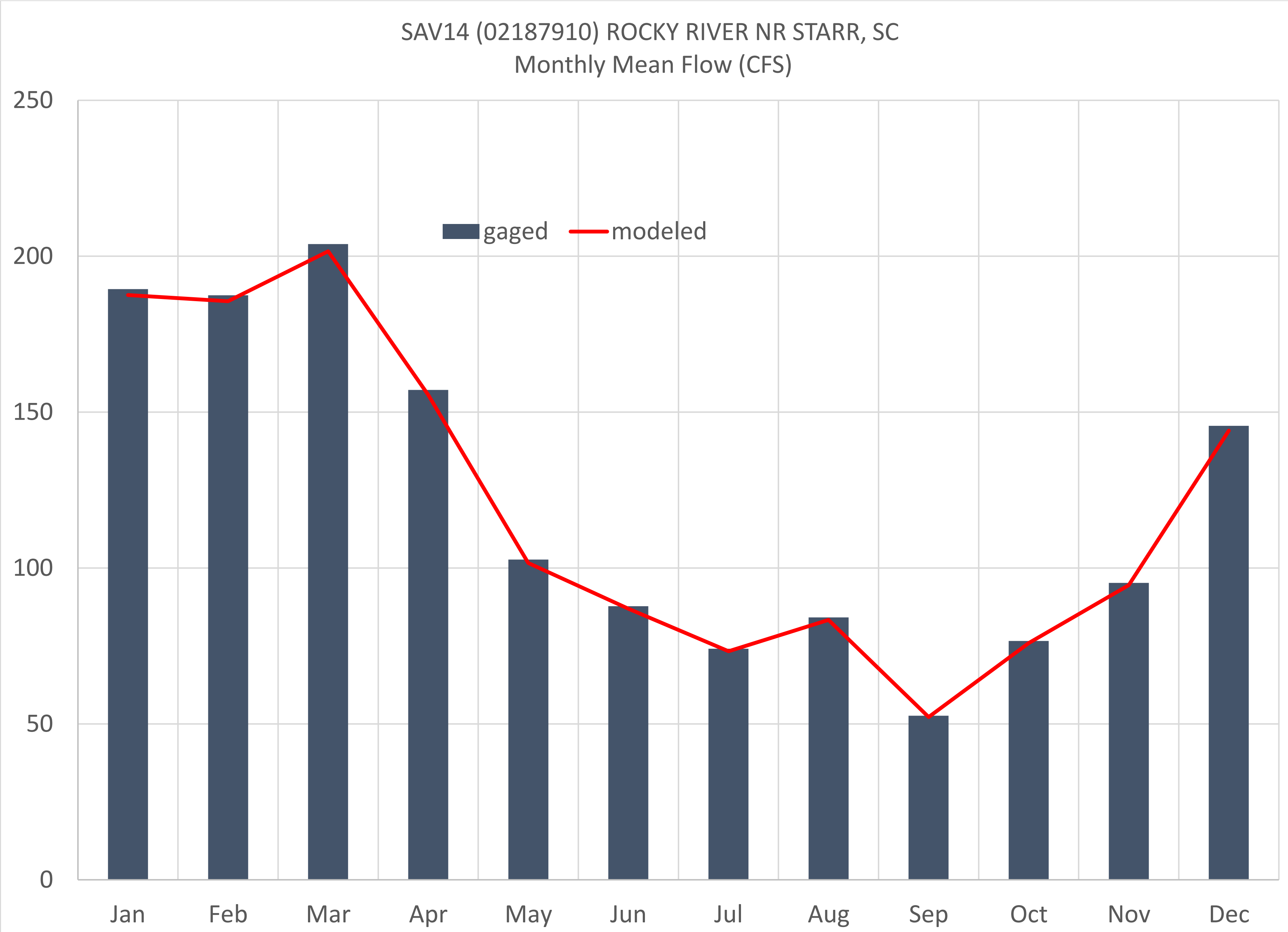


SAV14 (02187910) ROCKY RIVER NR STARR, SC (CFS)
modeled
gaged
700
600
500
400
300
200
100
0
Jan-83
Jul-88
Dec-93
Jun-99
Dec-04
Jun-10

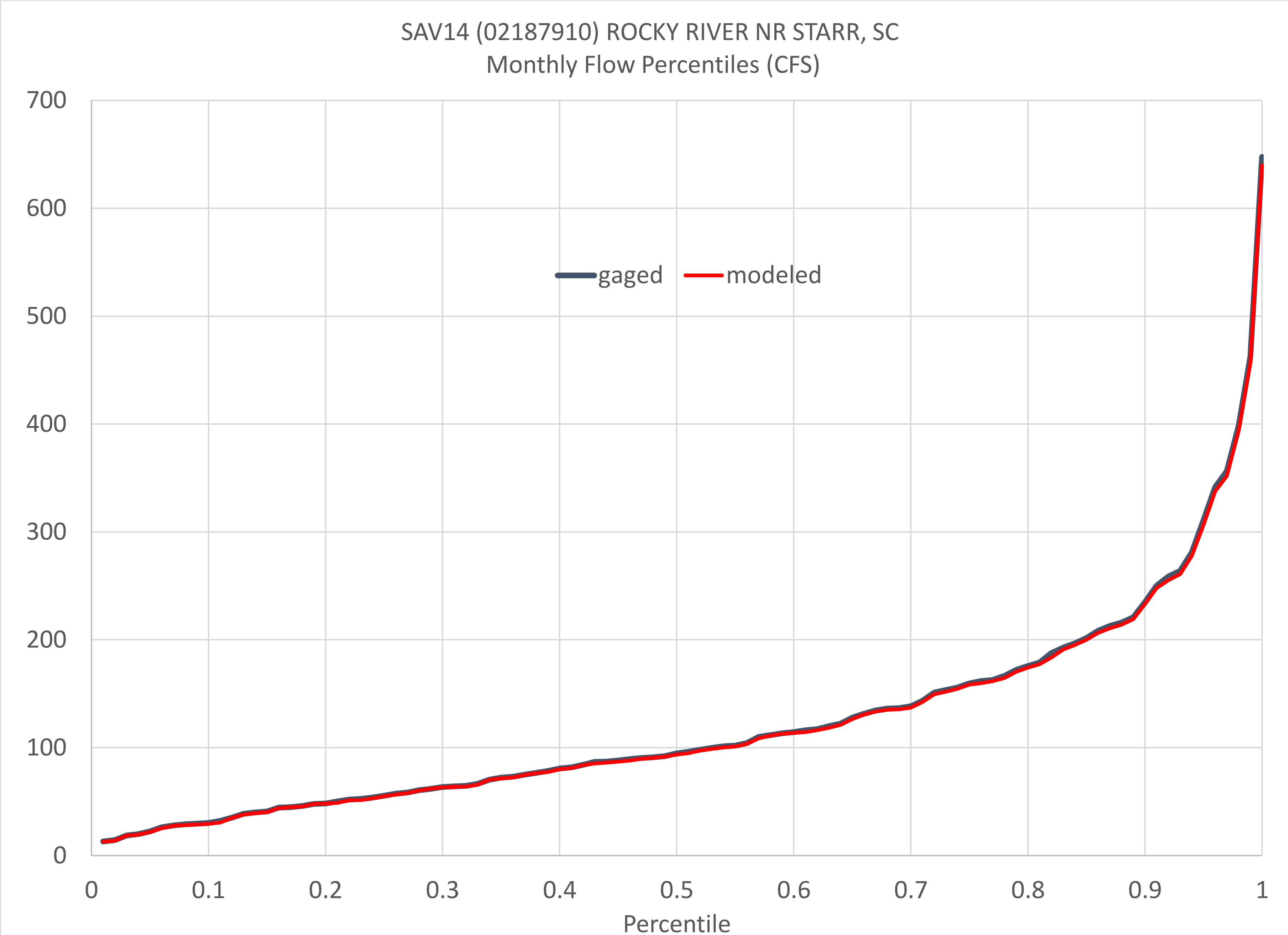


SAV14 (02187910) ROCKY RIVER NR STARR, SC
Cumulative Flow (CFS)
modeled
gaged
35,000
30,000
25,000
20,000
15,000
10,000
5,000
0
Jan-83
Jul-88
Dec-93
Jun-99
Dec-04
Jun-10

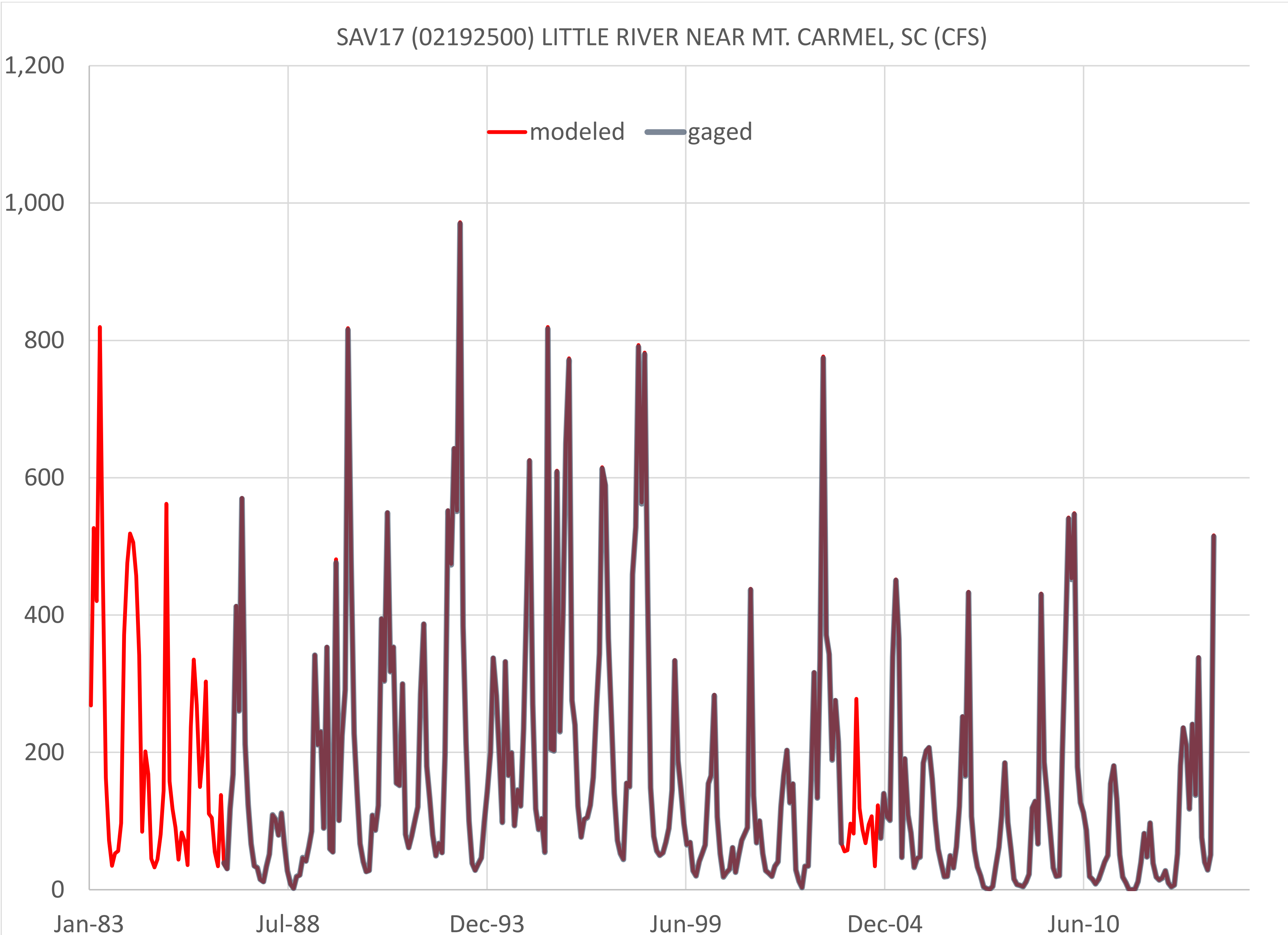

SAV14 (02187910) ROCKY RIVER NR STARR, SC (CFS)
Annual Average Flow
gaged
modeled
250
200
150
100
50
0
1983
1988
1993
1998
2003
2008
2013



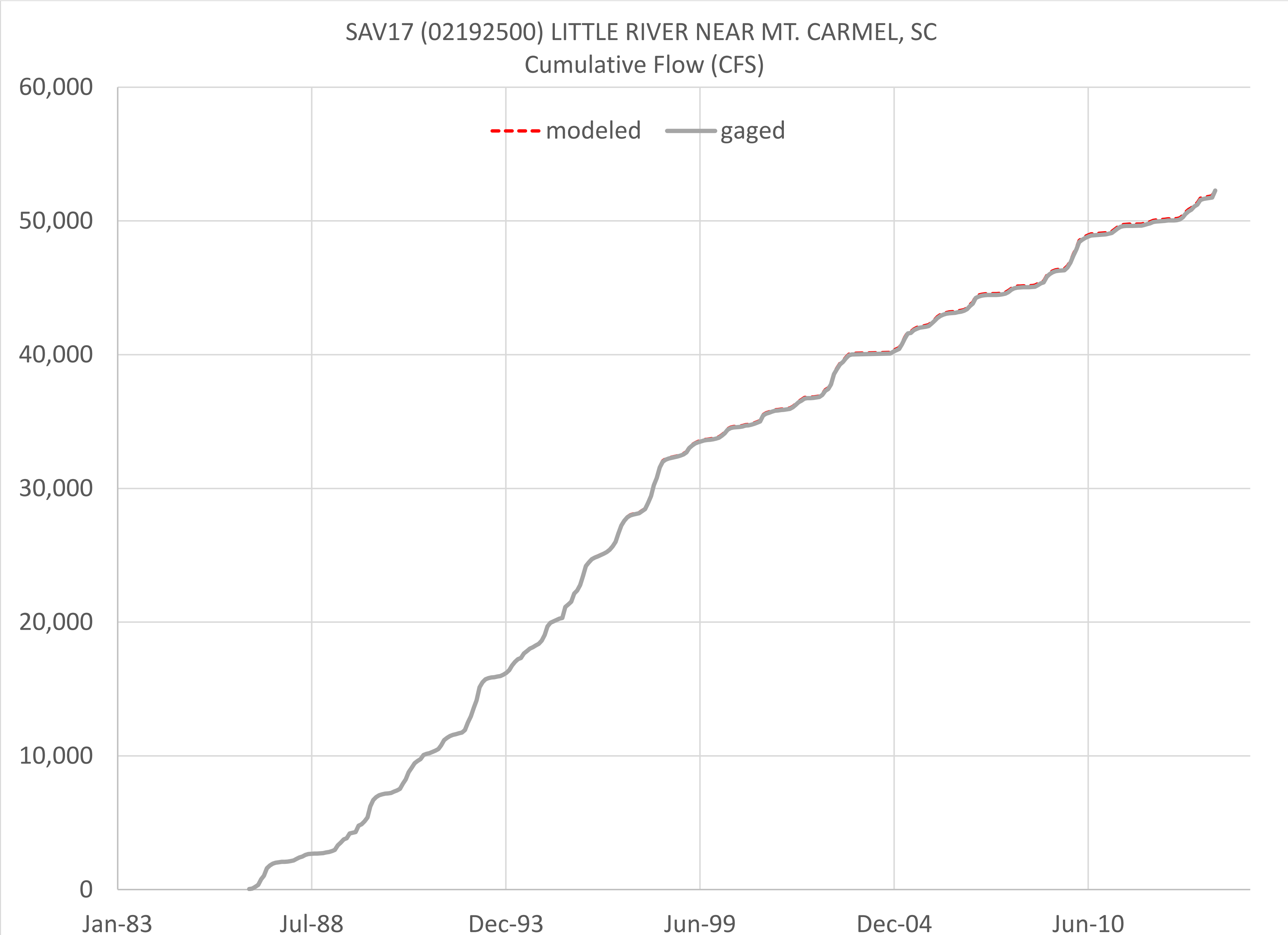
SAV14 (02187910) ROCKY RIVER NR STARR, SC
Monthly Mean Flow (CFS)
gaged
modeled
250
200
150
100
50
0
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec



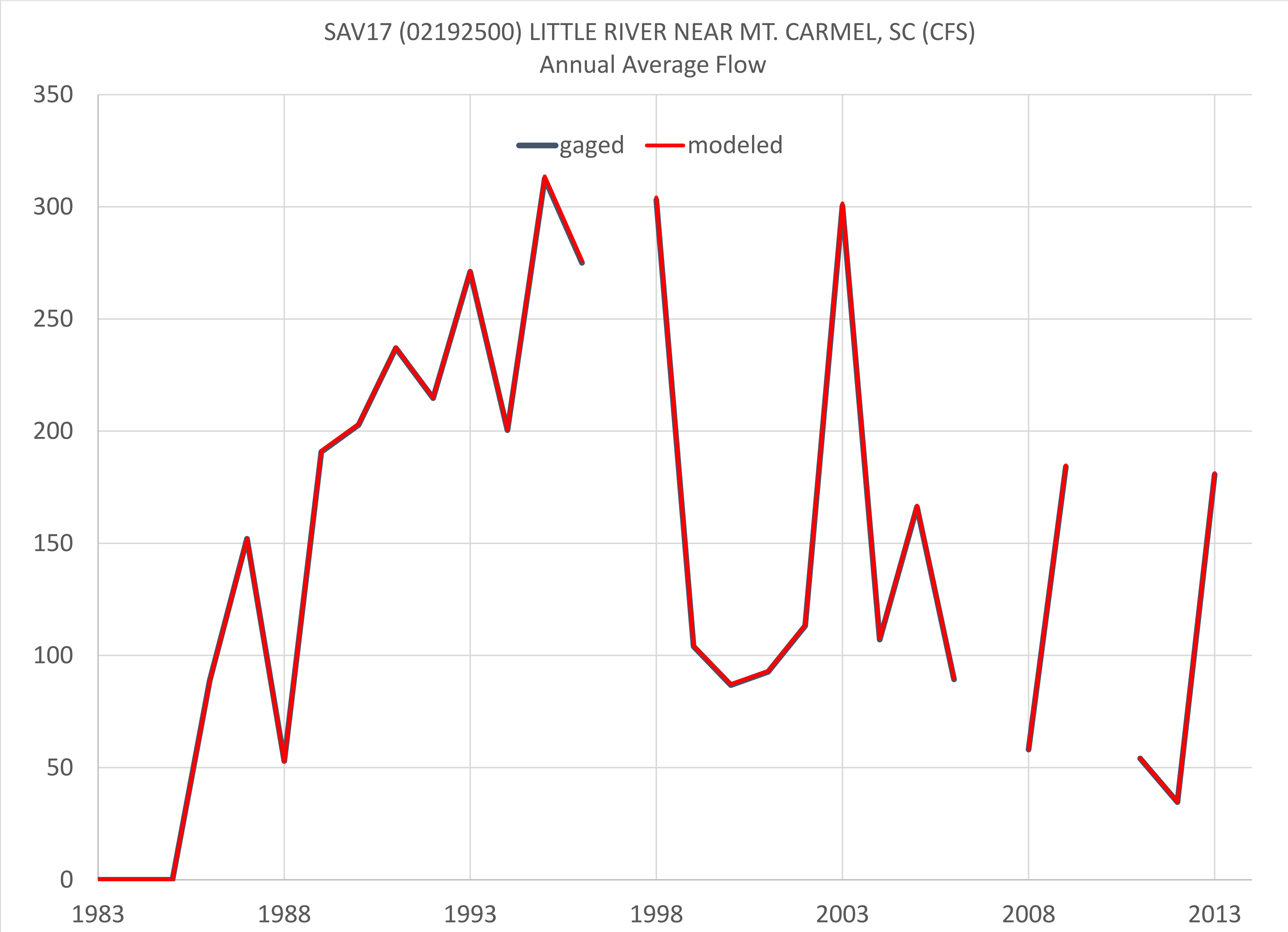
SAV14 (02187910) ROCKY RIVER NR STARR, SC
Monthly Flow Percentiles (CFS)
700
600
500
400
300
200
100
0
gaged
modeled
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
Percentile

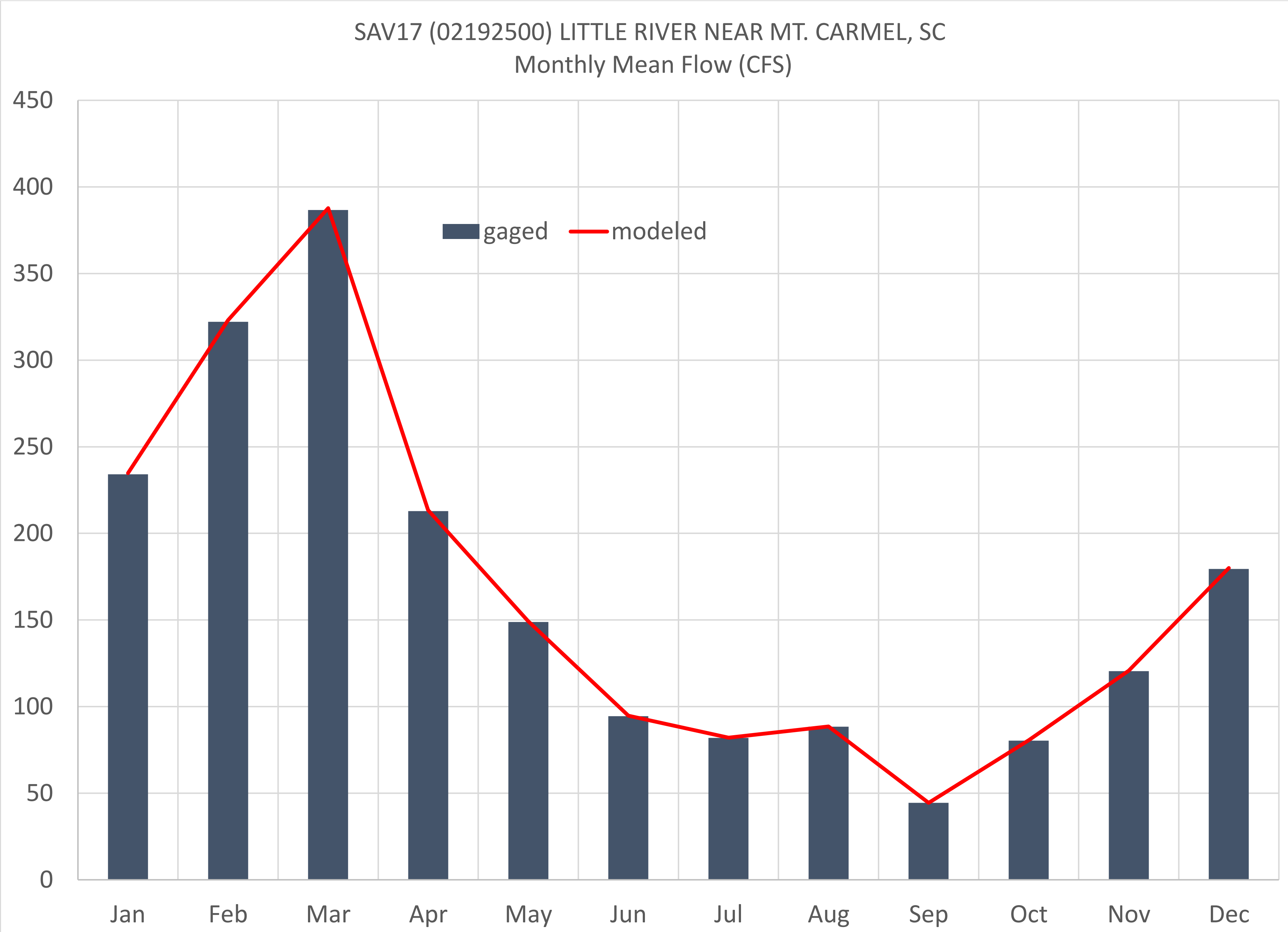


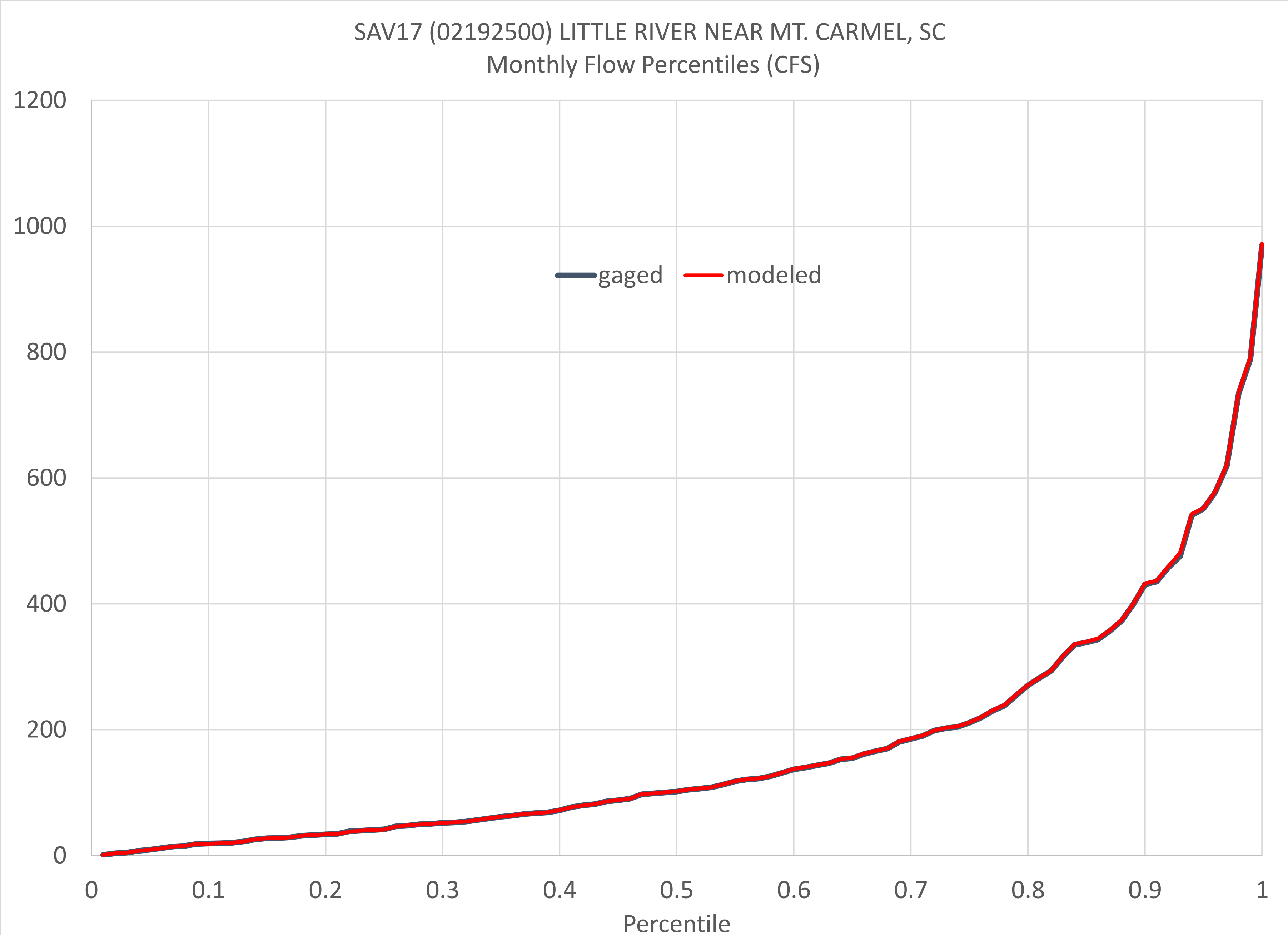
SAV17 (02192500) LITTLE RIVER NEAR MT. CARMEL, SC (CFS)
modeled
gaged
1,200
1,000
800
600
400
200
0
Jan-83
Jul-88
Dec-93
Jun-99
Dec-04
Jun-10

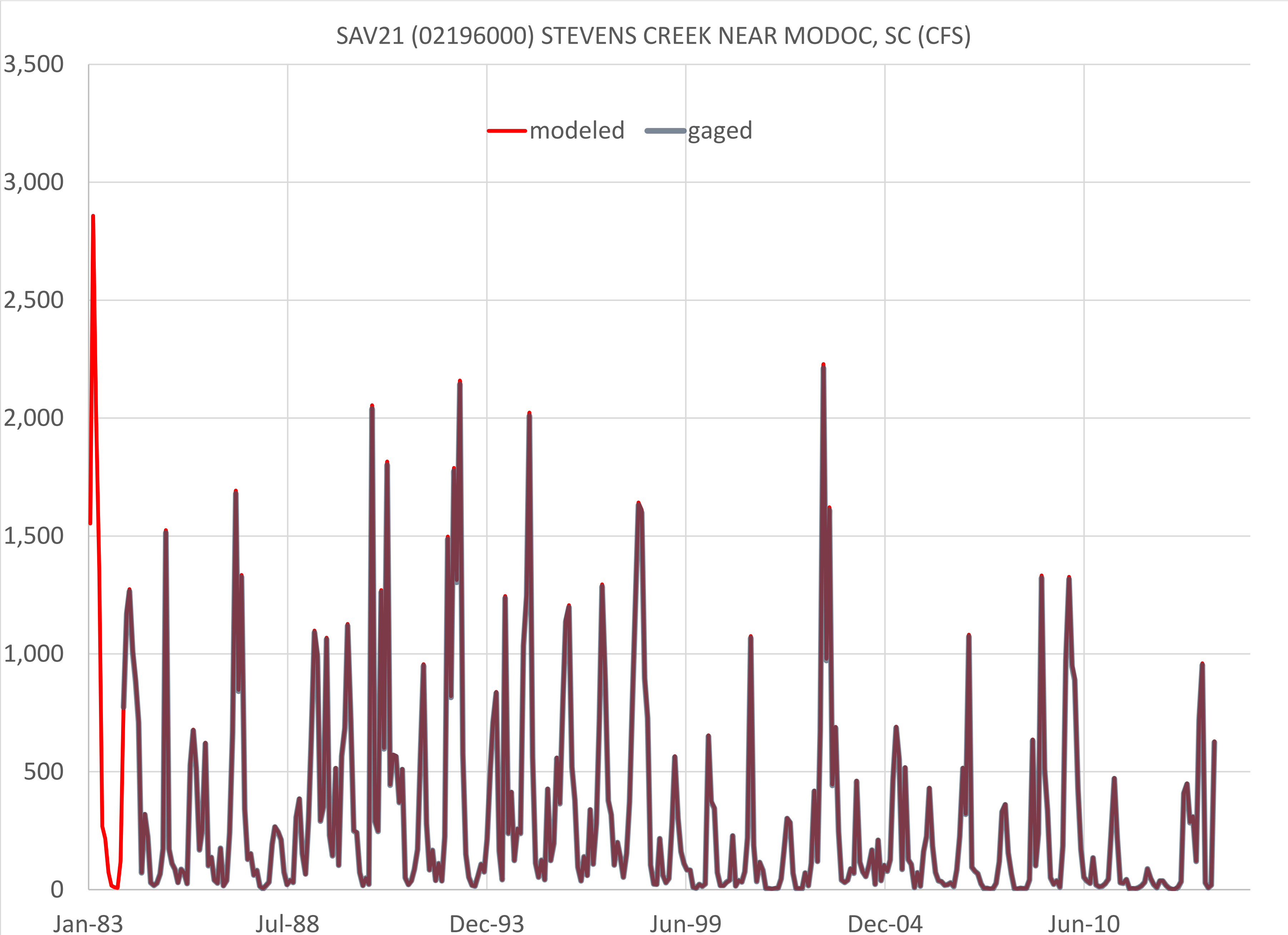


SAV17 (02192500) LITTLE RIVER NEAR MT. CARMEL, SC
Cumulative Flow (CFS)
modeled
gaged
60,000
50,000
40,000
30,000
20,000
10,000
0
Jan-83
Jul-88
Dec-93
Jun-99
Dec-04
Jun-10

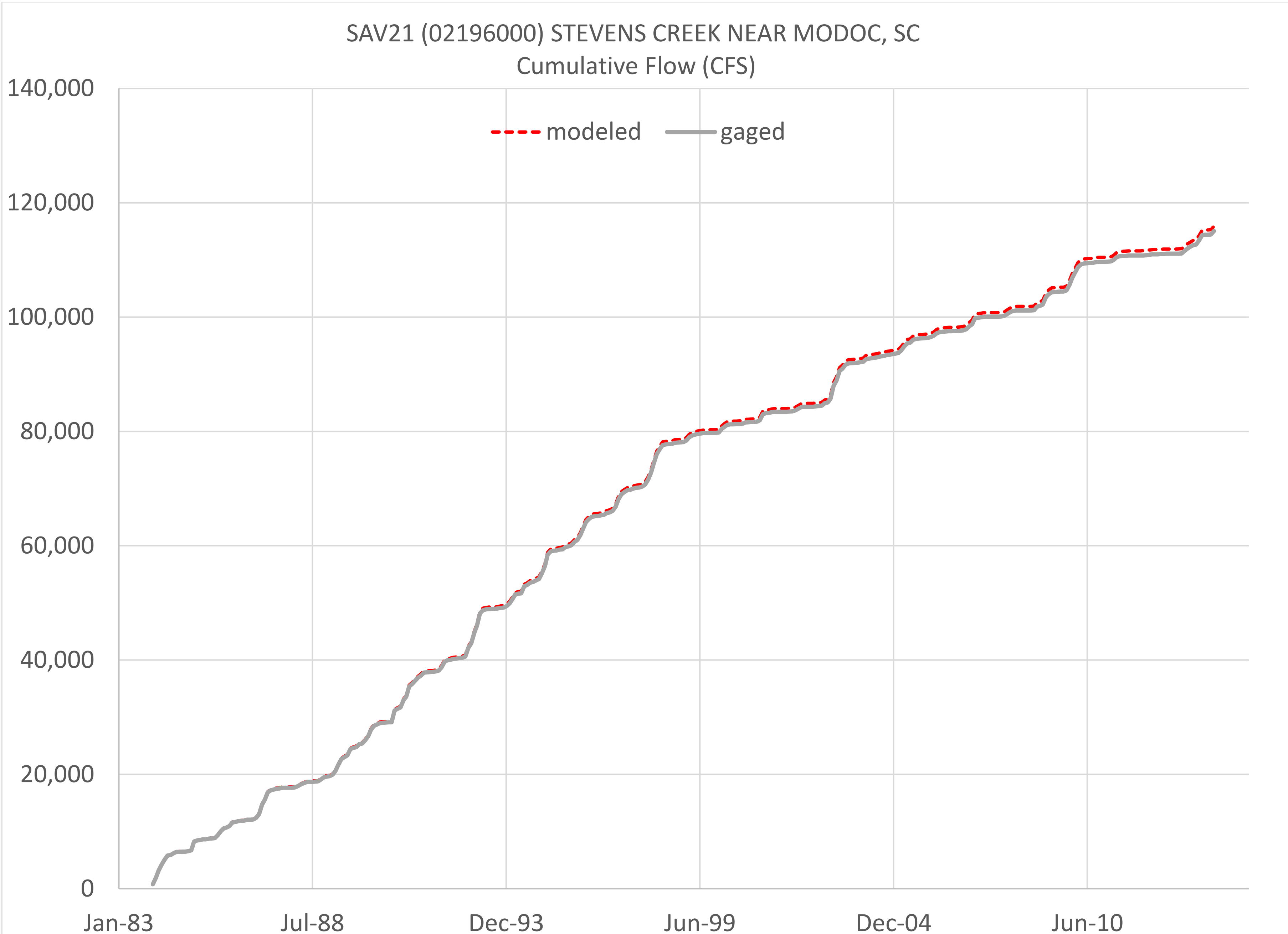

SAV17 (02192500) LITTLE RIVER NEAR MT. CARMEL, SC (CFS)
Annual Average Flow
gaged
modeled
350
300
250
200
150
100
50
0
1983
1988
1993
1998
2003
2008
2013

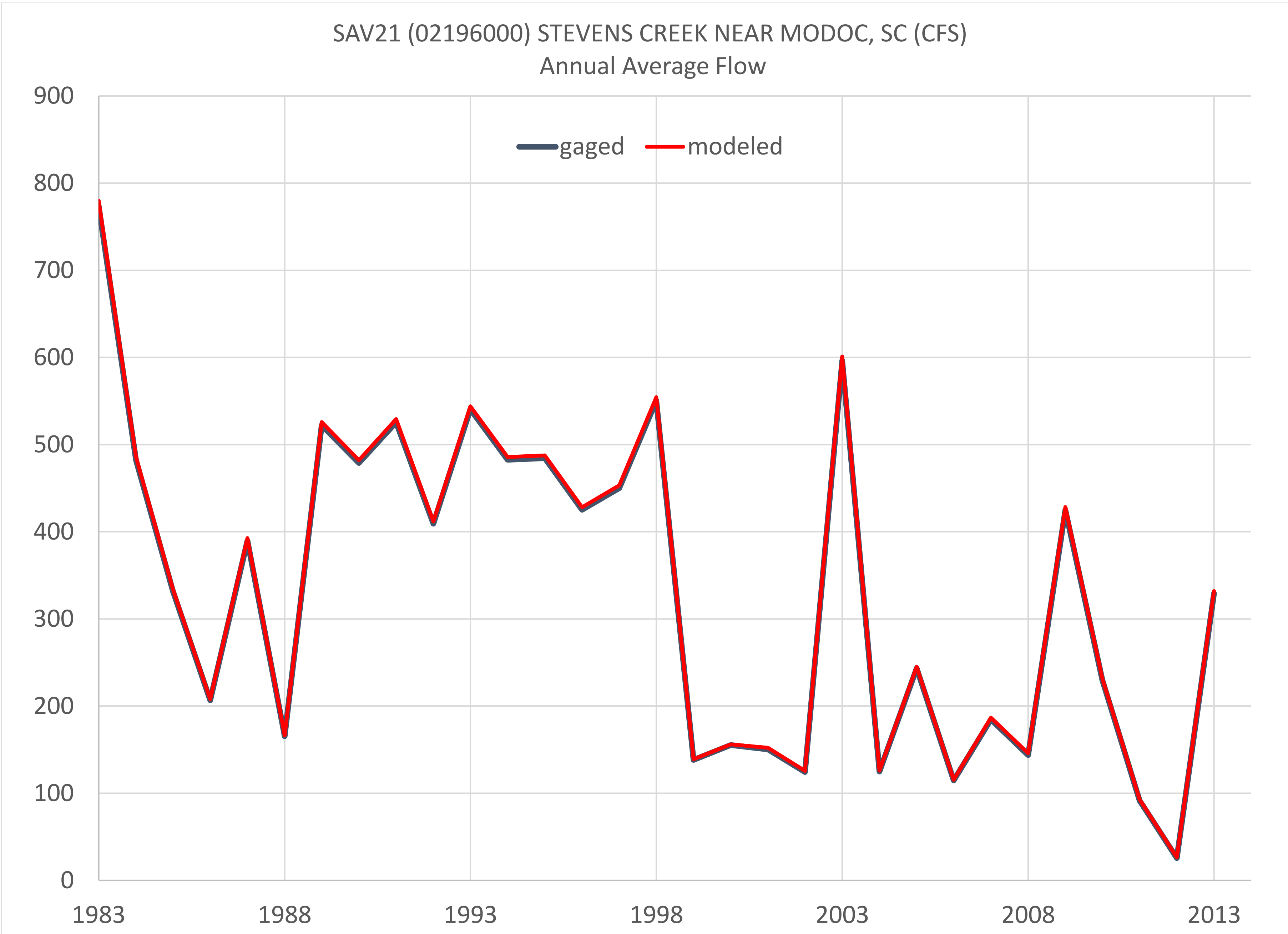

SAV17 (02192500) LITTLE RIVER NEAR MT. CARMEL, SC
Monthly Mean Flow (CFS)
450
400
350
300
250
200
150
100
50
0
gaged
modeled
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec


SAV17 (02192500) LITTLE RIVER NEAR MT. CARMEL, 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

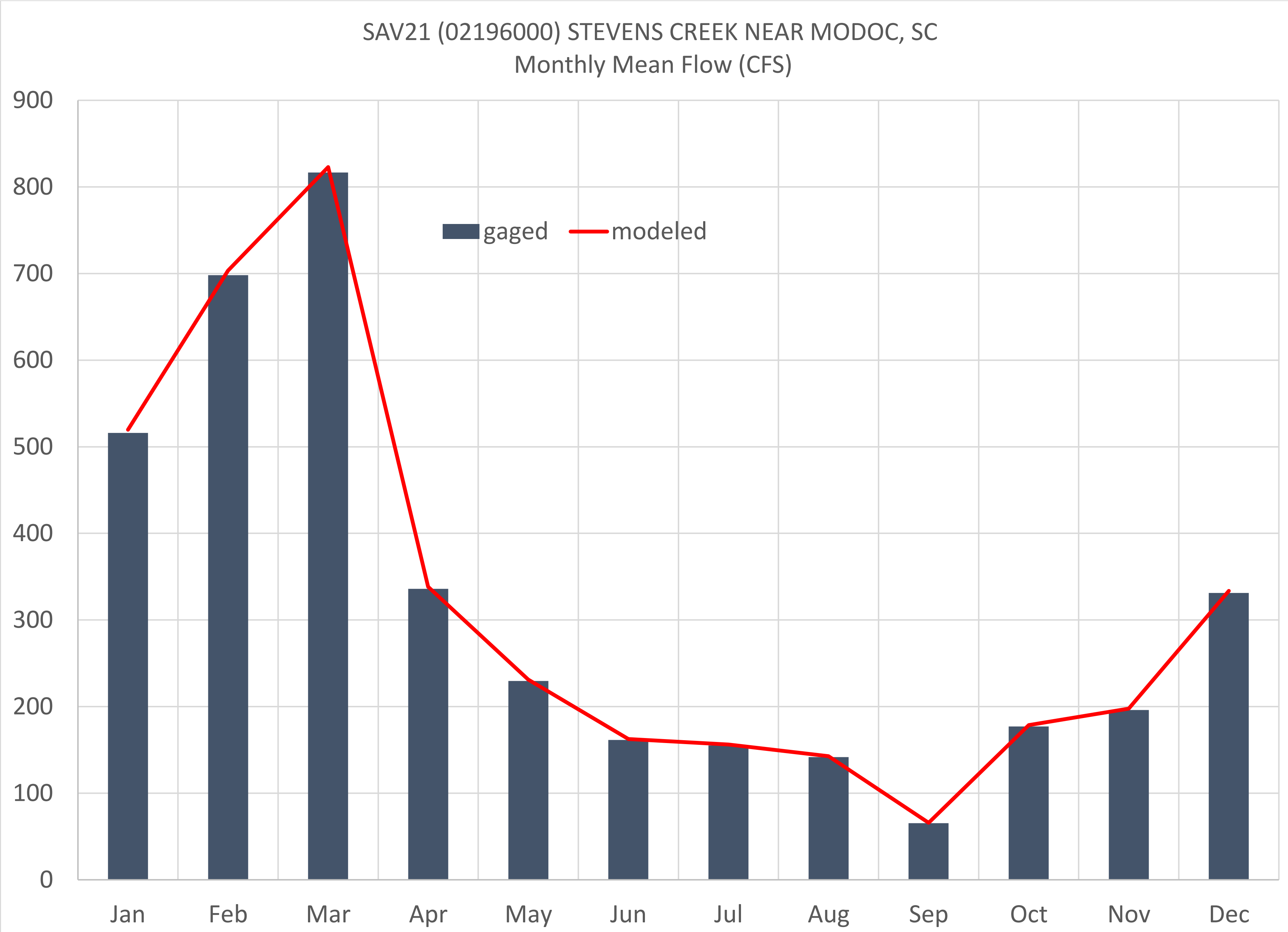


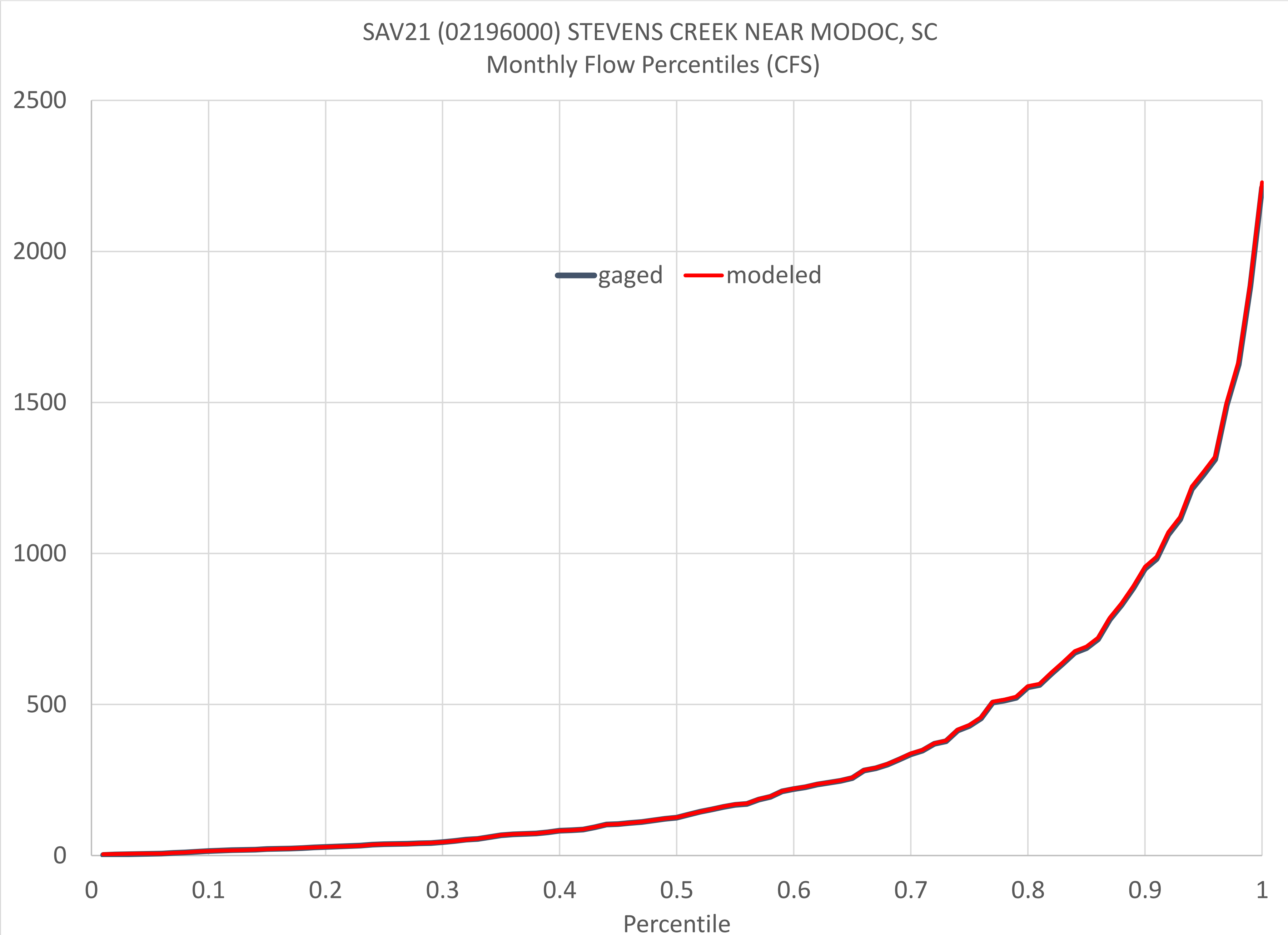
SAV21 (02196000) STEVENS CREEK NEAR MODOC, SC (CFS)
modeled
gaged
3,500
3,000
2,500
2,000
1,500
1,000
500
0
Jan-83
Jul-88
Dec-93
Jun-99
Dec-04
Jun-10

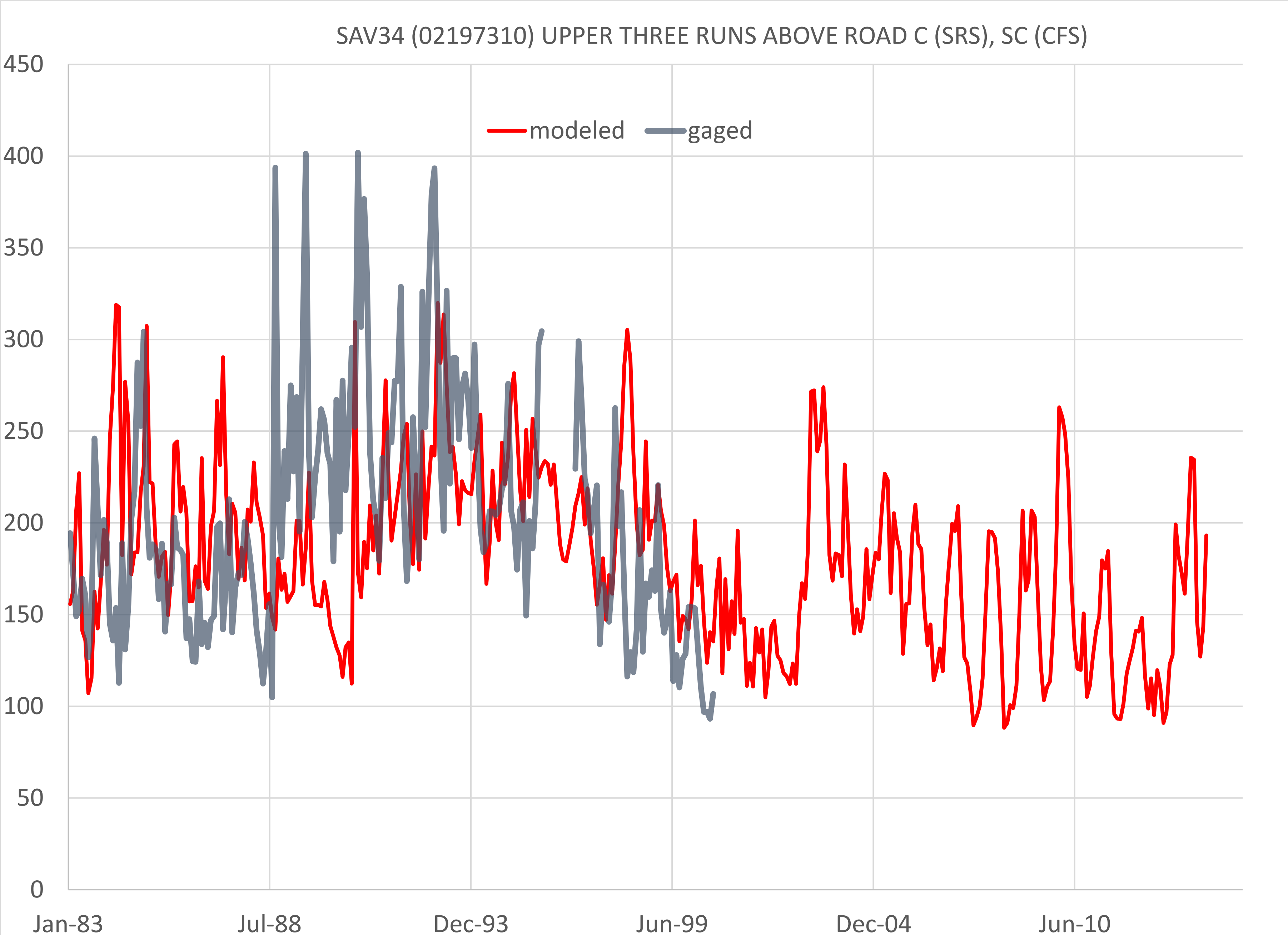

SAV21 (02196000) STEVENS CREEK NEAR MODOC, SC
Cumulative Flow (CFS)
modeled
gaged
140,000
120,000
100,000
80,000
60,000
40,000
20,000
0
Jan-83
Jul-88
Dec-93
Jun-99
Dec-04
Jun-10

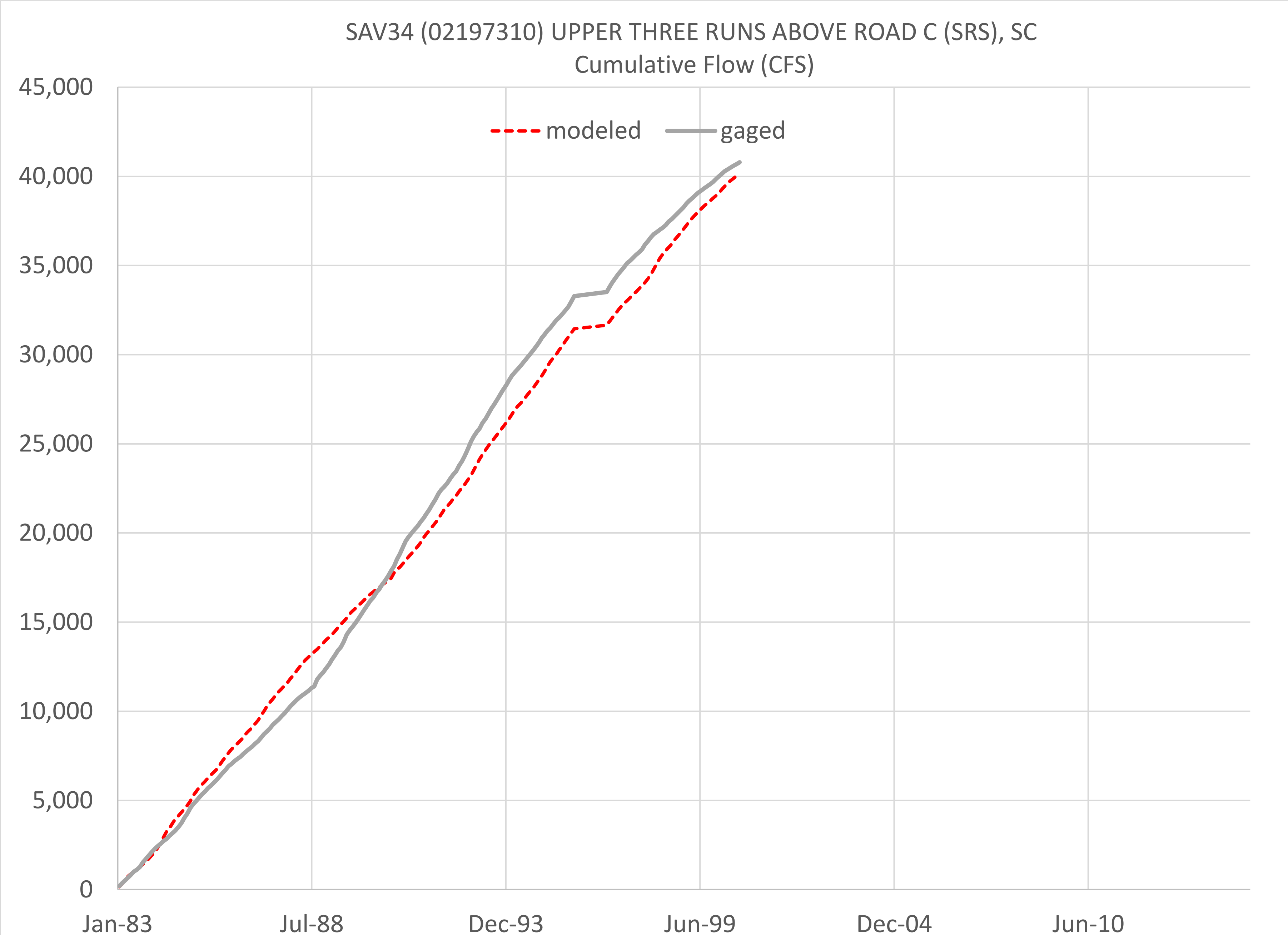


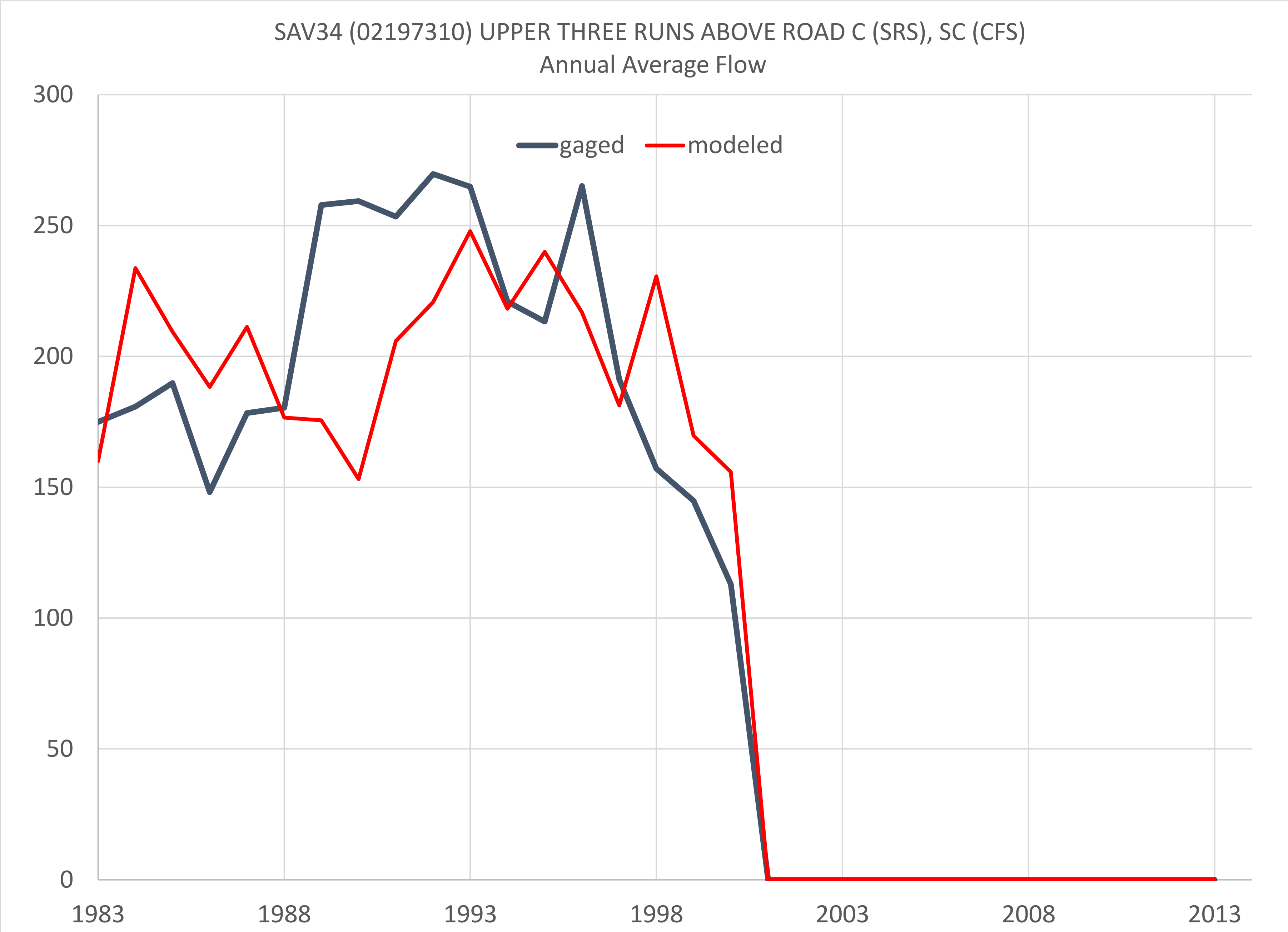
SAV21 (02196000) STEVENS CREEK NEAR MODOC, SC (CFS)
Annual Average Flow
gaged
modeled
900
800
700
600
500
400
300
200
100
0
1983
1988
1993
1998
2003
2008
2013

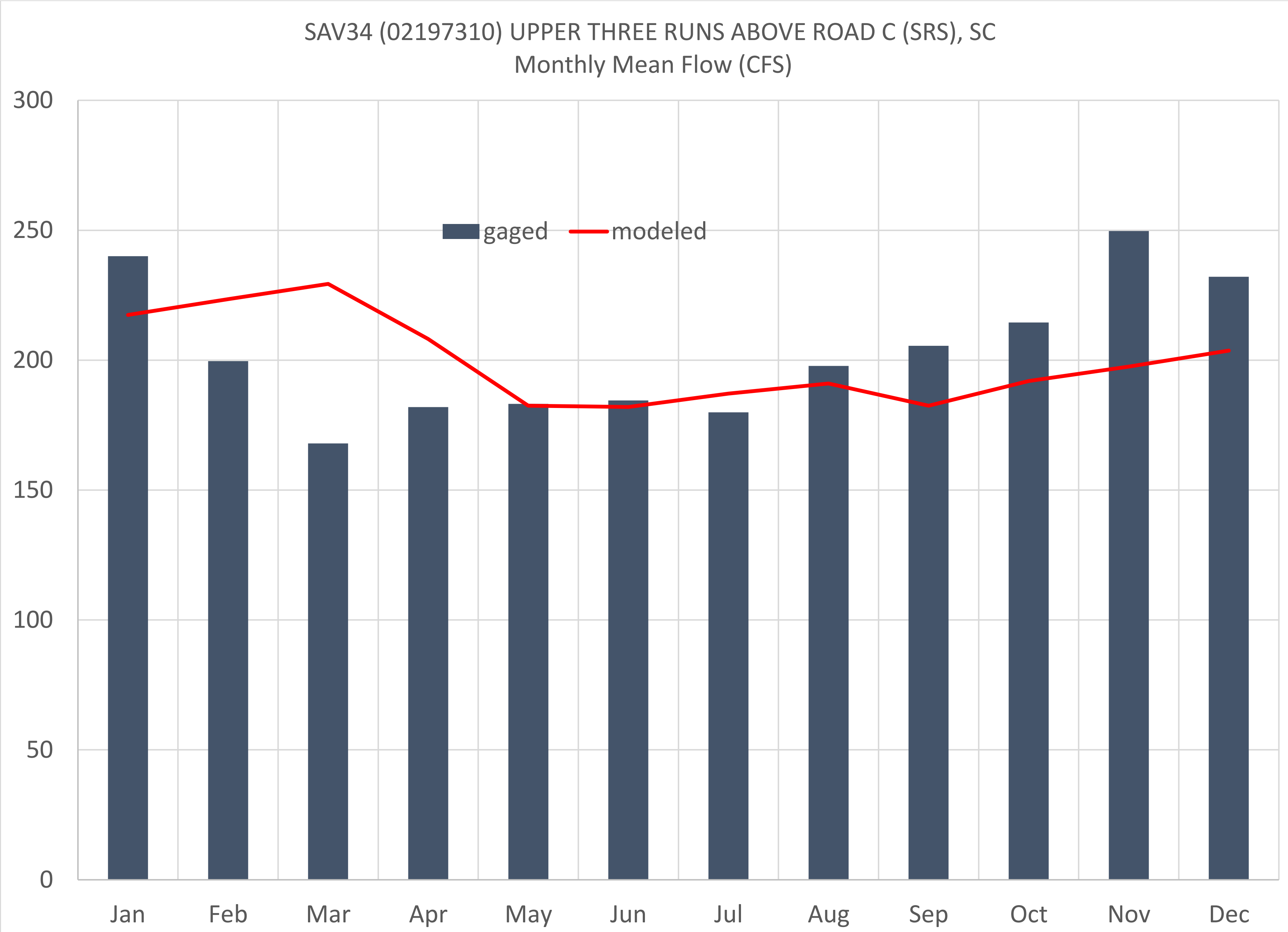

SAV21 (02196000) STEVENS CREEK NEAR MODOC, SC
Monthly Mean Flow (CFS)
900
800
700
600
500
400
300
200
100
0
gaged
modeled
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec

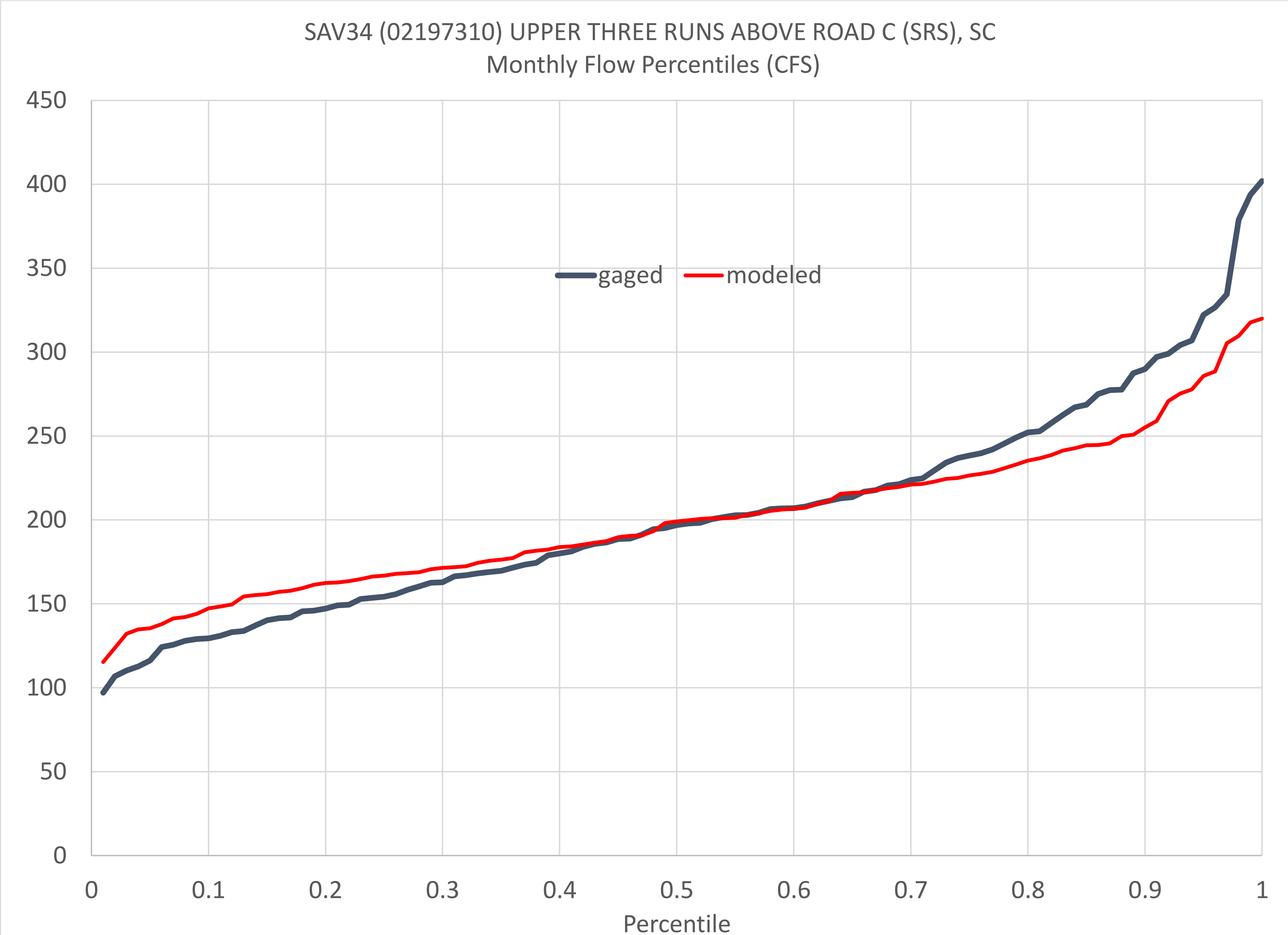

SAV21 (02196000) STEVENS CREEK NEAR MODOC, SC
Monthly Flow Percentiles (CFS)
2500
2000
1500
1000
500
0
gaged
modeled
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
Percentile

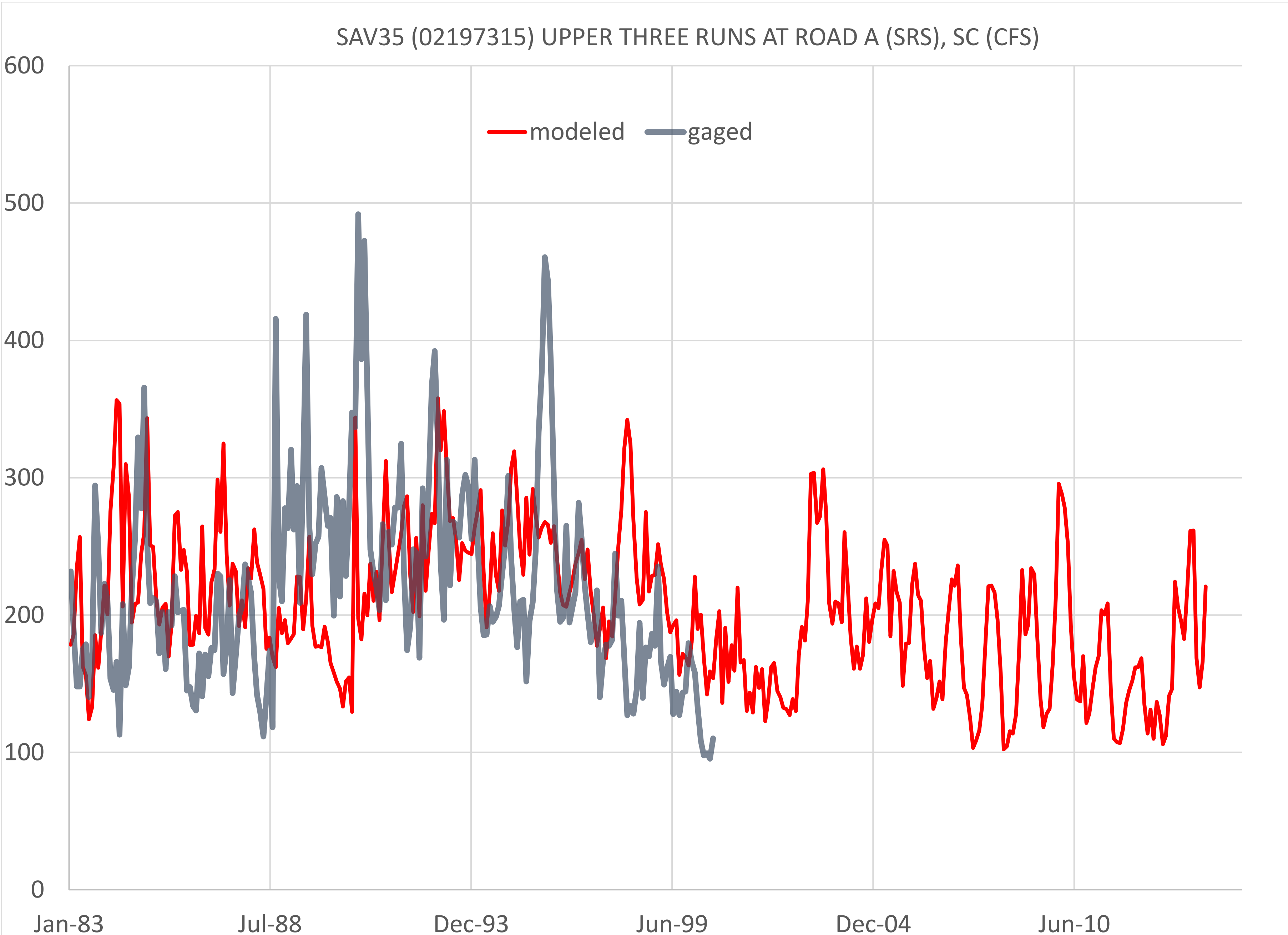

SAV34 (02197310) UPPER THREE RUNS ABOVE ROAD C (SRS), SC (CFS)
modeled
gaged
450
400
350
300
250
200
150
100
50
0
Jan-83
Jul-88
Dec-93
Jun-99
Dec-04
Jun-10

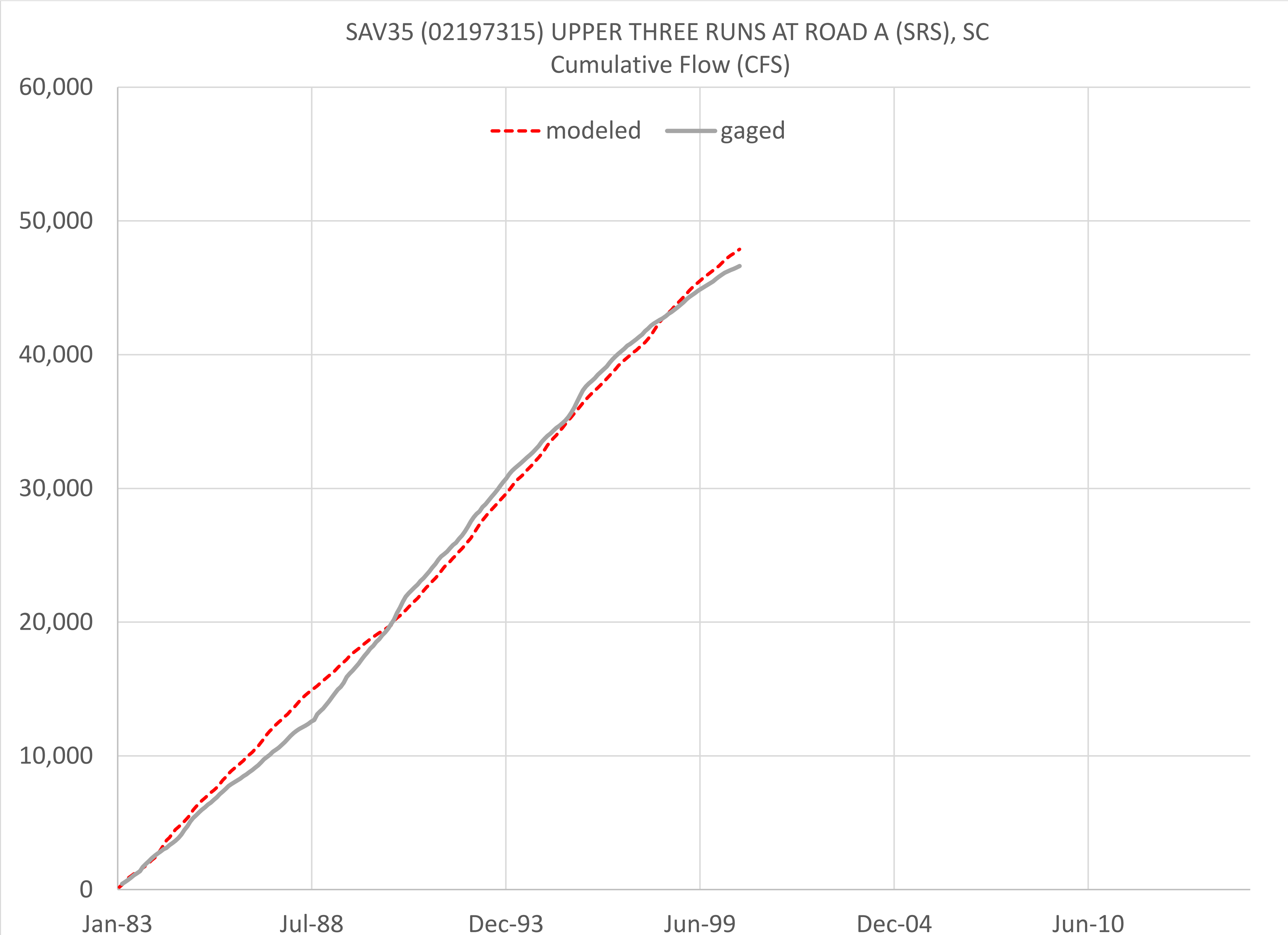

SAV34 (02197310) UPPER THREE RUNS ABOVE ROAD C (SRS), SC
Cumulative Flow (CFS)
modeled
gaged
45,000
40,000
35,000
30,000
25,000
20,000
15,000
10,000
5,000
0
Jan-83
Jul-88
Dec-93
Jun-99
Dec-04
Jun-10

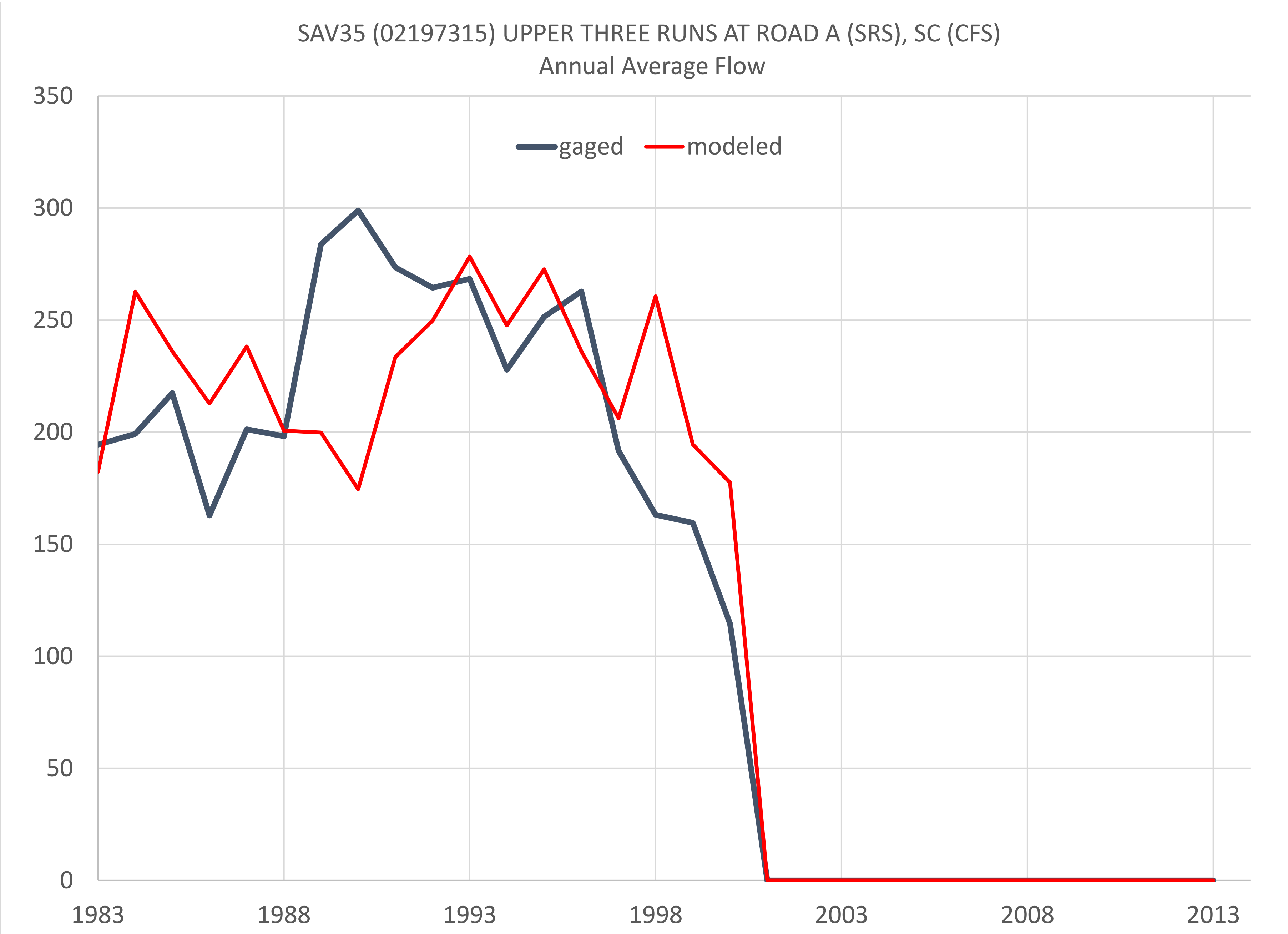

SAV34 (02197310) UPPER THREE RUNS ABOVE ROAD C (SRS), SC (CFS)
Annual Average Flow
gaged
modeled
300
250
200
150
100
50
0
1983
1988
1993
1998
2003
2008
2013


SAV34 (02197310) UPPER THREE RUNS ABOVE ROAD C (SRS), SC
Monthly Mean Flow (CFS)
gaged
modeled
300
250
200
150
100
50
0
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec

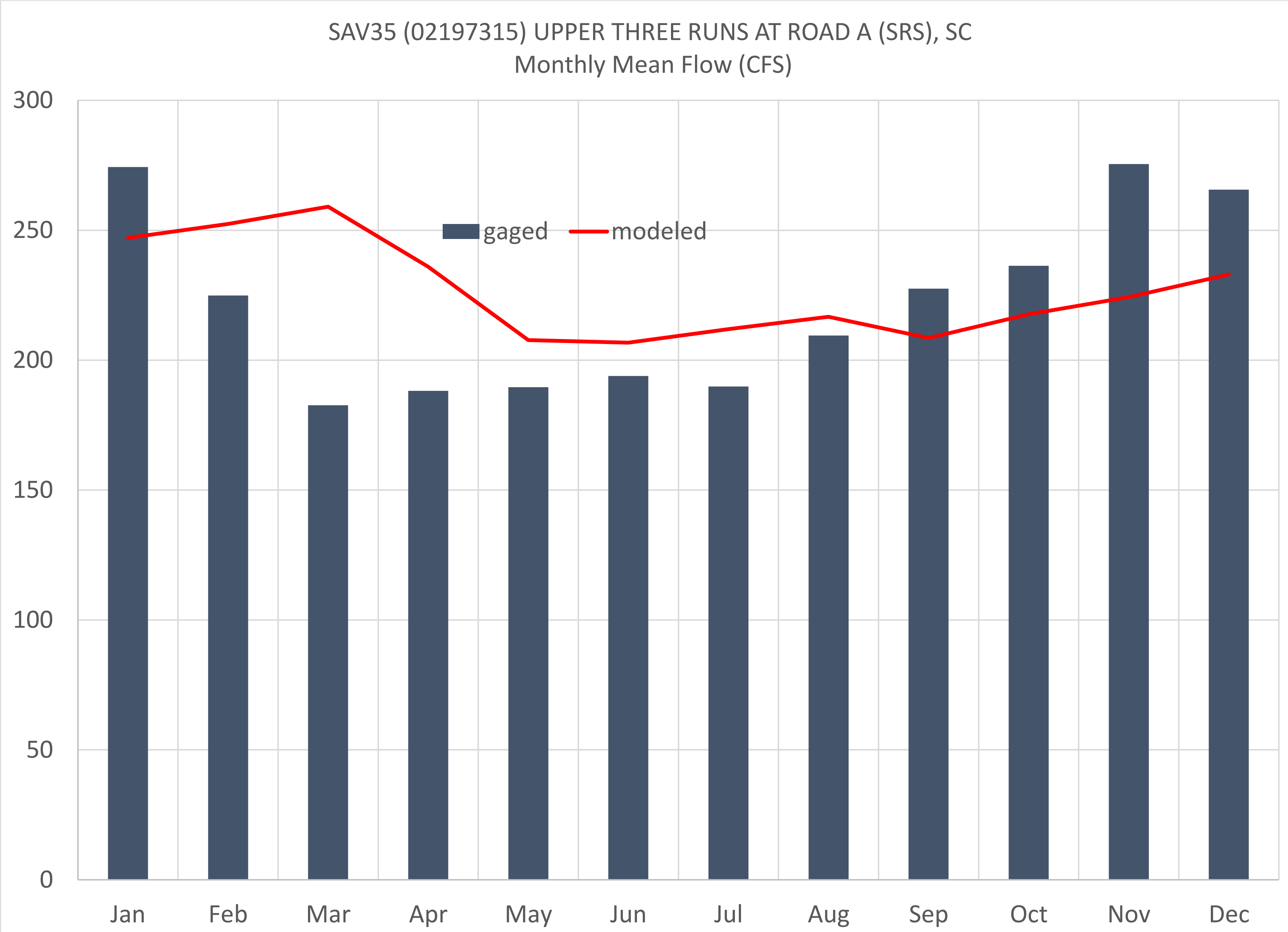

SAV34 (02197310) UPPER THREE RUNS ABOVE ROAD C (SRS), SC
Monthly Flow Percentiles (CFS)
gaged
modeled
450
400
350
300
250
200
150
100
50
0
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
Percentile

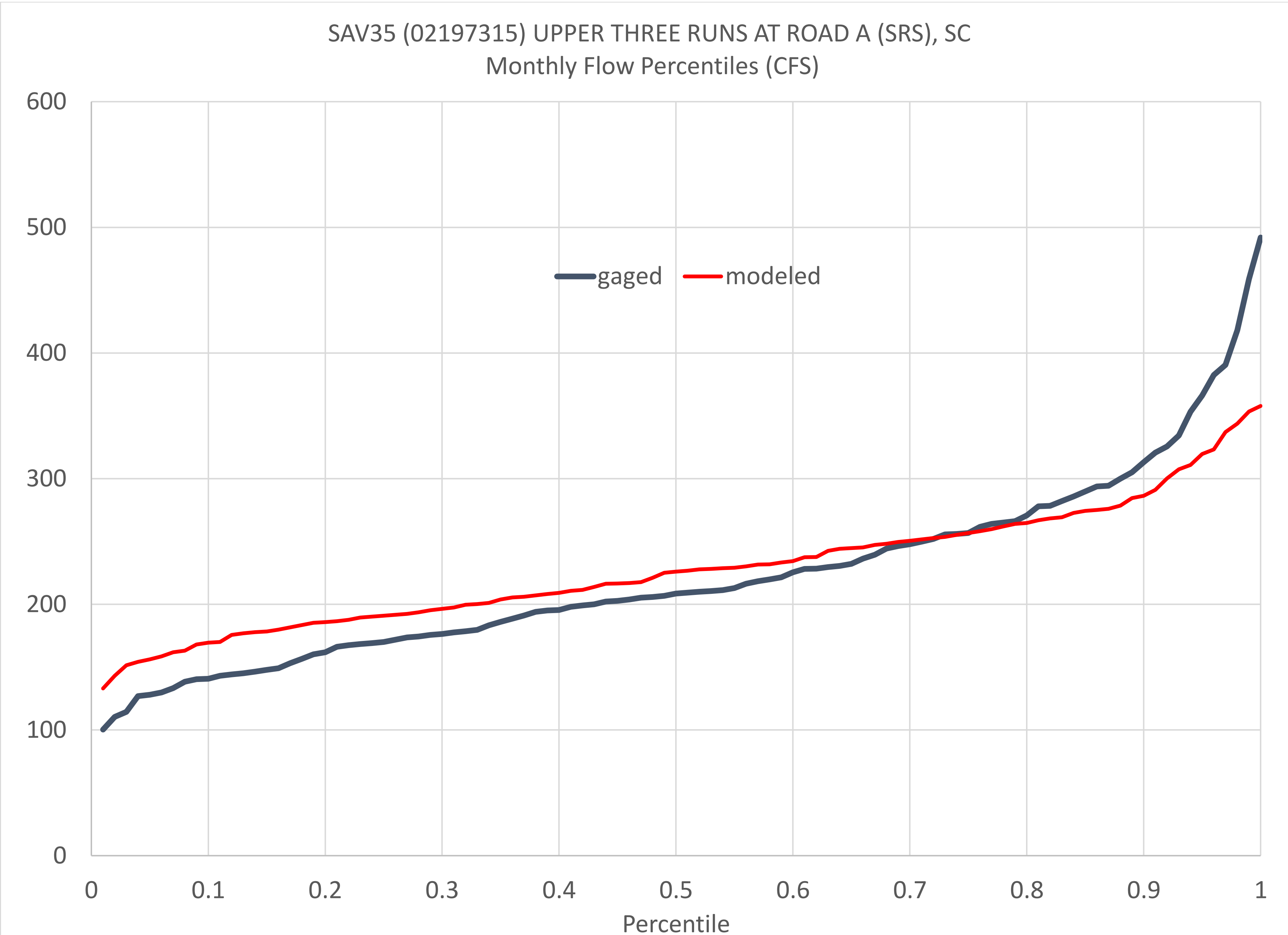

SAV35 (02197315) UPPER THREE RUNS AT ROAD A (SRS), SC (CFS)
modeled
gaged
600
500
400
300
200
100
0
Jan-83
Jul-88
Dec-93
Jun-99
Dec-04
Jun-10

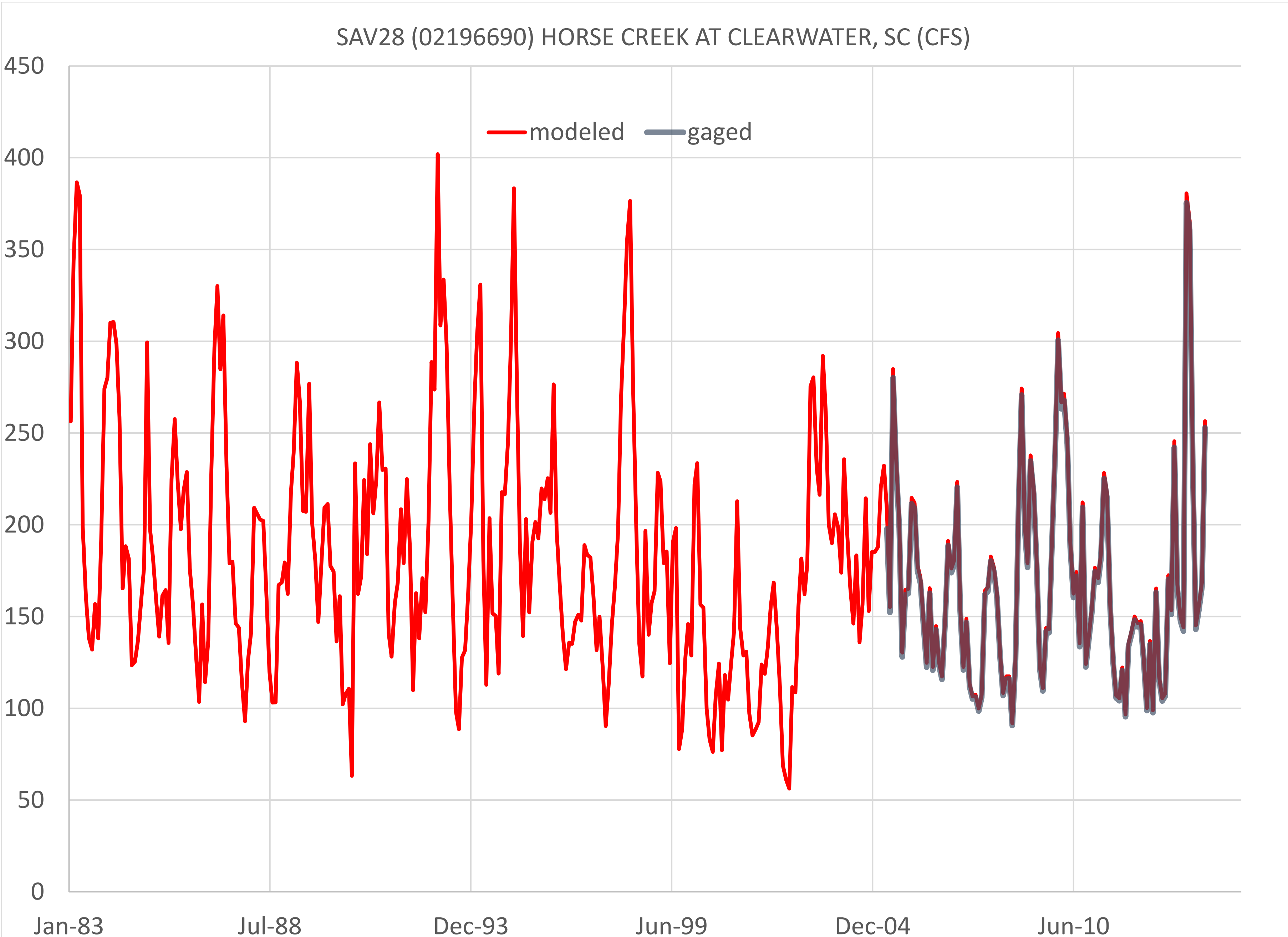

SAV35 (02197315) UPPER THREE RUNS AT ROAD A (SRS), SC
Cumulative Flow (CFS)
modeled
gaged
60,000
50,000
40,000
30,000
20,000
10,000
0
Jan-83
Jul-88
Dec-93
Jun-99
Dec-04
Jun-10

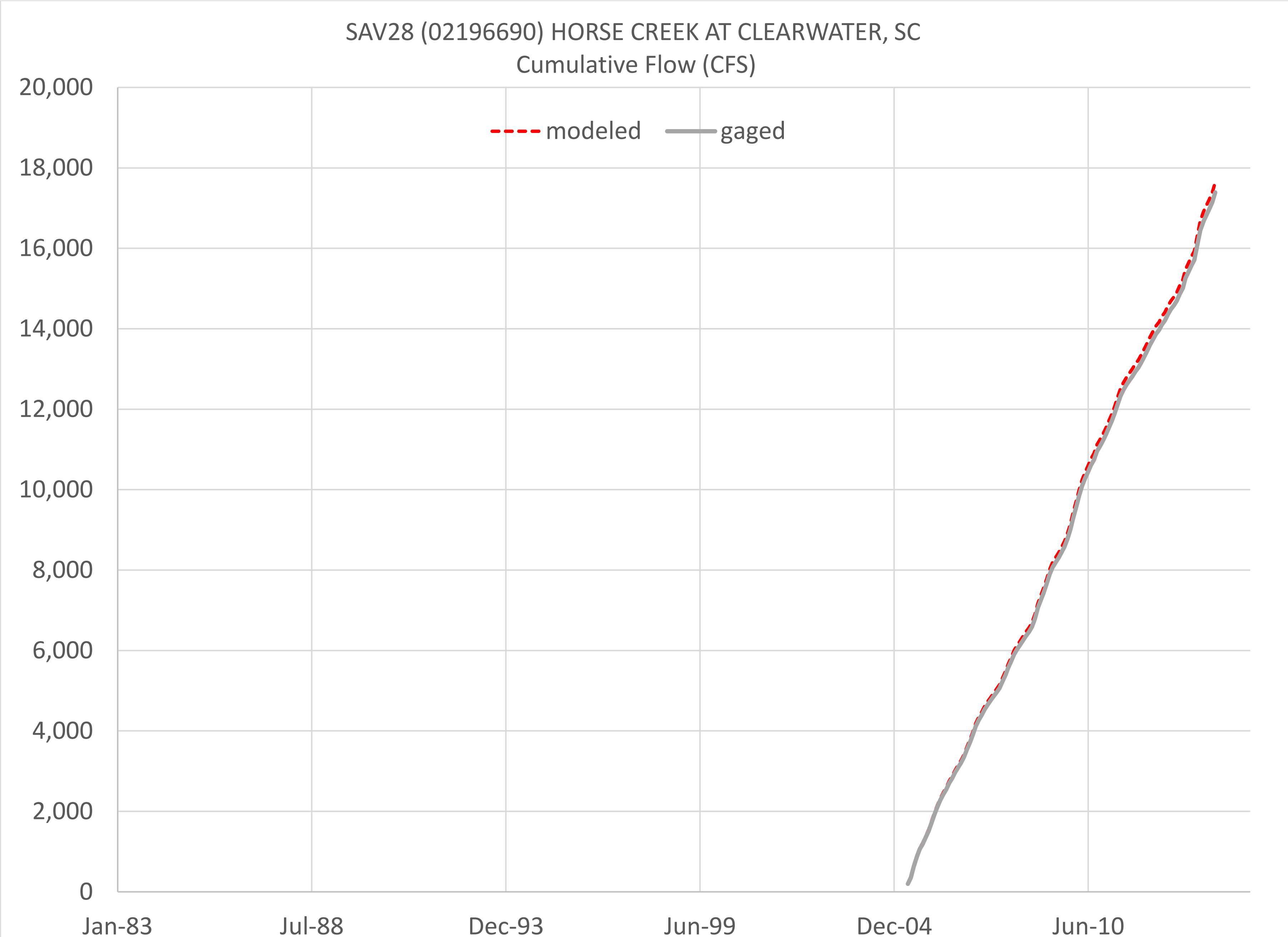


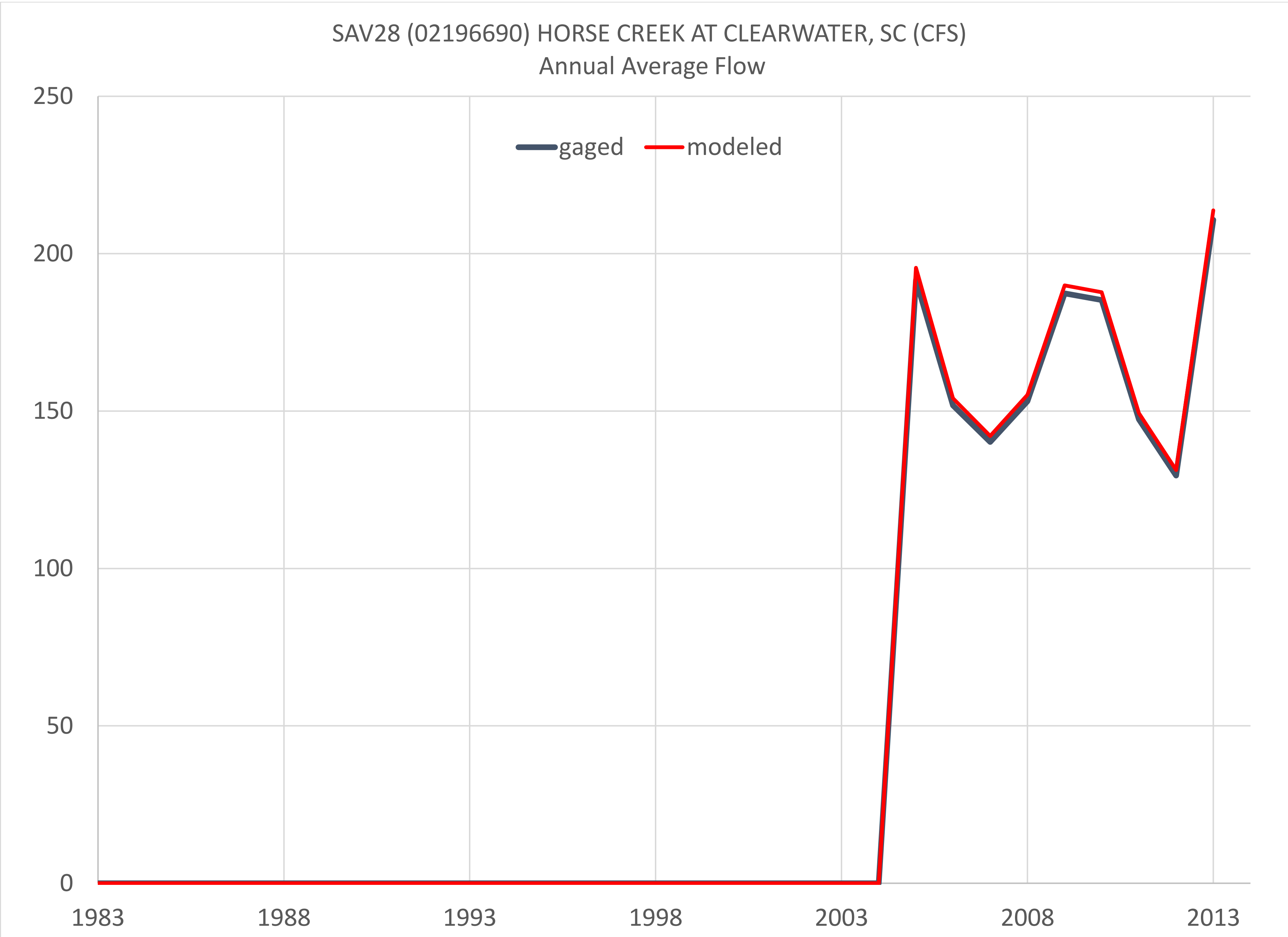
SAV35 (02197315) UPPER THREE RUNS AT ROAD A (SRS), SC (CFS)
Annual Average Flow
gaged
modeled
350
300
250
200
150
100
50
0
1983
1988
1993
1998
2003
2008
2013

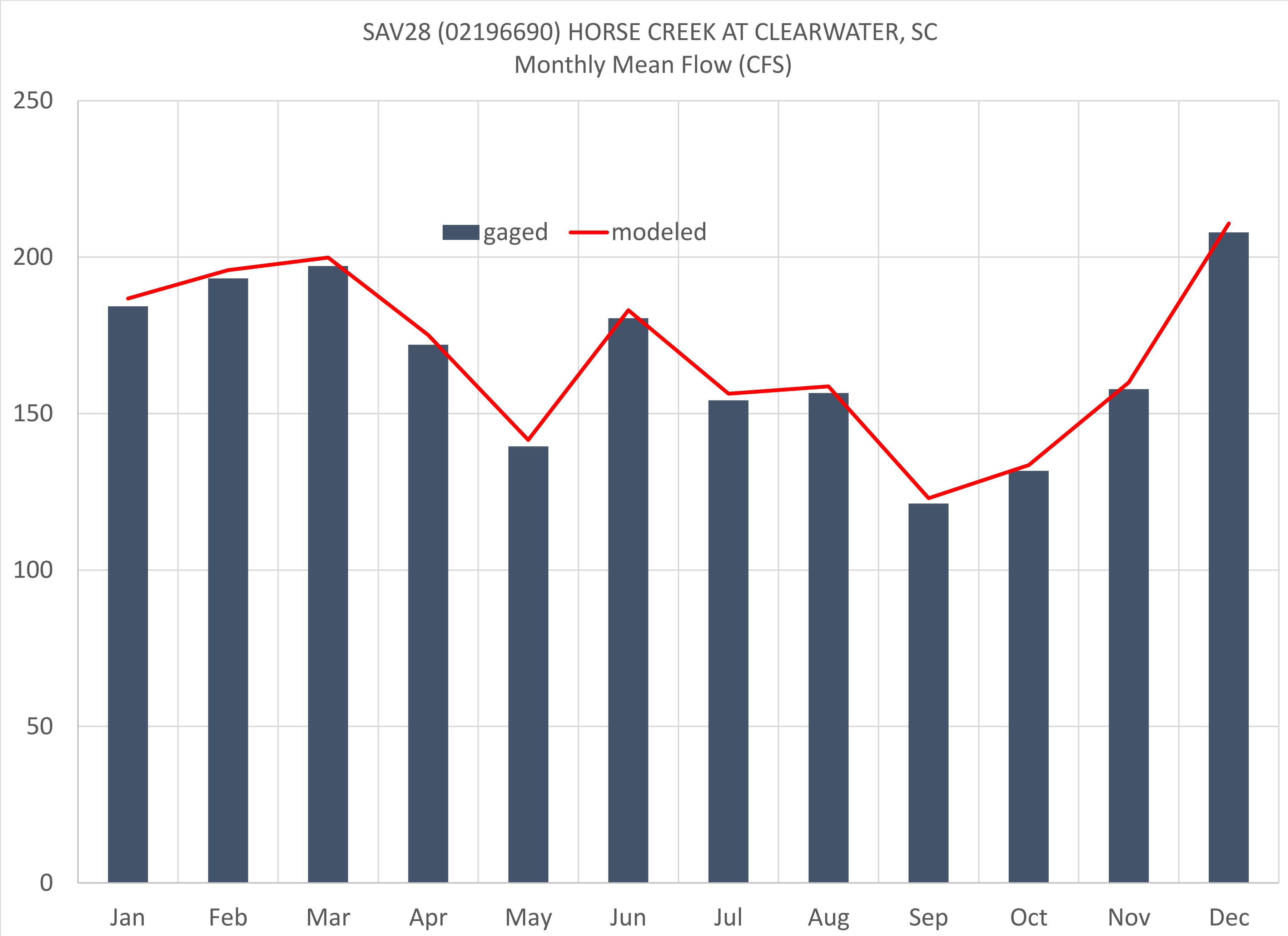

SAV35 (02197315) UPPER THREE RUNS AT ROAD A (SRS), SC
Monthly Mean Flow (CFS)
gaged
modeled
300
250
200
150
100
50
0
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec

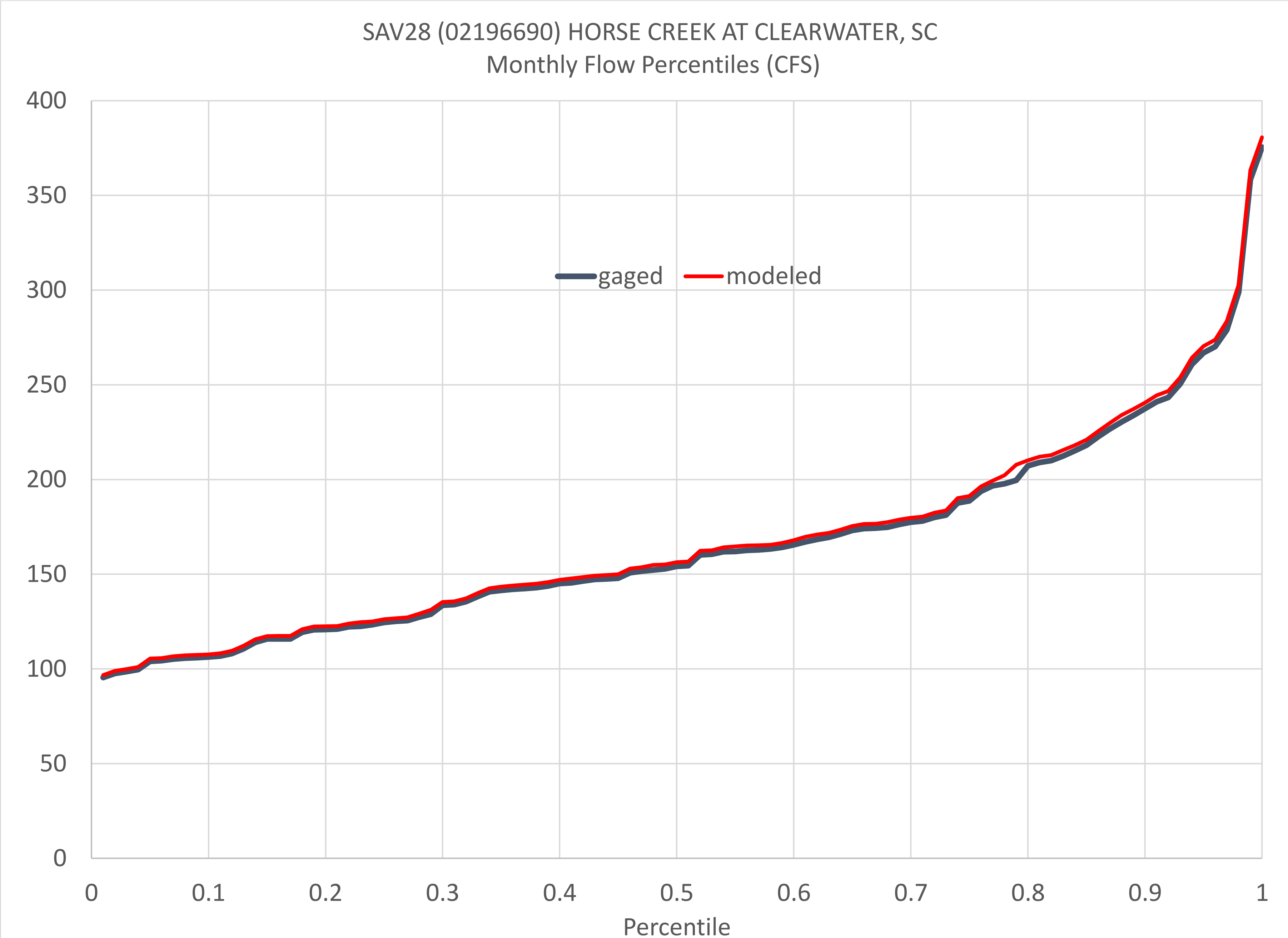

SAV35 (02197315) UPPER THREE RUNS AT ROAD A (SRS), SC
Monthly Flow Percentiles (CFS)
600
500
400
300
200
100
0
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
Percentile
gaged
modeled


SAV28 (02196690) HORSE CREEK AT CLEARWATER, SC (CFS)
modeled
gaged
450
400
350
300
250
200
150
100
50
0
Jan-83
Jul-88
Dec-93
Jun-99
Dec-04
Jun-10

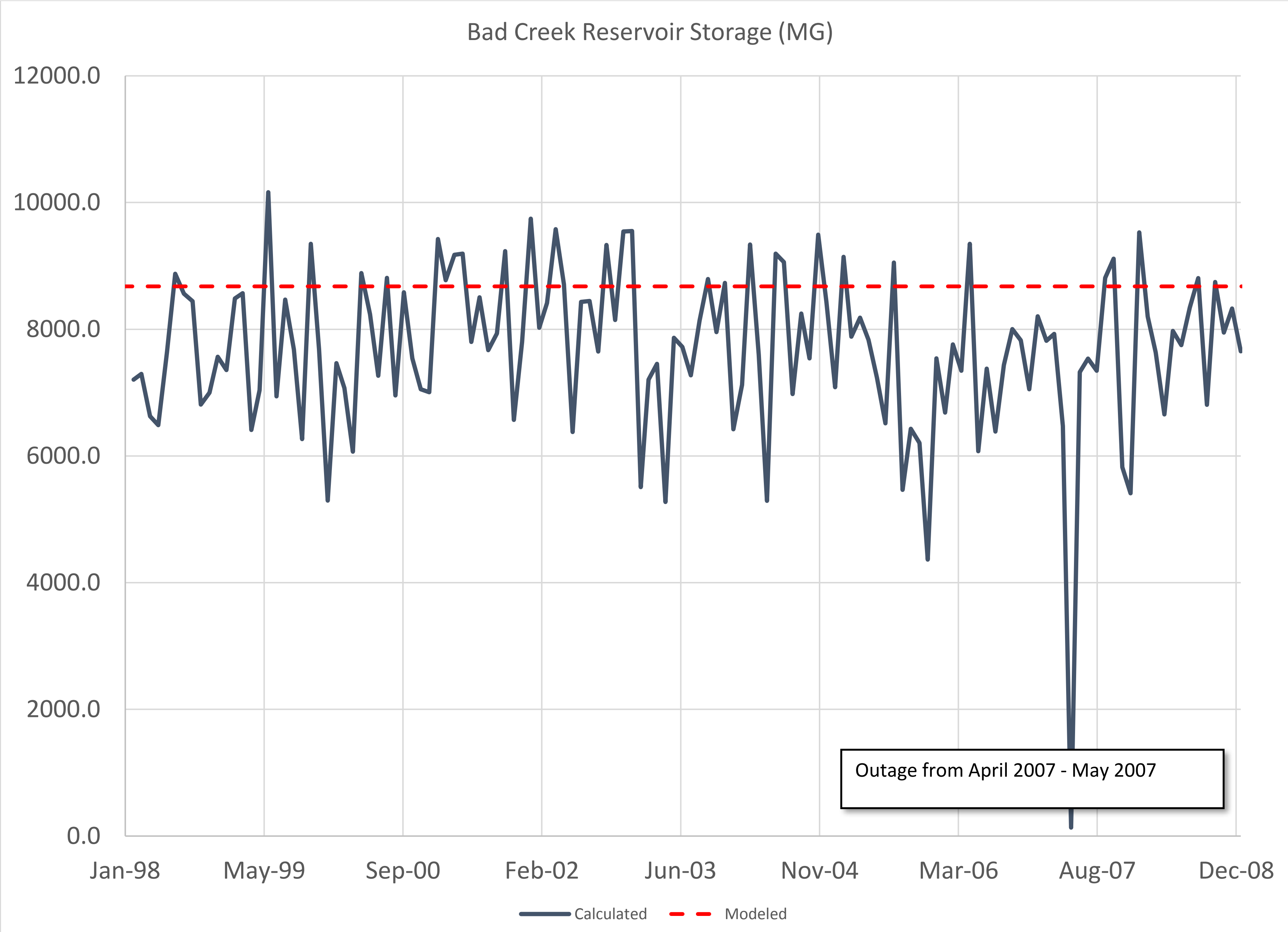

SAV28 (02196690) HORSE CREEK AT CLEARWATER, SC
Cumulative Flow (CFS)
modeled
gaged
20,000
18,000
16,000
14,000
12,000
10,000
8,000
6,000
4,000
2,000
0
Jan-83
Jul-88
Dec-93
Jun-99
Dec-04
Jun-10

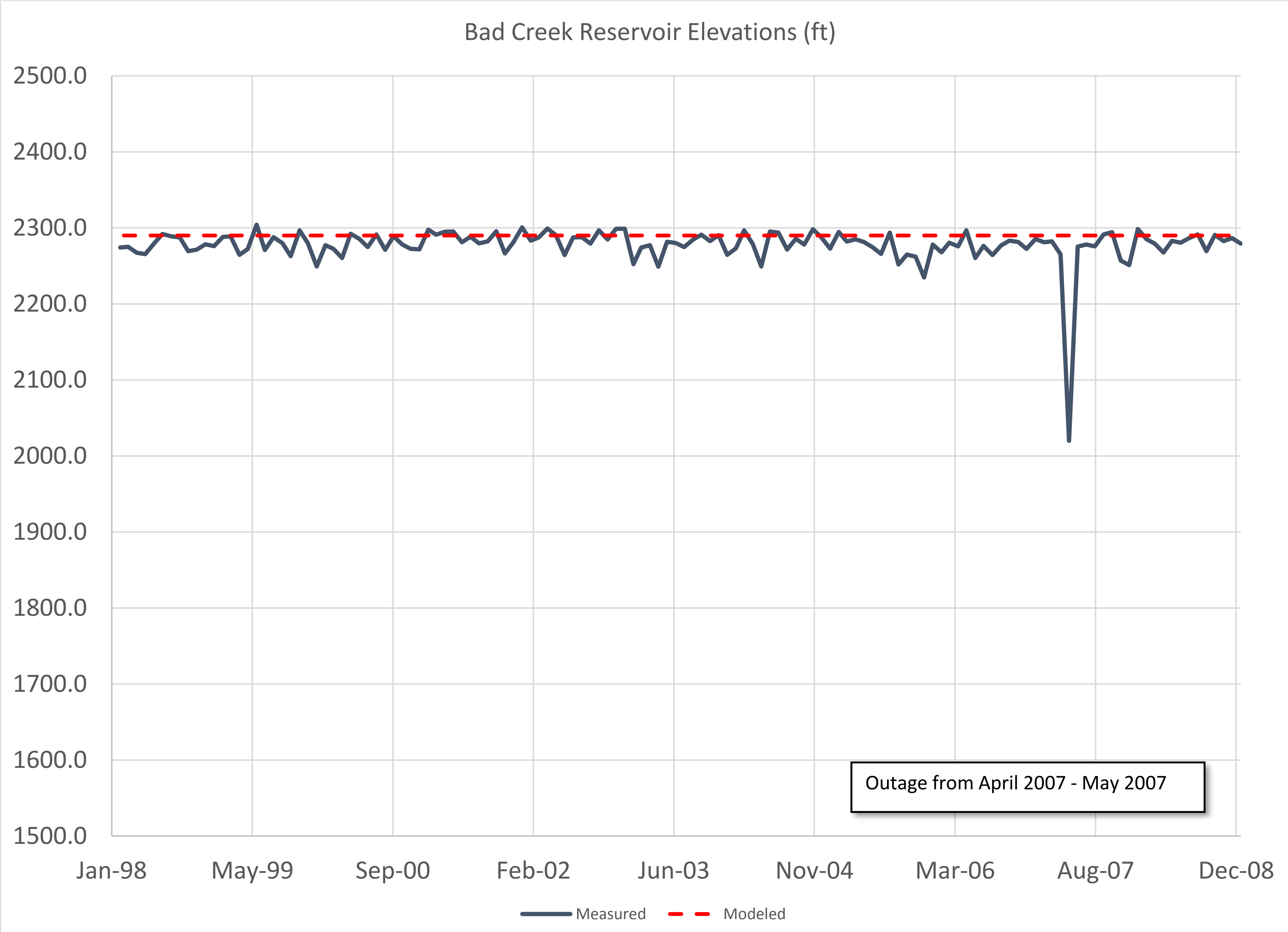

SAV28 (02196690) HORSE CREEK AT CLEARWATER, SC (CFS)
Annual Average Flow
gaged
modeled
250
200
150
100
50
0
1983
1988
1993
1998
2003
2008
2013


SAV28 (02196690) HORSE CREEK AT CLEARWATER, SC
Monthly Mean Flow (CFS)
gaged
modeled
250
200
150
100
50
0
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec

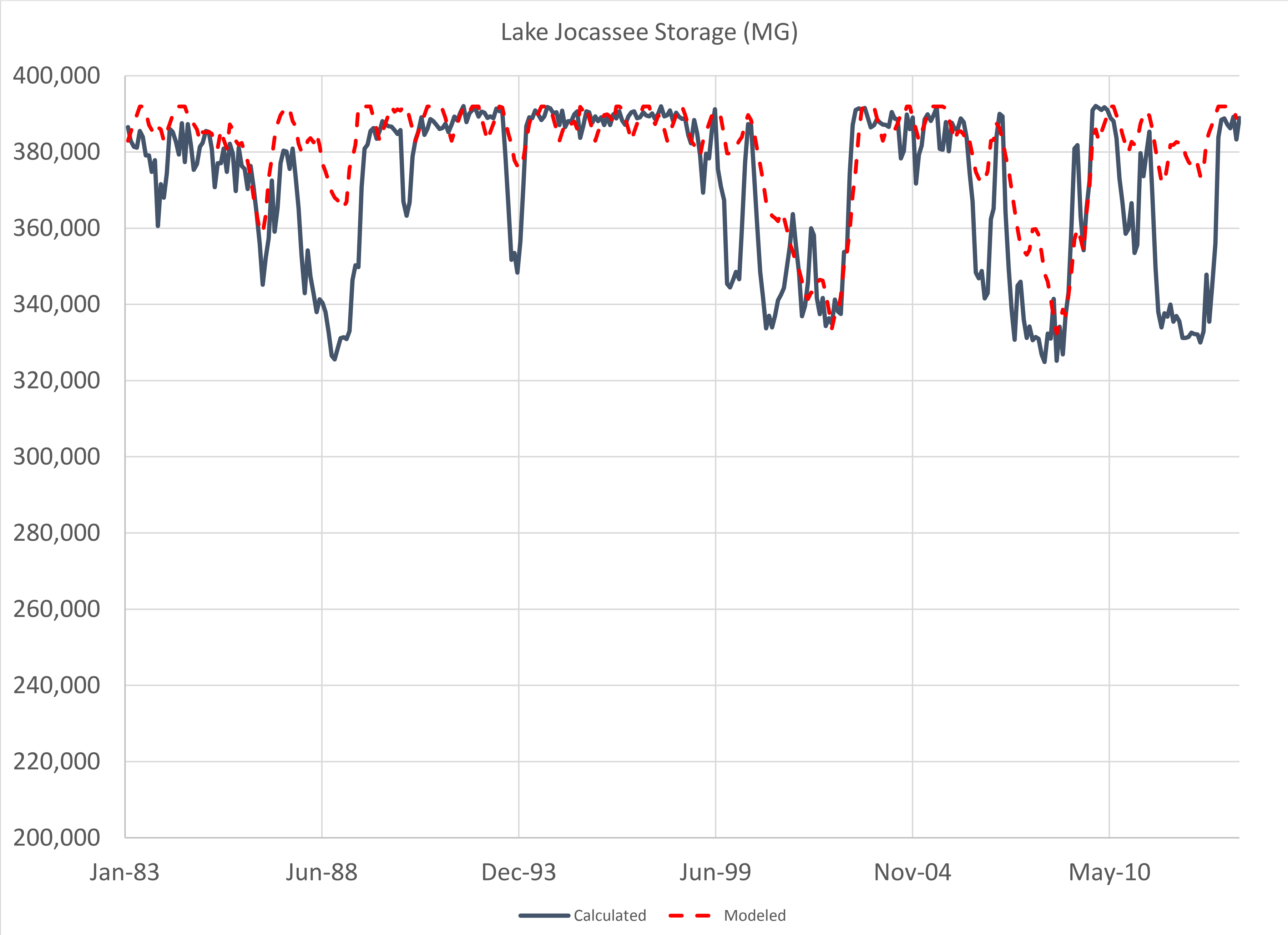


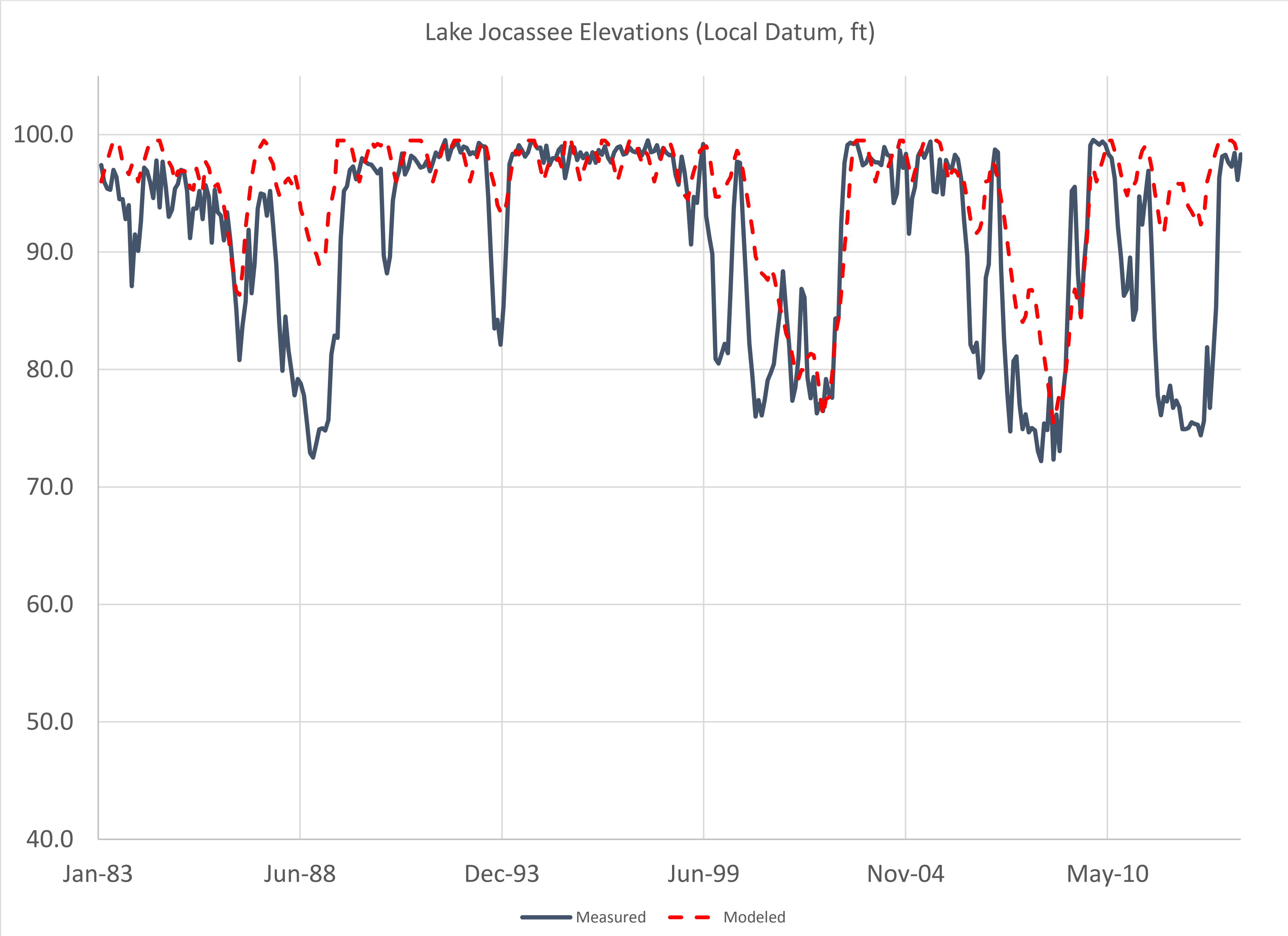
SAV28 (02196690) HORSE CREEK AT CLEARWATER, SC
Monthly Flow Percentiles (CFS)
gaged
modeled
400
350
300
250
200
150
100
50
0
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
Percentile


Bad Creek Reservoir Storage (MG)
12000.0
10000.0
8000.0
6000.0
4000.0
2000.0
0.0
Jan-98
May-99
Sep-00
Feb-02
Jun-03
Nov-04
Mar-06
Aug-07
Dec-08
Outage from April 2007 - May 2007
Calculated
Modeled

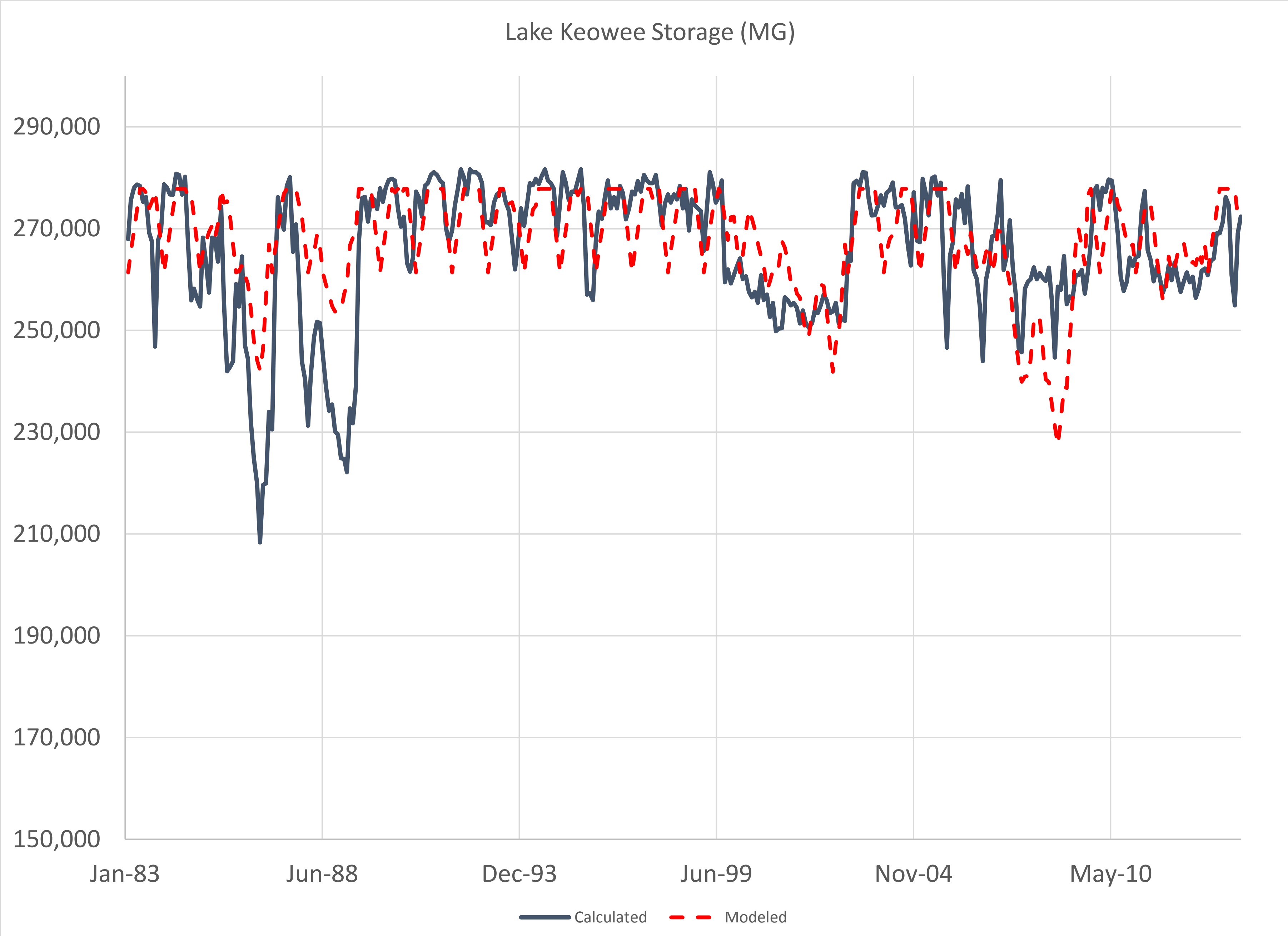


Bad Creek Reservoir Elevations (ft)
2500.0
2400.0
2300.0
2200.0
2100.0
2000.0
1900.0
1800.0
1700.0
1600.0
1500.0
Jan-98
May-99
Sep-00
Feb-02
Jun-03
Nov-04
Mar-06
Aug-07
Dec-08
Outage from April 2007 - May 2007
Measured
Modeled

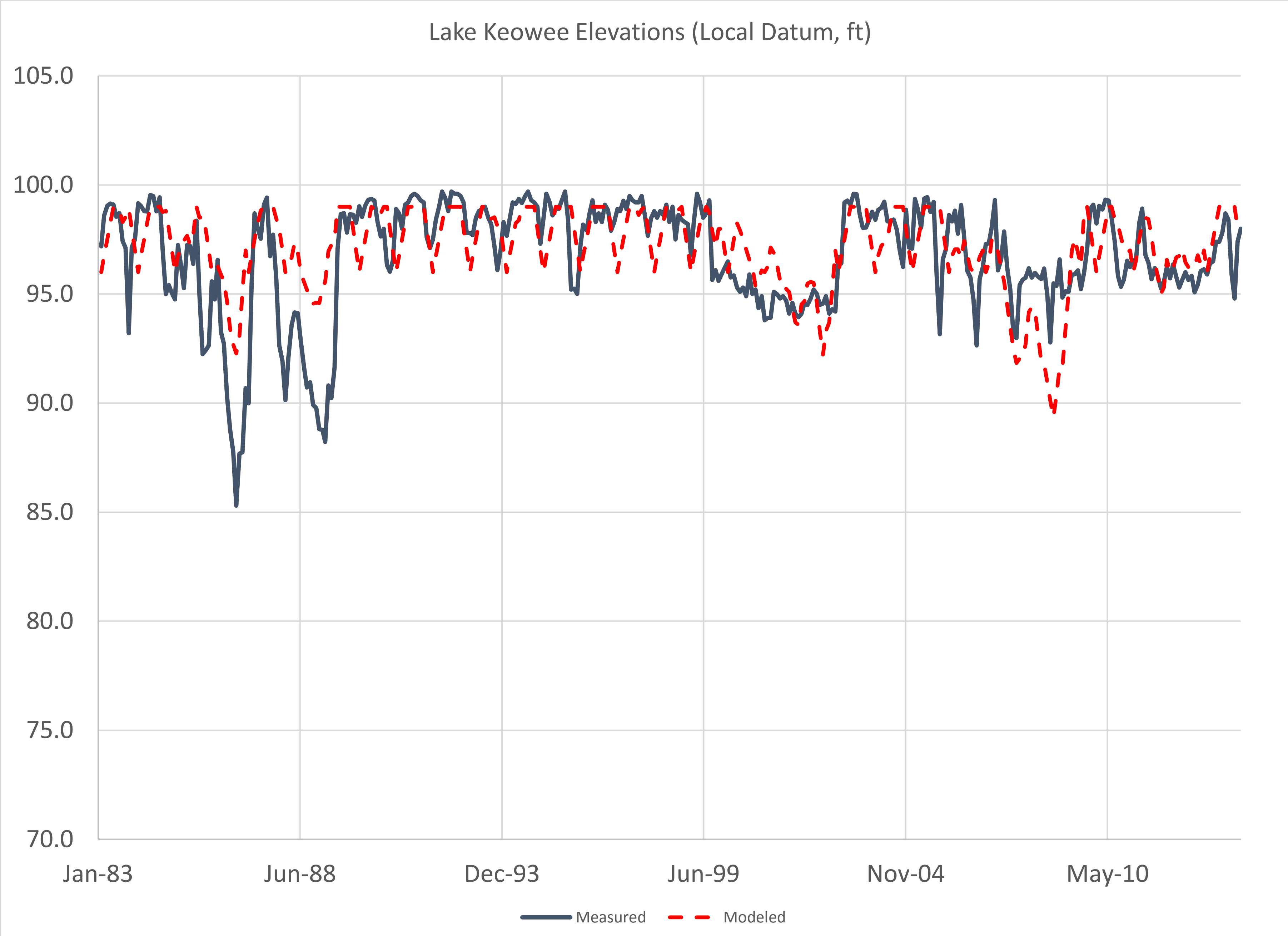

Lake Jocassee Storage (MG)
400,000
380,000
360,000
340,000
320,000
300,000
280,000
260,000
240,000
220,000
200,000
Jan-83
Jun-88
Dec-93
Jun-99
Nov-04
May-10
Calculated
Modeled



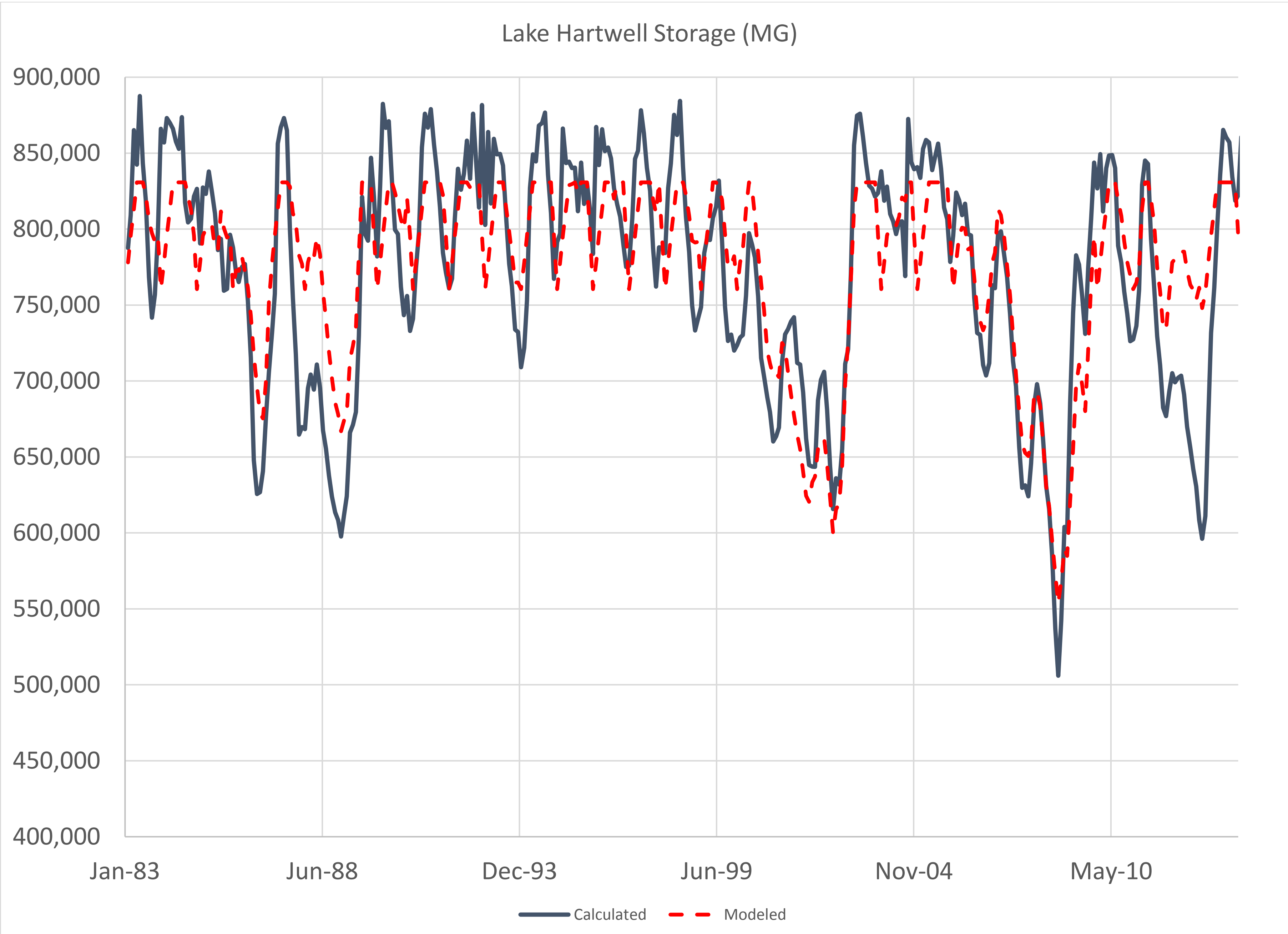
Lake Jocassee Elevations (Local Datum, ft)
100.0
90.0
80.0
70.0
60.0
50.0
40.0
Jan-83
Jun-88
Dec-93
Jun-99
Nov-04
May-10
Measured
Modeled

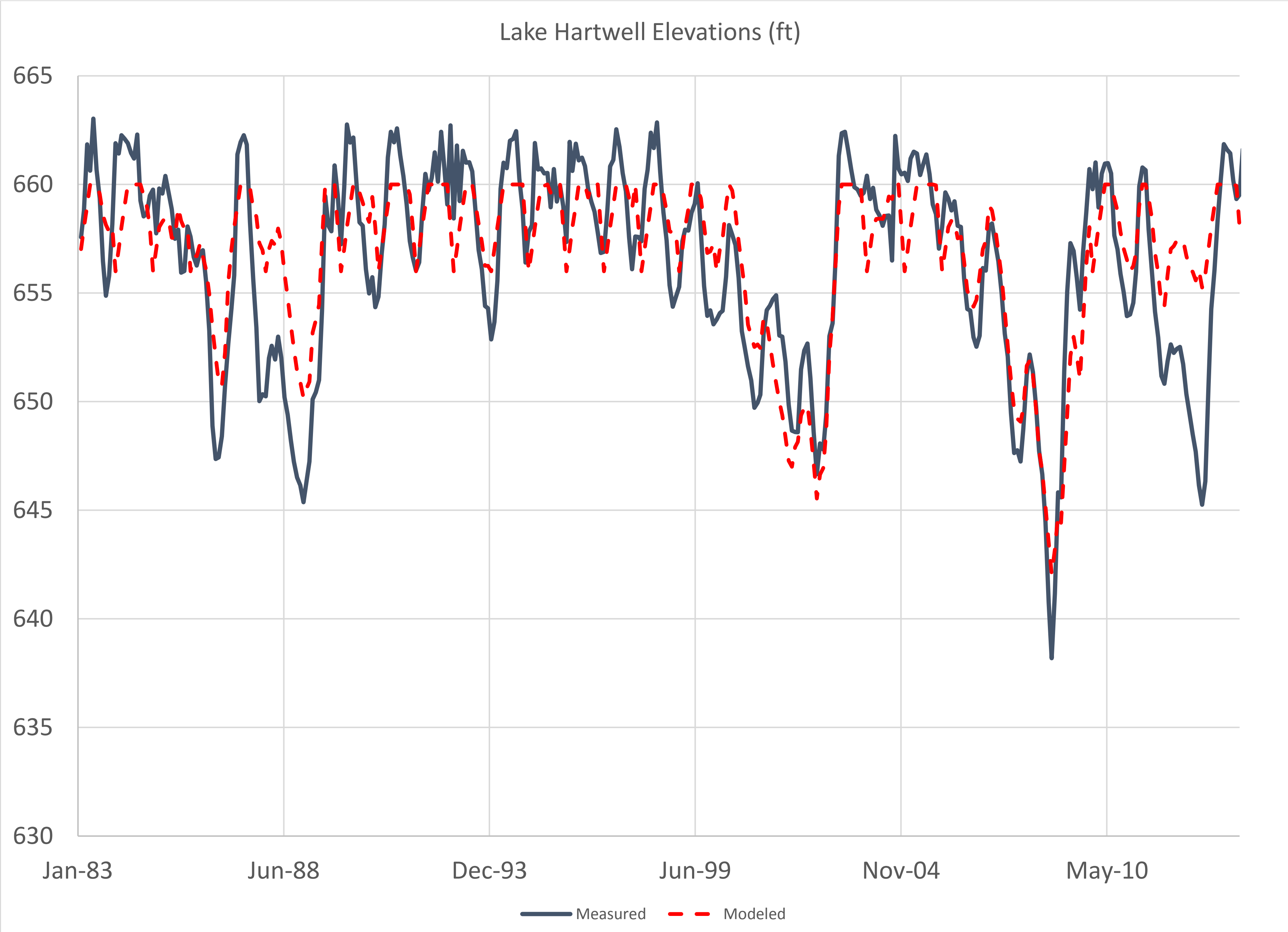


Lake Keowee Storage (MG)
290,000
270,000
250,000
230,000
210,000
190,000
170,000
150,000
Jan-83
Jun-88
Dec-93
Jun-99
Nov-04
May-10
Calculated
Modeled

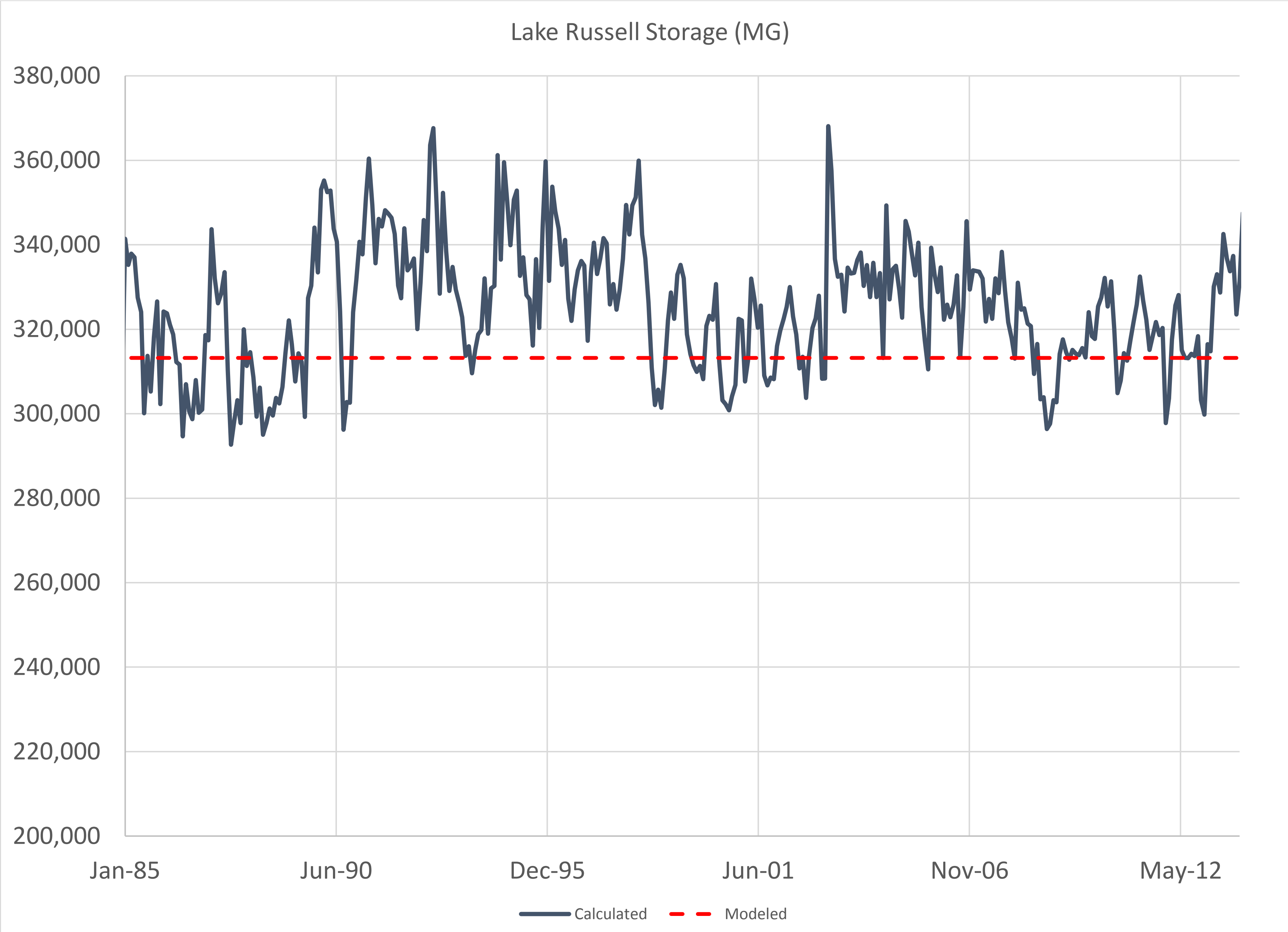


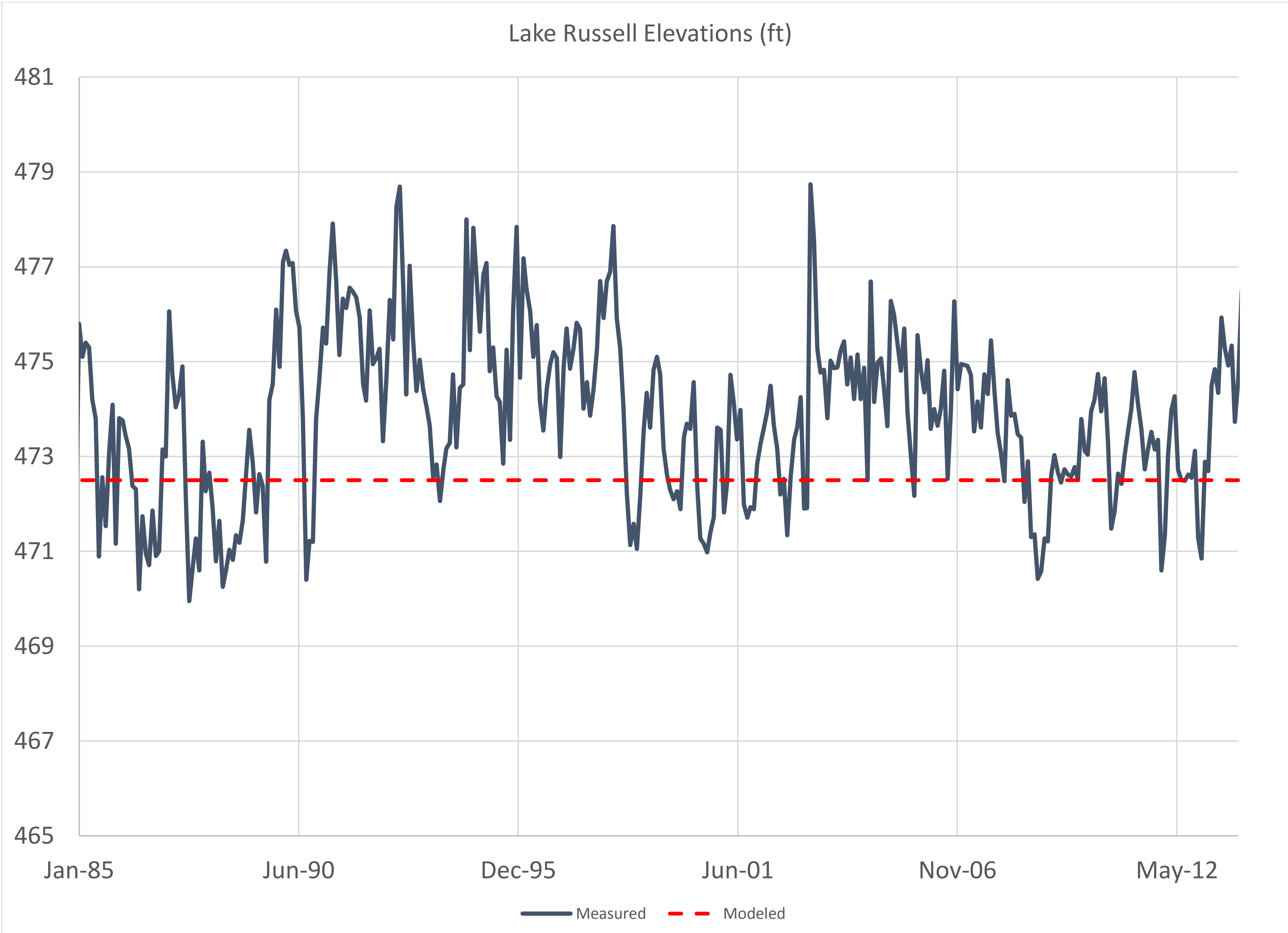
Lake Keowee Elevations (Local Datum, ft)
105.0
100.0
95.0
90.0
85.0
80.0
75.0
70.0
Jan-83
Jun-88
Dec-93
Jun-99
Nov-04
May-10
Measured
Modeled


Lake Hartwell Storage (MG)
900,000
850,000
800,000
750,000
700,000
650,000
600,000
550,000
500,000
450,000
400,000
Jan-83
Jun-88
Dec-93
Jun-99
Nov-04
May-10
Calculated
Modeled

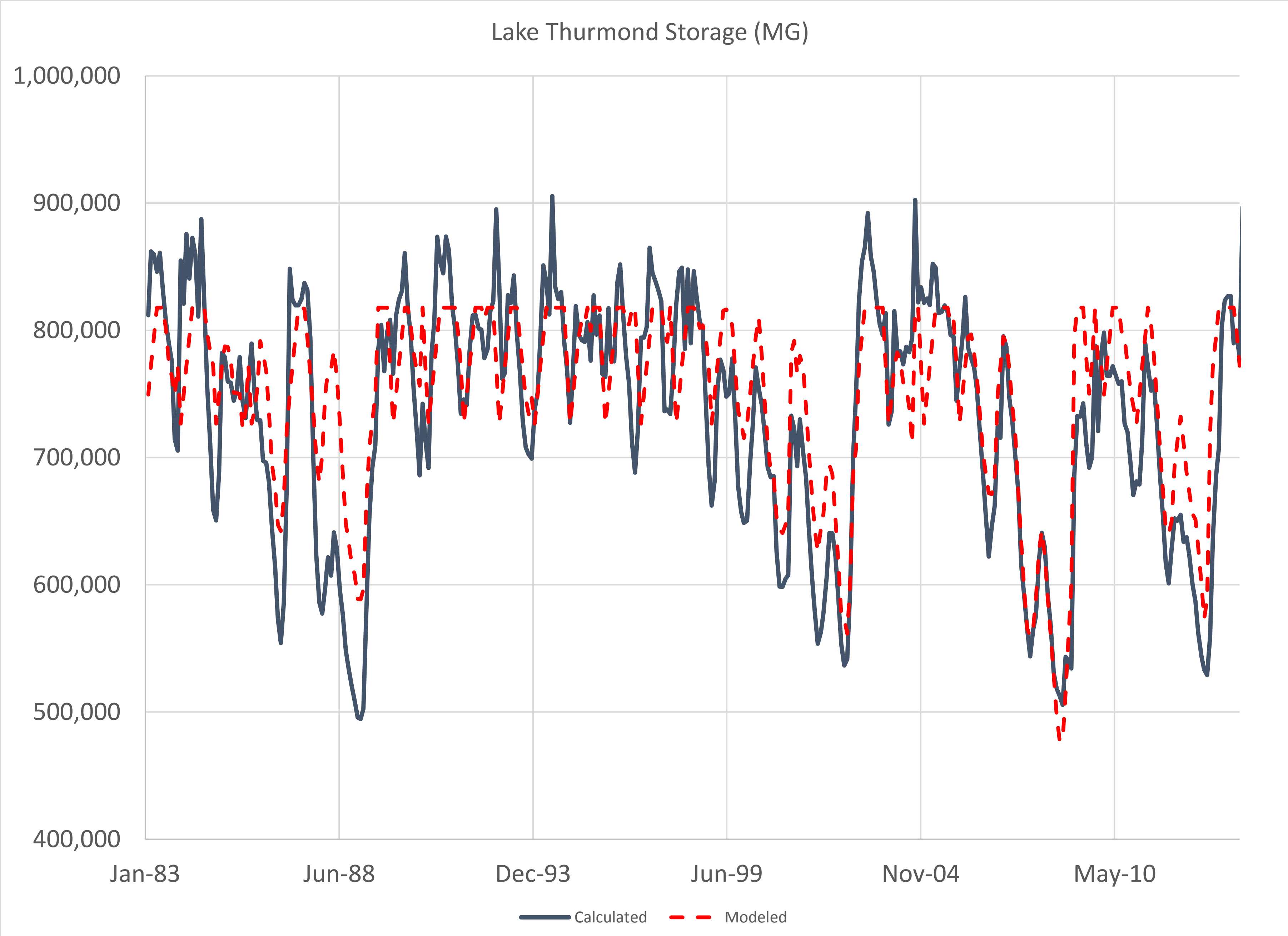


Lake Hartwell Elevations (ft)
665
660
655
650
645
640
635
630
Jan-83
Jun-88
Dec-93
Jun-99
Nov-04
May-10
Measured
Modeled

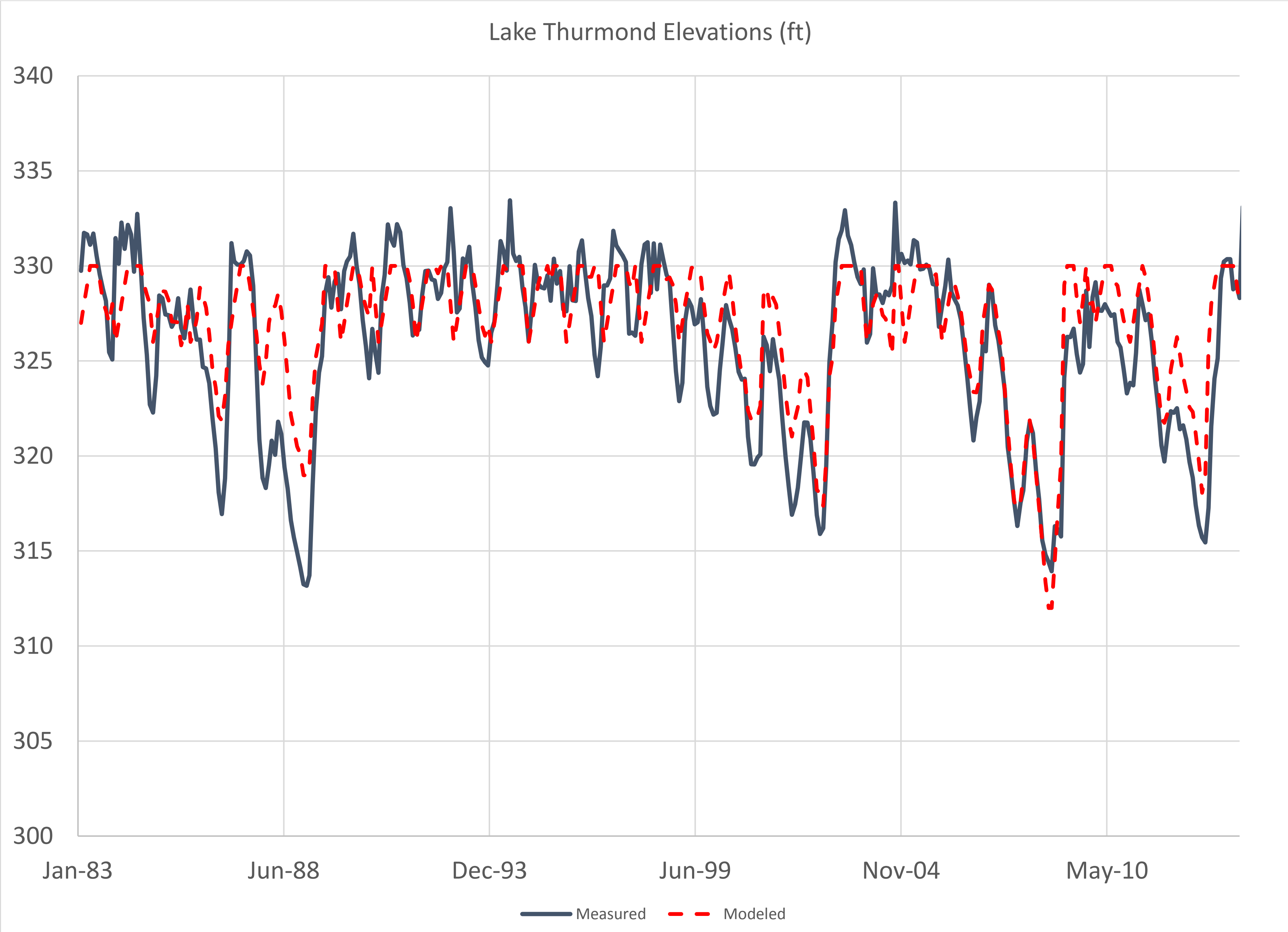

Lake Russell Storage (MG)
380,000
360,000
340,000
320,000
300,000
280,000
260,000
240,000
220,000
200,000
Jan-85
Jun-90
Dec-95
Jun-01
Nov-06
May-12
Calculated
Modeled



Lake Russell Elevations (ft)
481
479
477
475
473
471
469
467
465
Jan-85
Jun-90
Dec-95
Jun-01
Nov-06
May-12
Measured
Modeled



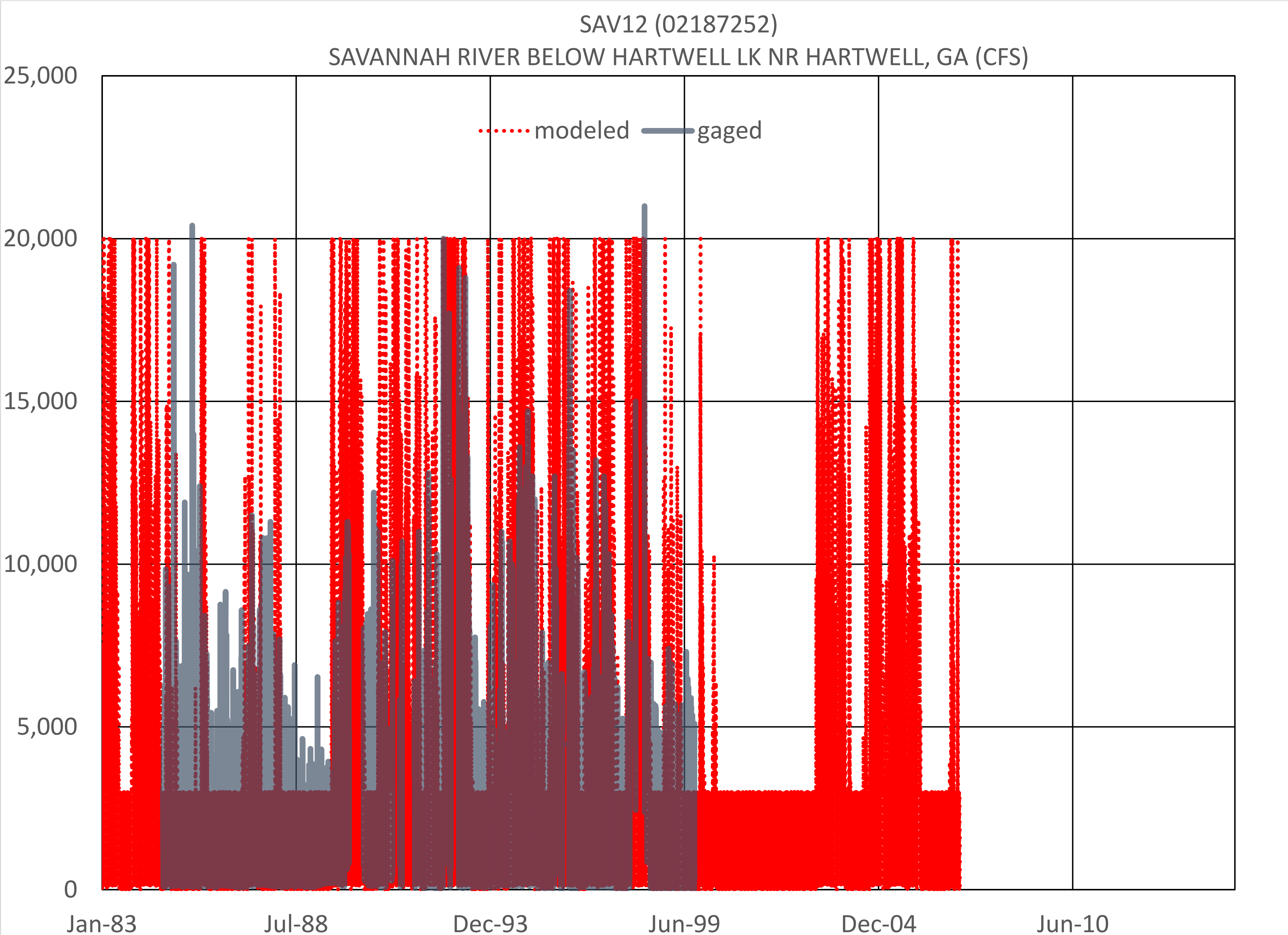
Lake Thurmond Storage (MG)
1,000,000
900,000
800,000
700,000
600,000
500,000
400,000
Jan-83
Jun-88
Dec-93
Jun-99
Nov-04
May-10
Calculated
Modeled

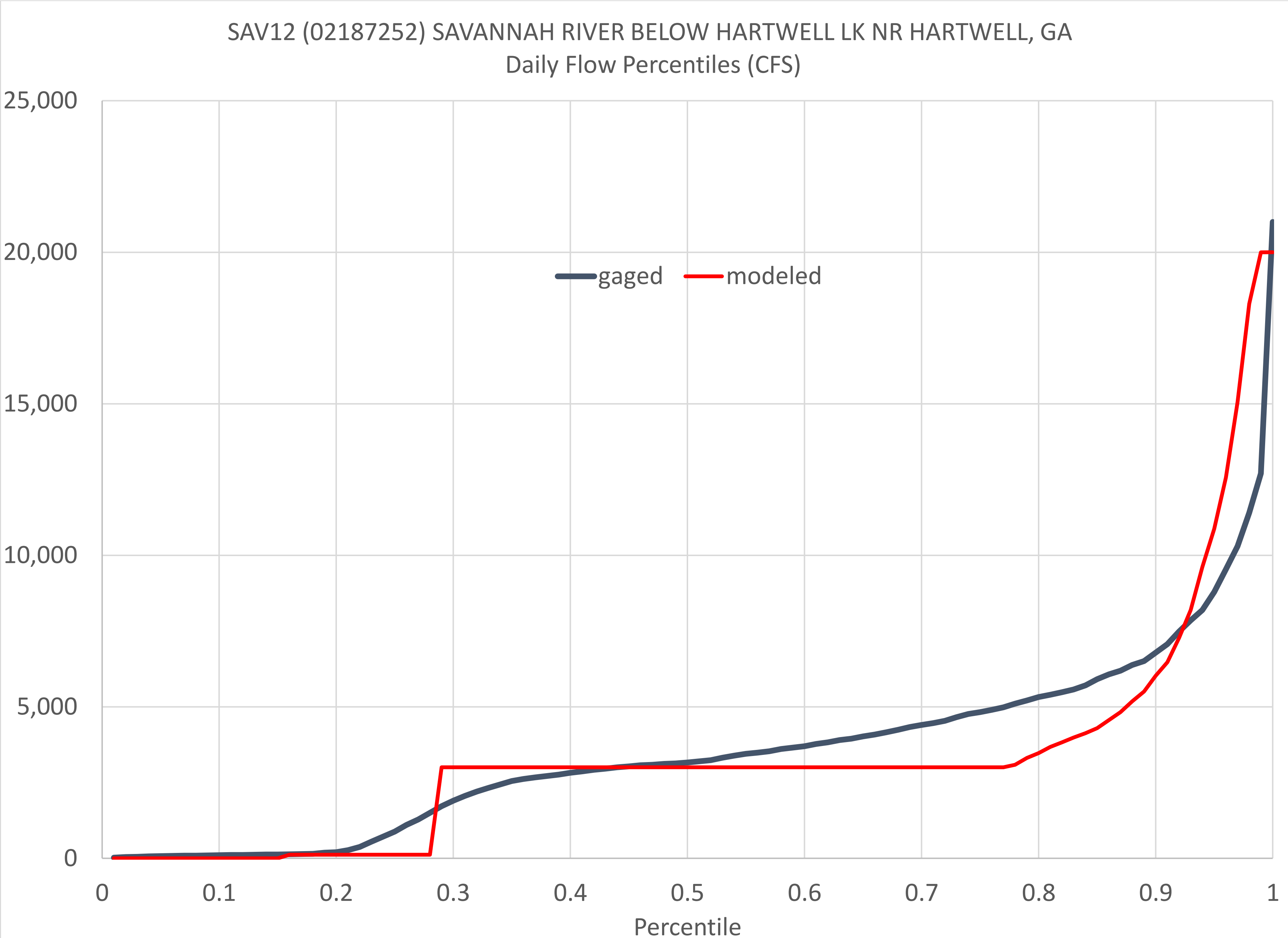

Lake Thurmond Elevations (ft)
340
335
330
325
320
315
310
305
300
Jan-83
Jun-88
Dec-93
Jun-99
Nov-04
May-10
Measured
Modeled

Appendix B

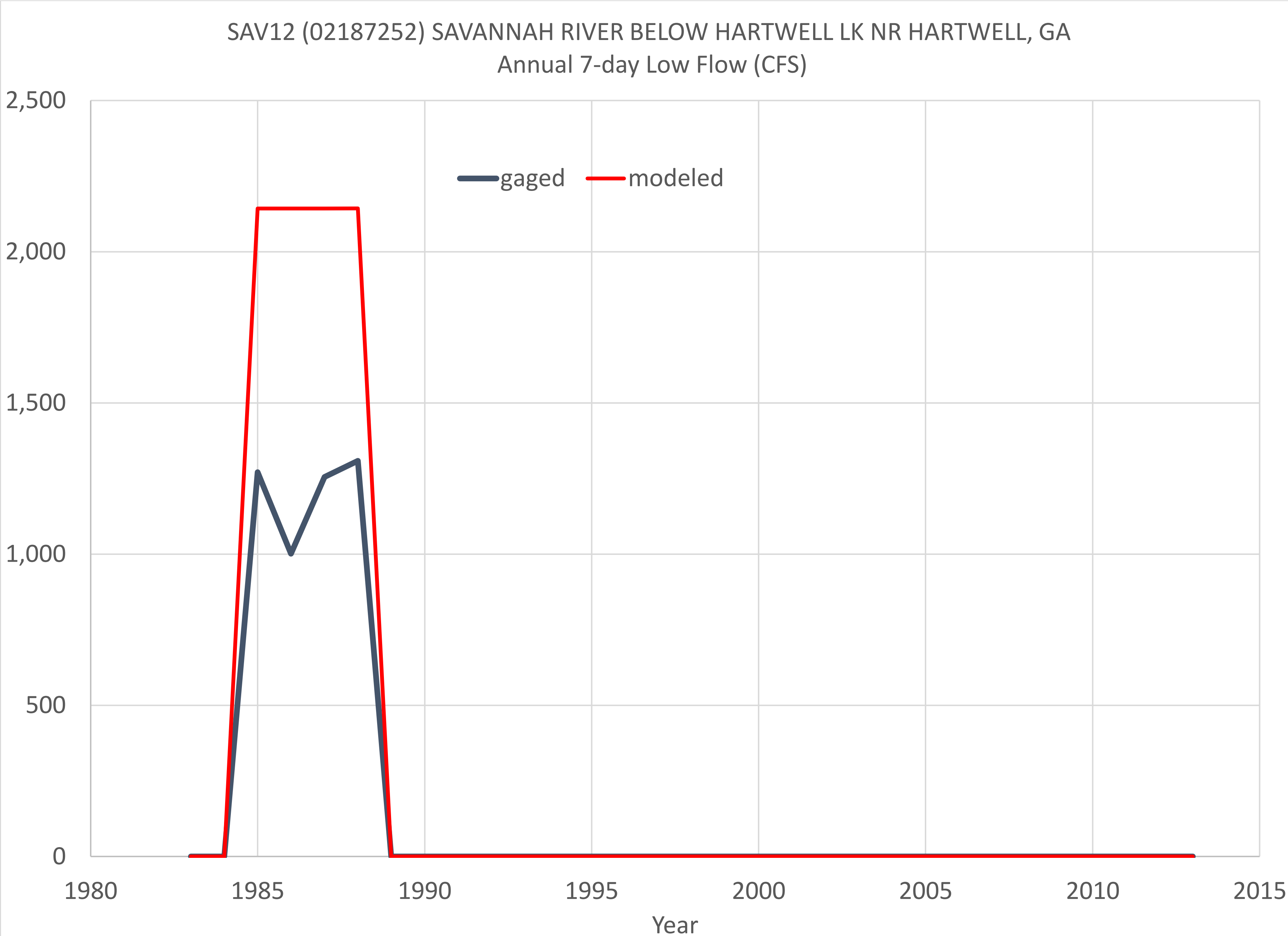
Savannah River Basin Model Daily Calibration Results

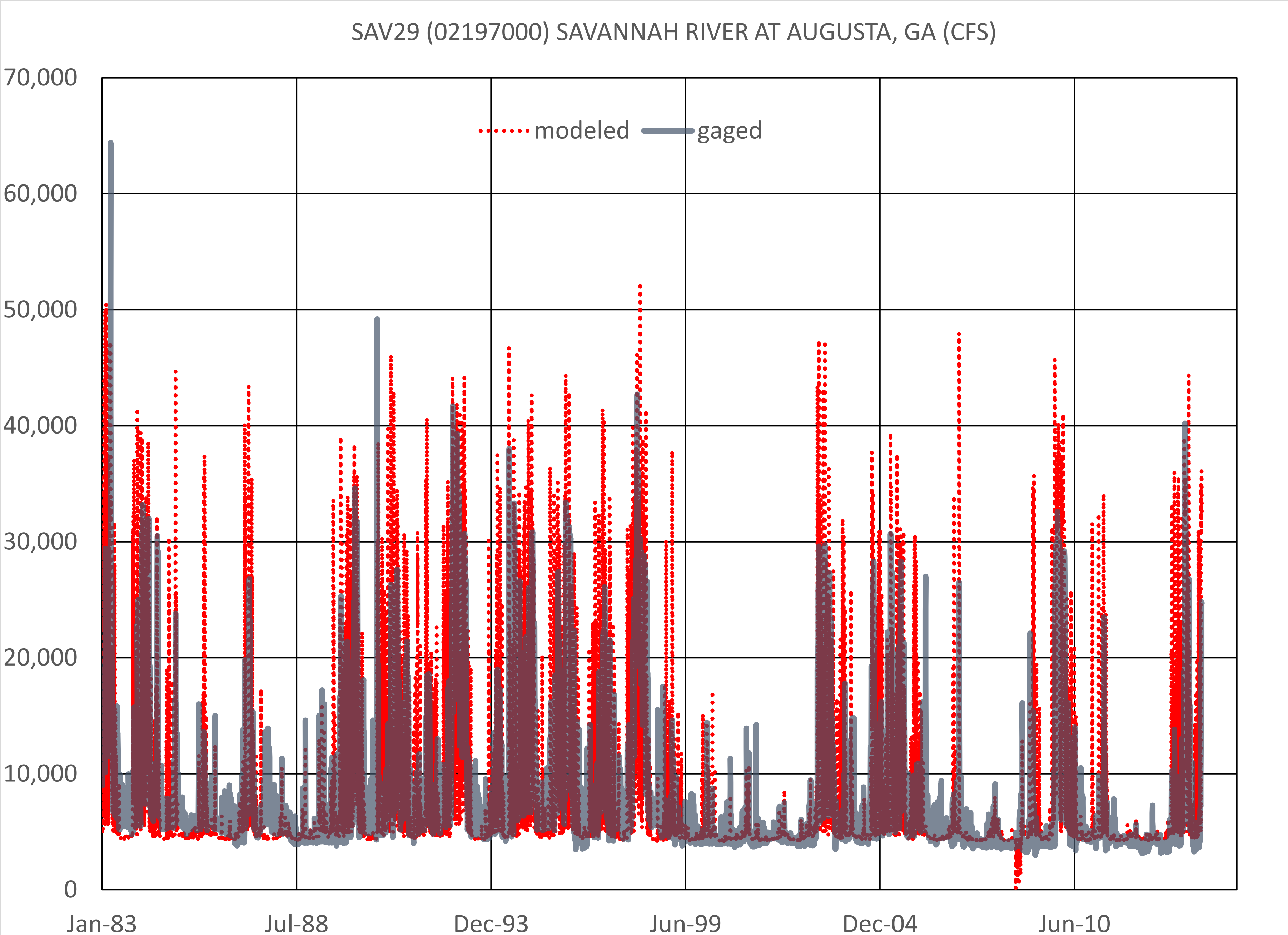
CDM Smith

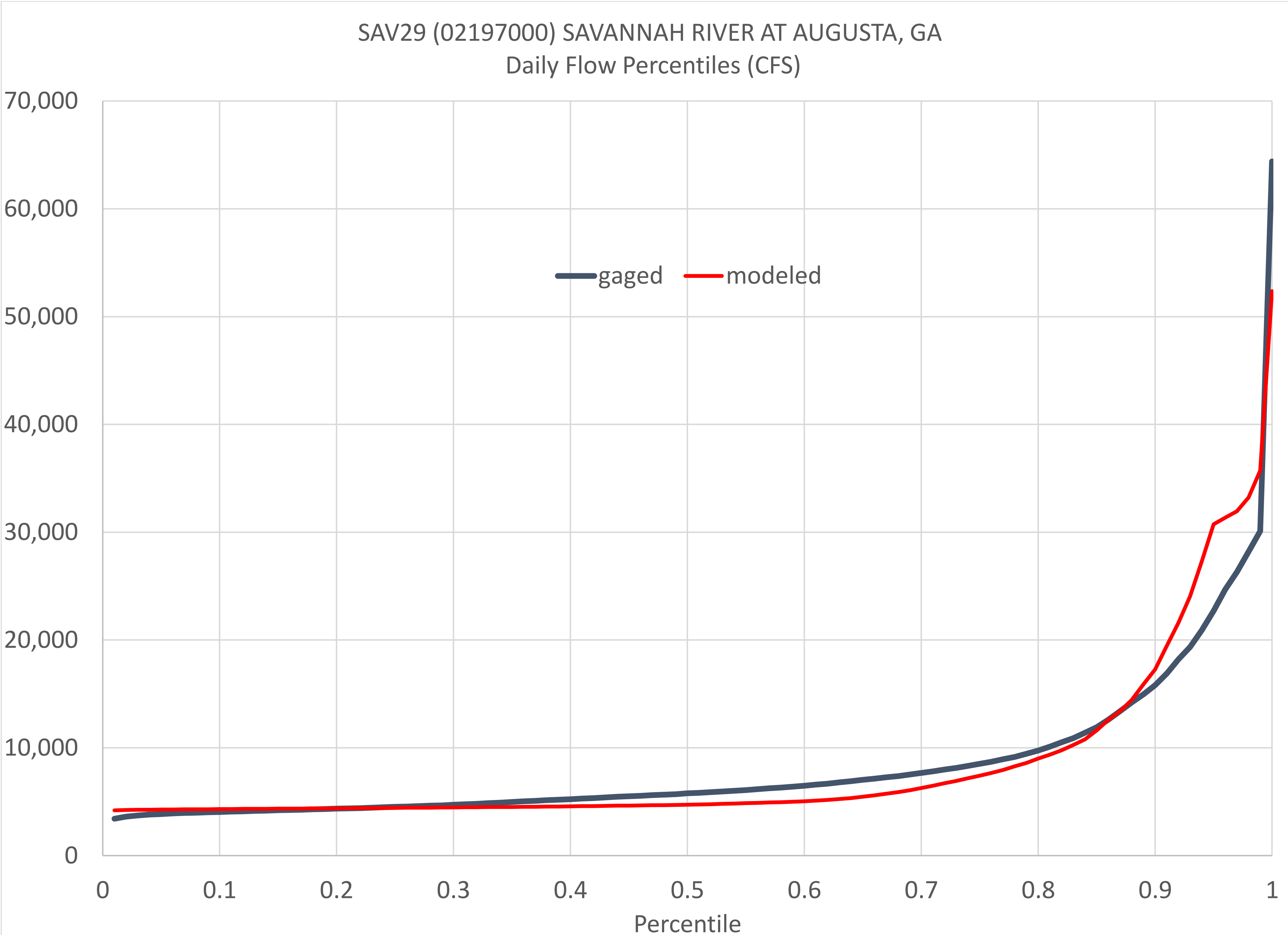

SAV12 (02187252)
SAVANNAH RIVER BELOW HARTWELL LK NR HARTWELL, GA (CFS)
modeled
gaged
25,000
20,000
15,000
10,000
5,000
0
Jan-83
Jul-88
Dec-93
Jun-99
Dec-04
Jun-10



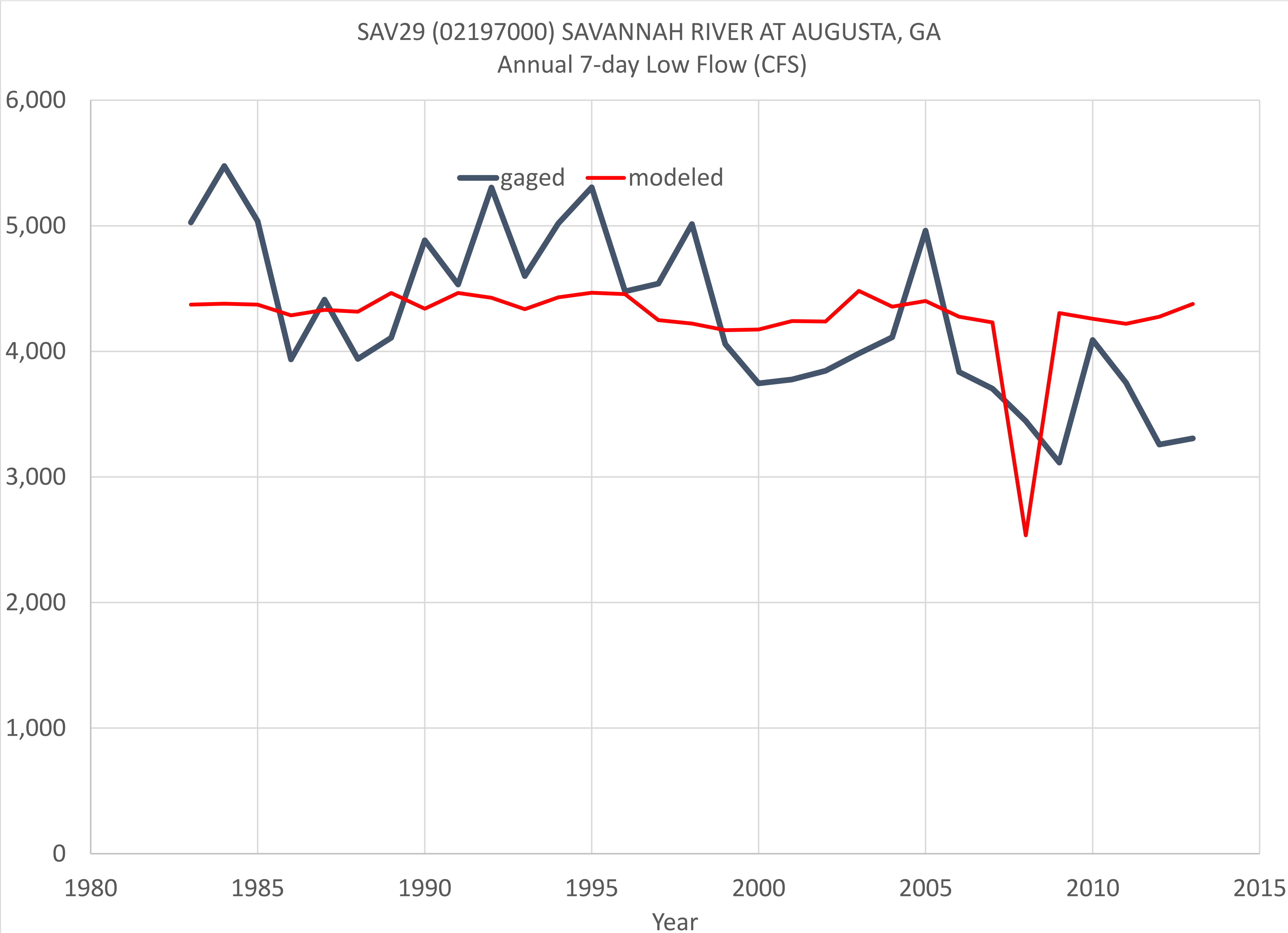
SAV12 (02187252) SAVANNAH RIVER BELOW HARTWELL LK NR HARTWELL, GA
Daily Flow Percentiles (CFS)
25,000
20,000
15,000
10,000
5,000
0
gaged
modeled
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
Percentile

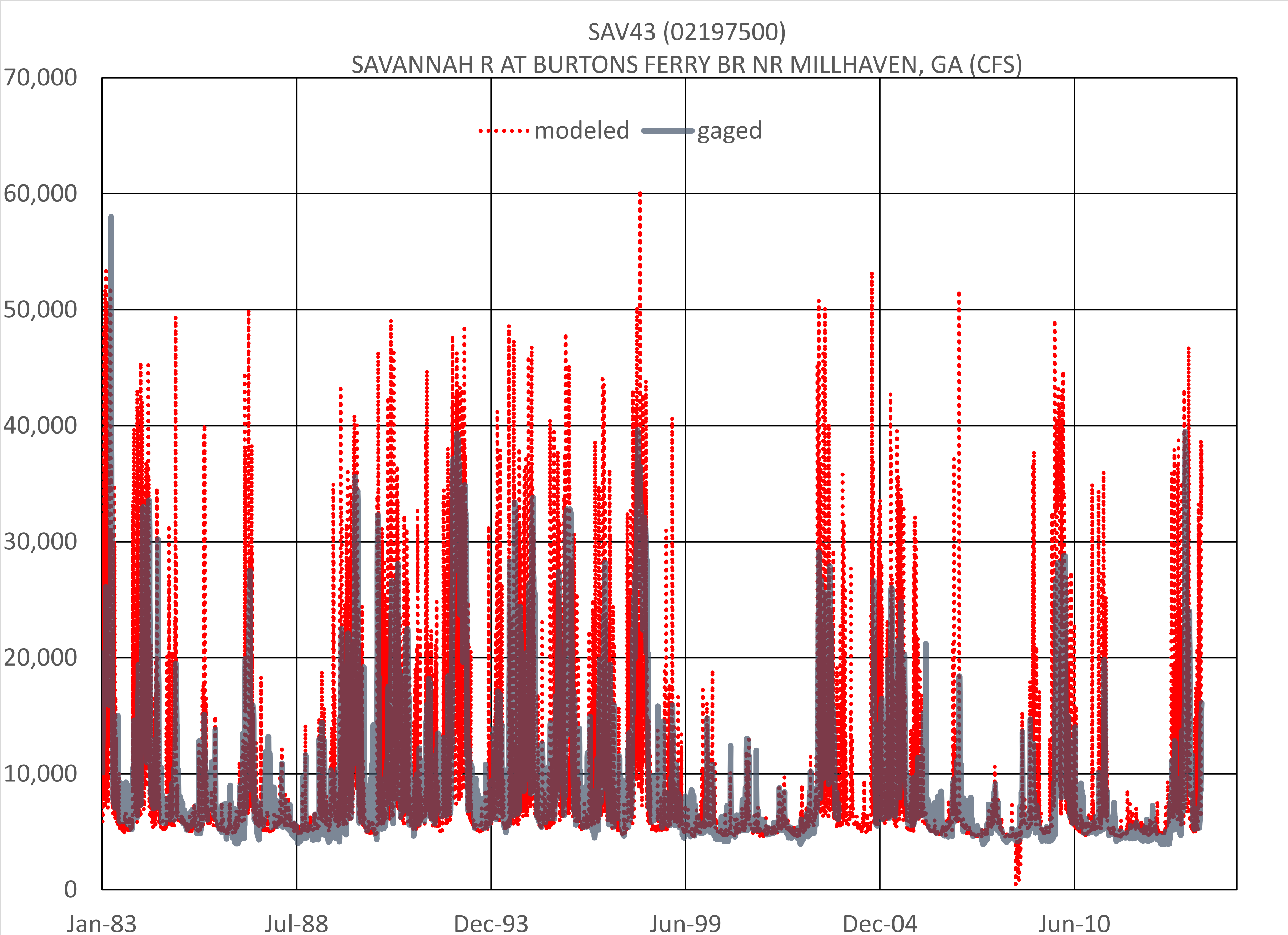

SAV12 (02187252) SAVANNAH RIVER BELOW HARTWELL LK NR HARTWELL, GA
Annual 7-day Low Flow (CFS)
gaged
modeled
2,500
2,000
1,500
1,000
500
0
1980
1985
1990
1995
2000
2005
2010
2015
Year

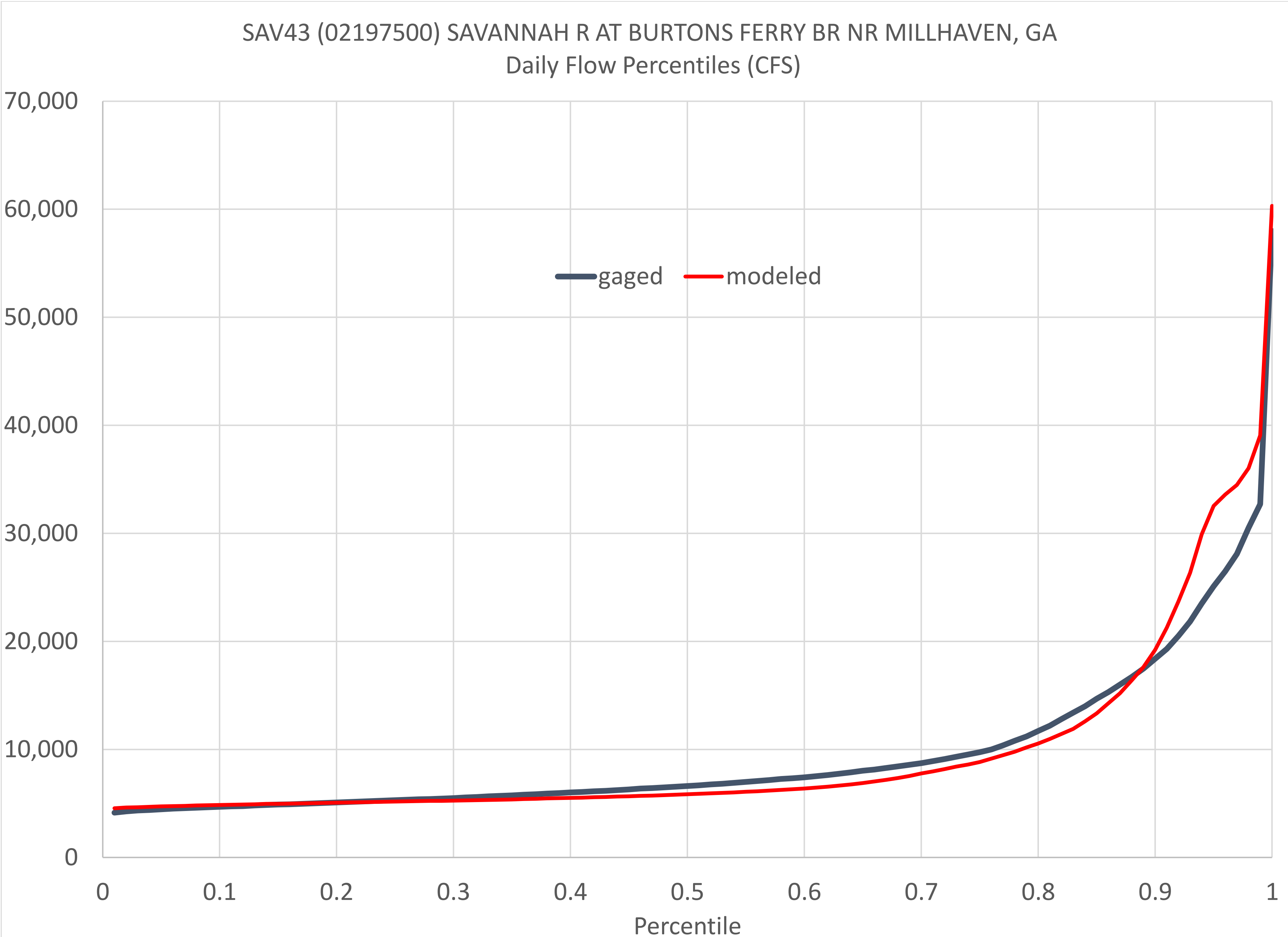

SAV29 (02197000) SAVANNAH RIVER AT AUGUSTA, GA (CFS)
modeled
gaged
70,000
60,000
50,000
40,000
30,000
20,000
10,000
0
Jan-83
Jul-88
Dec-93
Jun-99
Dec-04
Jun-10



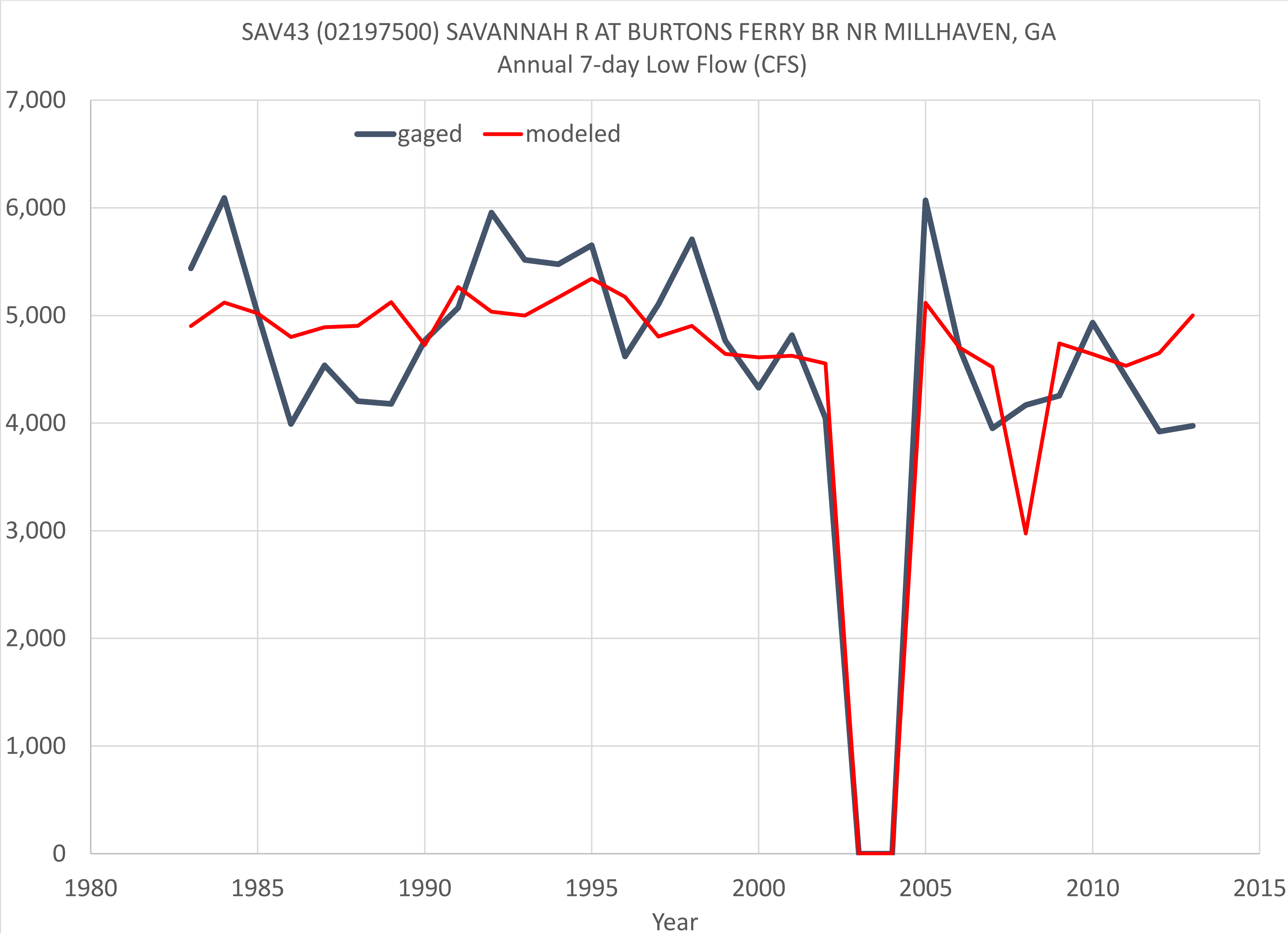
SAV29 (02197000) SAVANNAH RIVER AT AUGUSTA, GA
Daily Flow Percentiles (CFS)
gaged
modeled
70,000
60,000
50,000
40,000
30,000
20,000
10,000
0
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
Percentile

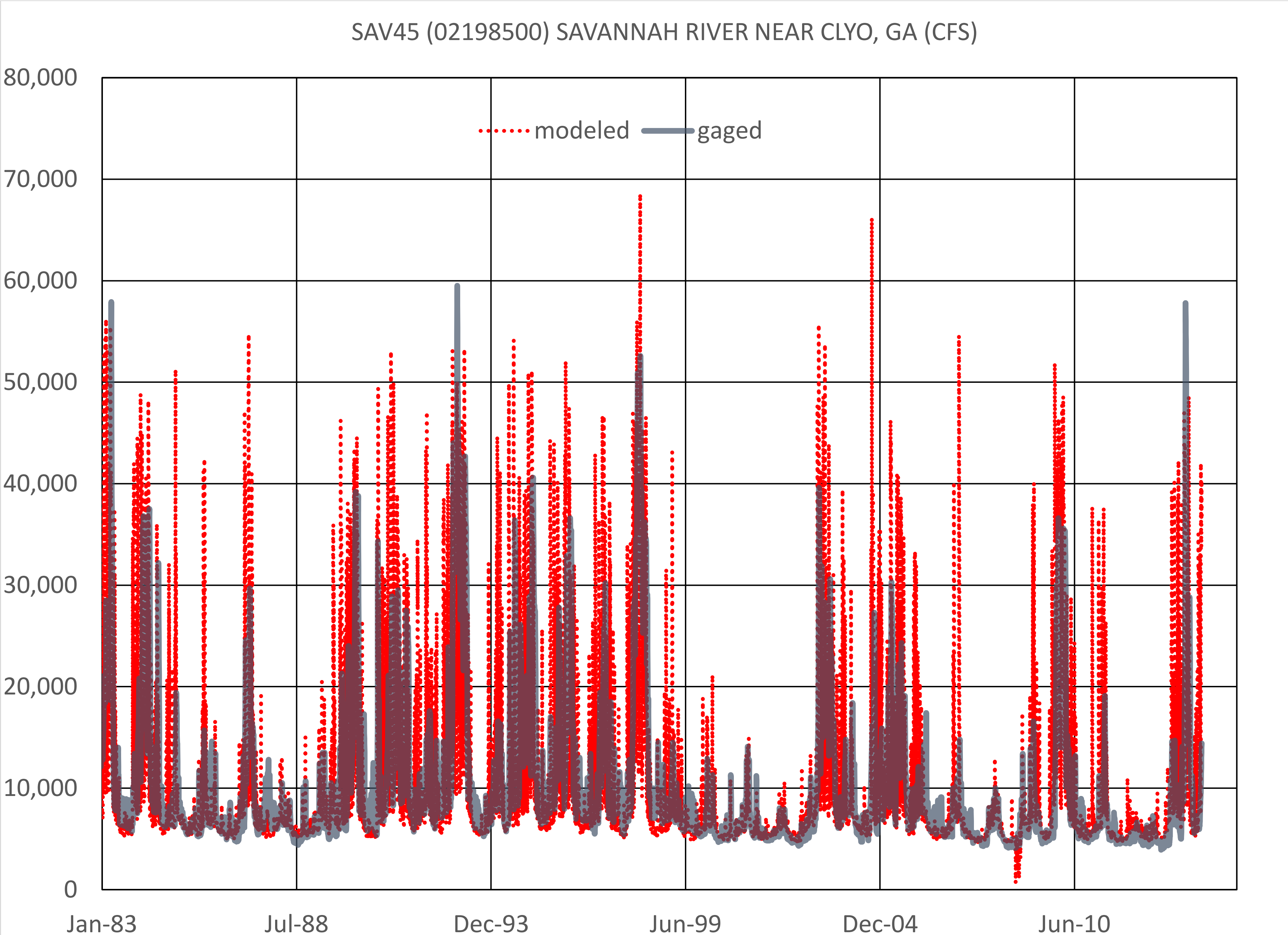

SAV29 (02197000) SAVANNAH RIVER AT AUGUSTA, GA
Annual 7-day Low Flow (CFS)
gaged
modeled
6,000
5,000
4,000
3,000
2,000
1,000
0
1980
1985
1990
1995
2000
2005
2010
2015
Year


SAV43 (02197500)
SAVANNAH R AT BURTONS FERRY BR NR MILLHAVEN, GA (CFS)
modeled
gaged
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

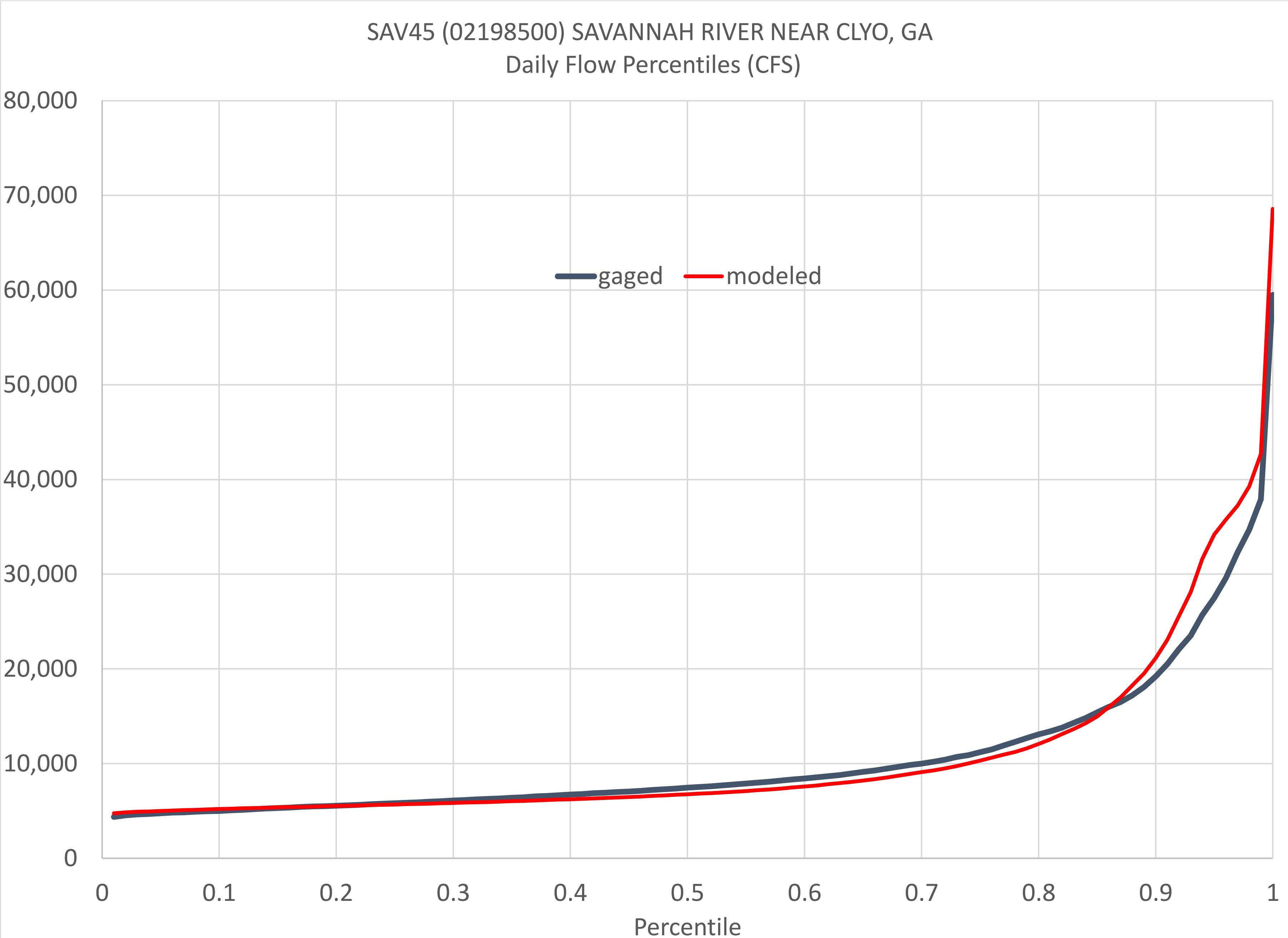


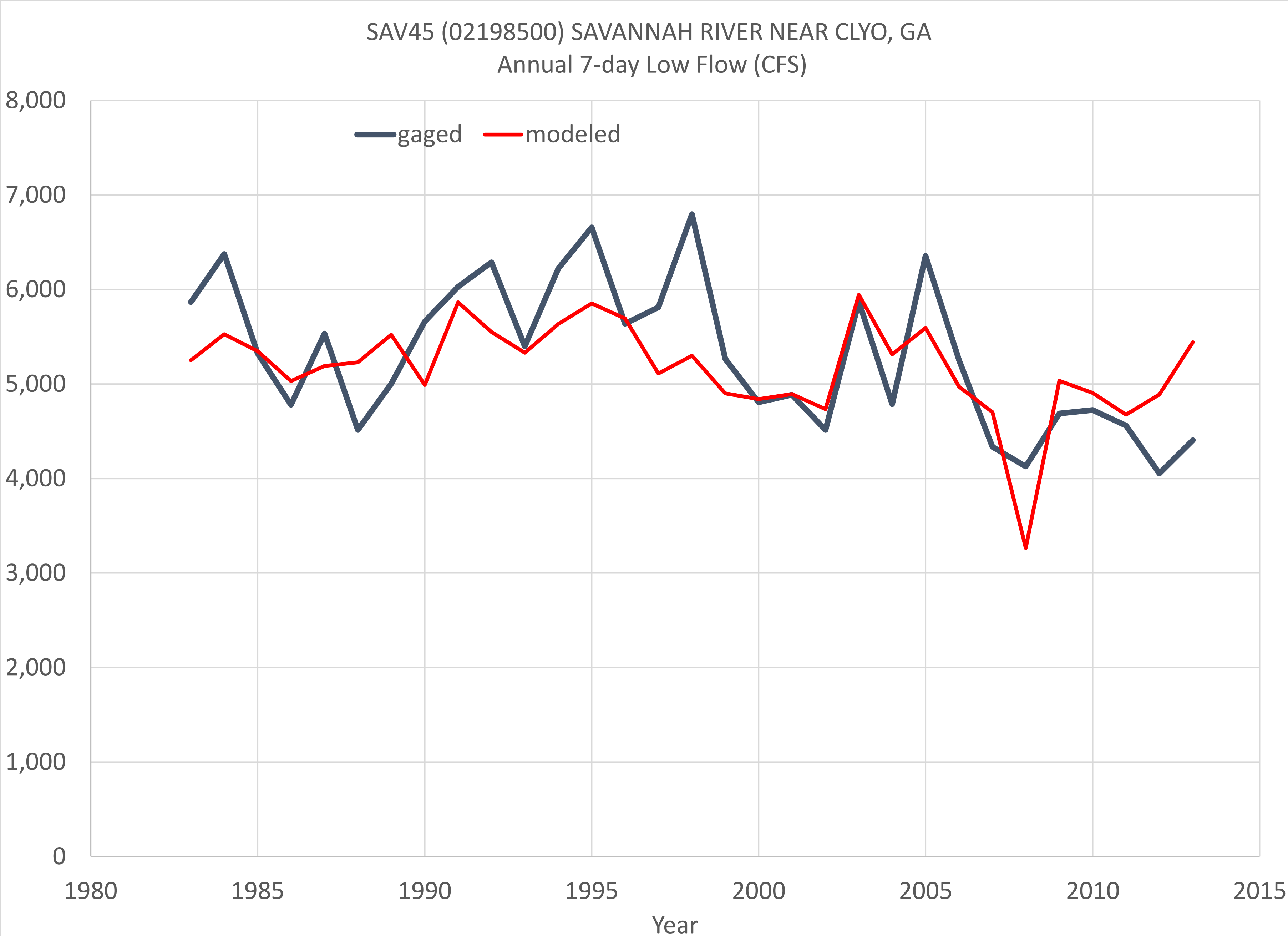
SAV43 (02197500) SAVANNAH R AT BURTONS FERRY BR NR MILLHAVEN, GA
Daily Flow Percentiles (CFS)
gaged
modeled
70,000
60,000
50,000
40,000
30,000
20,000
10,000
0
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
Percentile


SAV43 (02197500) SAVANNAH R AT BURTONS FERRY BR NR MILLHAVEN, GA
Annual 7-day Low Flow (CFS)
7,000
6,000
5,000
4,000
3,000
2,000
1,000
0
gaged
modeled
1980
1985
1990
1995
2000
2005
2010
2015
Year

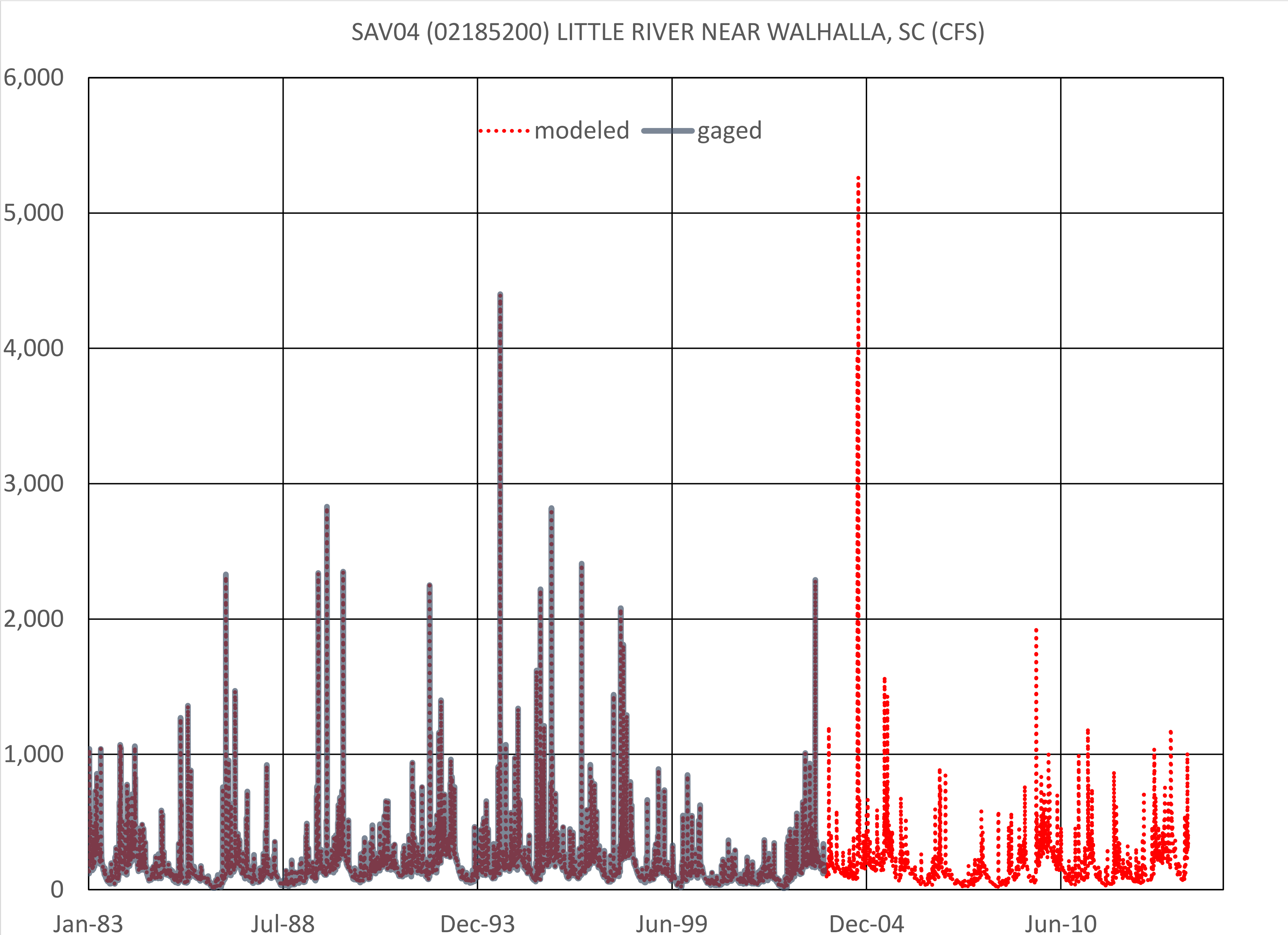


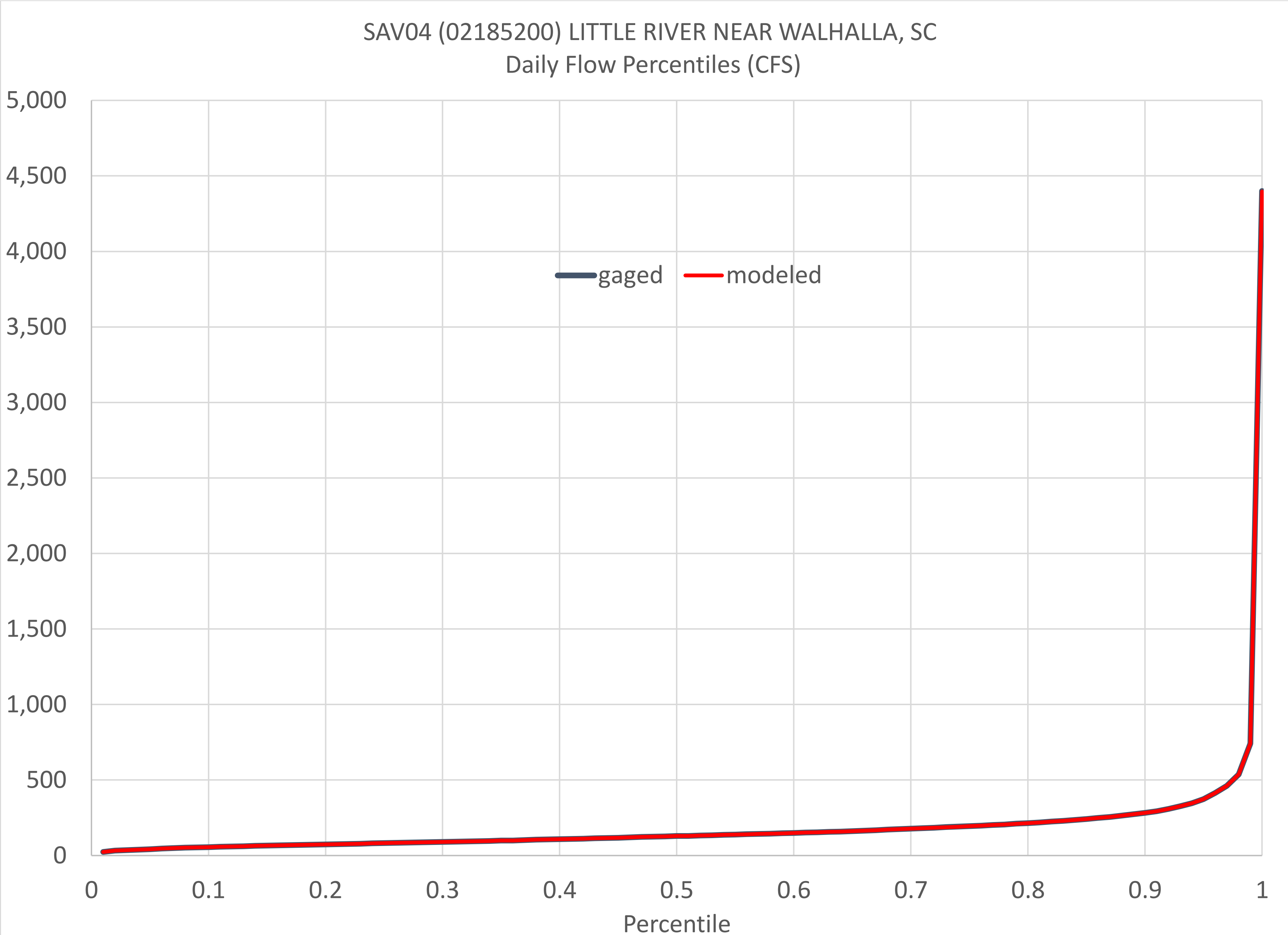
SAV45 (02198500) SAVANNAH RIVER NEAR CLYO, GA (CFS)
modeled
gaged
80,000
70,000
60,000
50,000
40,000
30,000
20,000
10,000
0
Jan-83
Jul-88
Dec-93
Jun-99
Dec-04
Jun-10


SAV45 (02198500) SAVANNAH RIVER NEAR CLYO, GA
Daily Flow Percentiles (CFS)
gaged
modeled
80,000
70,000
60,000
50,000
40,000
30,000
20,000
10,000
0
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
Percentile

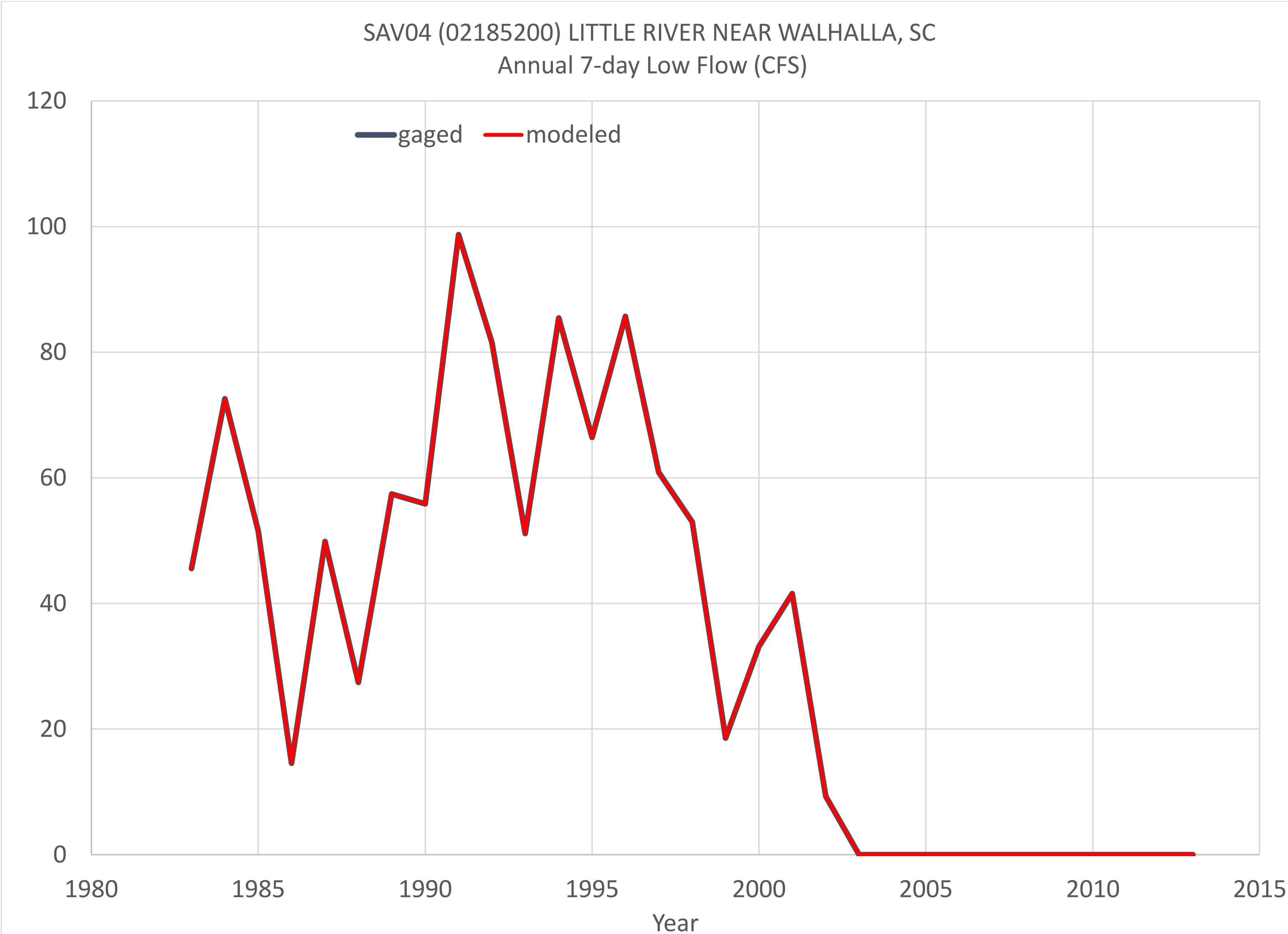


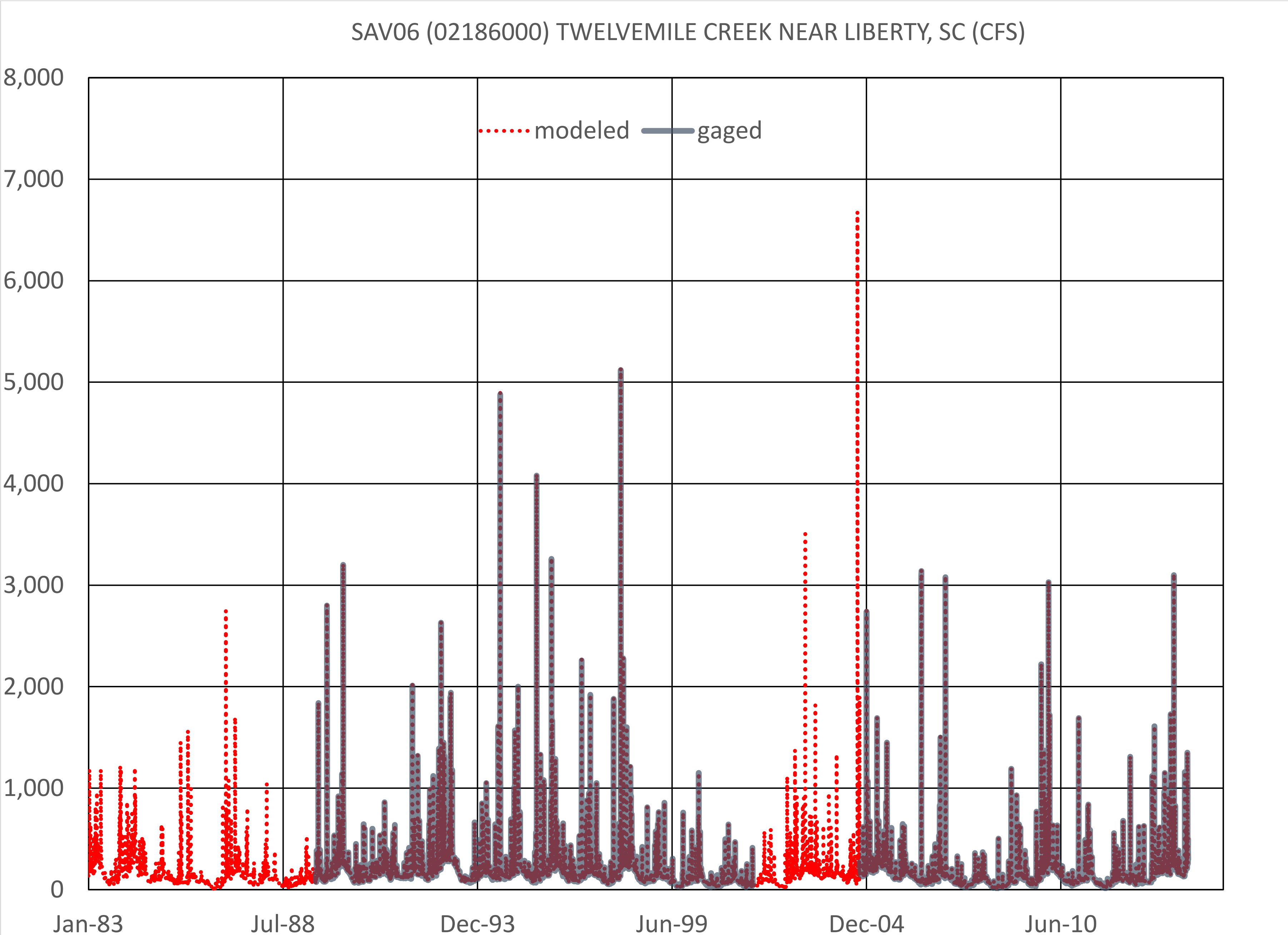
SAV45 (02198500) SAVANNAH RIVER NEAR CLYO, GA
Annual 7-day Low Flow (CFS)
gaged
modeled
8,000
7,000
6,000
5,000
4,000
3,000
2,000
1,000
0
1980
1985
1990
1995
2000
2005
2010
2015
Year


SAV04 (02185200) LITTLE RIVER NEAR WALHALLA, 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

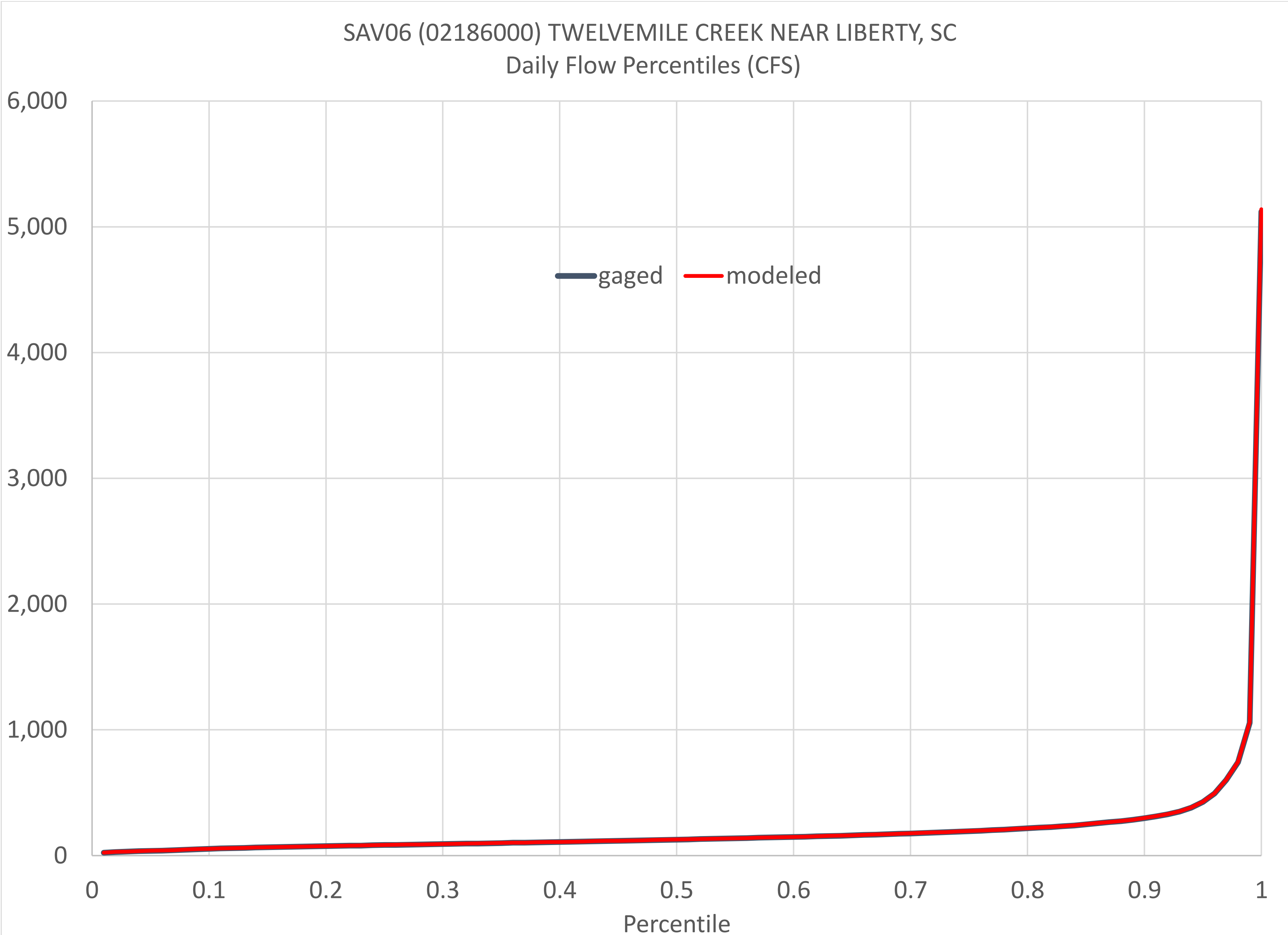


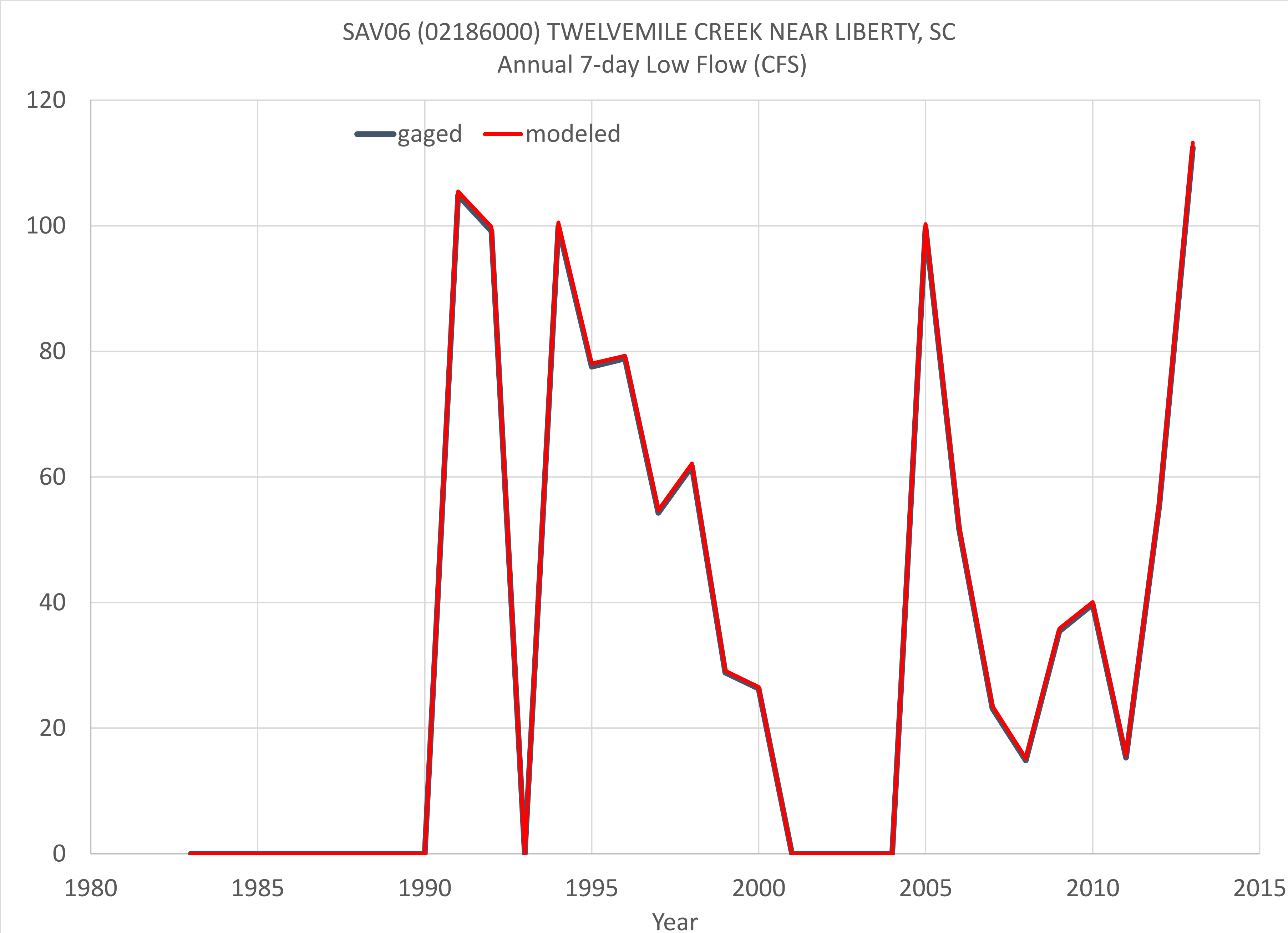
SAV04 (02185200) LITTLE RIVER NEAR WALHALLA, SC
Daily Flow Percentiles (CFS)
gaged
modeled
5,000
4,500
4,000
3,500
3,000
2,500
2,000
1,500
1,000
500
0
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
Percentile

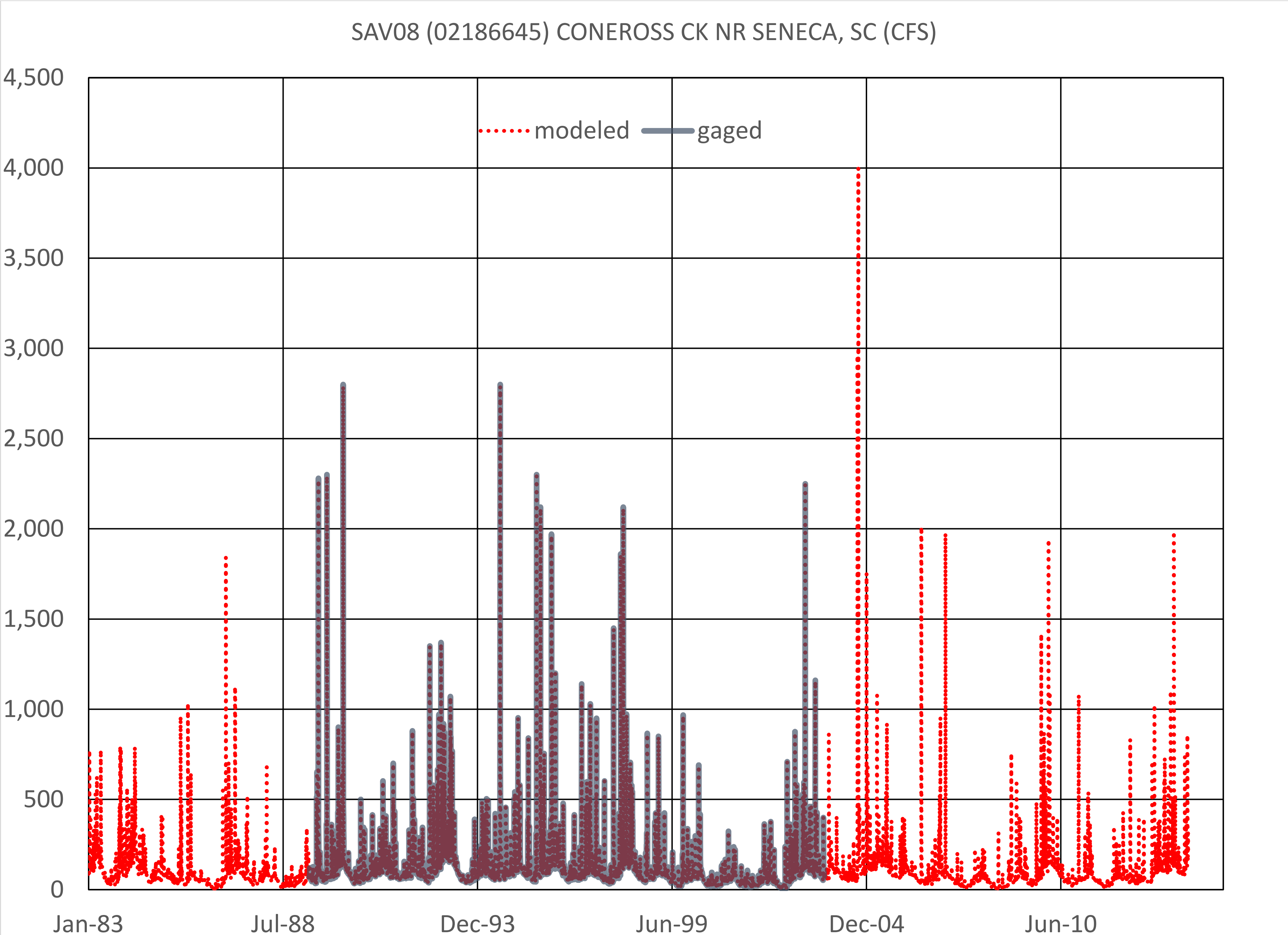

SAV04 (02185200) LITTLE RIVER NEAR WALHALLA, SC
Annual 7-day Low Flow (CFS)
gaged
modeled
120
100
80
60
40
20
0
1980
1985
1990
1995
2000
2005
2010
2015
Year

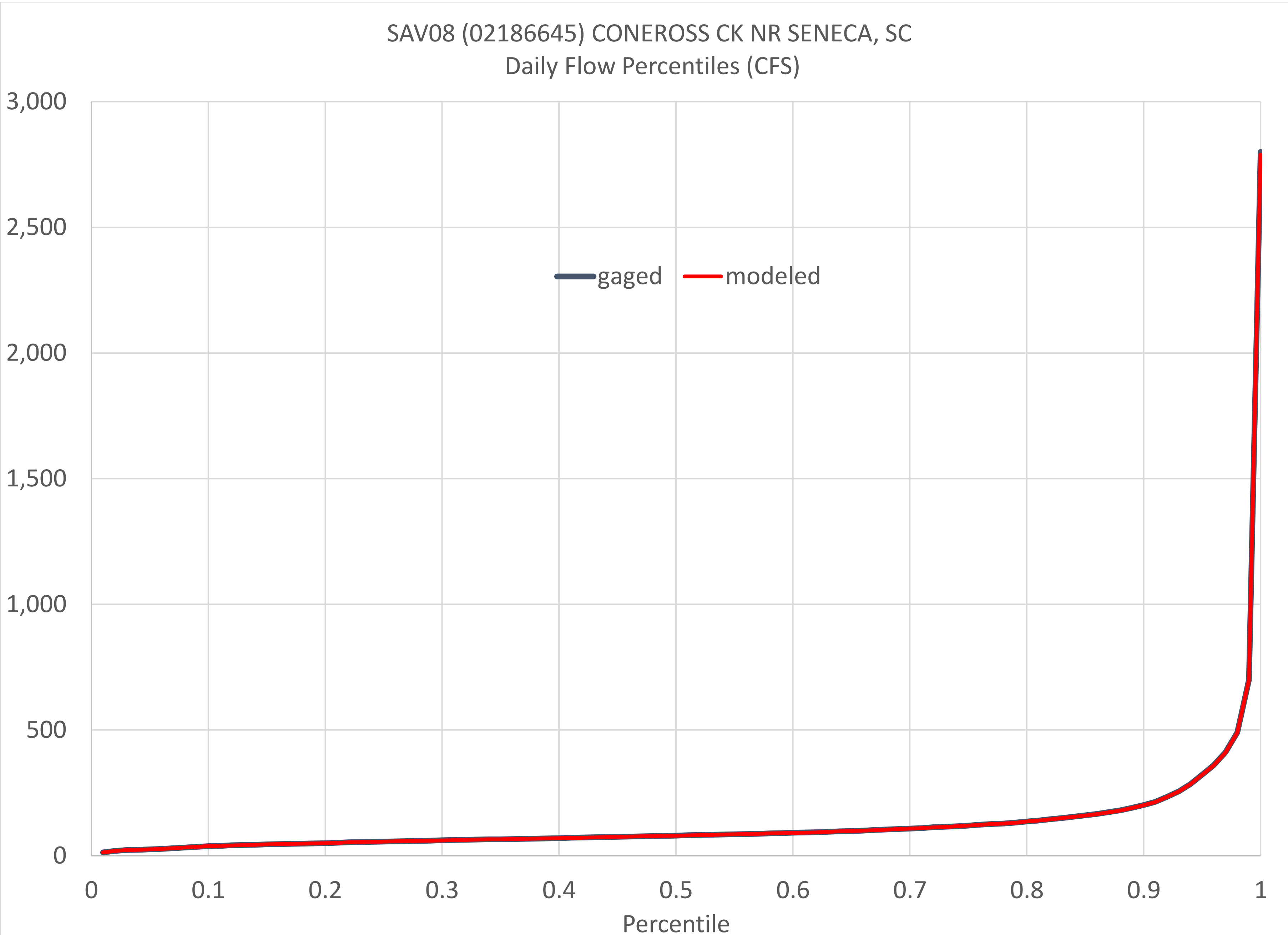


SAV06 (02186000) TWELVEMILE CREEK NEAR LIBERTY, SC (CFS)
modeled
gaged
8,000
7,000
6,000
5,000
4,000
3,000
2,000
1,000
0
Jan-83
Jul-88
Dec-93
Jun-99
Dec-04
Jun-10

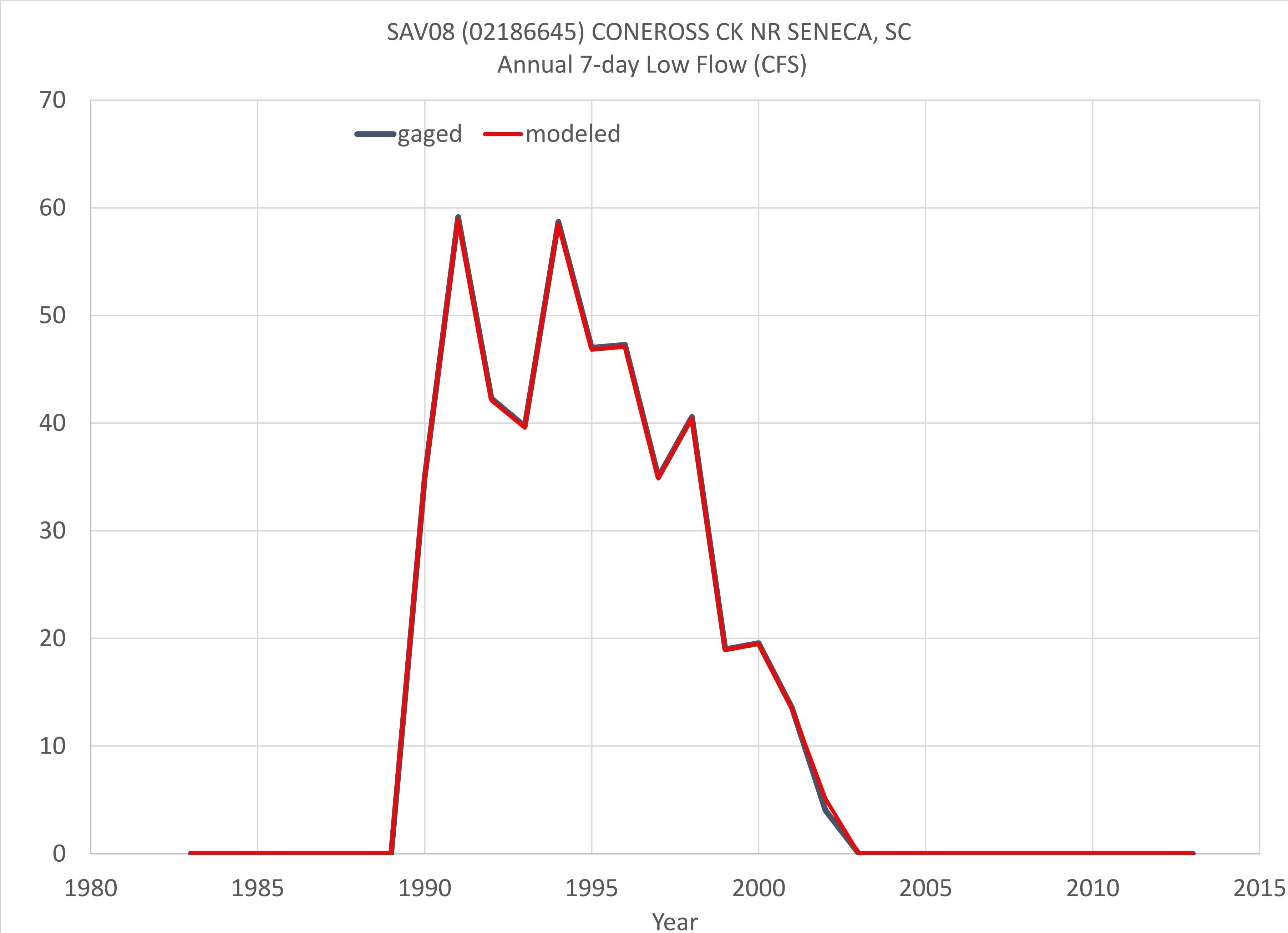

SAV06 (02186000) TWELVEMILE CREEK NEAR LIBERTY, SC
Daily Flow Percentiles (CFS)
gaged
modeled
6,000
5,000
4,000
3,000
2,000
1,000
0
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
Percentile


SAV06 (02186000) TWELVEMILE CREEK NEAR LIBERTY, SC
Annual 7-day Low Flow (CFS)
gaged
modeled
120
100
80
60
40
20
0
1980
1985
1990
1995
2000
2005
2010
2015
Year

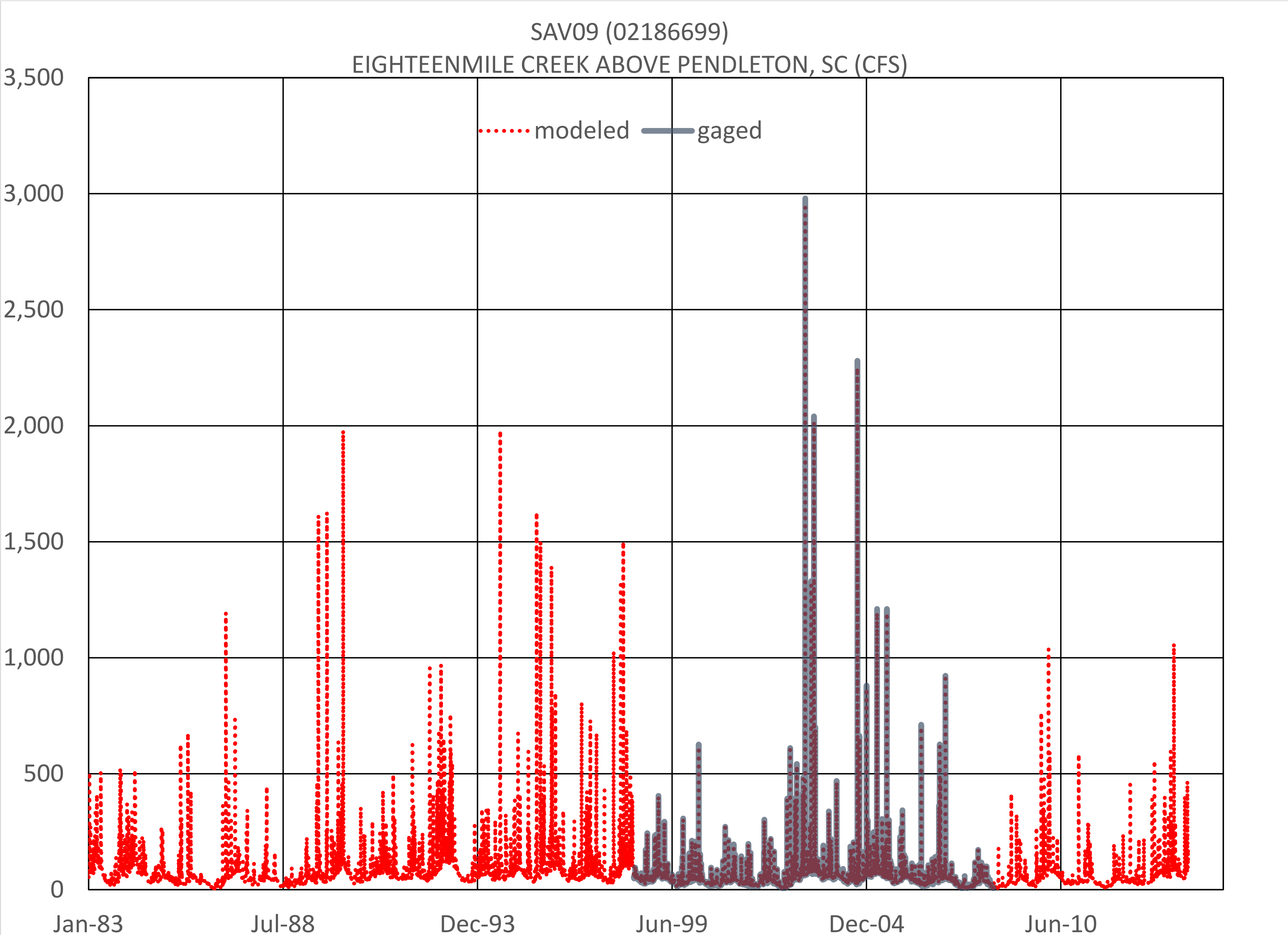

SAV08 (02186645) CONEROSS CK NR SENECA, SC (CFS)
modeled
gaged
4,500
4,000
3,500
3,000
2,500
2,000
1,500
1,000
500
0
Jan-83
Jul-88
Dec-93
Jun-99
Dec-04
Jun-10



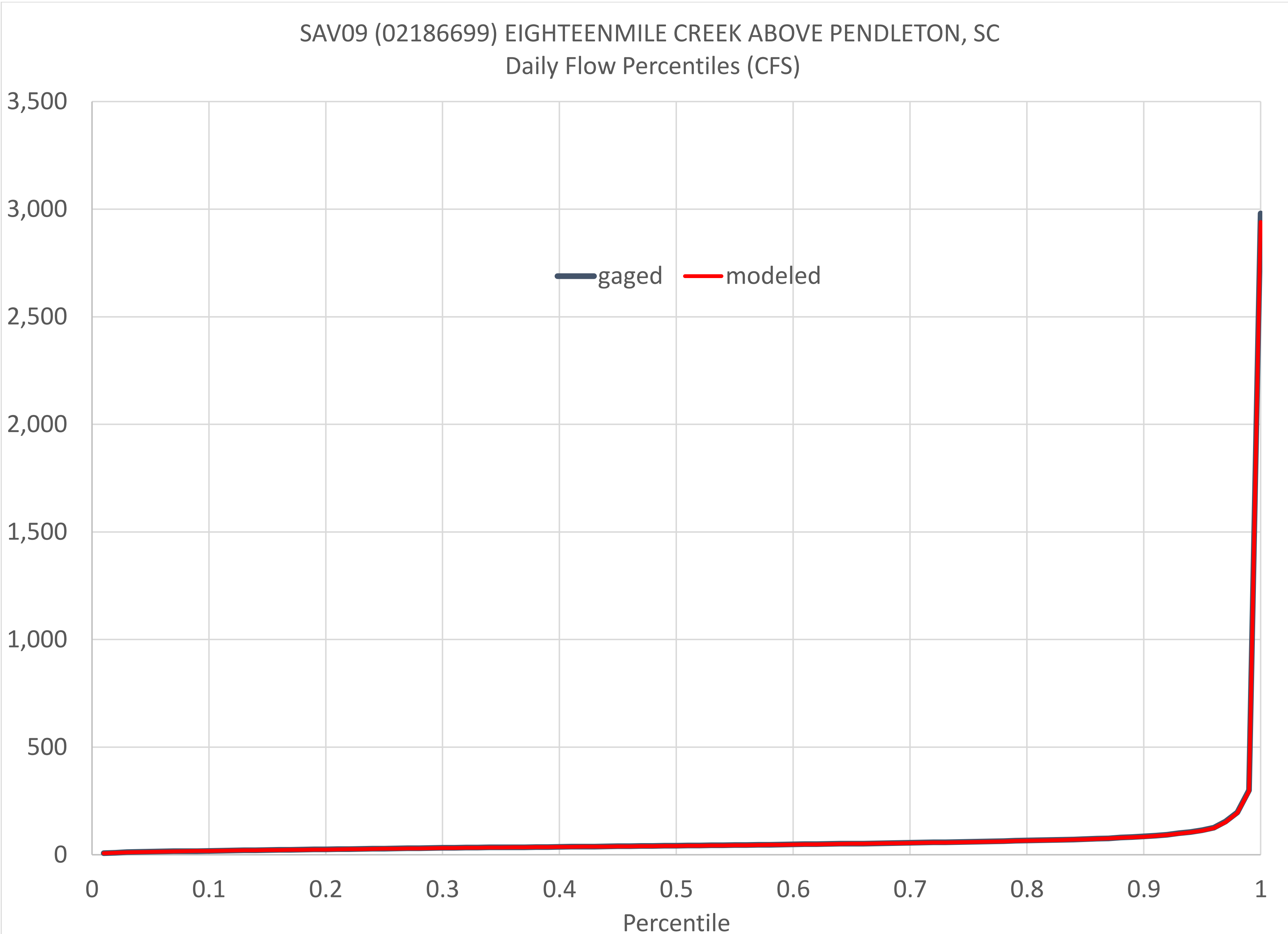
SAV08 (02186645) CONEROSS CK NR SENECA, SC
Daily Flow Percentiles (CFS)
3,000
2,500
2,000
1,500
1,000
500
0
gaged
modeled
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
Percentile



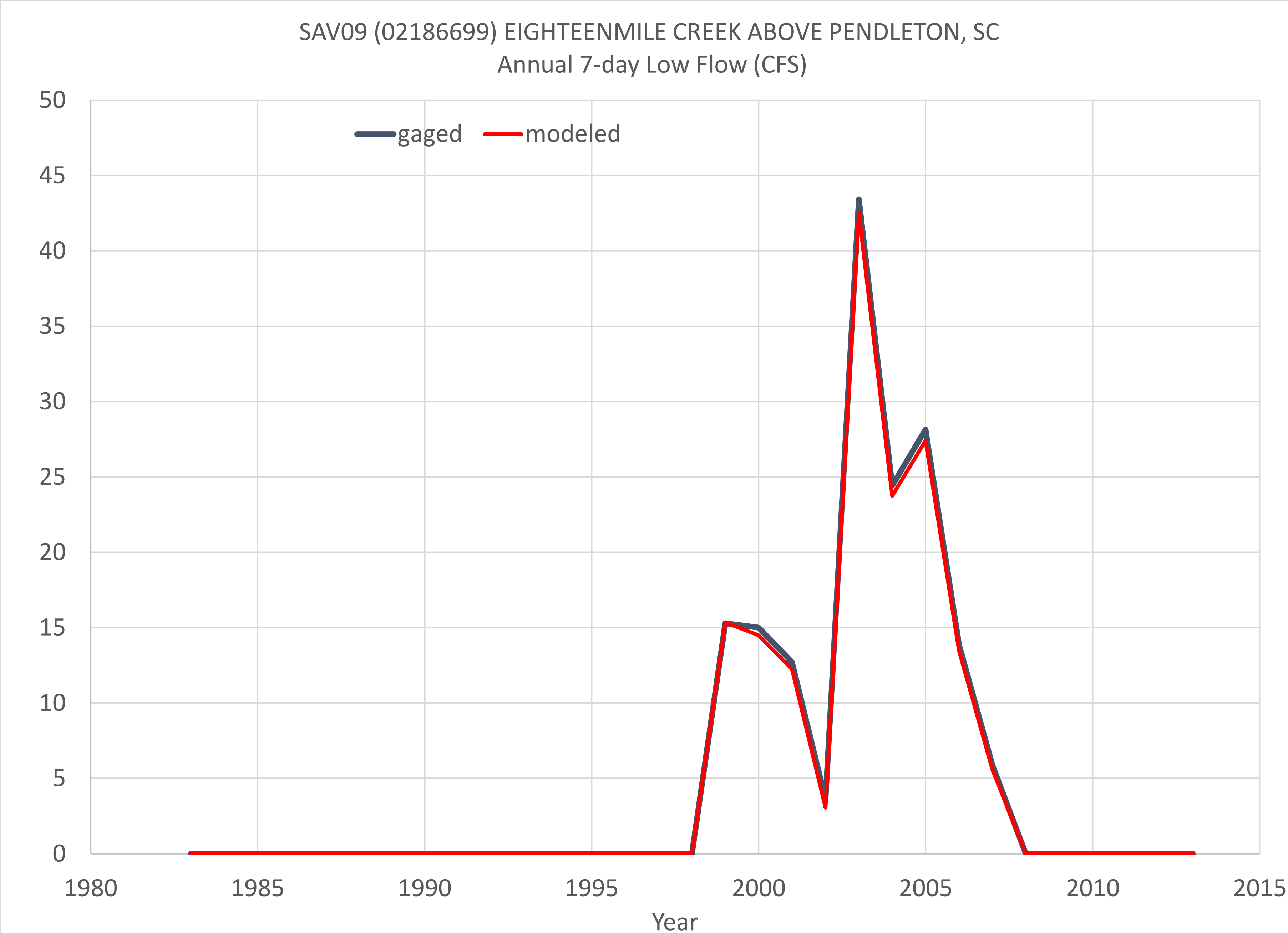
SAV08 (02186645) CONEROSS CK NR SENECA, SC
Annual 7-day Low Flow (CFS)
gaged
modeled
0
10
20
30
40
50
60
70
1980
1985
1990
1995
2000
2005
2010
2015
Year



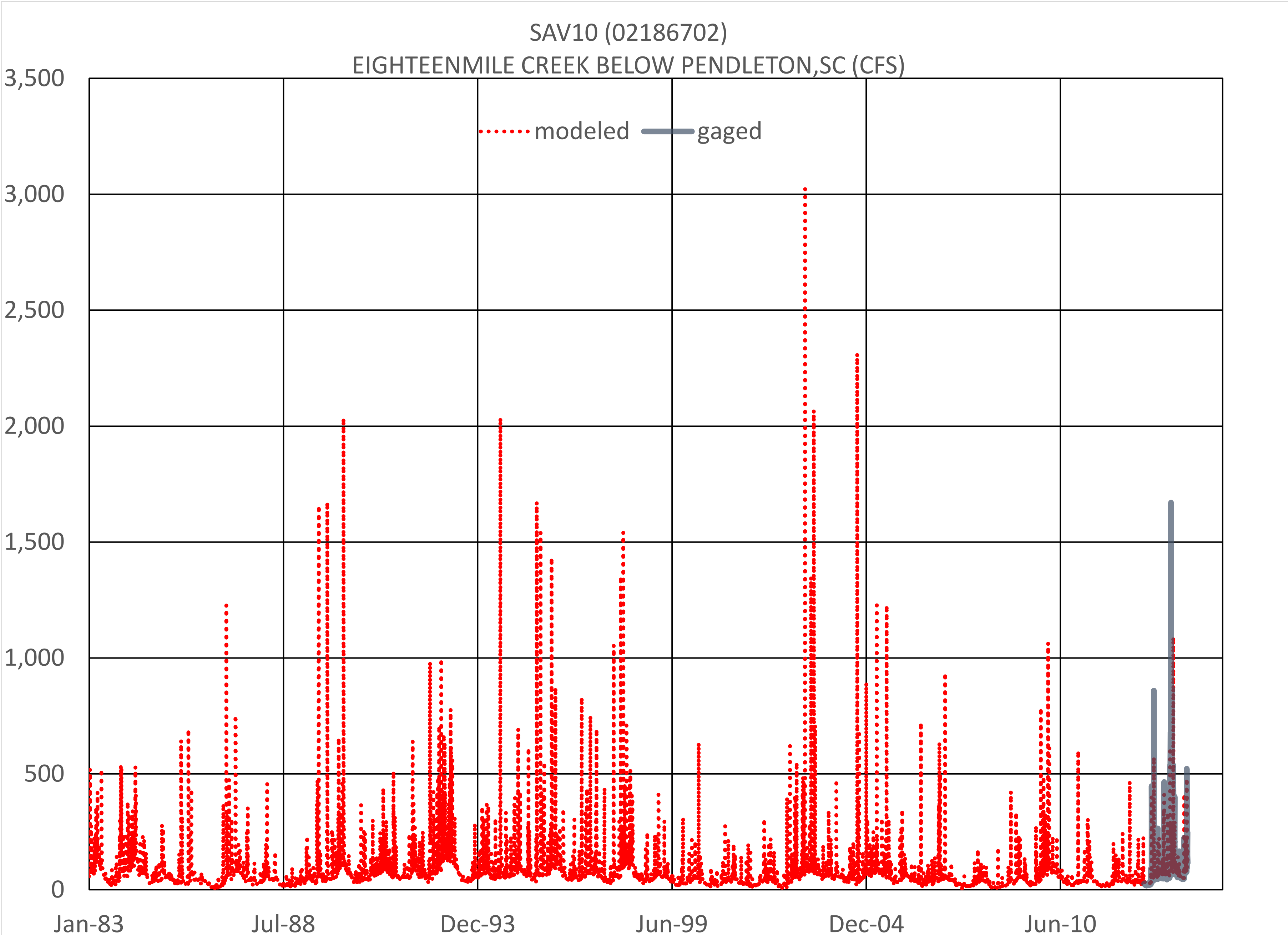
SAV09 (02186699)
EIGHTEENMILE CREEK ABOVE PENDLETON, SC (CFS)
modeled
gaged
3,500
3,000
2,500
2,000
1,500
1,000
500
0
Jan-83
Jul-88
Dec-93
Jun-99
Dec-04
Jun-10



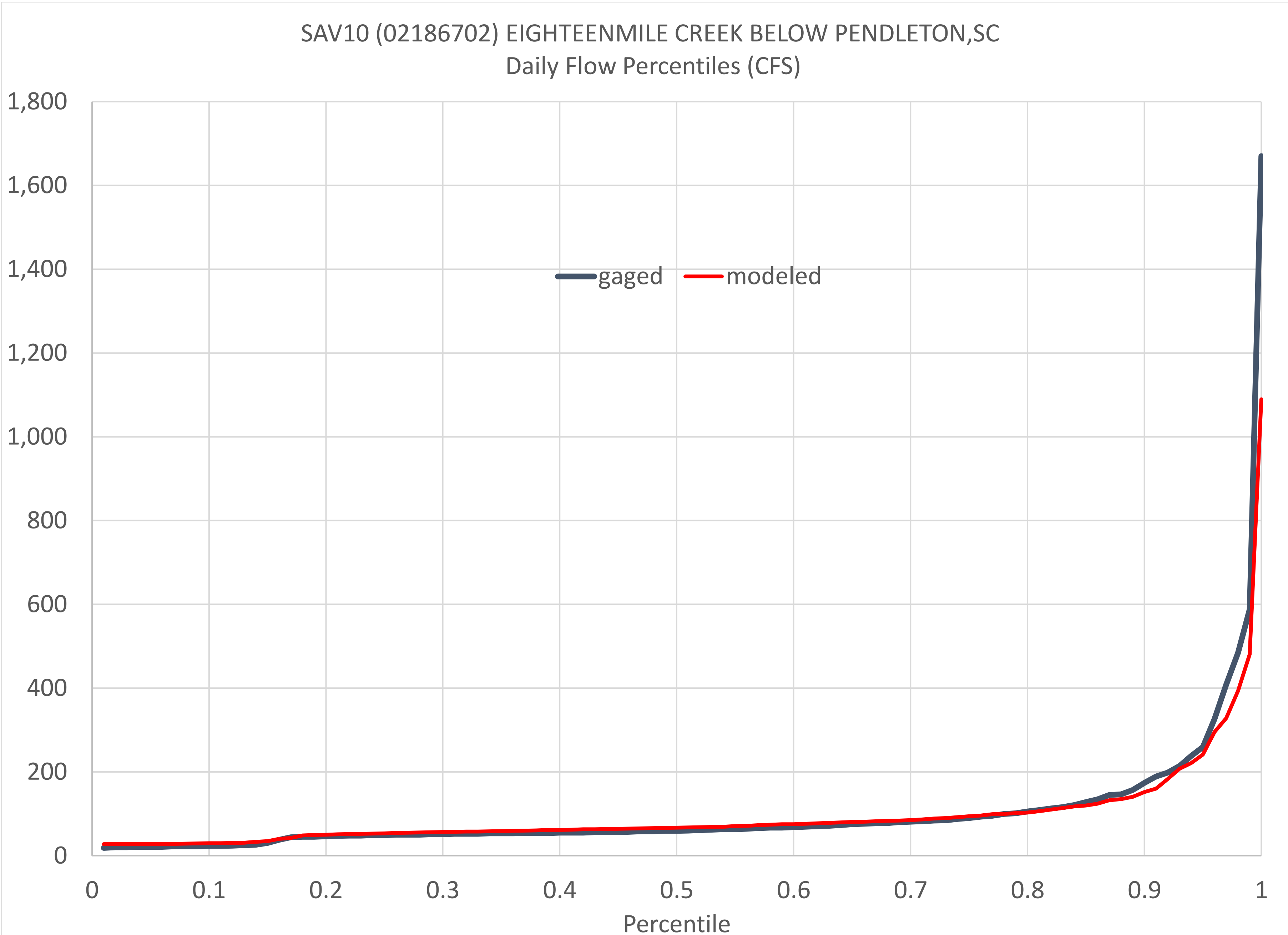
SAV09 (02186699) EIGHTEENMILE CREEK ABOVE PENDLETON, SC
Daily Flow Percentiles (CFS)
3,500
3,000
2,500
2,000
1,500
1,000
500
0
gaged
modeled
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
Percentile

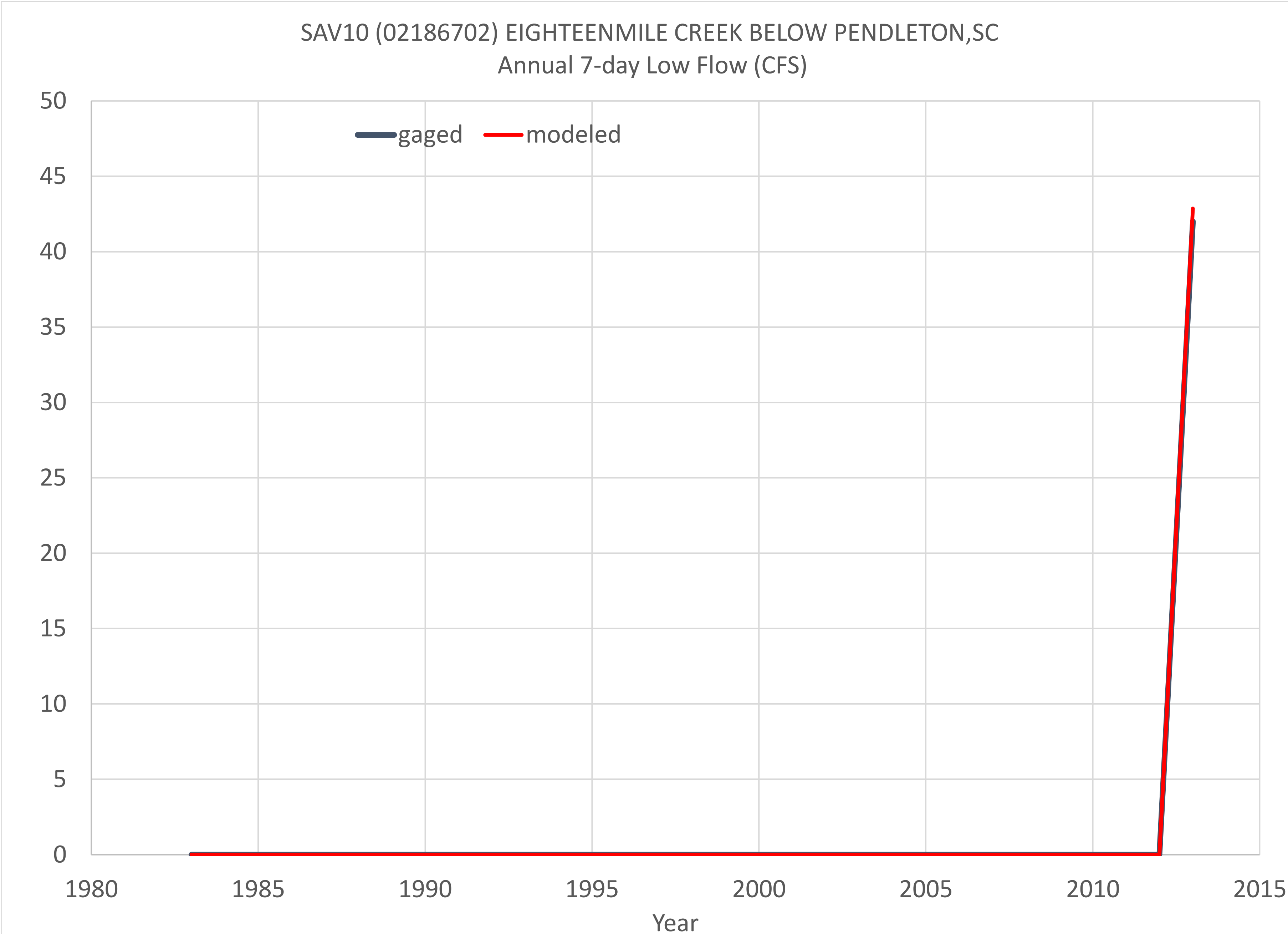


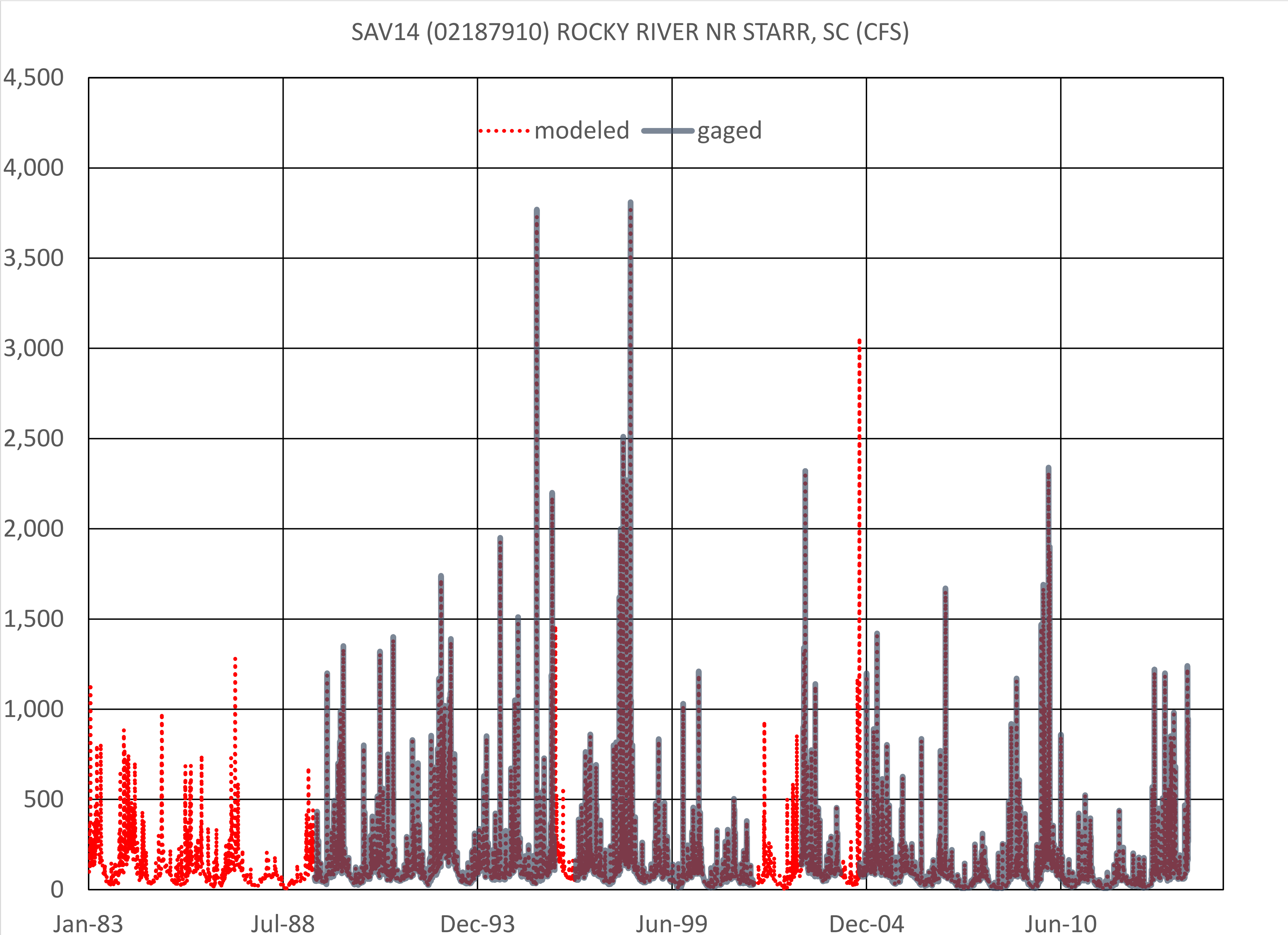
SAV09 (02186699) EIGHTEENMILE CREEK ABOVE PENDLETON, SC
Annual 7-day Low Flow (CFS)
gaged
modeled
50
45
40
35
30
25
20
15
10
5
0
1980
1985
1990
1995
2000
2005
2010
2015
Year



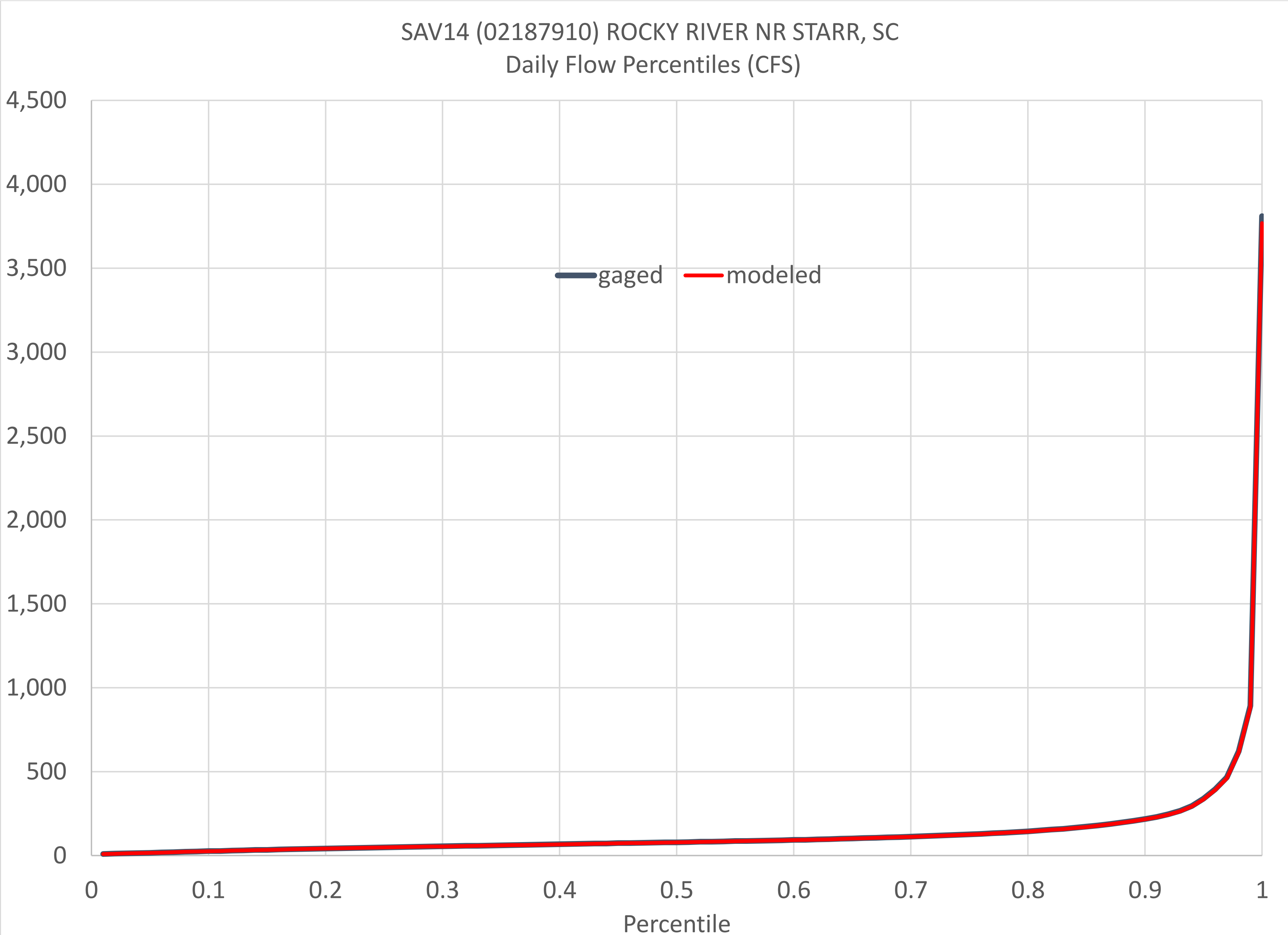
SAV10 (02186702)
EIGHTEENMILE CREEK BELOW PENDLETON,SC (CFS)
modeled
gaged
3,500
3,000
2,500
2,000
1,500
1,000
500
0
Jan-83
Jul-88
Dec-93
Jun-99
Dec-04
Jun-10

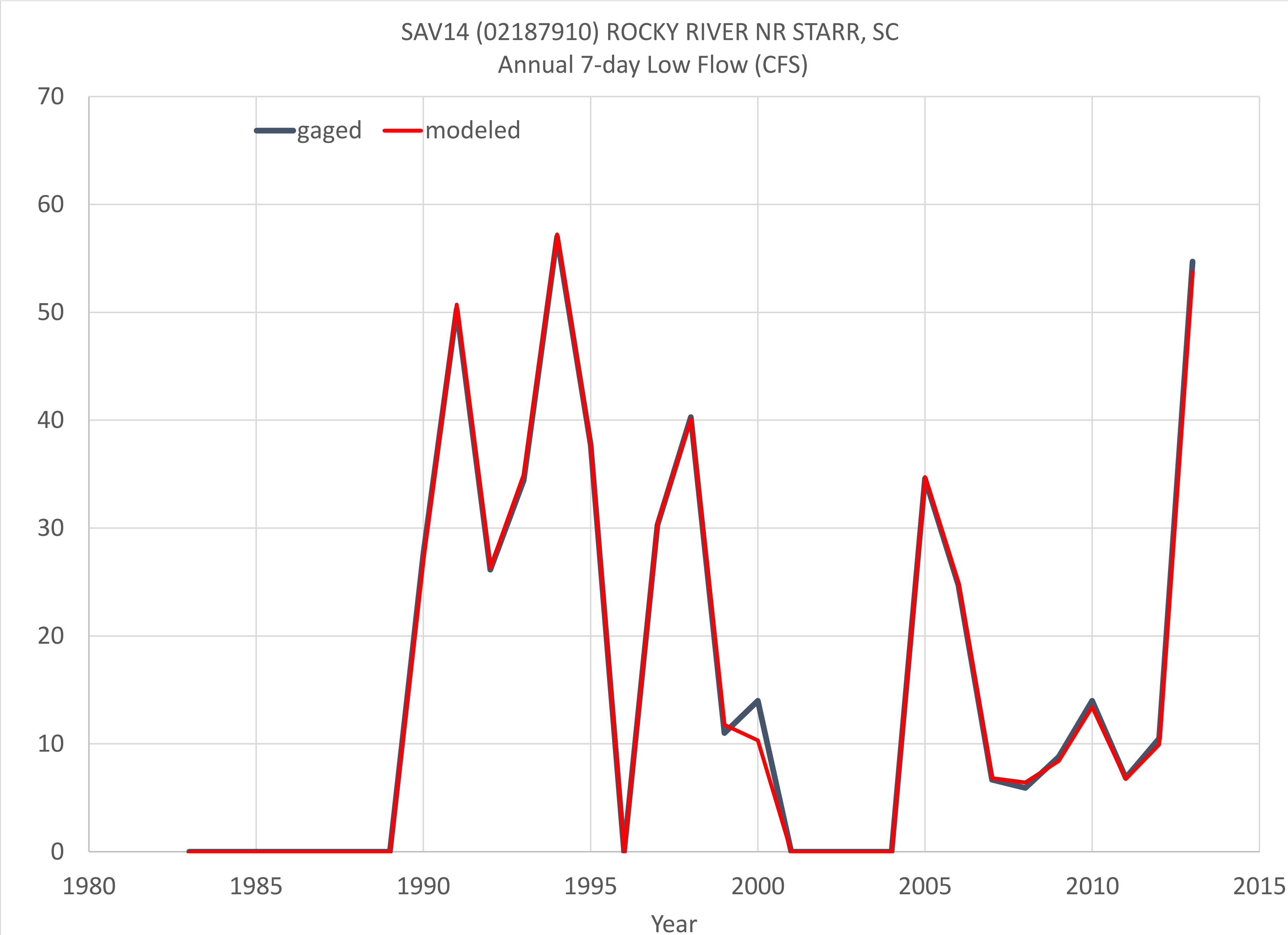

SAV10 (02186702) EIGHTEENMILE CREEK BELOW PENDLETON,SC
Daily Flow Percentiles (CFS)
1,800
1,600
1,400
1,200
1,000
800
600
400
200
0
gaged
modeled
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
Percentile


SAV10 (02186702) EIGHTEENMILE CREEK BELOW PENDLETON,SC
Annual 7-day Low Flow (CFS)
gaged
modeled
50
45
40
35
30
25
20
15
10
5
0
1980
1985
1990
1995
2000
2005
2010
2015
Year

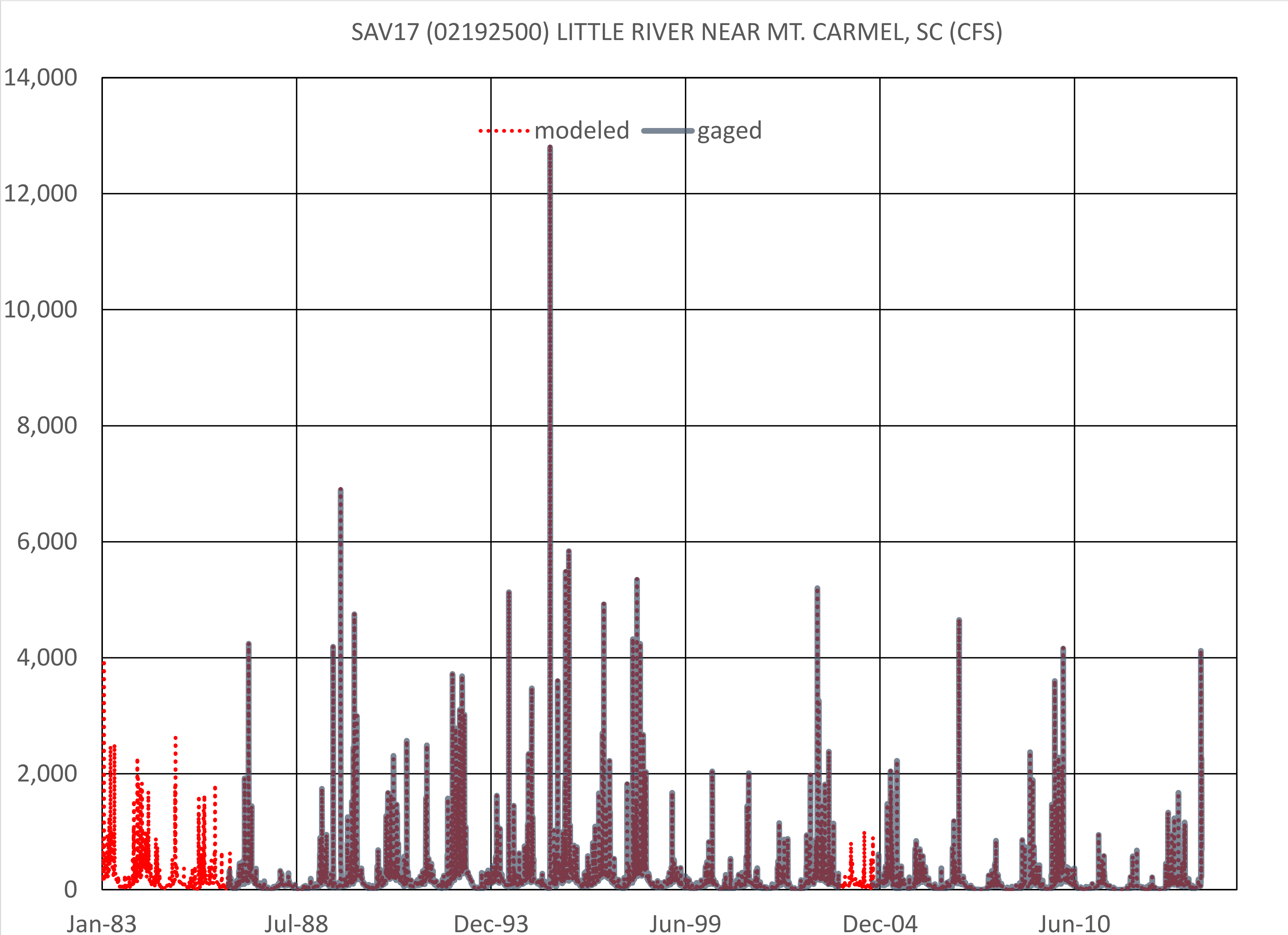


SAV14 (02187910) ROCKY RIVER NR STARR, SC (CFS)
modeled
gaged
4,500
4,000
3,500
3,000
2,500
2,000
1,500
1,000
500
0
Jan-83
Jul-88
Dec-93
Jun-99
Dec-04
Jun-10

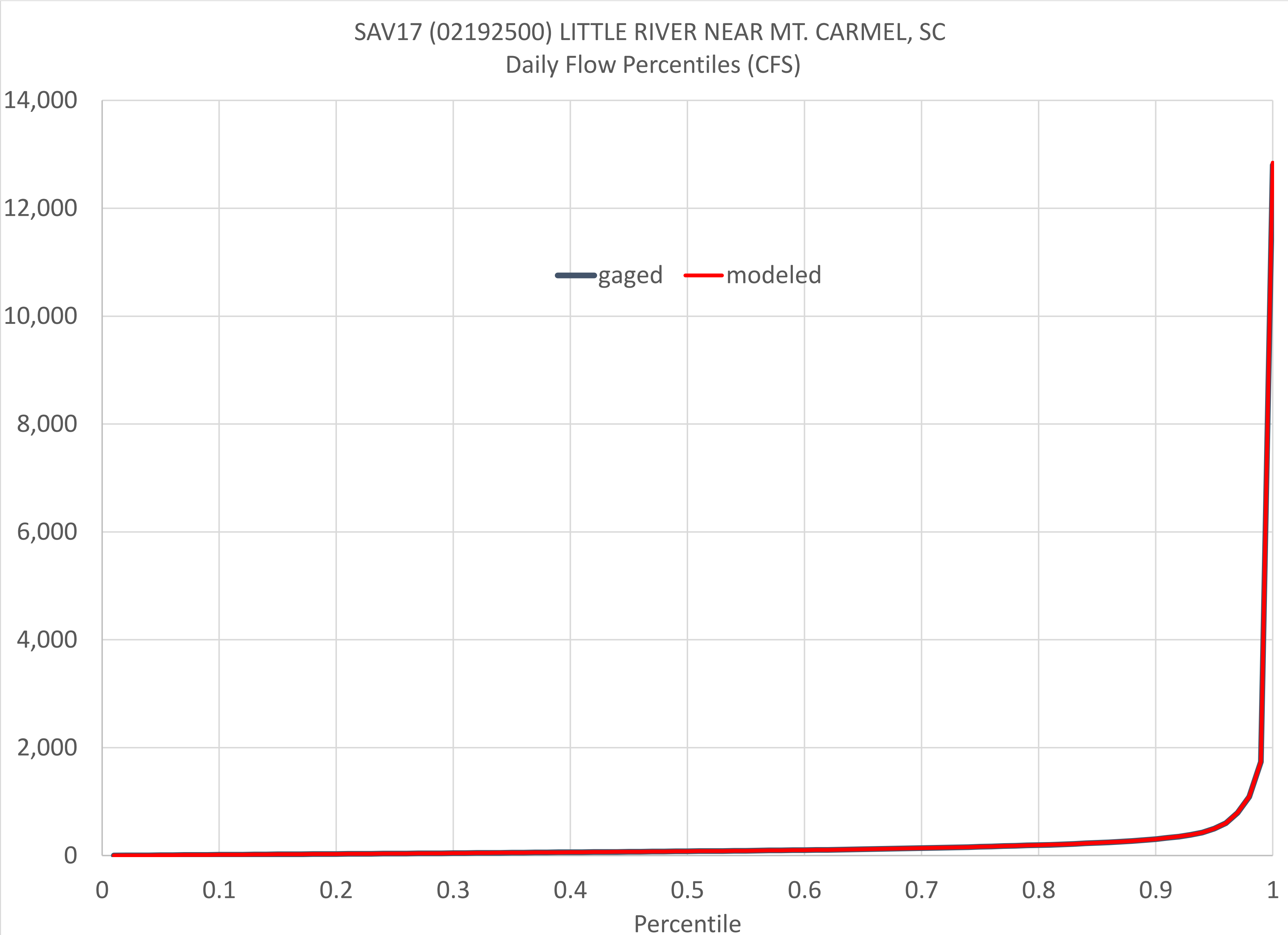

SAV14 (02187910) ROCKY RIVER NR STARR, SC
Daily Flow Percentiles (CFS)
gaged
modeled
4,500
4,000
3,500
3,000
2,500
2,000
1,500
1,000
500
0
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
Percentile

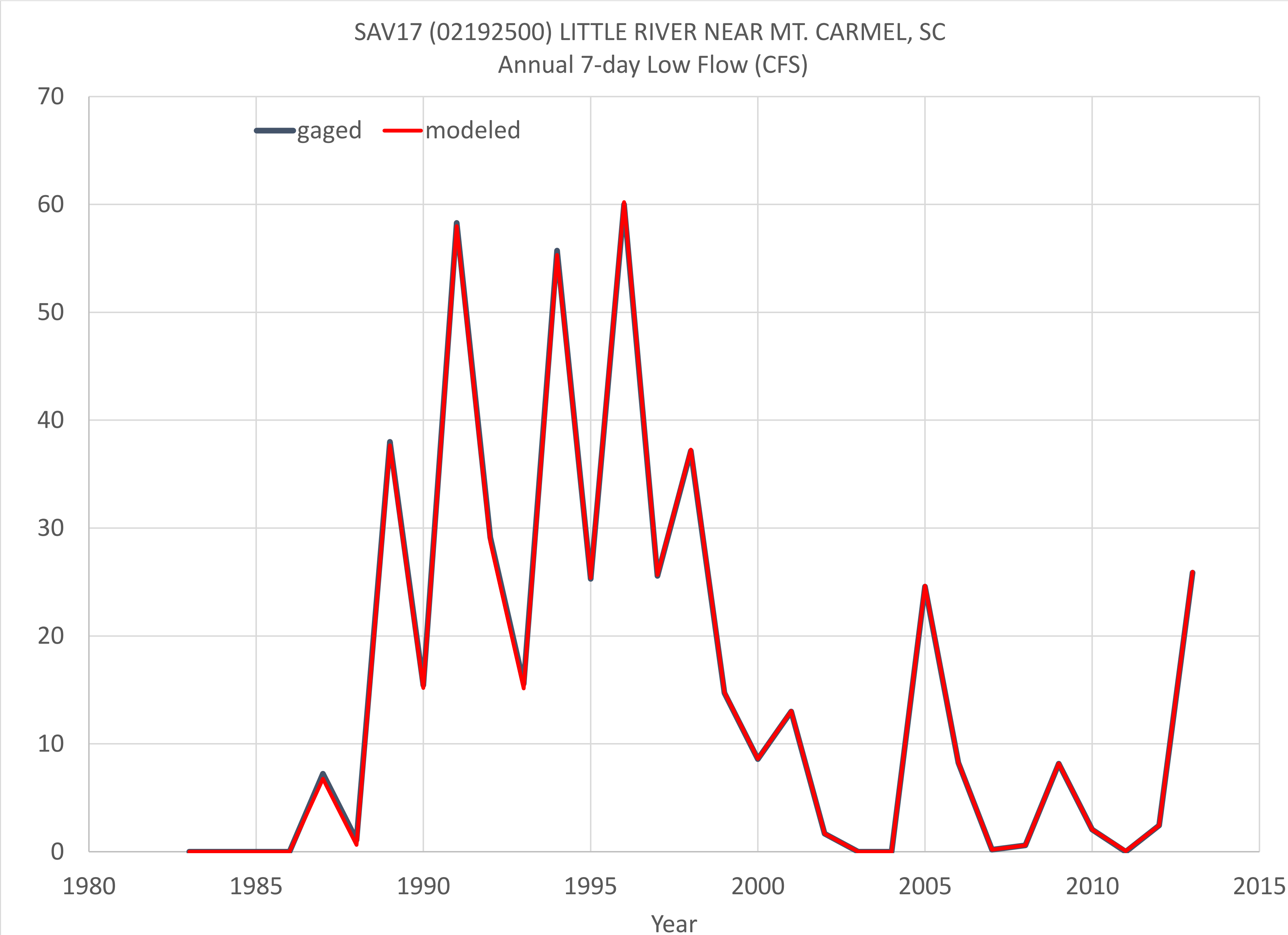


SAV14 (02187910) ROCKY RIVER NR STARR, SC
Annual 7-day Low Flow (CFS)
gaged
modeled
0
10
20
30
40
50
60
70
1980
1985
1990
1995
2000
2005
2010
2015
Year

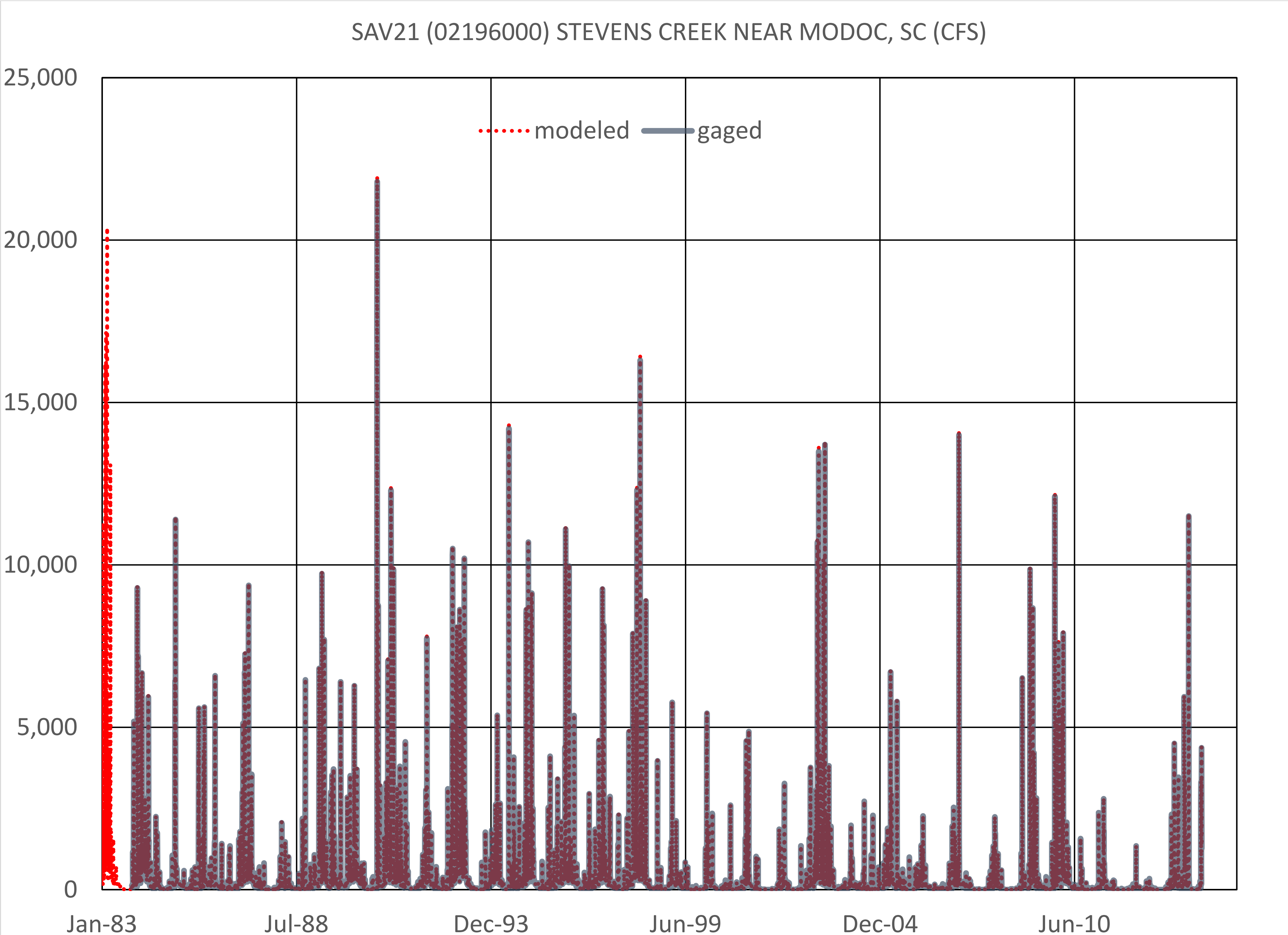


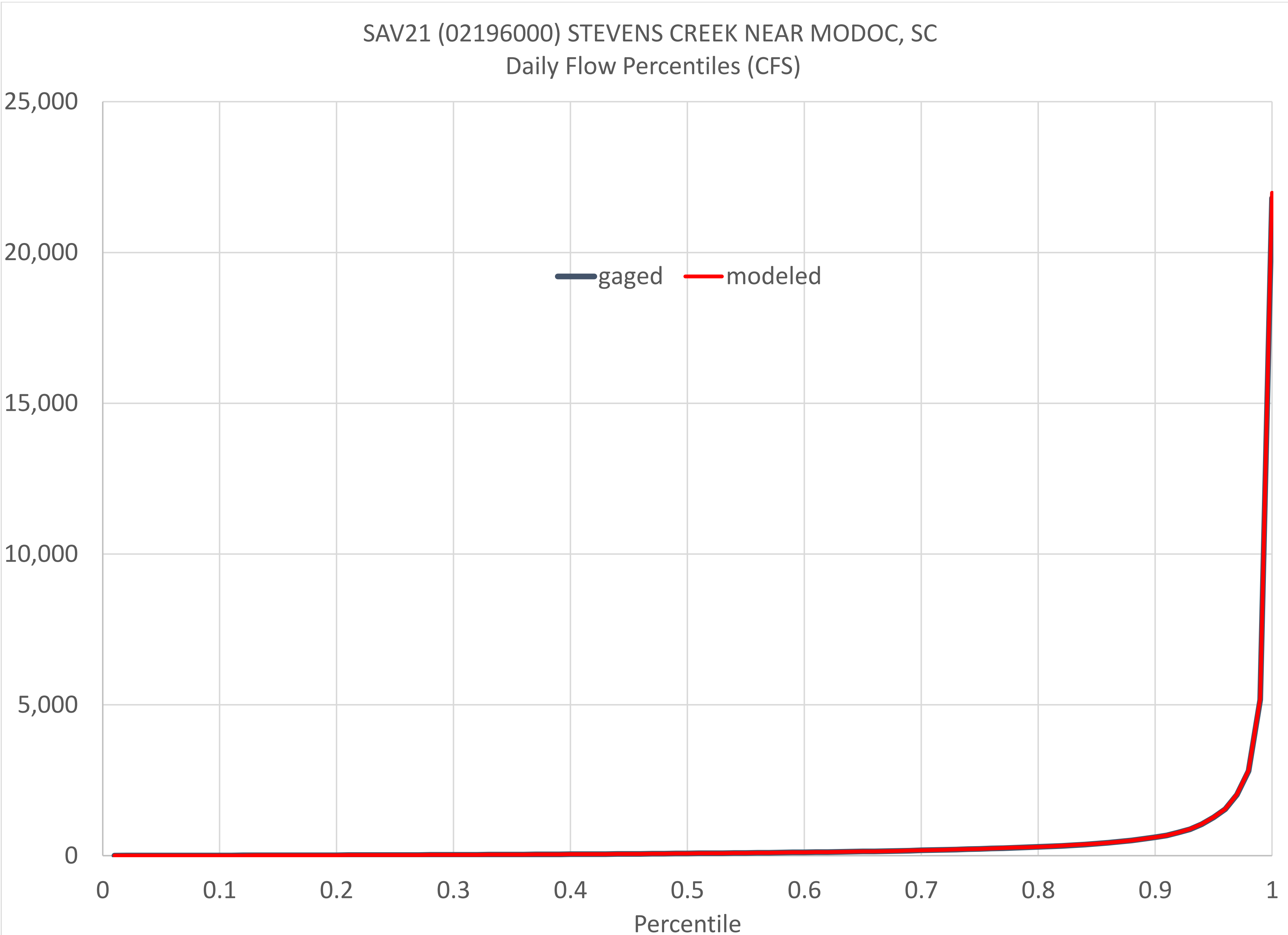
SAV17 (02192500) LITTLE RIVER NEAR MT. CARMEL, SC (CFS)
modeled
gaged
14,000
12,000
10,000
8,000
6,000
4,000
2,000
0
Jan-83
Jul-88
Dec-93
Jun-99
Dec-04
Jun-10

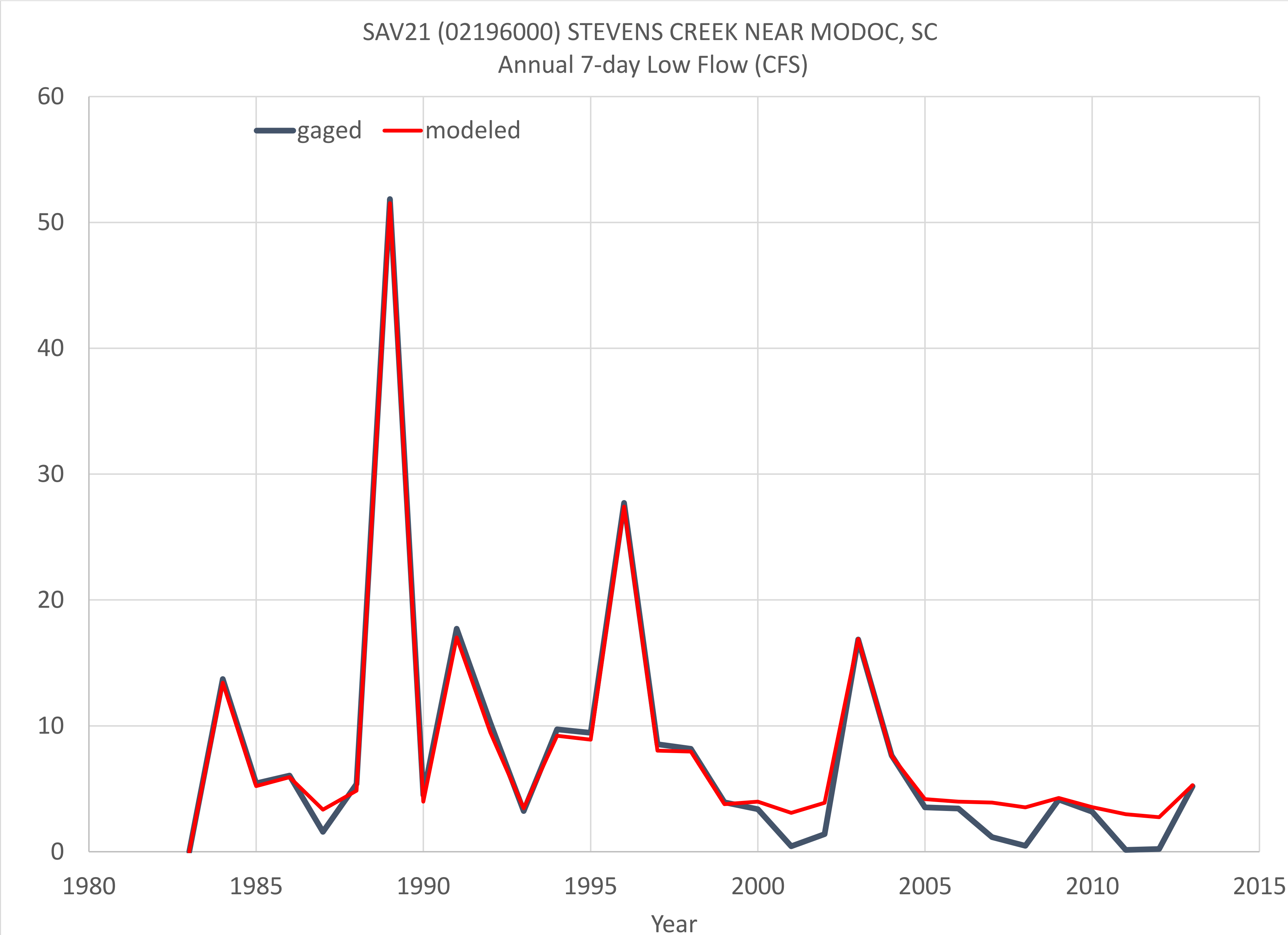

SAV17 (02192500) LITTLE RIVER NEAR MT. CARMEL, SC
Daily Flow Percentiles (CFS)
14,000
12,000
10,000
8,000
6,000
4,000
2,000
0
gaged
modeled
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
Percentile



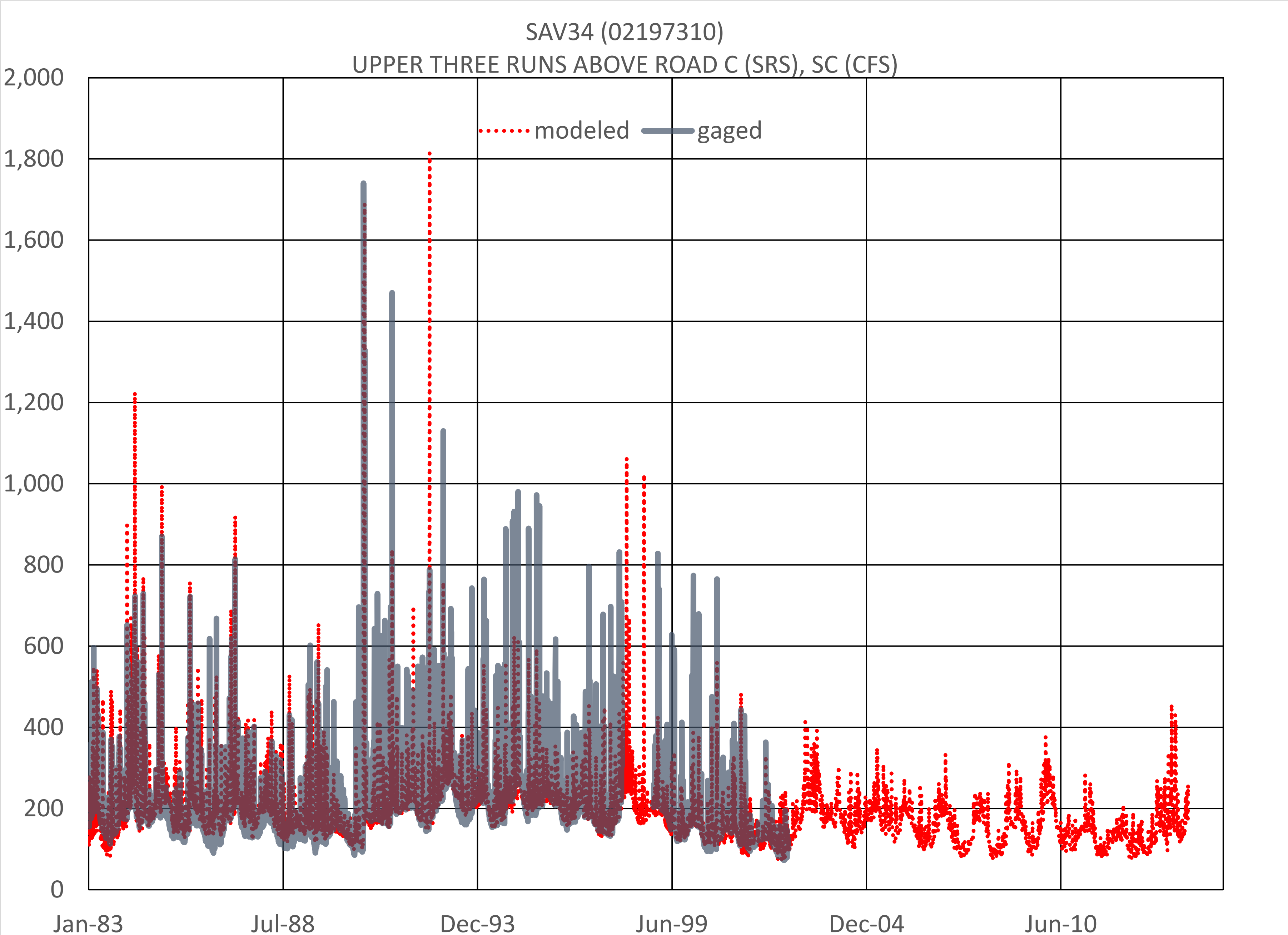
SAV17 (02192500) LITTLE RIVER NEAR MT. CARMEL, SC
Annual 7-day Low Flow (CFS)
gaged
modeled
0
10
20
30
40
50
60
70
1980
1985
1990
1995
2000
2005
2010
2015
Year

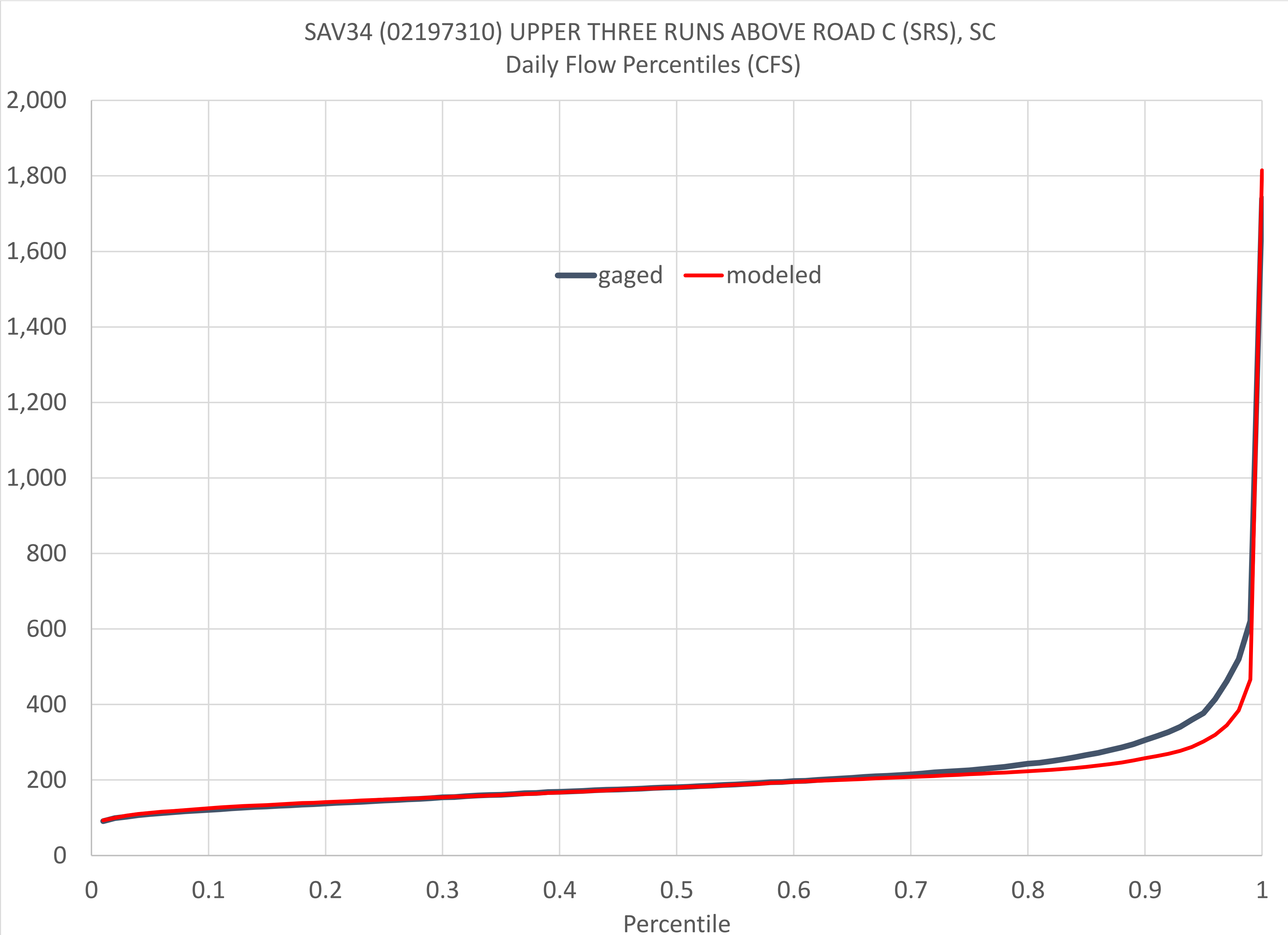

SAV21 (02196000) STEVENS CREEK NEAR MODOC, SC (CFS)
modeled
gaged
25,000
20,000
15,000
10,000
5,000
0
Jan-83
Jul-88
Dec-93
Jun-99
Dec-04
Jun-10


SAV21 (02196000) STEVENS CREEK NEAR MODOC, SC
Daily Flow Percentiles (CFS)
gaged
modeled
25,000
20,000
15,000
10,000
5,000
0
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
Percentile

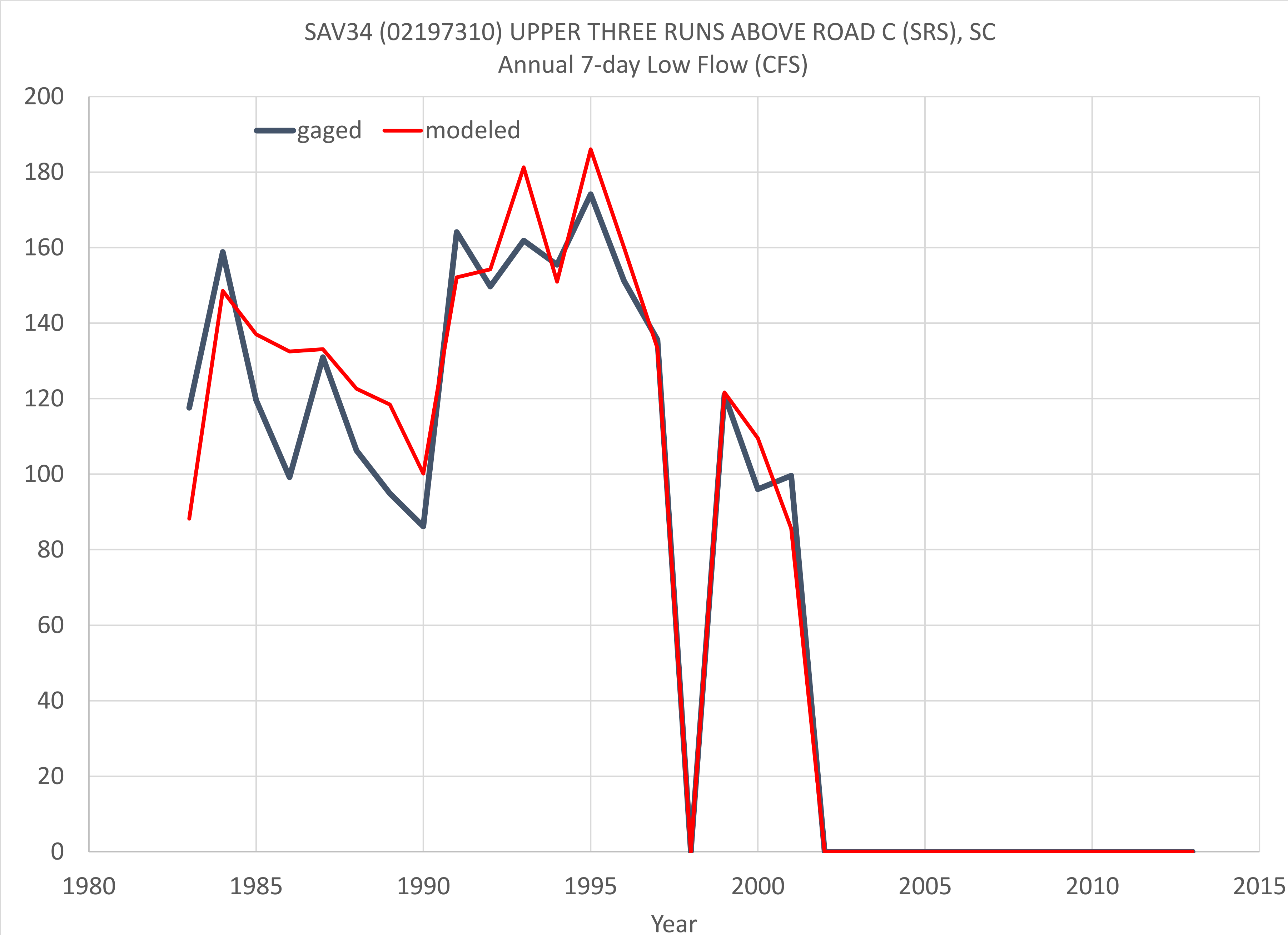


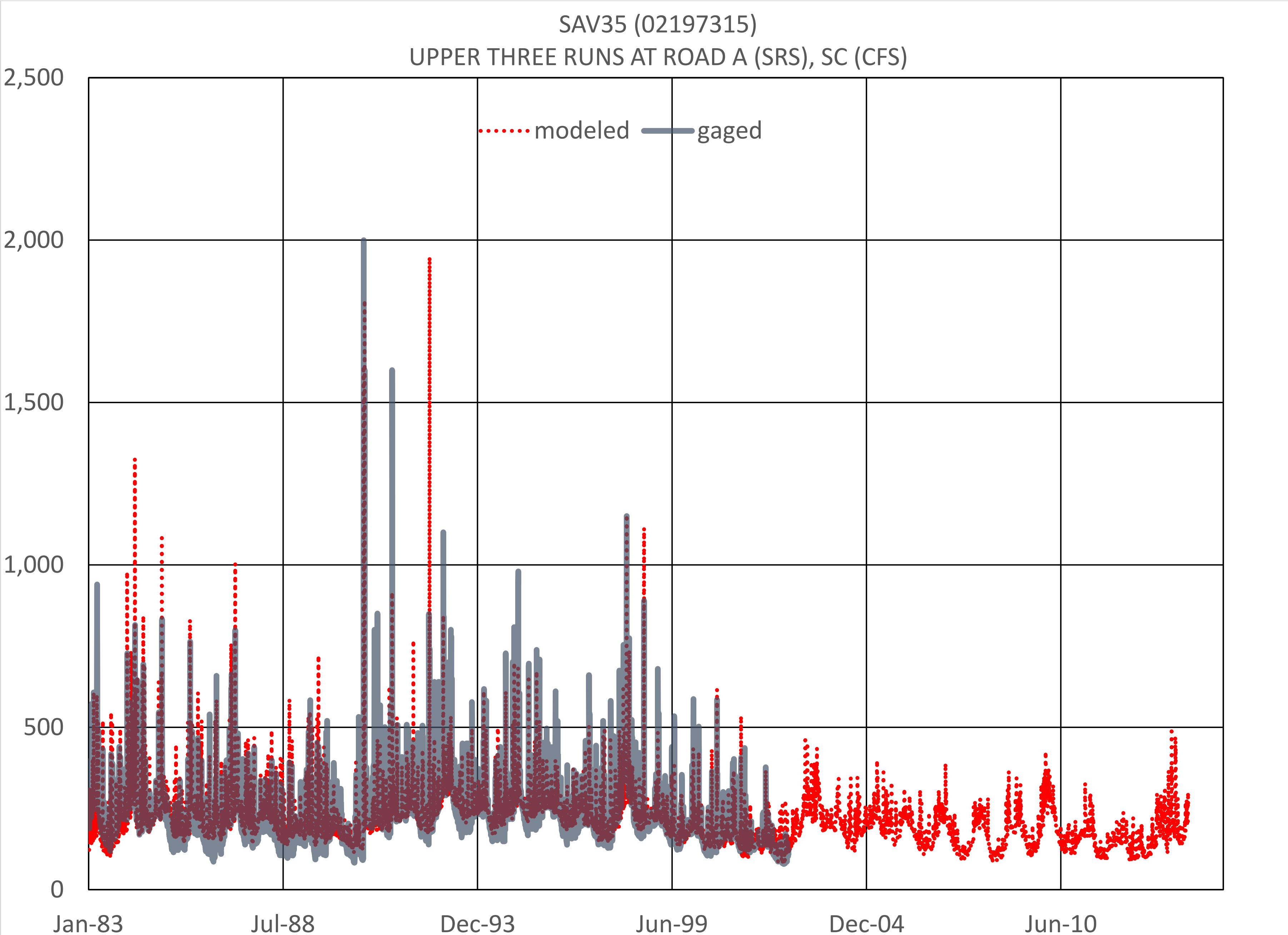
SAV21 (02196000) STEVENS CREEK NEAR MODOC, SC
Annual 7-day Low Flow (CFS)
gaged
modeled
60
50
40
30
20
10
0
1980
1985
1990
1995
2000
2005
2010
2015
Year

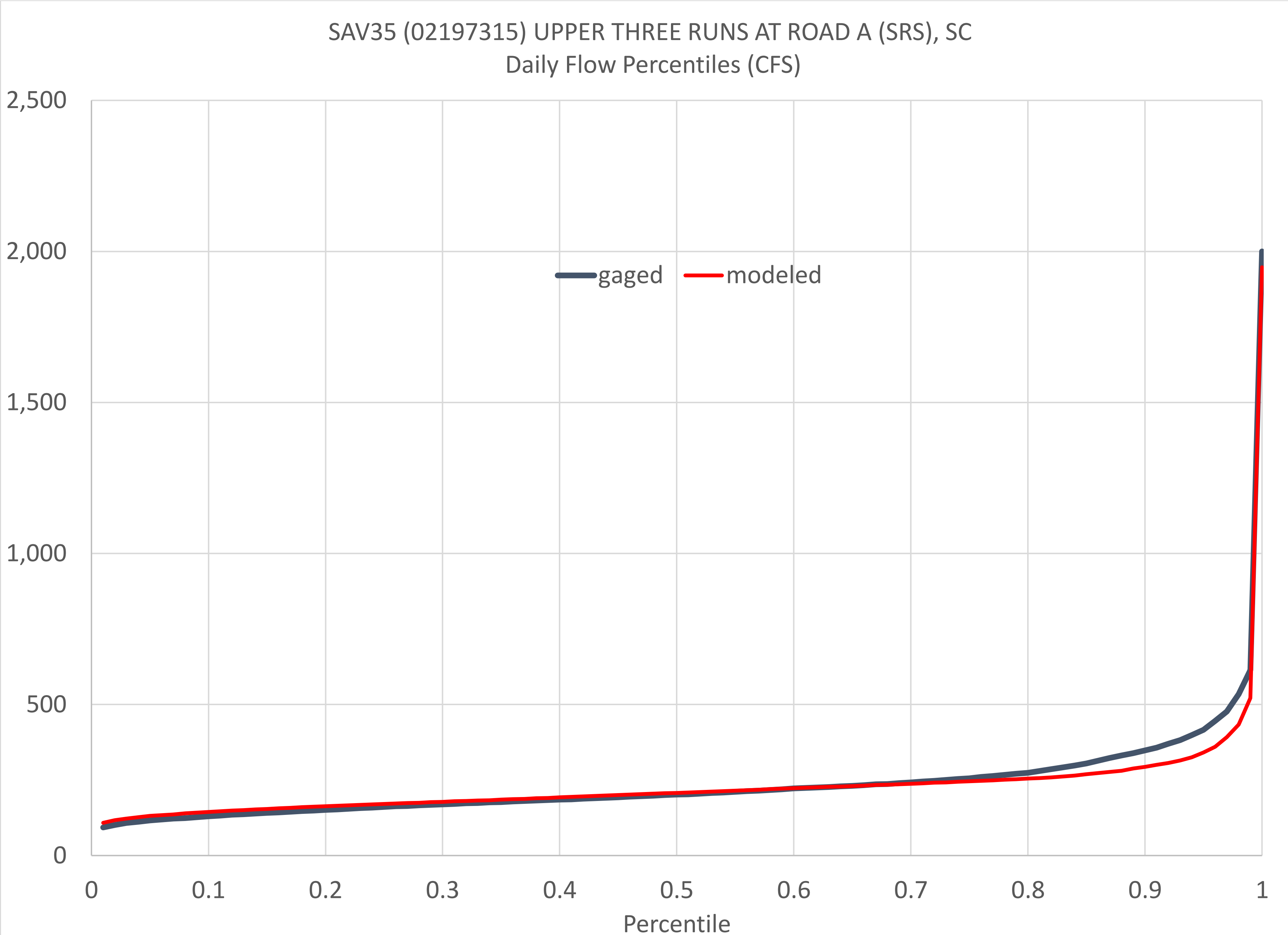

SAV34 (02197310)
UPPER THREE RUNS ABOVE ROAD C (SRS), SC (CFS)
modeled
gaged
2,000
1,800
1,600
1,400
1,200
1,000
800
600
400
200
0
Jan-83
Jul-88
Dec-93
Jun-99
Dec-04
Jun-10

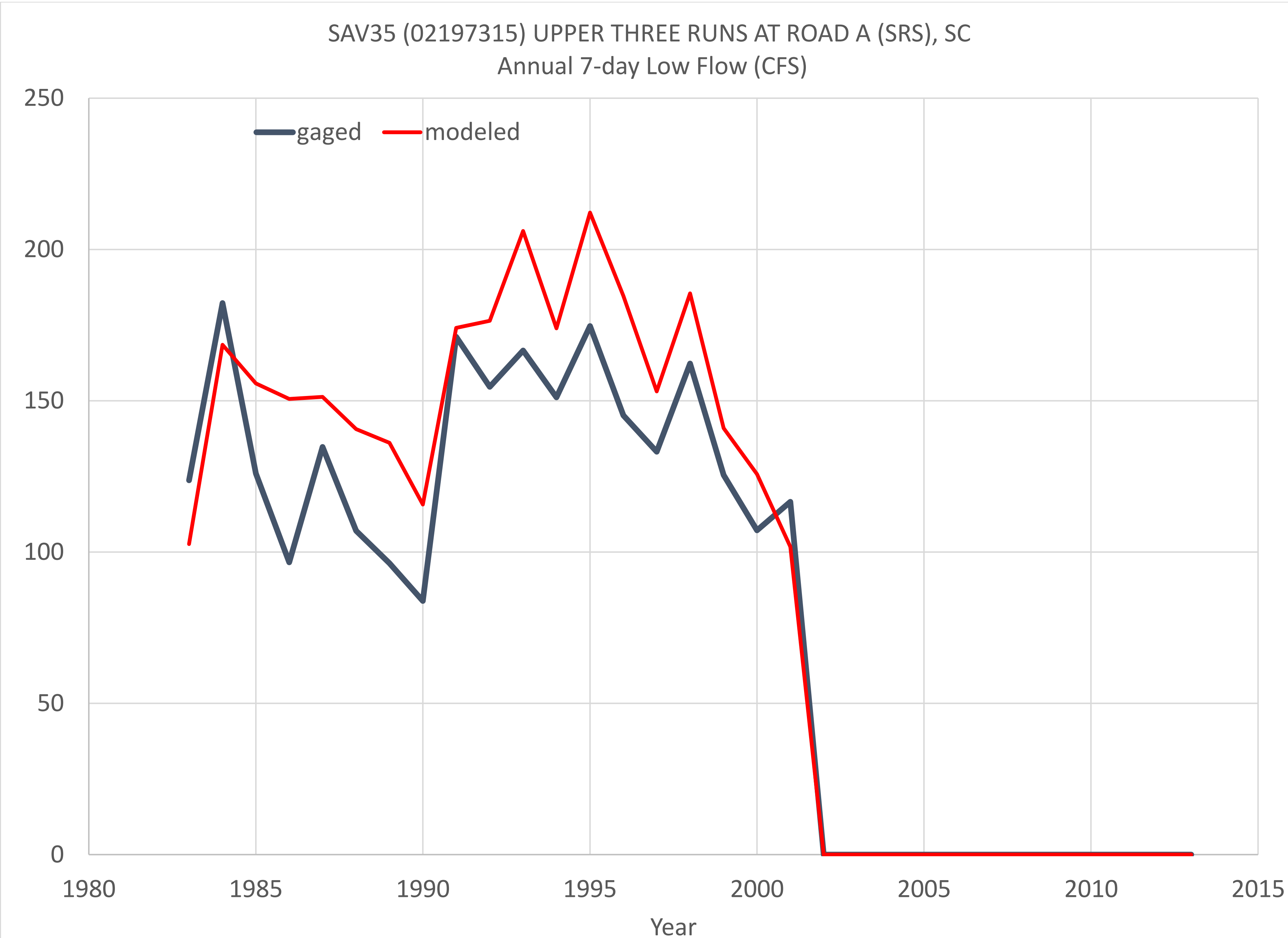


SAV34 (02197310) UPPER THREE RUNS ABOVE ROAD C (SRS), SC
Daily Flow Percentiles (CFS)
2,000
1,800
1,600
1,400
1,200
1,000
800
600
400
200
0
gaged
modeled
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
Percentile

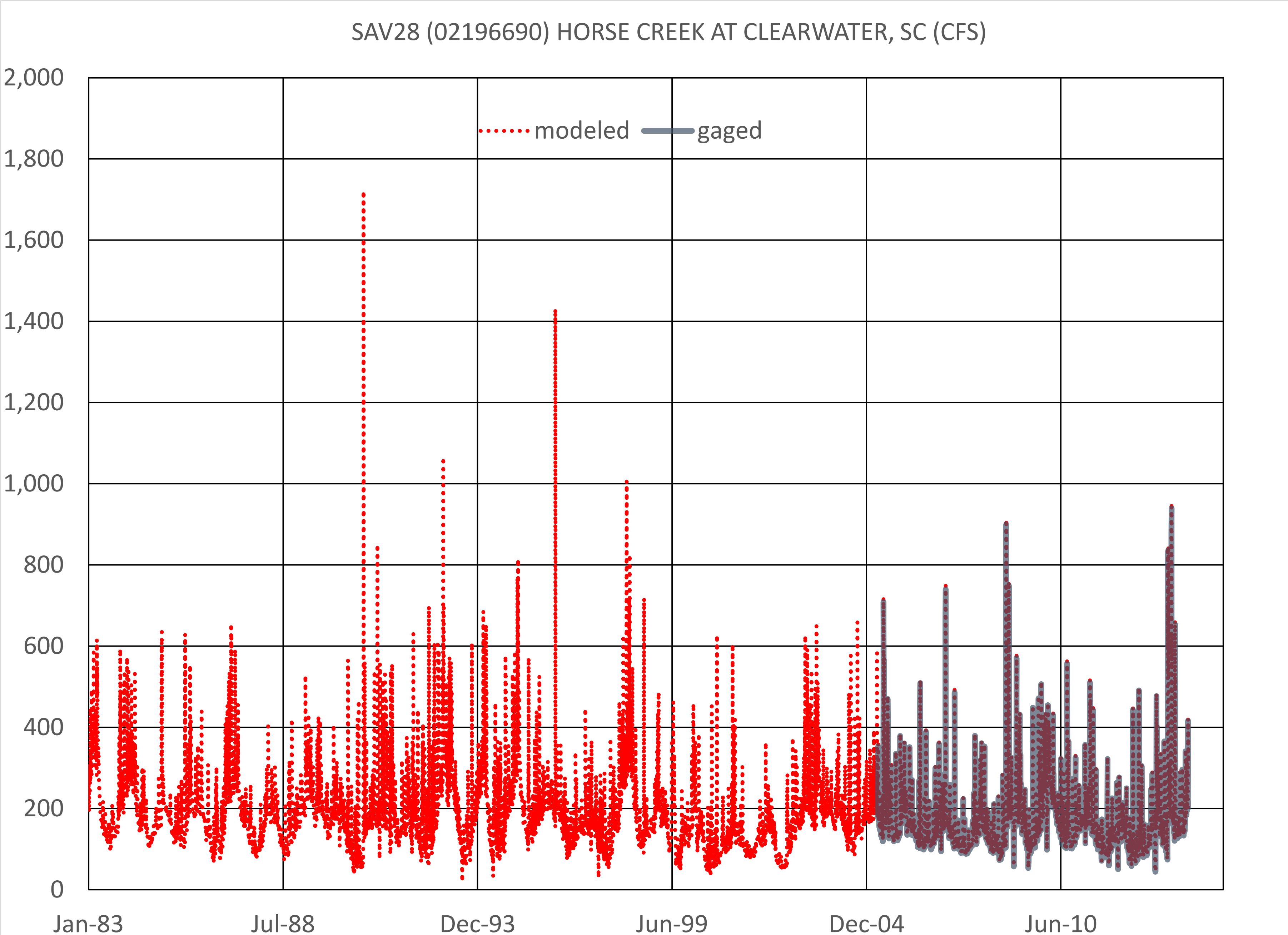

SAV34 (02197310) UPPER THREE RUNS ABOVE ROAD C (SRS), SC
Annual 7-day Low Flow (CFS)
gaged
modeled
200
180
160
140
120
100
80
60
40
20
0
1980
1985
1990
1995
2000
2005
2010
2015
Year

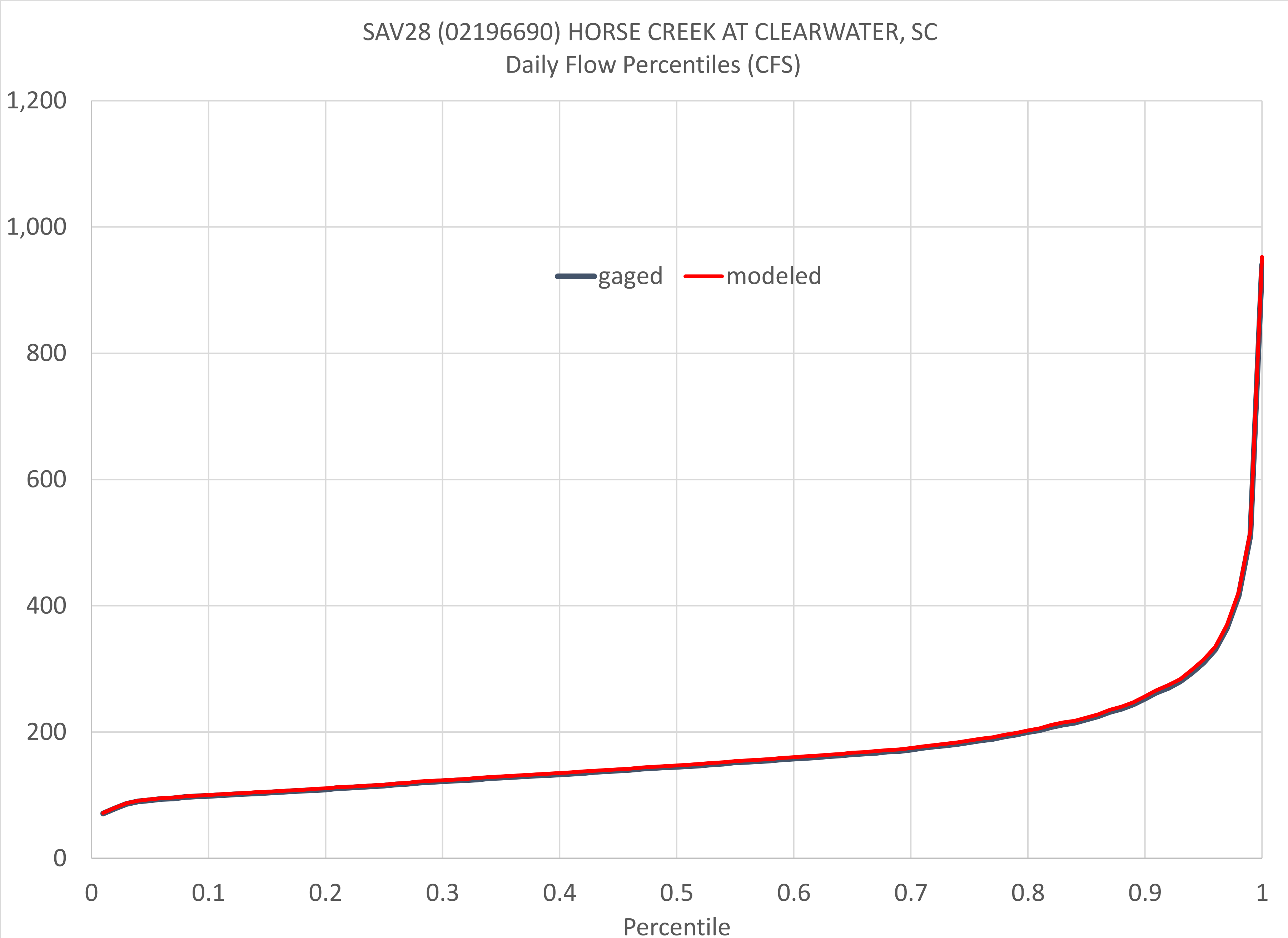

SAV35 (02197315)
UPPER THREE RUNS AT ROAD A (SRS), SC (CFS)
modeled
gaged
2,500
2,000
1,500
1,000
500
0
Jan-83
Jul-88
Dec-93
Jun-99
Dec-04
Jun-10


SAV35 (02197315) UPPER THREE RUNS AT ROAD A (SRS), SC
Daily Flow Percentiles (CFS)
2,500
2,000
1,500
1,000
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

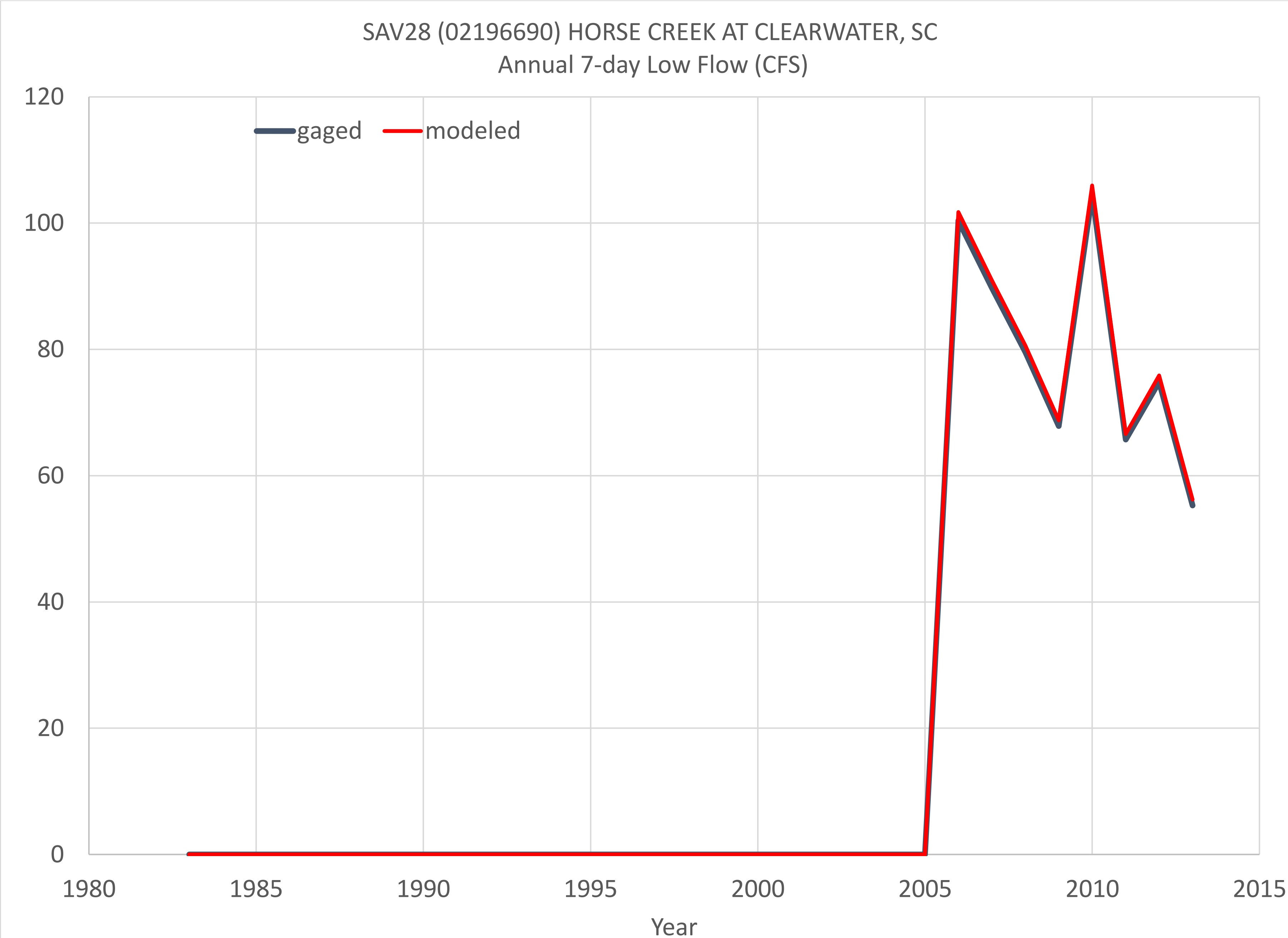


SAV35 (02197315) UPPER THREE RUNS AT ROAD A (SRS), SC
Annual 7-day Low Flow (CFS)
250
200
150
100
50
0
gaged
modeled
1980
1985
1990
1995
2000
2005
2010
2015
Year


SAV28 (02196690) HORSE CREEK AT CLEARWATER, SC (CFS)
modeled
gaged
2,000
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



SAV28 (02196690) HORSE CREEK AT CLEARWATER, SC
Daily Flow Percentiles (CFS)
gaged
modeled
1,200
1,000
800
600
400
200
0
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
Percentile


SAV28 (02196690) HORSE CREEK AT CLEARWATER, SC
Annual 7-day Low Flow (CFS)
gaged
modeled
0
20
40
60
80
100
120
1980
1985
1990
1995
2000
2005
2010
2015
Year

Annual 7 day Low Flows: Modeled

Year	SAVANNAH RIVER BELOW HARTWELL LK NR HARTWELL, GA	SAVANNAH RIVER AT AUGUSTA, GA	SAVANNAH R AT BURTONS FERRY BR NR MILLHAVEN, GA	SAVANNAH RIVER NEAR CLYO, GA	LITTLE RIVER NEAR WALHALLA, SC	TWELVEMILE CREEK NEAR LIBERTY, SC	CONEROSS CK NR SENECA, SC	EIGHTEENMILE CREEK ABOVE PENDLETON, SC	ROCKY RIVER NR STARR, SC	LITTLE RIVER NEAR MT. CARMEL, SC
ID->	SAV12	SAV29	SAV43	SAV45	SAV04	SAV06	SAV08	SAV09	SAV14	SAV17
1983		4,371.3	4,900.6	5,251.2	45.5					
1984		4,380.1	5,119.7	5,527.1	72.5					
1985	2,142.9	4,372.0	5,021.0	5,347.0	51.5					
1986	2,142.9	4,287.0	4,799.2	5,030.8	14.6					
1987	2,142.9	4,330.2	4,890.0	5,189.5	49.8					6.8
1988	2,142.9	4,316.2	4,903.5	5,228.5	27.4					0.6
1989		4,465.5	5,124.1	5,522.4	57.4					37.7
1990		4,340.3	4,724.5	4,990.6	55.8		34.9		27.1	15.2
1991		4,465.6	5,265.0	5,863.7	98.6	105.5	58.9		50.7	58.0
1992		4,426.2	5,035.7	5,549.9	81.5	99.8	42.1		26.3	28.7
1993		4,335.3	4,999.7	5,330.8	51.1		39.5		35.0	15.1
1994		4,429.6	5,168.7	5,634.7	85.4	100.5	58.5		57.2	55.3
1995		4,466.0	5,341.5	5,852.5	66.4	78.1	46.8		37.6	25.4
1996		4,456.2	5,172.3	5,692.9	85.6	79.3	47.1			60.2
1997		4,248.0	4,803.6	5,111.4	60.8	54.7	34.9		30.5	25.7
1998		4,222.0	4,902.8	5,298.6	53.0	62.1	40.4		40.1	37.3
1999		4,168.9	4,642.8	4,899.9	18.6	29.1	18.9	15.4	11.8	14.8
2000		4,174.5	4,610.2	4,840.3	33.1	26.5	19.5	14.5	10.3	8.6
2001		4,242.0	4,625.5	4,893.4	41.5		13.5	12.3		13.0
2002		4,237.2	4,553.1	4,734.2	9.3		5.1	3.1		1.7
2003		4,481.4		5,944.4				42.5		
2004		4,355.3		5,314.1				23.7		
2005		4,401.0	5,117.9	5,595.2		100.3		27.4	34.7	24.7
2006		4,275.6	4,704.1	4,970.5		52.1		13.4	25.0	8.3
2007		4,230.0	4,519.4	4,703.1		23.5		5.6	6.8	0.2
2008		2,534.9	2,974.7	3,264.4		15.2			6.4	0.6
2009		4,305.0	4,739.8	5,033.8		35.9			8.4	8.2
2010		4,258.8	4,640.3	4,905.5		40.1			13.4	2.1
2011		4,219.9	4,533.3	4,675.2		15.7			6.7	0.1
2012		4,276.7	4,652.2	4,887.7		56.0			9.9	2.4
2013		4,377.3	5,001.3	5,441.0		113.2			53.7	26.0

Note: blank cells indicate years when sufficient gaged flows were not availalable for comparison.

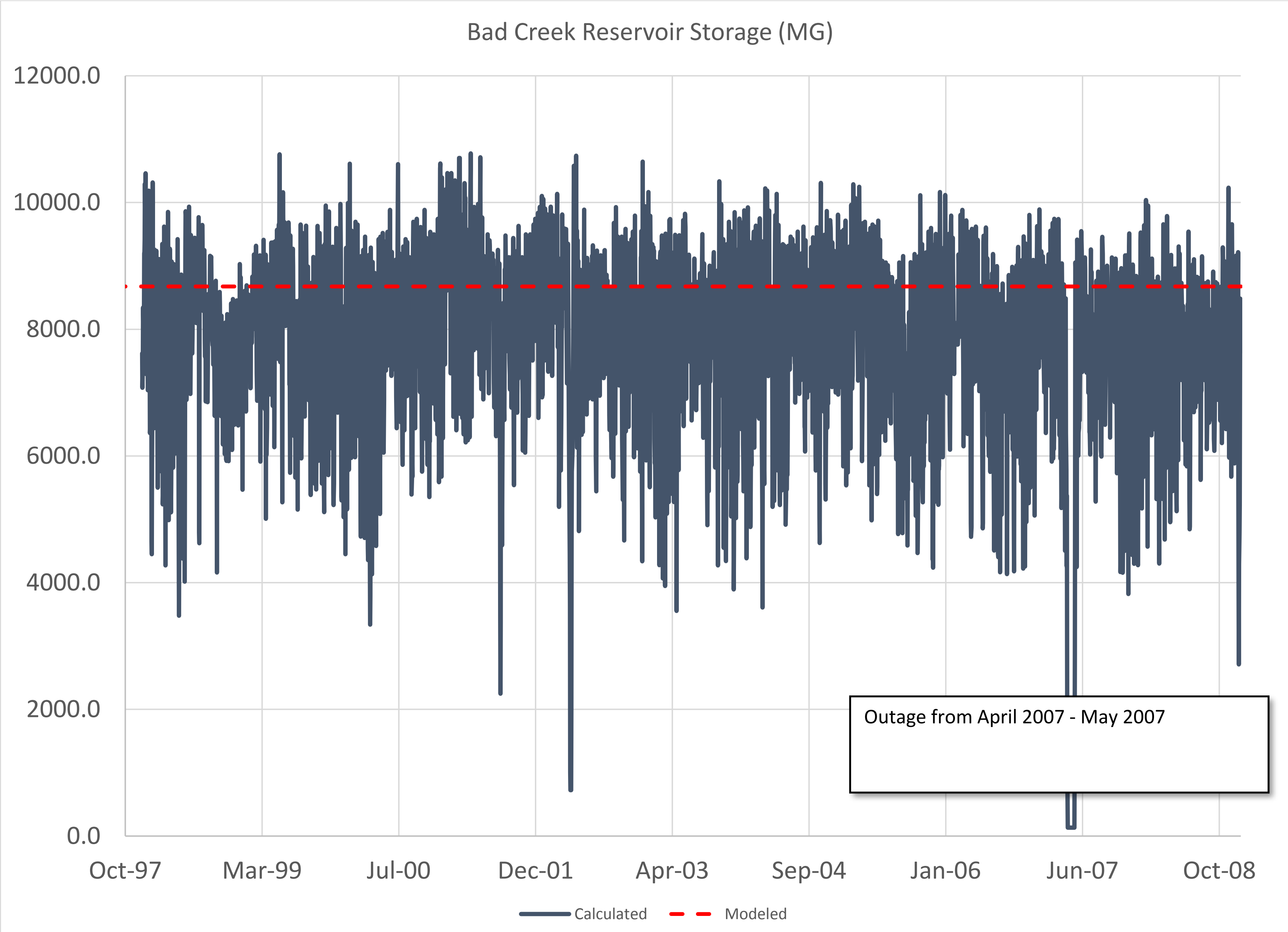
Annual 7 day Low Flows: Measured

Year	SAVANNAH RIVER BELOW HARTWELL LK NR HARTWELL, GA	SAVANNAH RIVER AT AUGUSTA, GA	SAVANNAH R AT BURTONS FERRY BR NR MILLHAVEN, GA	SAVANNAH RIVER NEAR CLYO, GA	LITTLE RIVER NEAR WALHALLA, SC	TWELVEMILE CREEK NEAR LIBERTY, SC	CONEROSS CK NR SENECA, SC	EIGHTEENMILE CREEK ABOVE PENDLETON, SC	ROCKY RIVER NR STARR, SC	LITTLE RIVER NEAR MT. CARMEL, SC
ID->	SAV12	SAV29	SAV43	SAV45	SAV04	SAV06	SAV08	SAV09	SAV14	SAV17
1983		5,025.7	5,438.6	5,867.1	45.6					
1984		5,475.7	6,091.4	6,374.3	72.6					
1985	1,270.9	5,037.1	5,018.6	5,324.3	51.6					
1986	1,000.9	3,935.7	3,991.4	4,780.0	14.6					
1987	1,254.9	4,412.9	4,535.7	5,532.9	49.9					7.2
1988	1,308.4	3,940.0	4,204.3	4,512.9	27.4					1.1
1989		4,108.6	4,178.6	5,002.9	57.4					38.0
1990		4,884.3	4,768.6	5,662.9	55.9		35.0		27.6	15.4
1991		4,531.4	5,071.4	6,030.0	98.7	104.9	59.1		50.3	58.3
1992		5,304.3	5,955.7	6,287.1	81.6	99.1	42.3		26.1	29.1
1993		4,600.0	5,517.1	5,398.6	51.1		39.7		34.4	15.6
1994		5,020.0	5,477.1	6,221.4	85.4	99.9	58.7		57.0	55.7
1995		5,307.1	5,651.4	6,657.1	66.4	77.6	47.0		37.7	25.3
1996		4,477.1	4,618.6	5,637.1	85.7	78.9	47.3			60.0
1997		4,540.0	5,102.9	5,811.4	60.9	54.3	35.0		30.3	25.6
1998		5,014.3	5,707.1	6,797.1	53.0	61.7	40.6		40.3	37.1
1999		4,057.1	4,765.7	5,264.3	18.6	28.9	19.0	15.3	11.0	14.7
2000		3,745.7	4,328.6	4,807.1	33.1	26.3	19.6	15.0	14.0	8.6
2001		3,775.7	4,817.1	4,885.7	41.6		13.6	12.7		13.0
2002		3,844.3	4,044.3	4,512.9	9.3		4.0	3.6		1.7
2003		3,982.9		5,871.4				43.4		
2004		4,112.9		4,787.1				24.4		
2005		4,961.4	6,070.0	6,355.7		99.7		28.1	34.6	24.6
2006		3,835.7	4,704.3	5,251.4		51.7		13.9	24.7	8.2
2007		3,702.9	3,951.4	4,335.7		23.1		5.9	6.7	0.2
2008		3,444.3	4,167.1	4,127.1		14.9			5.9	0.6
2009		3,114.3	4,254.3	4,688.6		35.4			8.8	8.2
2010		4,090.0	4,932.9	4,722.9		39.7			14.0	2.1
2011		3,751.4	4,427.1	4,558.6		15.3			6.9	0.0
2012		3,257.1	3,921.4	4,052.9		55.6			10.5	2.4
2013		3,307.1	3,974.3	4,405.7		112.4			54.7	25.9

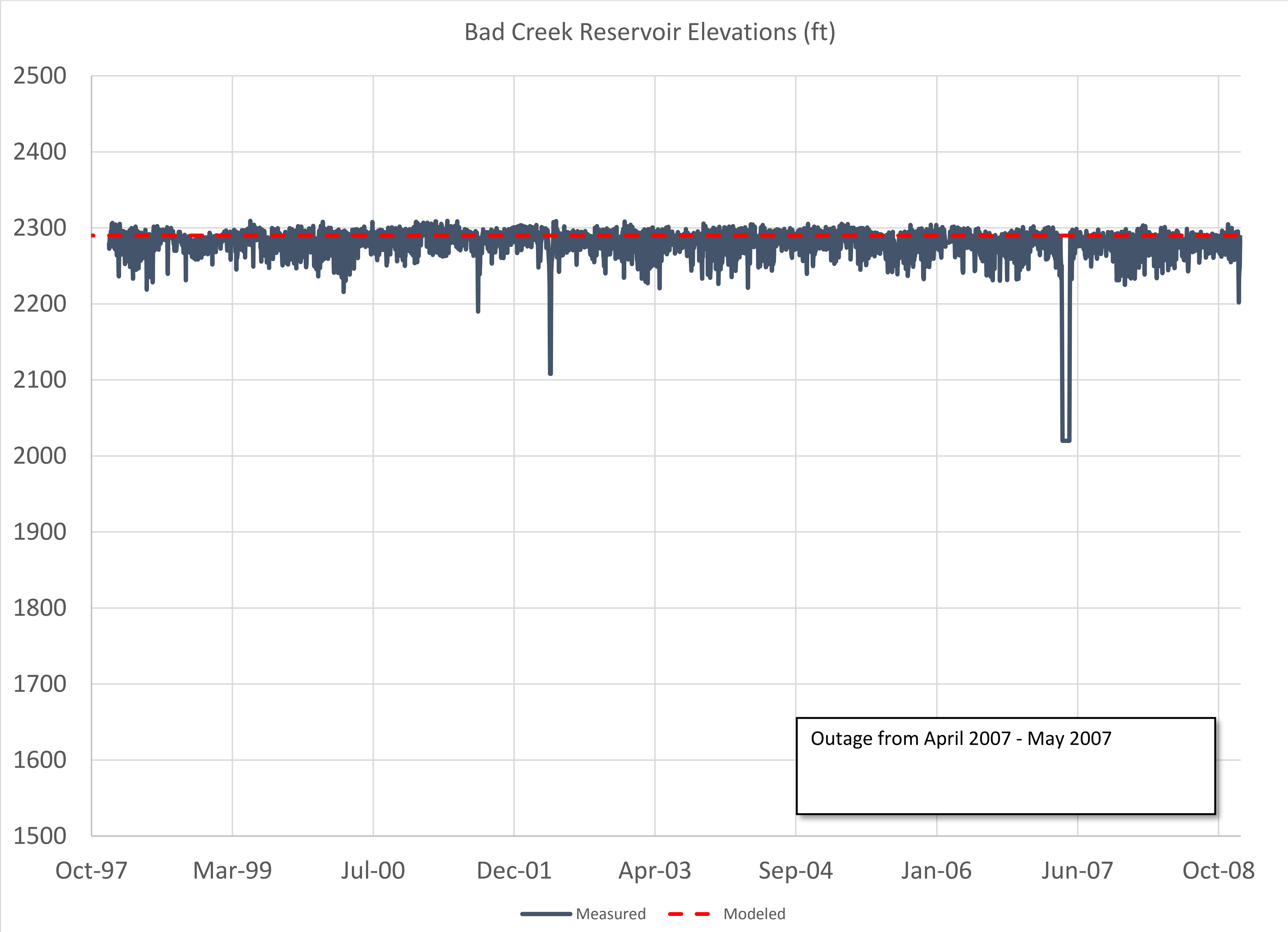
Note: blank cells indicate years when sufficient gaged flows were not availalable for comparison.

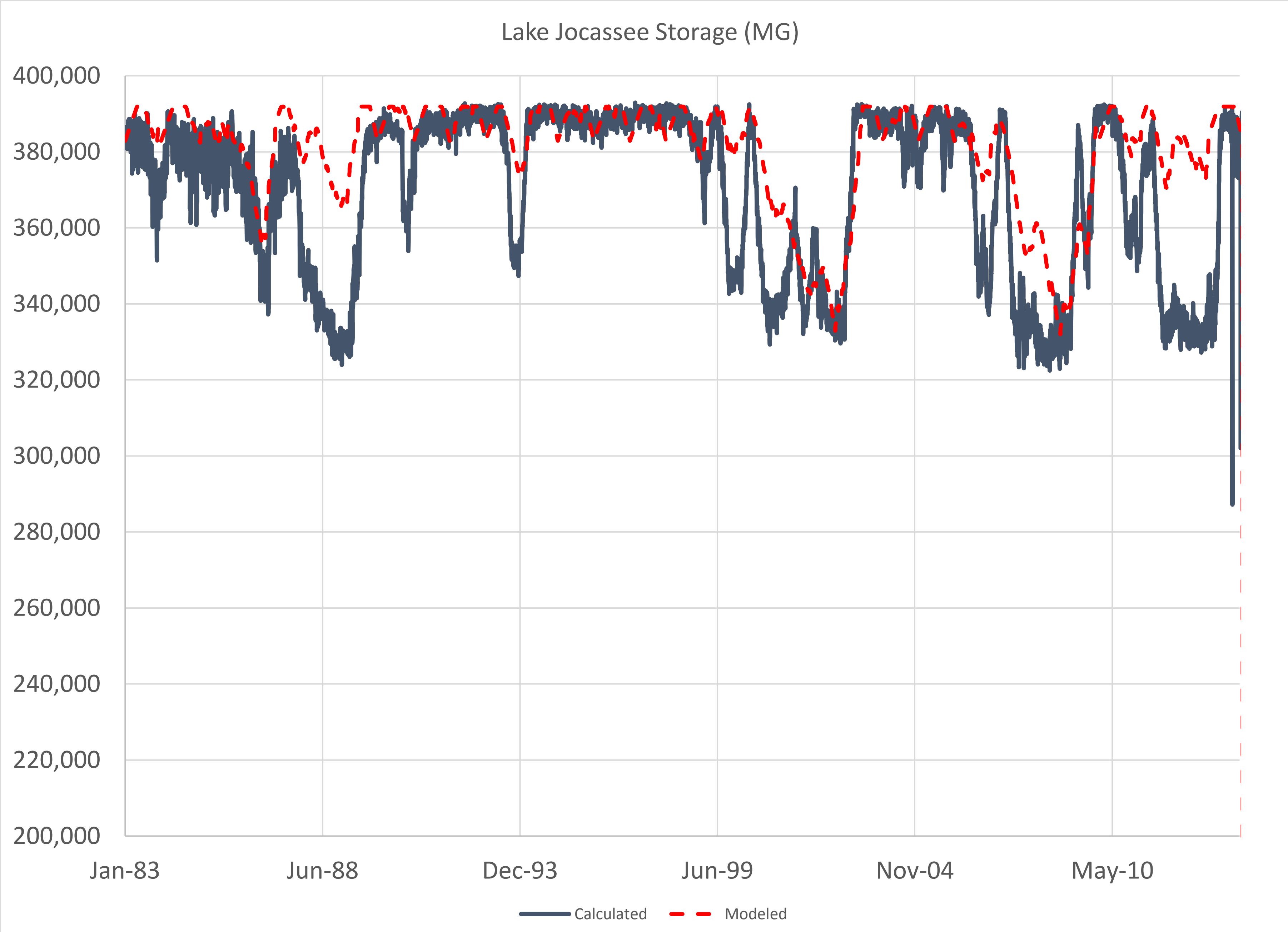
Approximate 7Q10 Comparison - Modeled vs. Measured

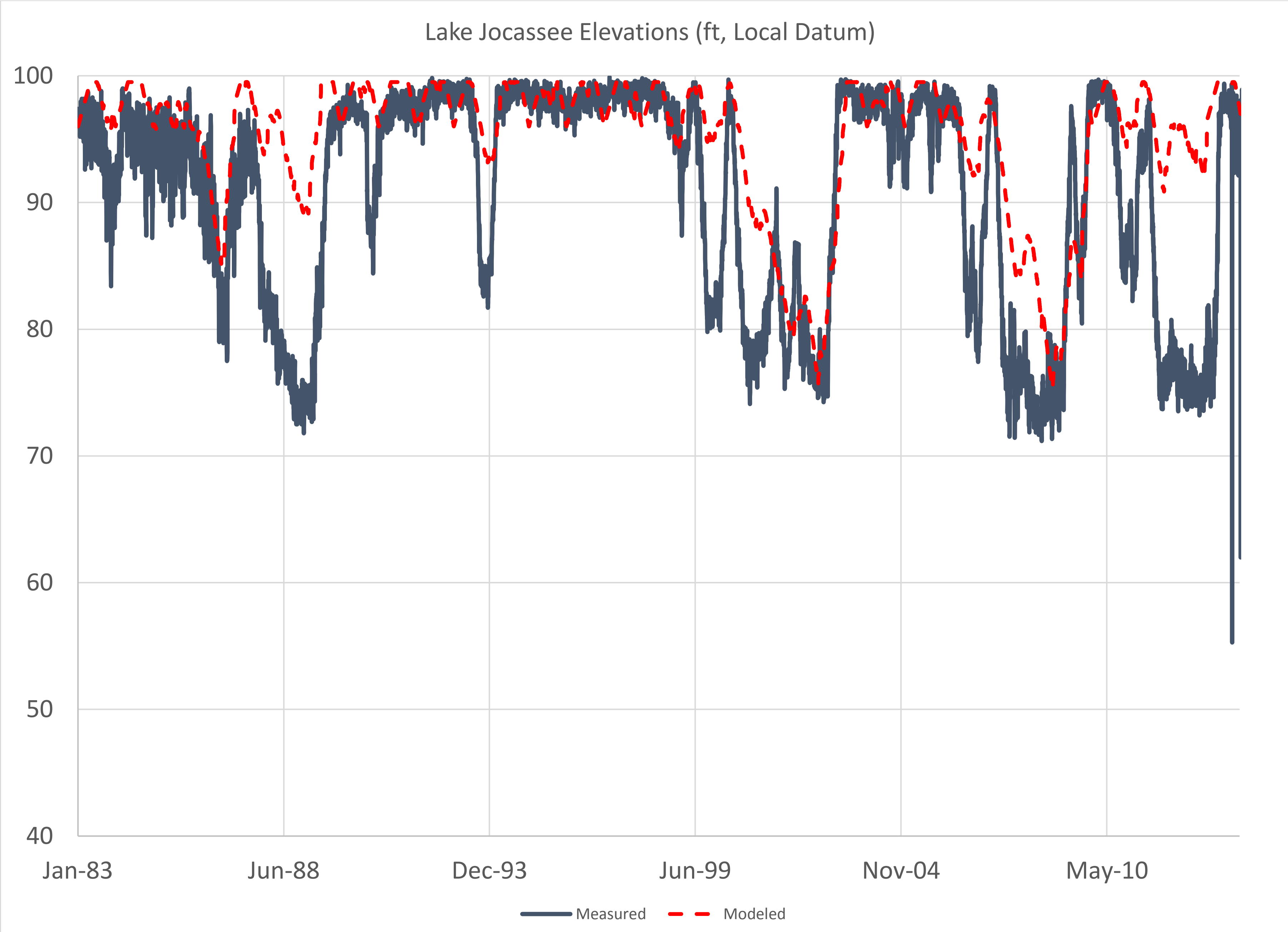
Year	SAVANNAH RIVER BELOW HARTWELL LK NR HARTWELL, GA	SAVANNAH RIVER AT AUGUSTA, GA	SAVANNAH R AT BURTONS FERRY BR NR MILLHAVEN, GA	SAVANNAH RIVER NEAR CLYO, GA	LITTLE RIVER NEAR WALHALLA, SC	TWELVEMILE CREEK NEAR LIBERTY, SC	CONEROSS CK NR SENECA, SC	EIGHTEENMILE CREEK ABOVE PENDLETON, SC	ROCKY RIVER NR STARR, SC	LITTLE RIVER NEAR MT. CARMEL, SC
ID->	SAV12	SAV29	SAV43	SAV45	SAV04	SAV06	SAV08	SAV09	SAV14	SAV17
Modeled	2,142.9	4,219.9	4,549.1	4,734.2	18.2	21.2	14.6	5.1	6.8	0.6
Measured	1,077.1	3,444.3	3,988.0	4,405.7	18.2	20.8	14.7	5.4	6.8	0.8
% Diff.	99.0%	22.5%	14.1%	7.5%	-0.1%	1.9%	-0.5%	-6.6%	-0.3%	-23.3%

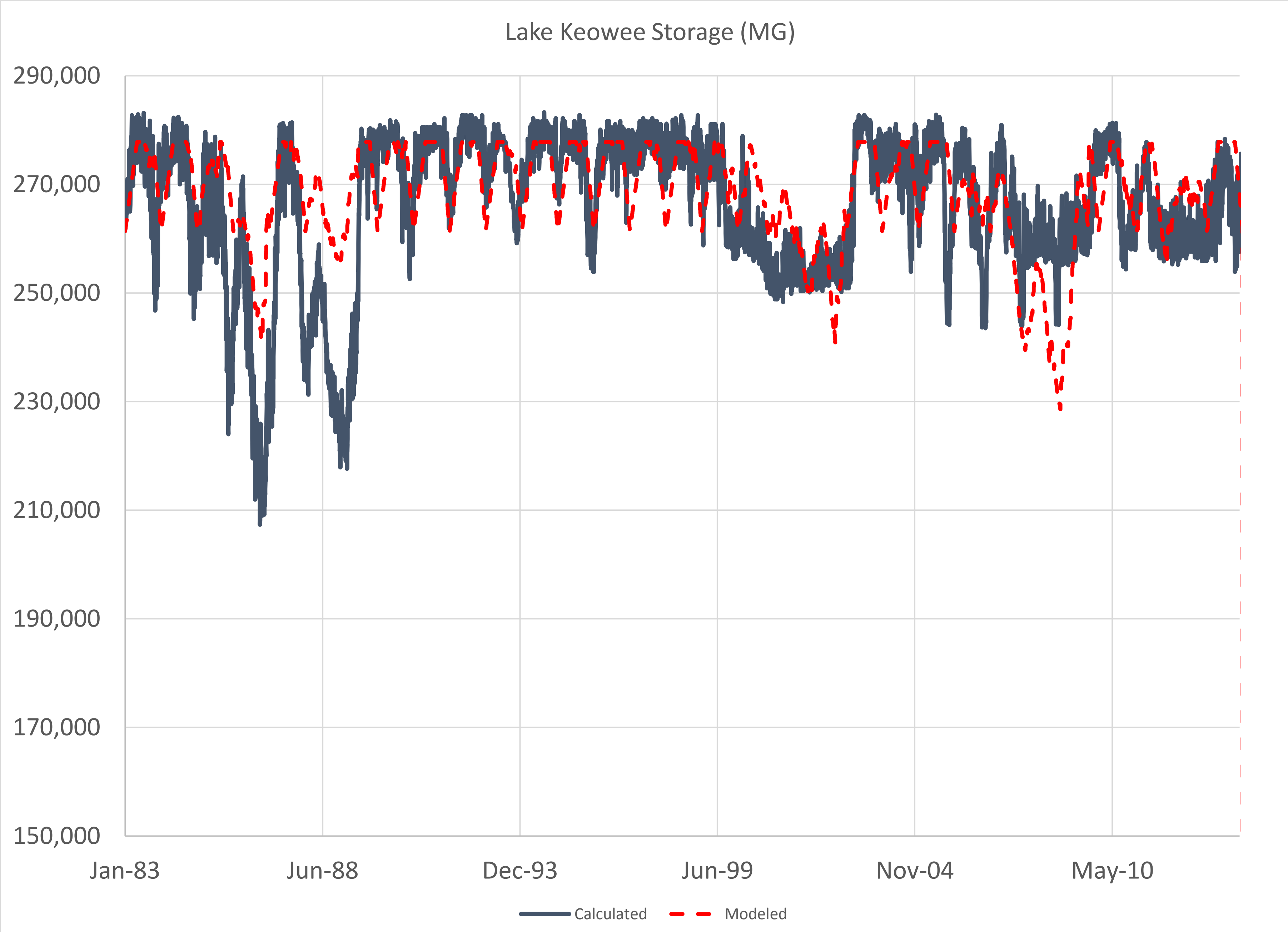


Bad Creek Reservoir Storage (MG)
12000.0
10000.0
8000.0
6000.0
4000.0
2000.0
0.0
Oct-97
Mar-99
Jul-00
Dec-01
Apr-03
Sep-04
Jan-06
Jun-07
Oct-08
Outage from April 2007 - May 2007
Calculated
Modeled

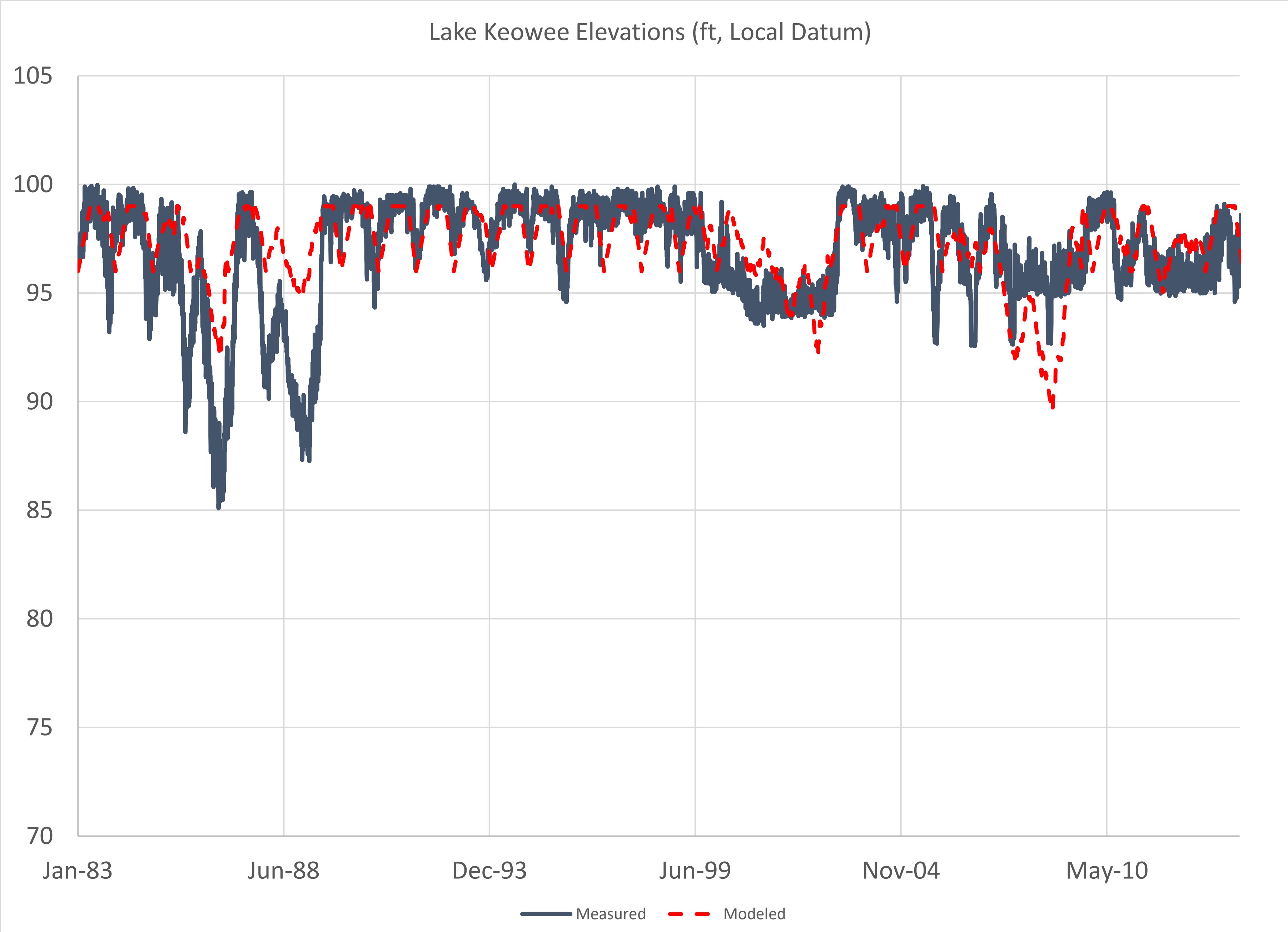

Bad Creek Reservoir Elevations (ft)
2500
2400
2300
2200
2100
2000
1900
1800
1700
1600
1500
Oct-97
Mar-99
Jul-00
Dec-01
Apr-03
Sep-04
Jan-06
Jun-07
Oct-08
Outage from April 2007 - May 2007
Measured
Modeled

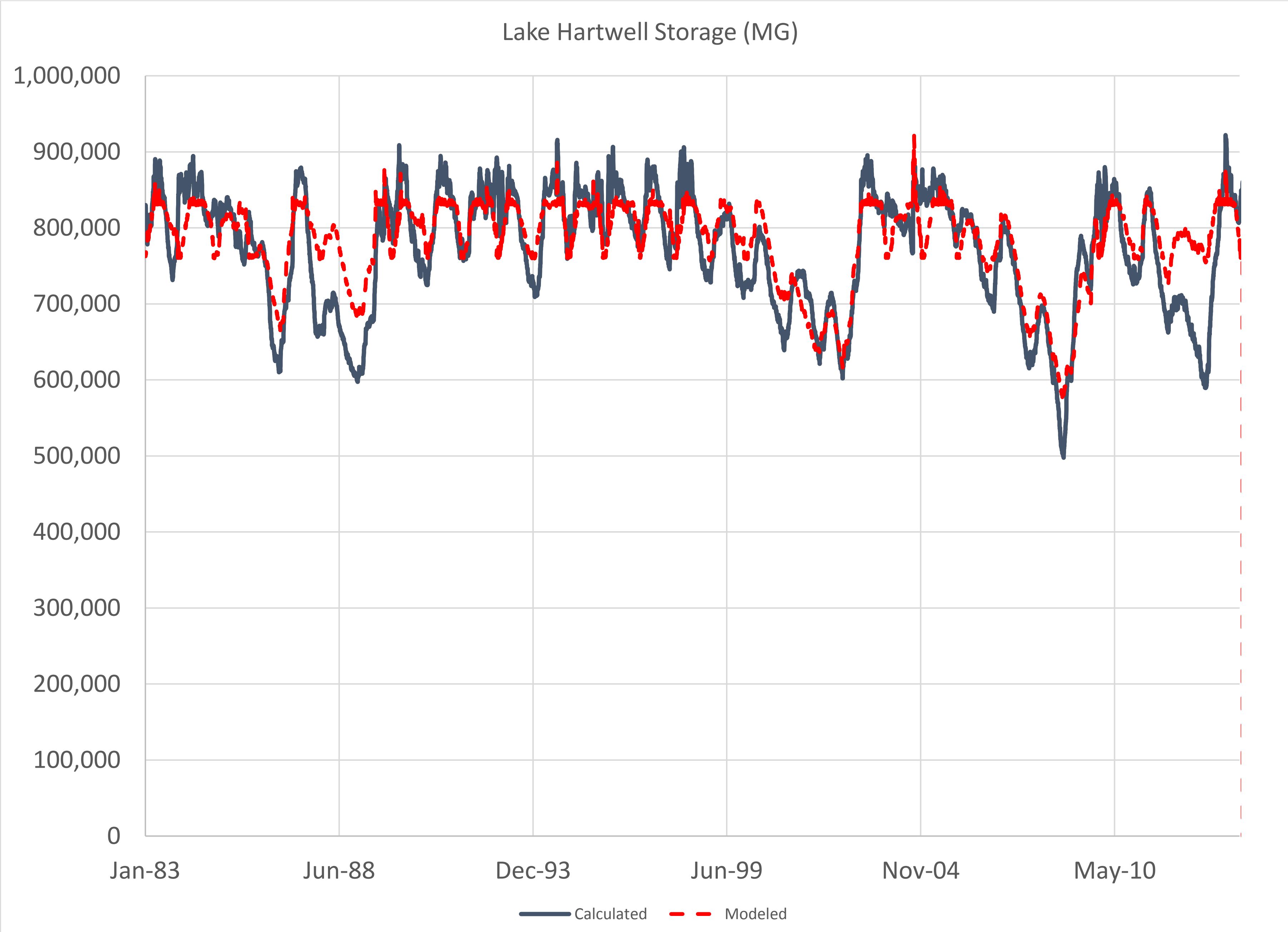

Lake Jocassee Storage (MG)
400,000
380,000
360,000
340,000
320,000
300,000
280,000
260,000
240,000
220,000
200,000
Jan-83
Jun-88
Dec-93
Jun-99
Nov-04
May-10
Calculated
Modeled


Lake Jocassee Elevations (ft, Local Datum)
100
90
80
70
60
50
40
Jan-83
Jun-88
Dec-93
Jun-99
Nov-04
May-10
Measured
Modeled

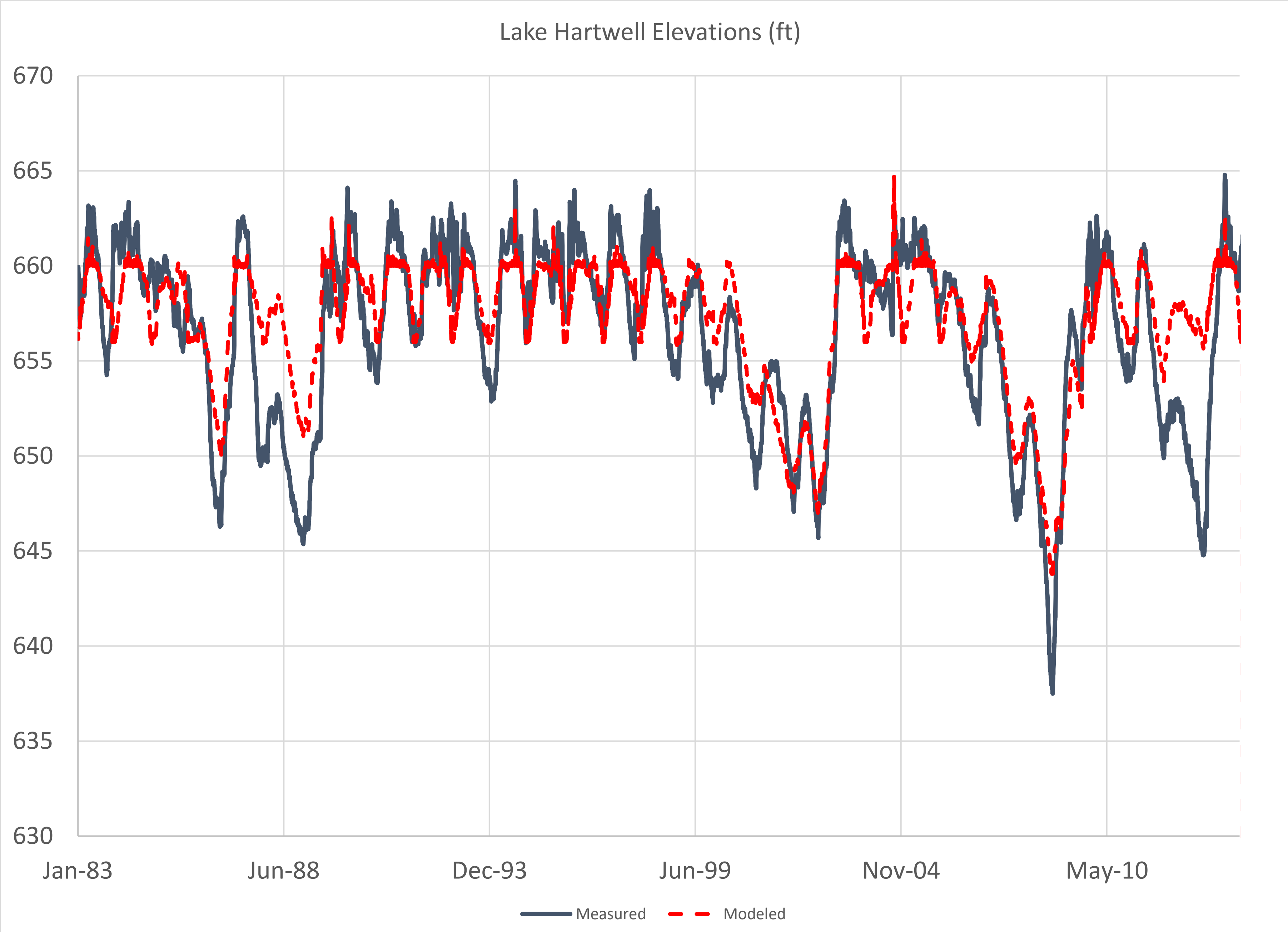


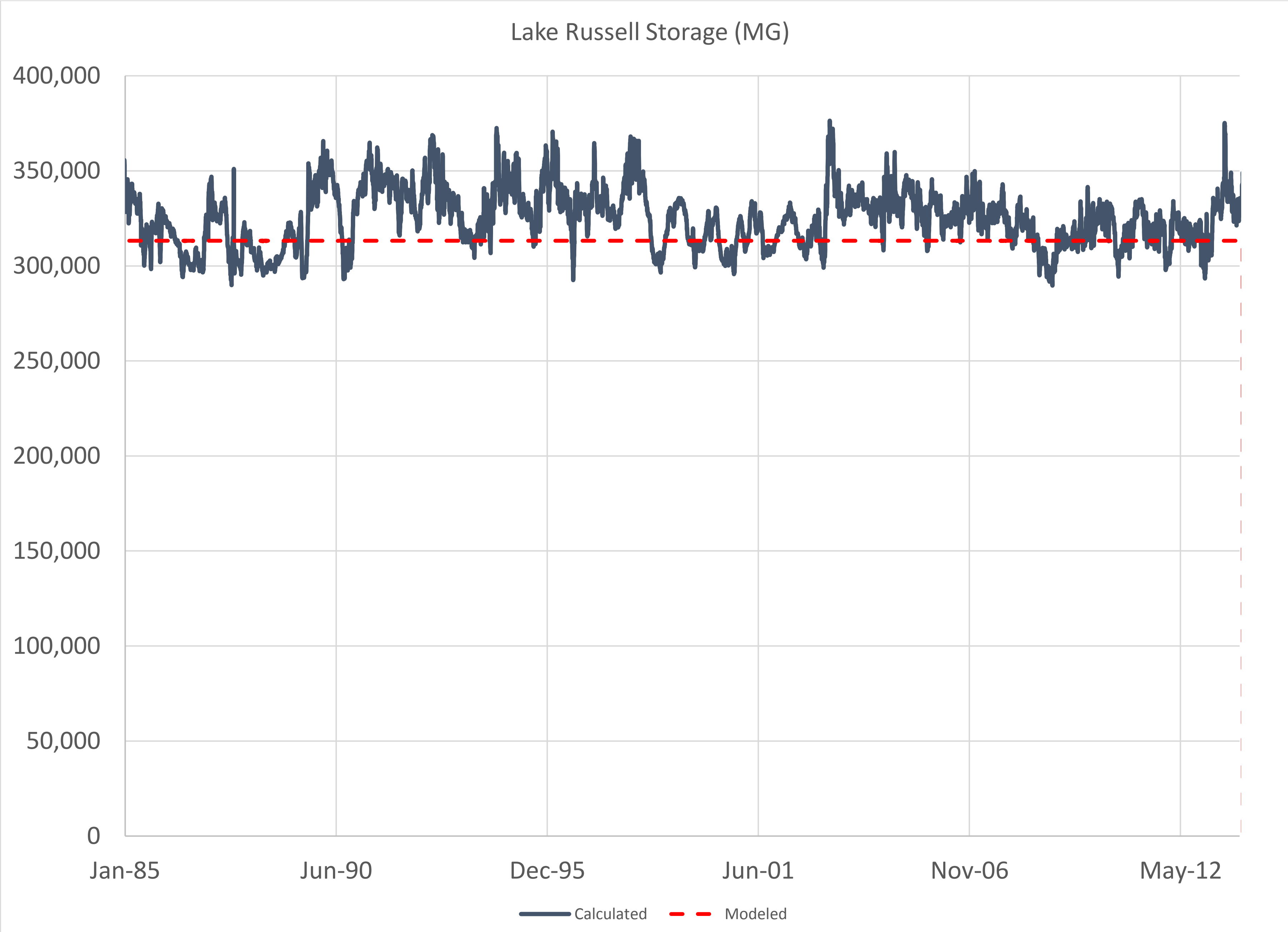
Lake Keowee Storage (MG)
290,000
270,000
250,000
230,000
210,000
190,000
170,000
150,000
Jan-83
Jun-88
Dec-93
Jun-99
Nov-04
May-10
Calculated
Modeled


Lake Keowee Elevations (ft, Local Datum)
105
100
95
90
85
80
75
70
Jan-83
Jun-88
Dec-93
Jun-99
Nov-04
May-10
Measured
Modeled

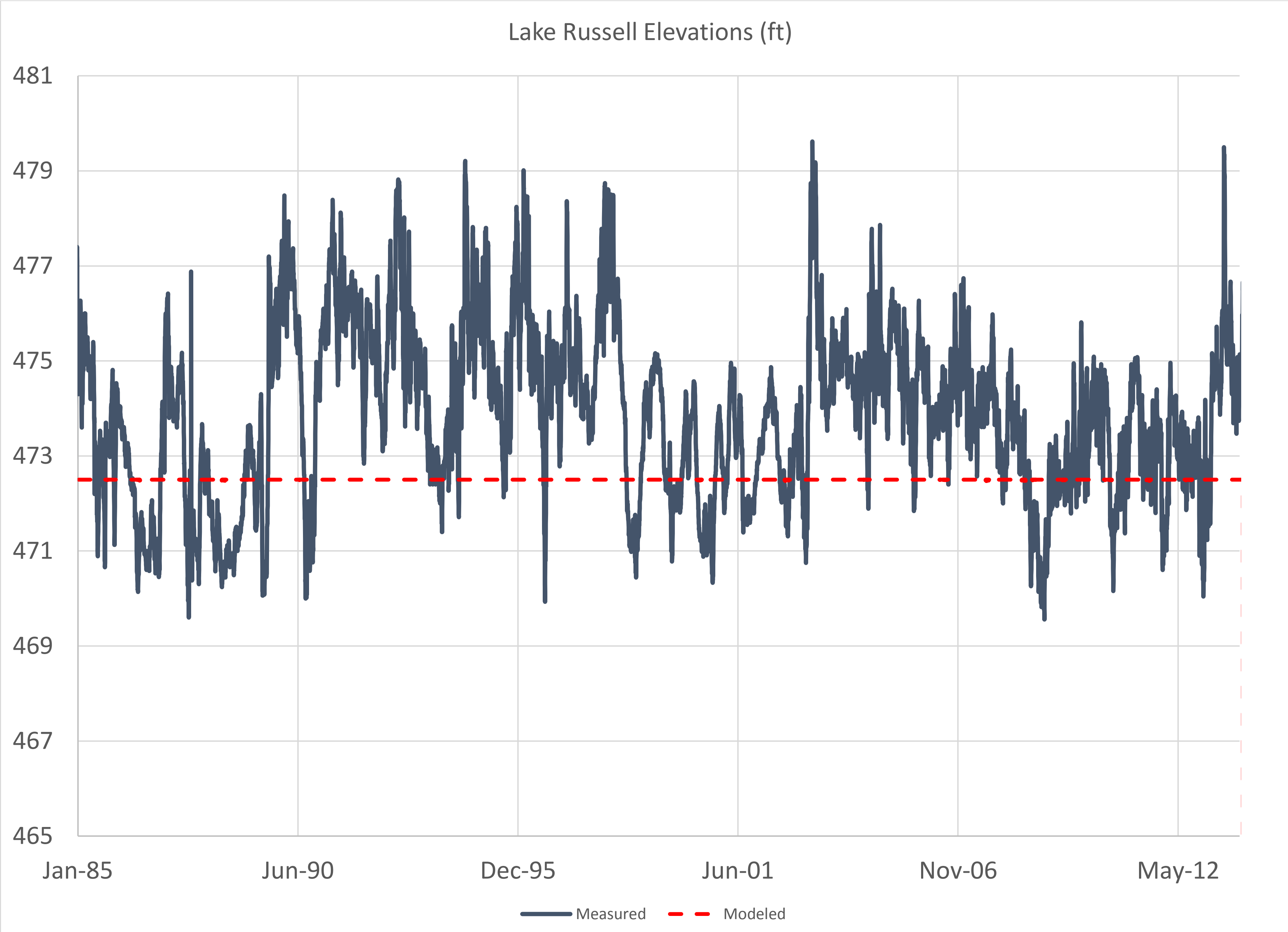


Lake Hartwell Storage (MG)
1,000,000
900,000
800,000
700,000
600,000
500,000
400,000
300,000
200,000
100,000
0
Jan-83
Jun-88
Dec-93
Jun-99
Nov-04
May-10
Calculated
Modeled

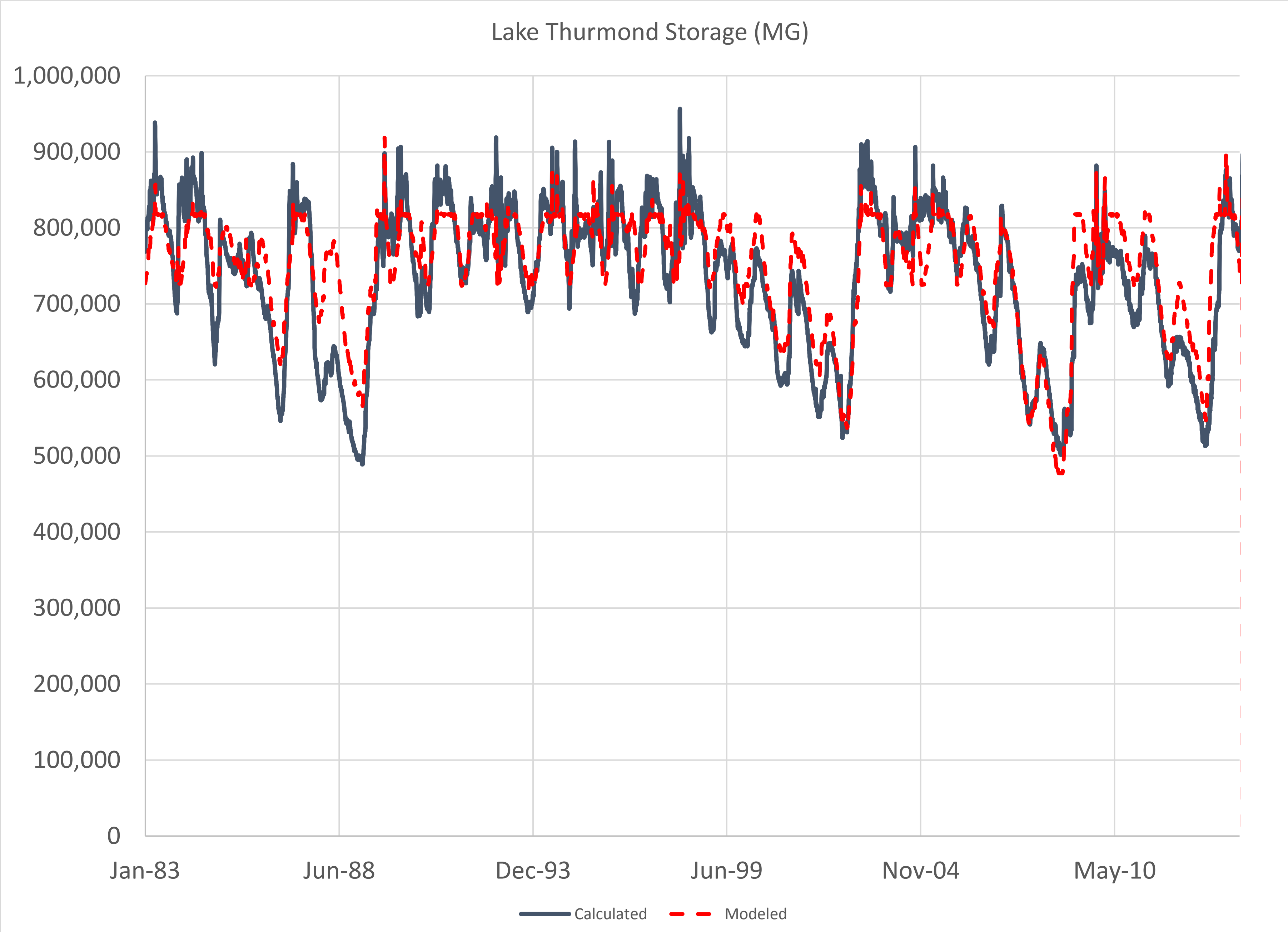

Lake Hartwell Elevations (ft)
670
665
660
655
650
645
640
635
630
Jan-83
Jun-88
Dec-93
Jun-99
Nov-04
May-10
Measured
Modeled



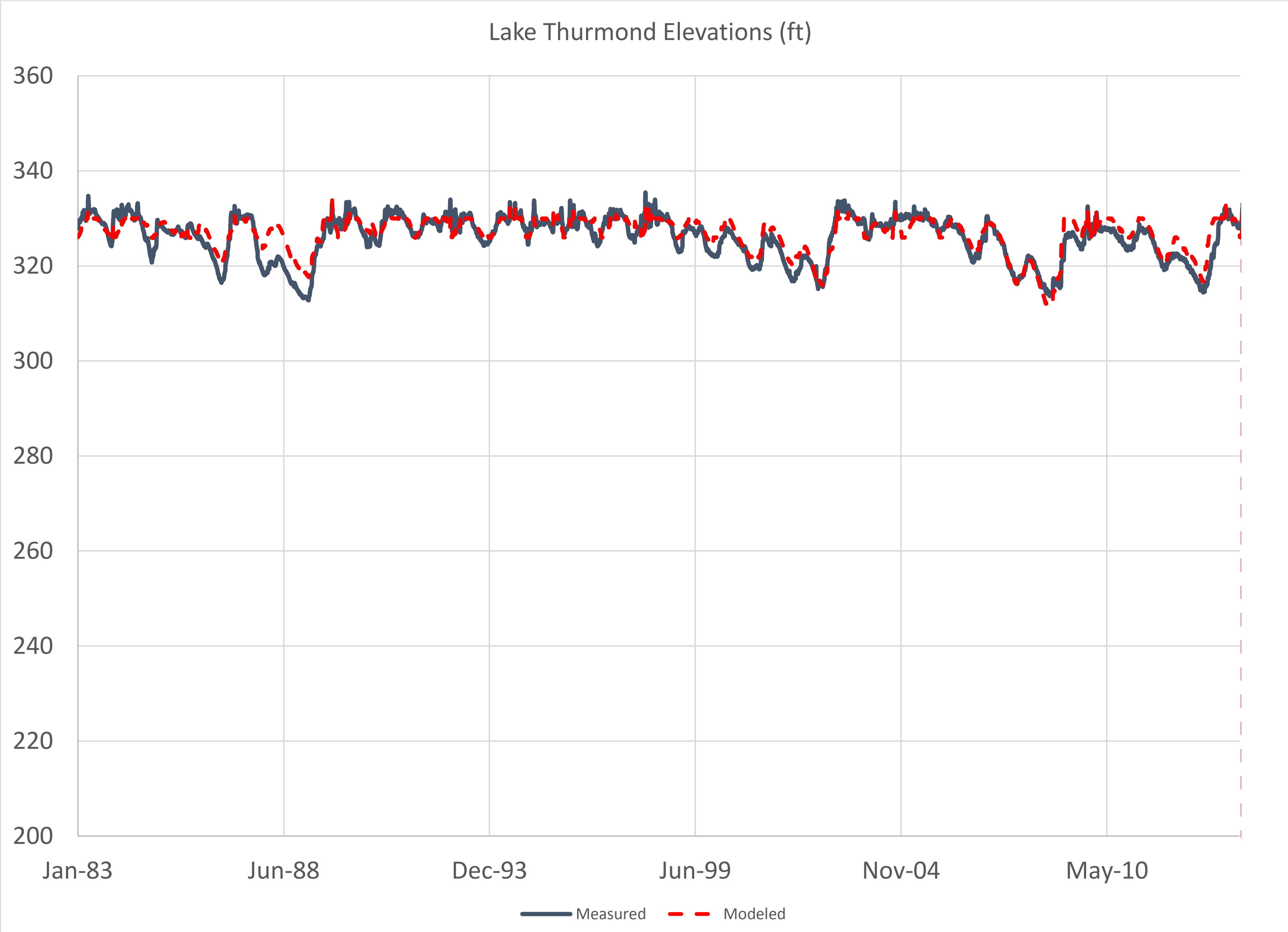
Lake Russell Storage (MG)
400,000
350,000
300,000
250,000
200,000
150,000
100,000
50,000
0
Jan-85
Jun-90
Dec-95
Jun-01
Nov-06
May-12
Calculated
Modeled



Lake Russell Elevations (ft)
481
479
477
475
473
471
469
467
465
Jan-85
Jun-90
Dec-95
Jun-01
Nov-06
May-12
Measured
Modeled



Lake Thurmond Storage (MG)
1,000,000
900,000
800,000
700,000
600,000
500,000
400,000
300,000
200,000
100,000
0
Jan-83
Jun-88
Dec-93
Jun-99
Nov-04
May-10
Calculated
Modeled

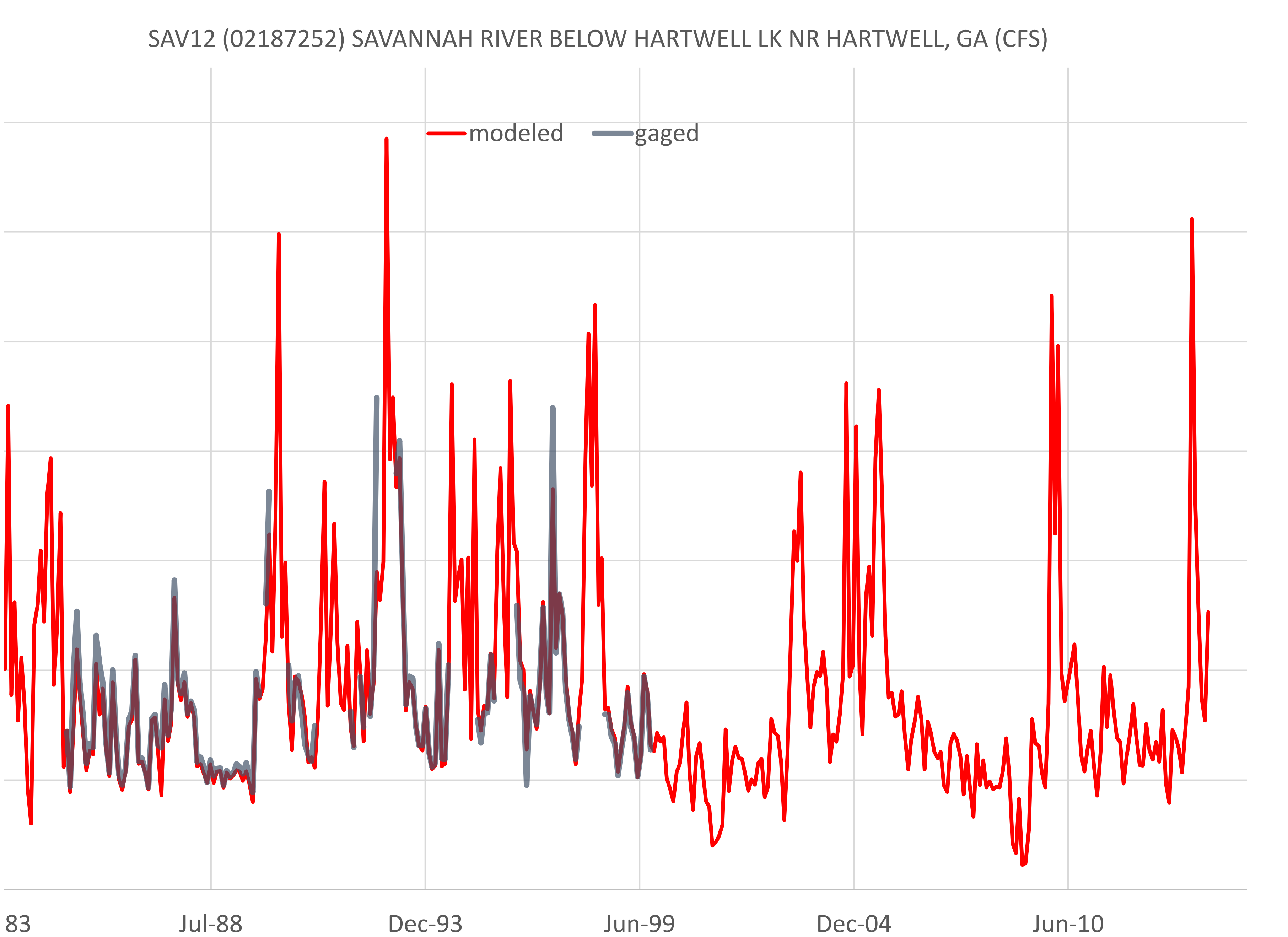


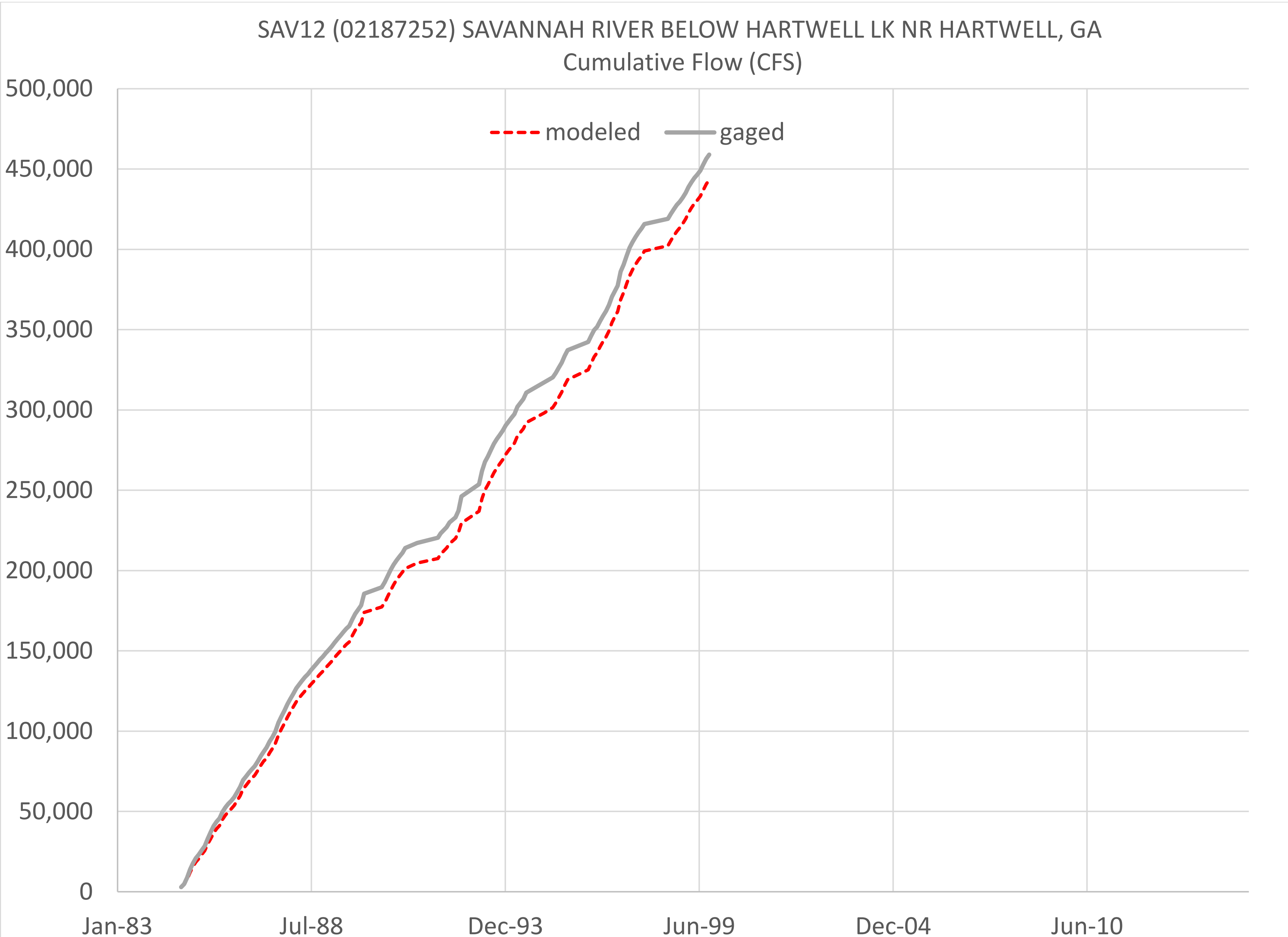
Lake Thurmond Elevations (ft)
360
340
320
300
280
260
240
220
200
Jan-83
Jun-88
Dec-93
Jun-99
Nov-04
May-10
Measured
Modeled

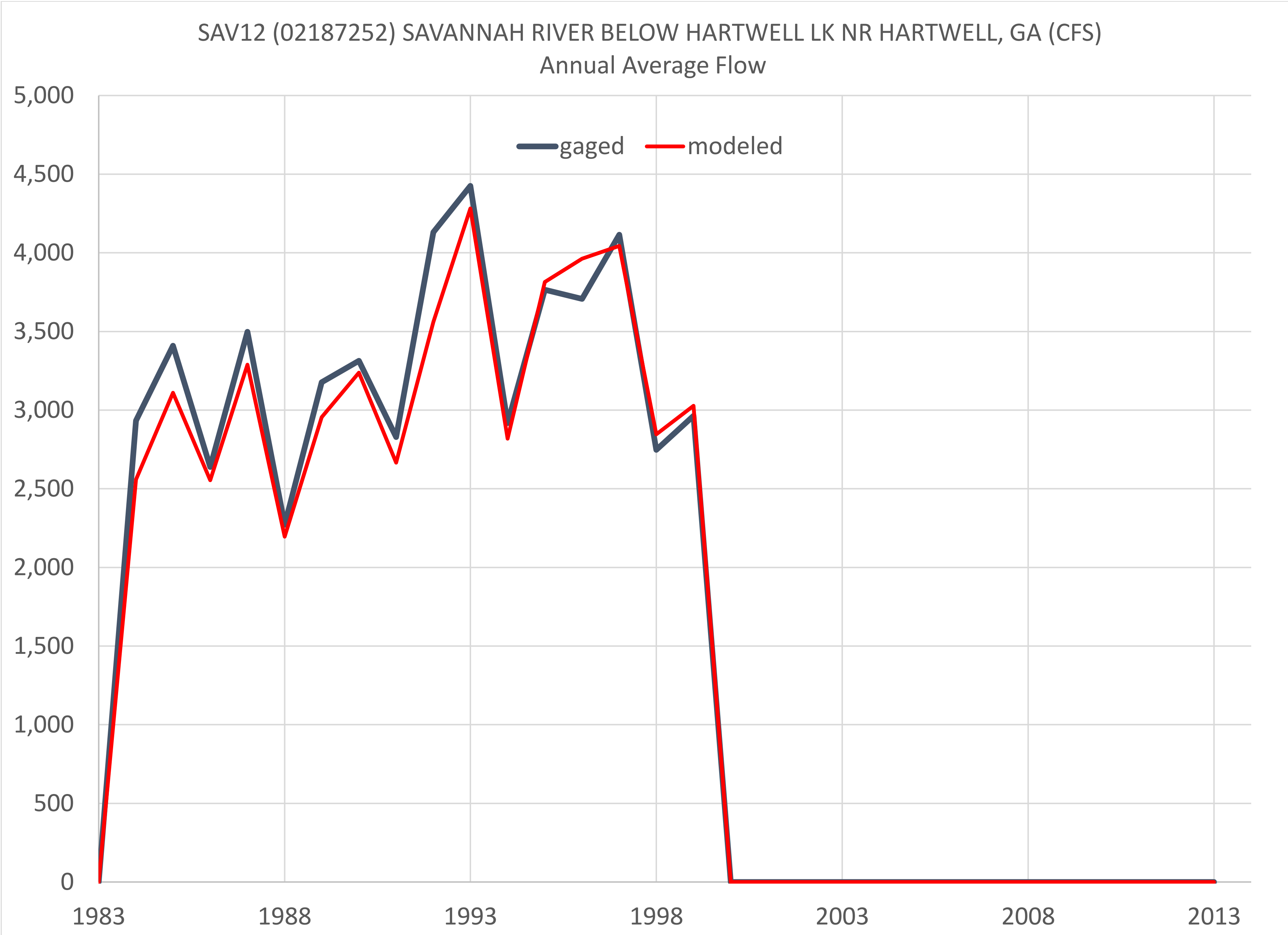
Appendix C

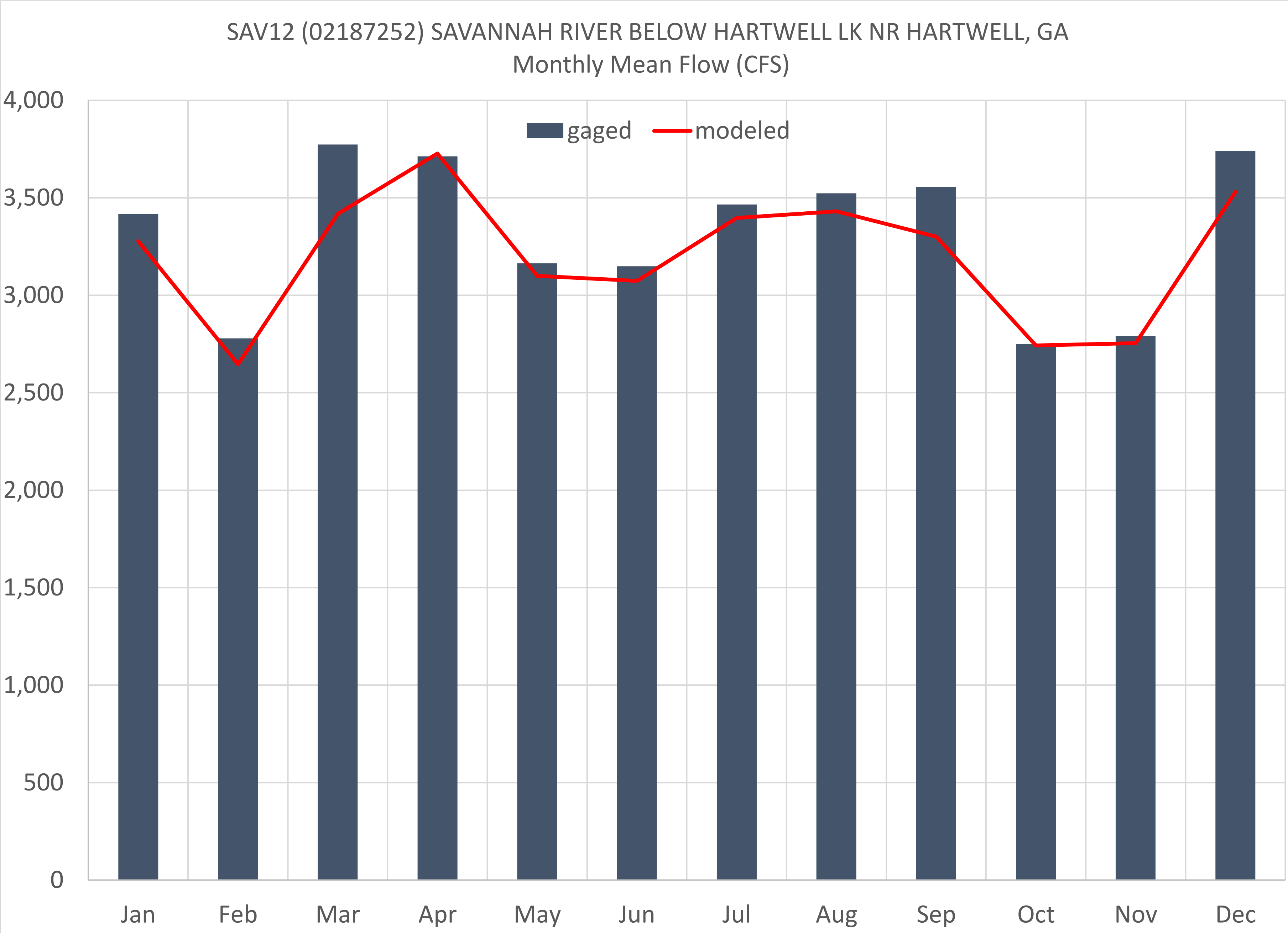
Prescribed Outflows Model Monthly Calibration Results

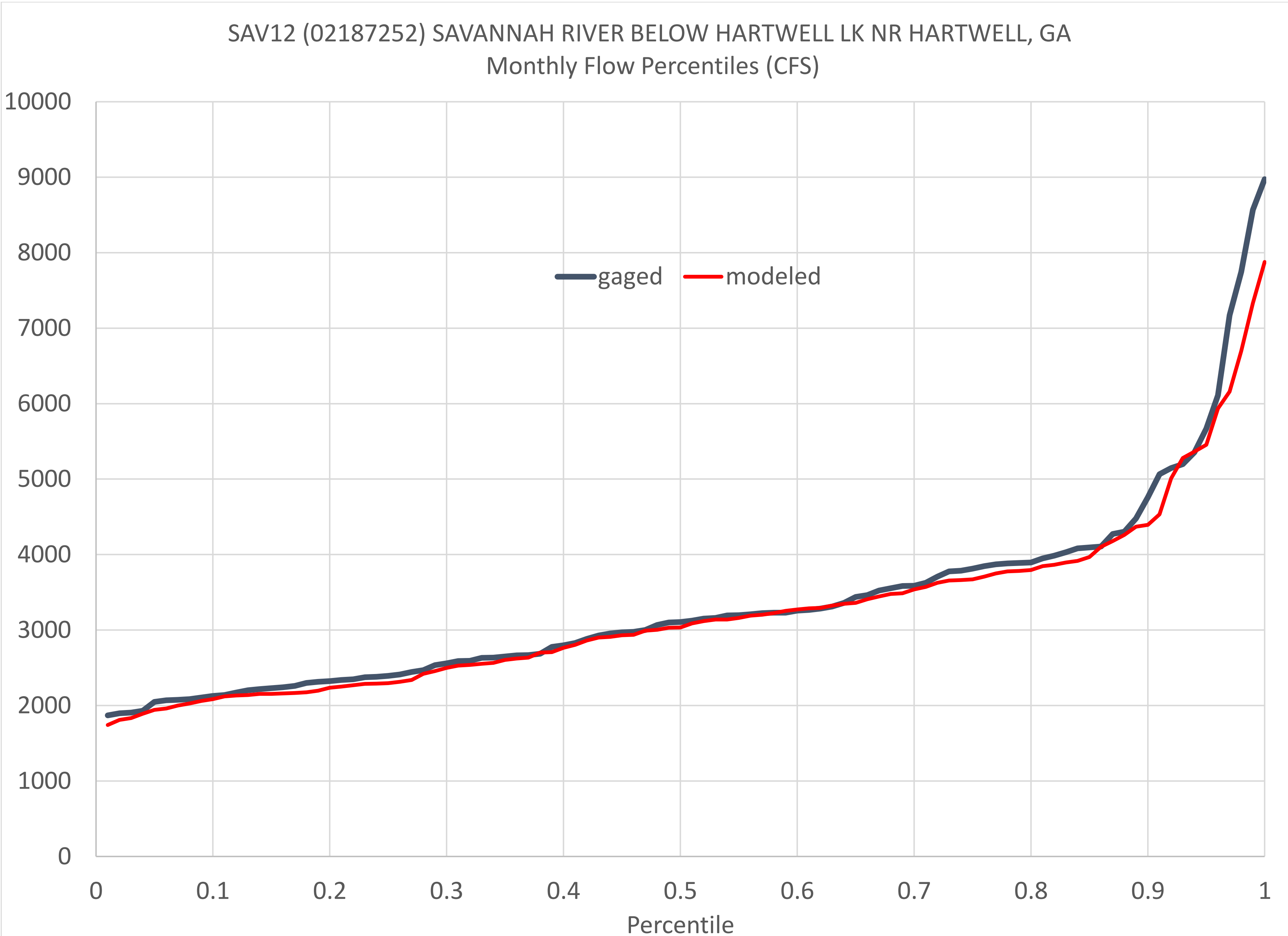
CDM Smith

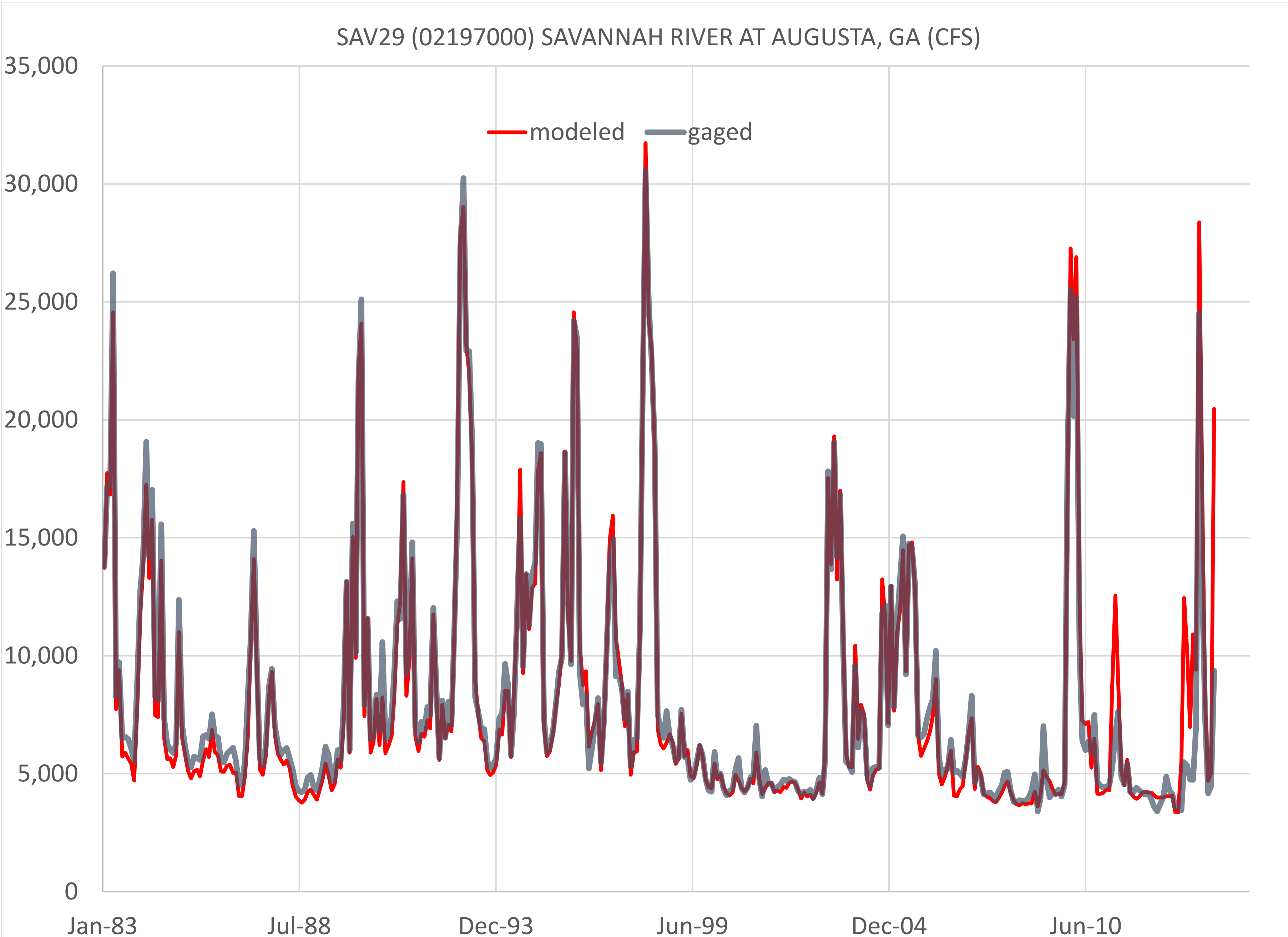

SAV12 (02187252) SAVANNAH RIVER BELOW HARTWELL LK NR HARTWELL, GA (CFS)
modeled
gaged
83
Jul-88
Dec-93
Jun-99
Dec-04
Jun-10

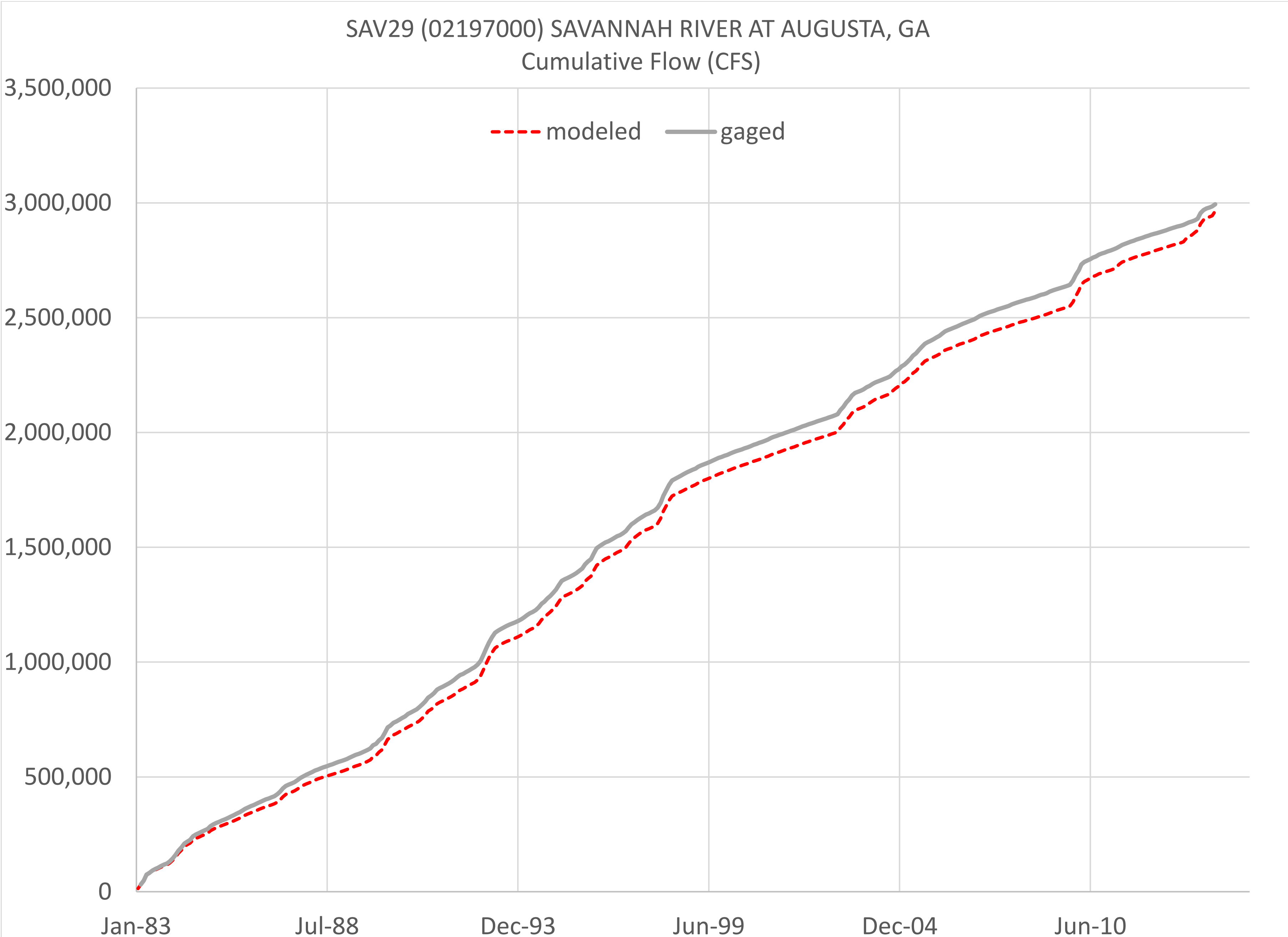

SAV12 (02187252) SAVANNAH RIVER BELOW HARTWELL LK NR HARTWELL, GA
Cumulative Flow (CFS)
modeled
gaged
500,000
450,000
400,000
350,000
300,000
250,000
200,000
150,000
100,000
50,000
0
Jan-83
Jul-88
Dec-93
Jun-99
Dec-04
Jun-10

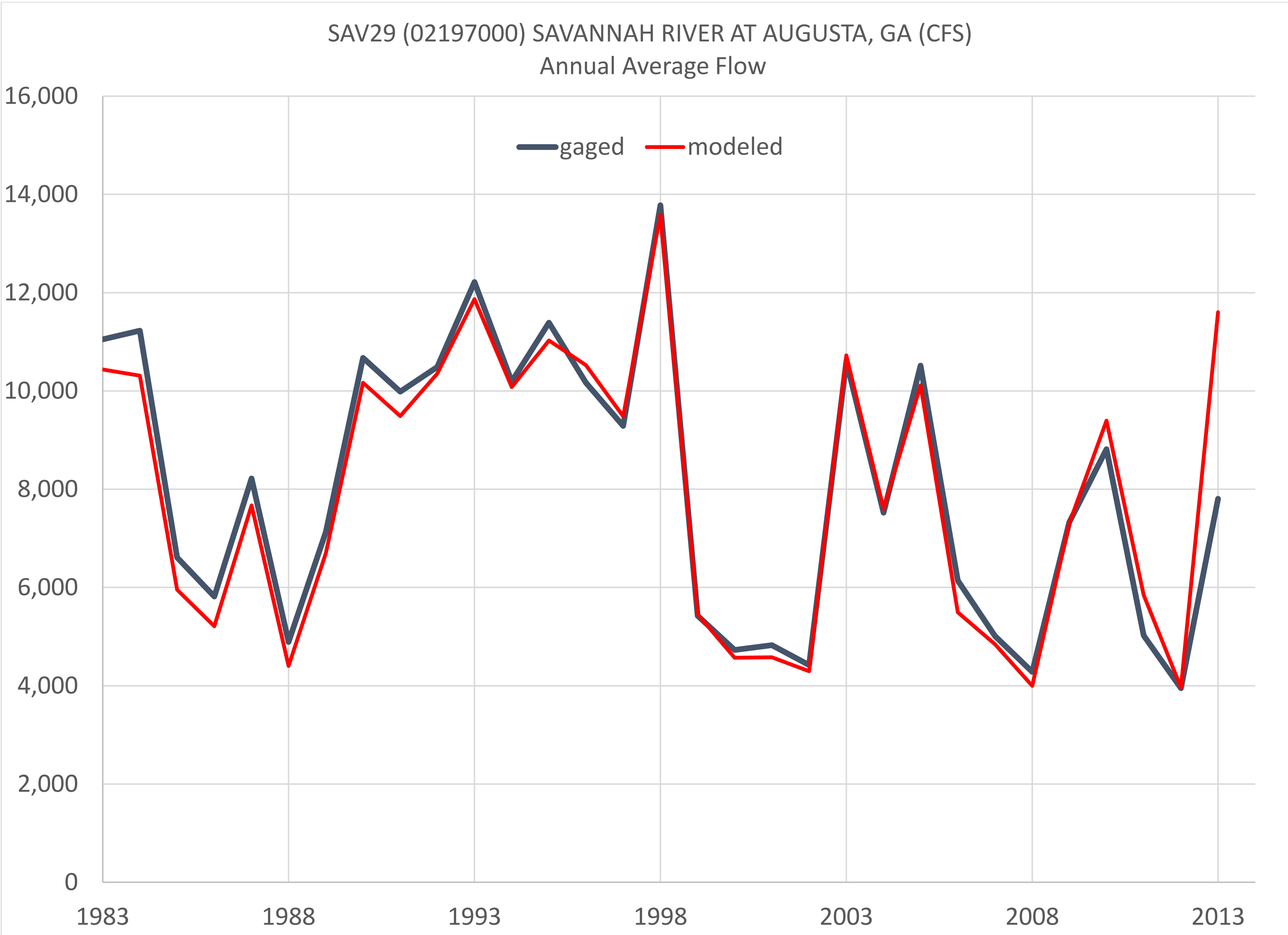

SAV12 (02187252) SAVANNAH RIVER BELOW HARTWELL LK NR HARTWELL, GA (CFS)
Annual Average Flow
gaged
modeled
5,000
4,500
4,000
3,500
3,000
2,500
2,000
1,500
1,000
500
0
1983
1988
1993
1998
2003
2008
2013

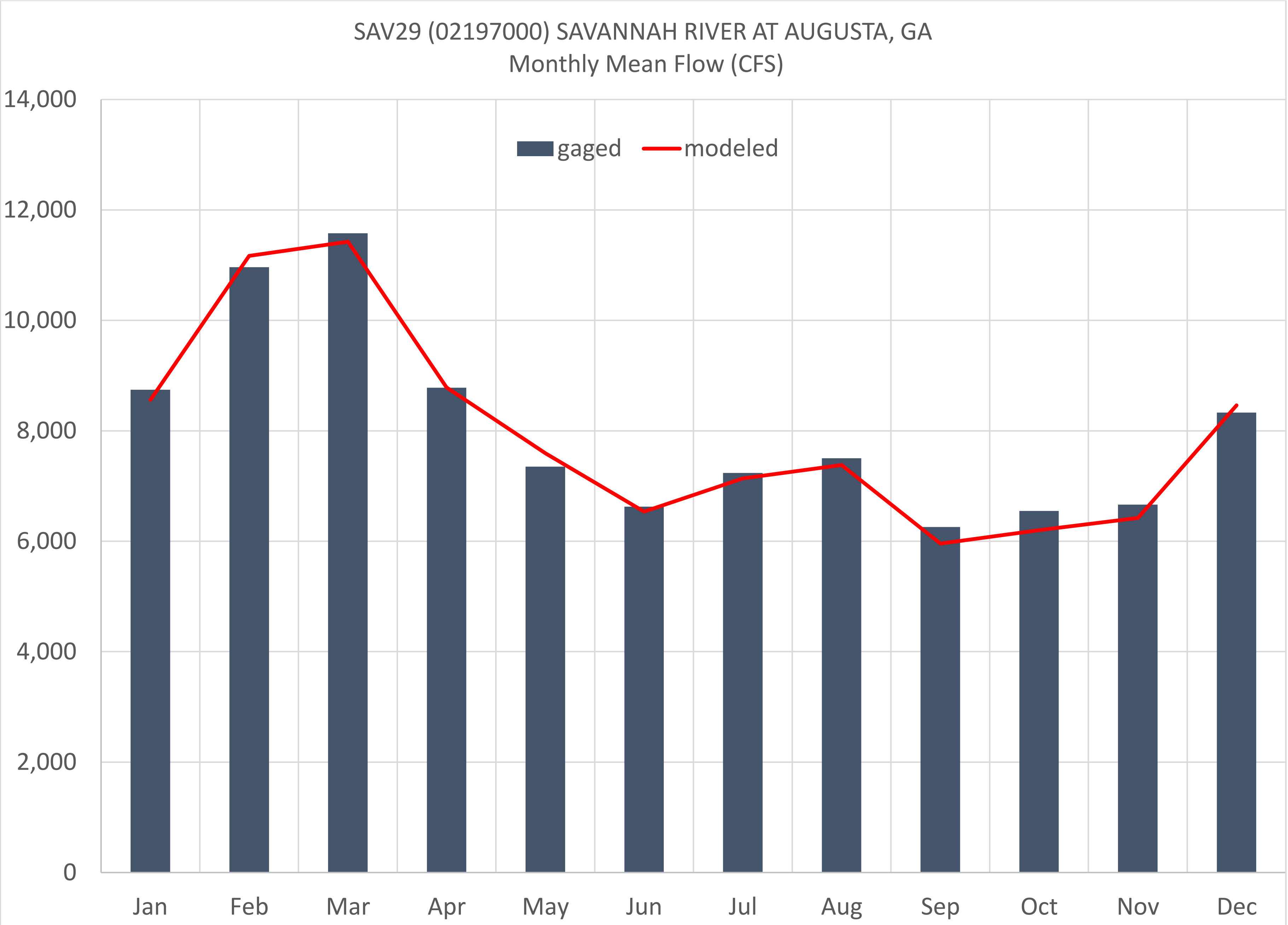

SAV12 (02187252) SAVANNAH RIVER BELOW HARTWELL LK NR HARTWELL, GA
Monthly Mean Flow (CFS)
gaged
modeled
4,000
3,500
3,000
2,500
2,000
1,500
1,000
500
0
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec


SAV12 (02187252) SAVANNAH RIVER BELOW HARTWELL LK NR HARTWELL, GA
Monthly Flow Percentiles (CFS)
gaged
modeled
10000
9000
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

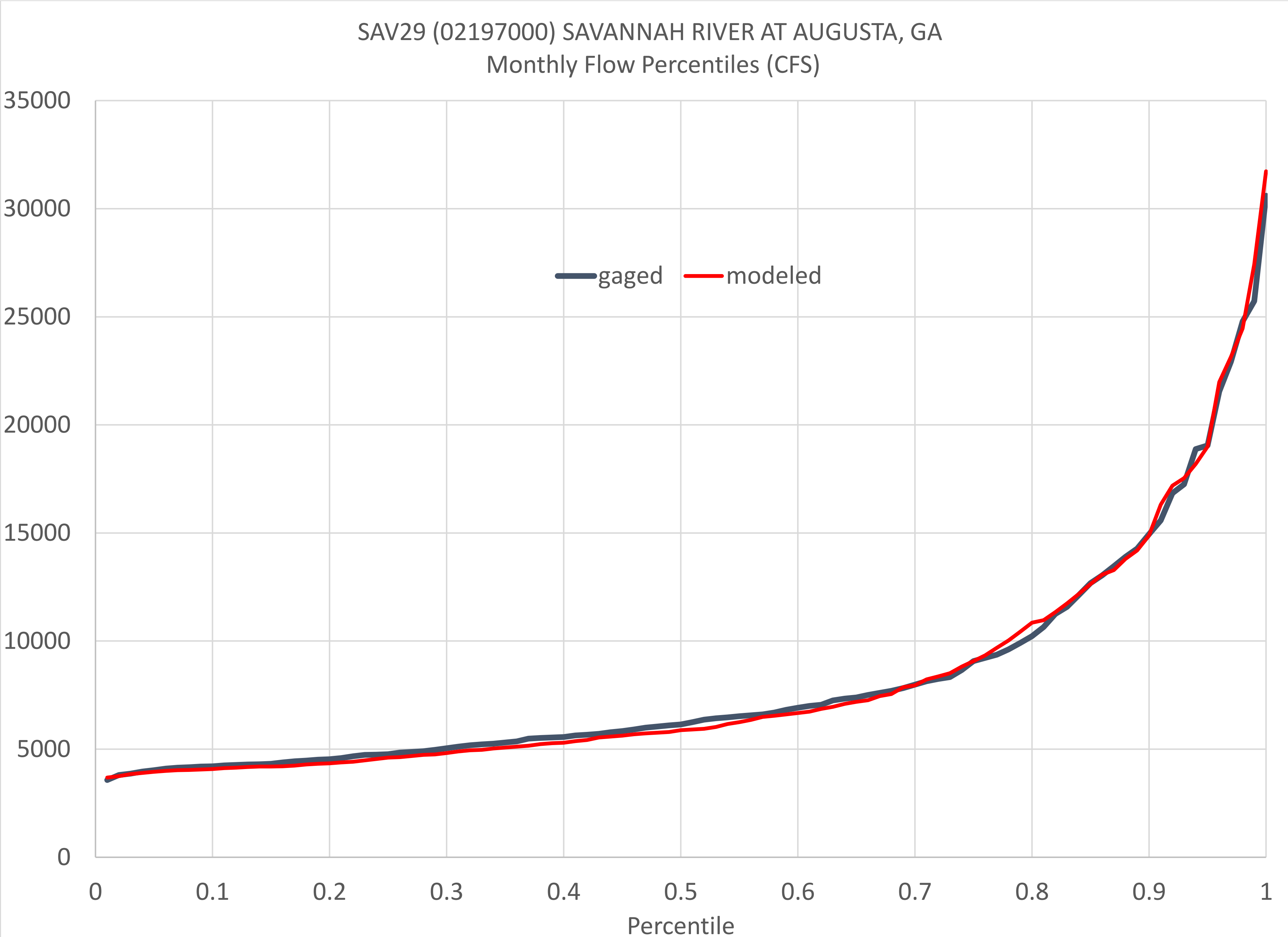

SAV29 (02197000) SAVANNAH RIVER AT AUGUSTA, GA (CFS)
modeled
gaged
35,000
30,000
25,000
20,000
15,000
10,000
5,000
0
Jan-83
Jul-88
Dec-93
Jun-99
Dec-04
Jun-10

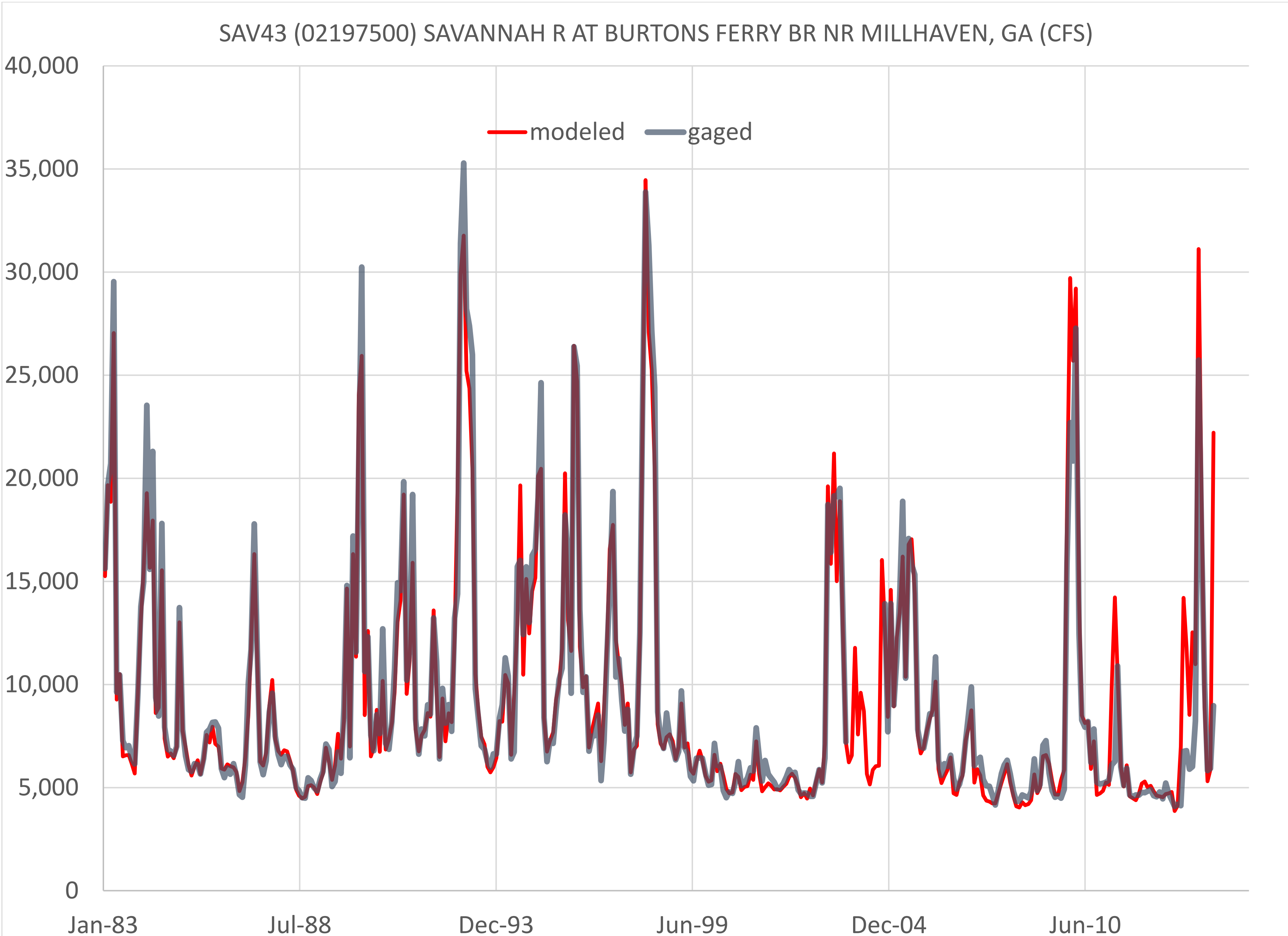

SAV29 (02197000) SAVANNAH RIVER AT AUGUSTA, GA
Cumulative Flow (CFS)
modeled
gaged
3,500,000
3,000,000
2,500,000
2,000,000
1,500,000
1,000,000
500,000
0
Jan-83
Jul-88
Dec-93
Jun-99
Dec-04
Jun-10


SAV29 (02197000) SAVANNAH RIVER AT AUGUSTA, GA (CFS)
Annual Average Flow
gaged
modeled
16,000
14,000
12,000
10,000
8,000
6,000
4,000
2,000
0
1983
1988
1993
1998
2003
2008
2013

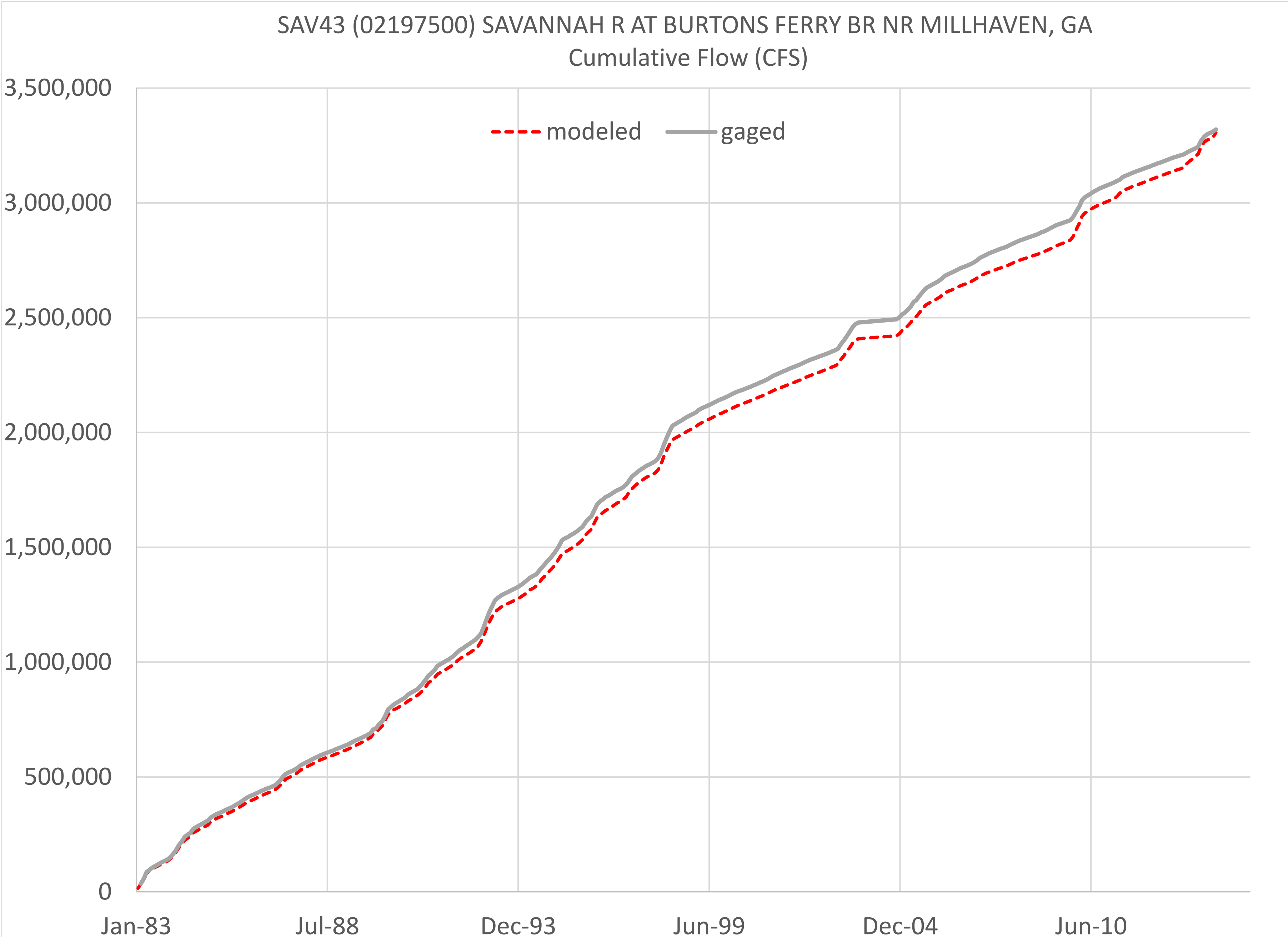


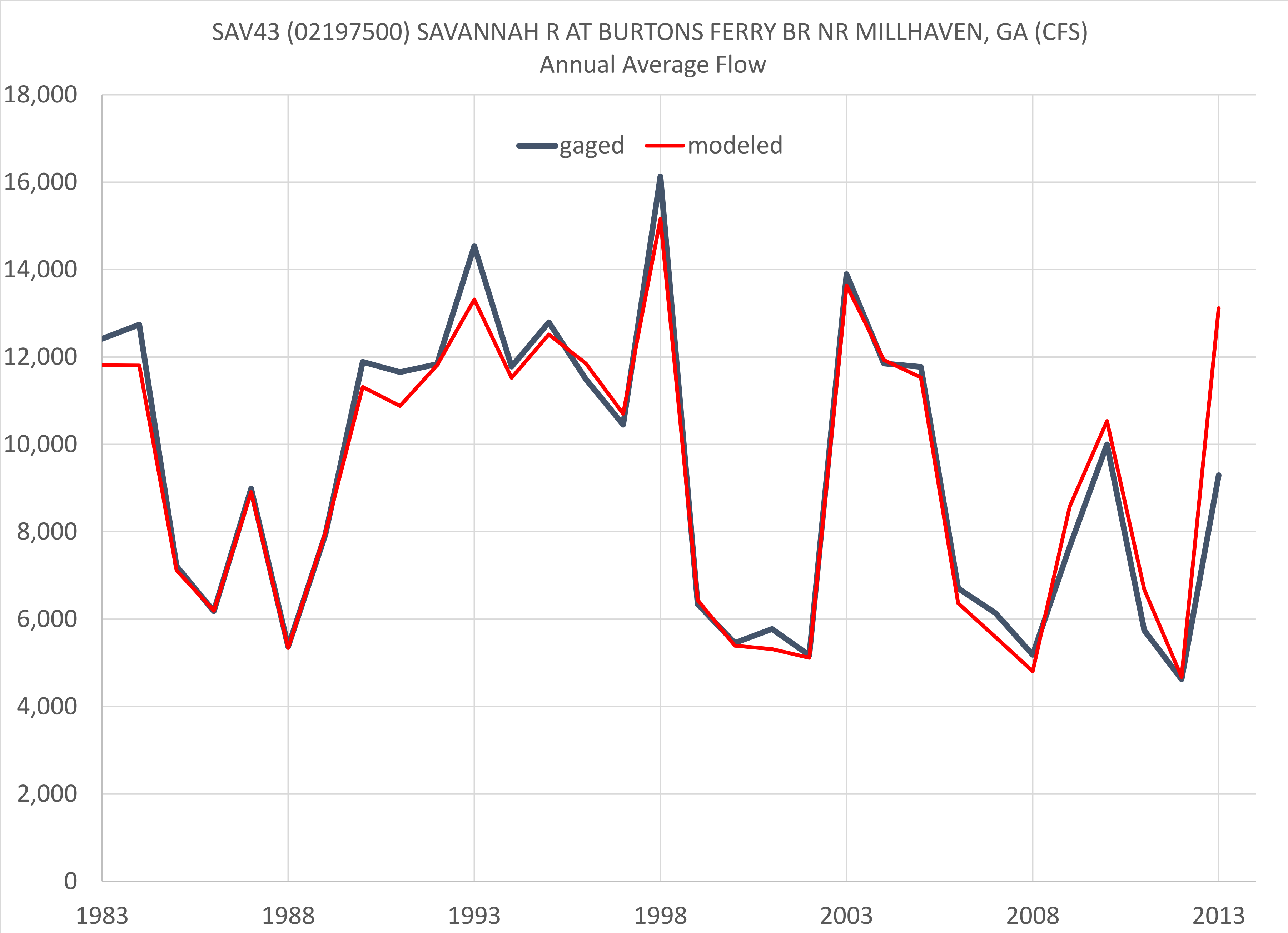
SAV29 (02197000) SAVANNAH RIVER AT AUGUSTA, GA
Monthly Mean Flow (CFS)
14,000
12,000
10,000
8,000
6,000
4,000
2,000
0
gaged
modeled
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec


SAV29 (02197000) SAVANNAH RIVER AT AUGUSTA, GA
Monthly Flow Percentiles (CFS)
gaged
modeled
35000
30000
25000
20000
15000
10000
5000
0
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
Percentile

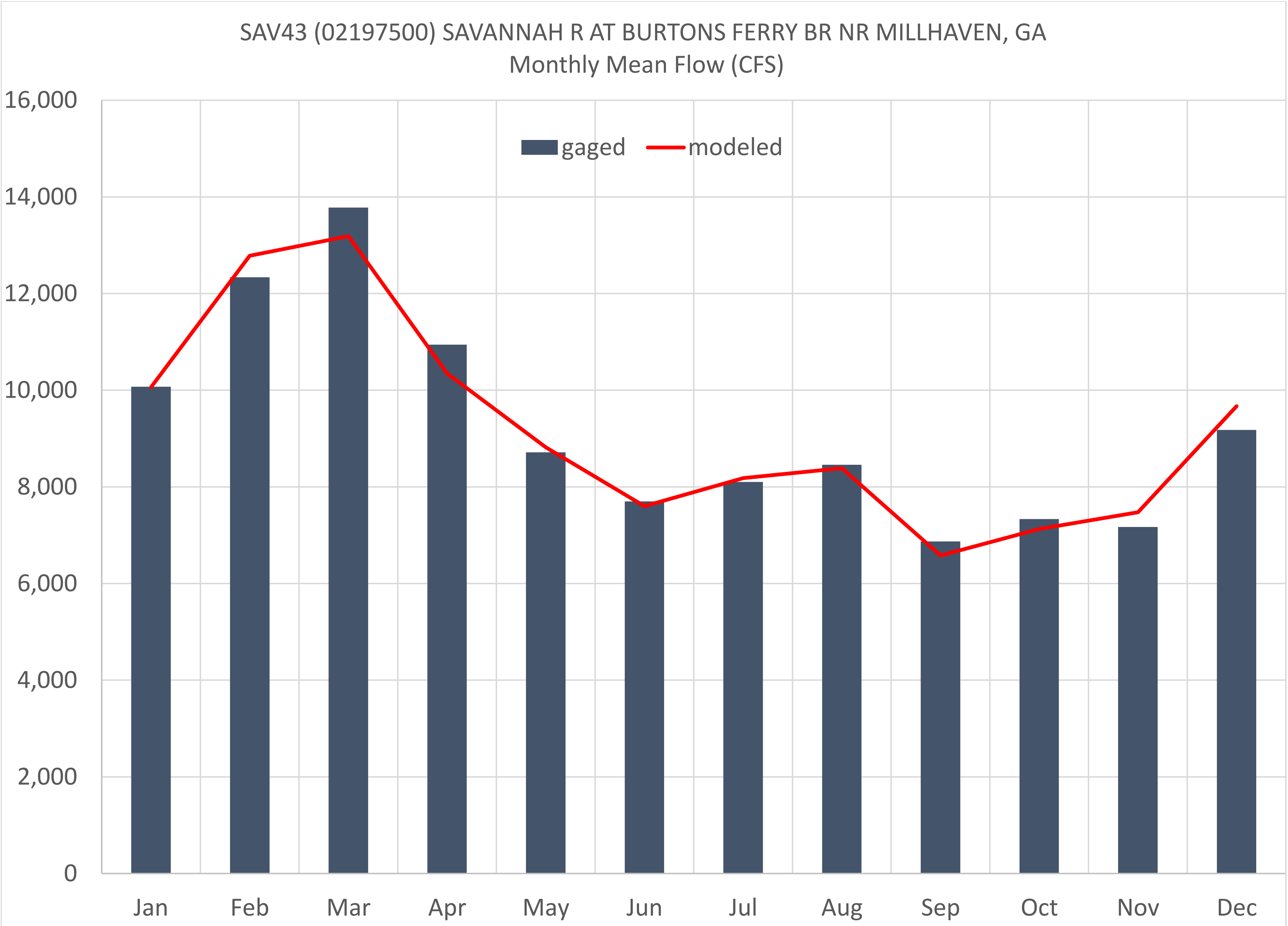


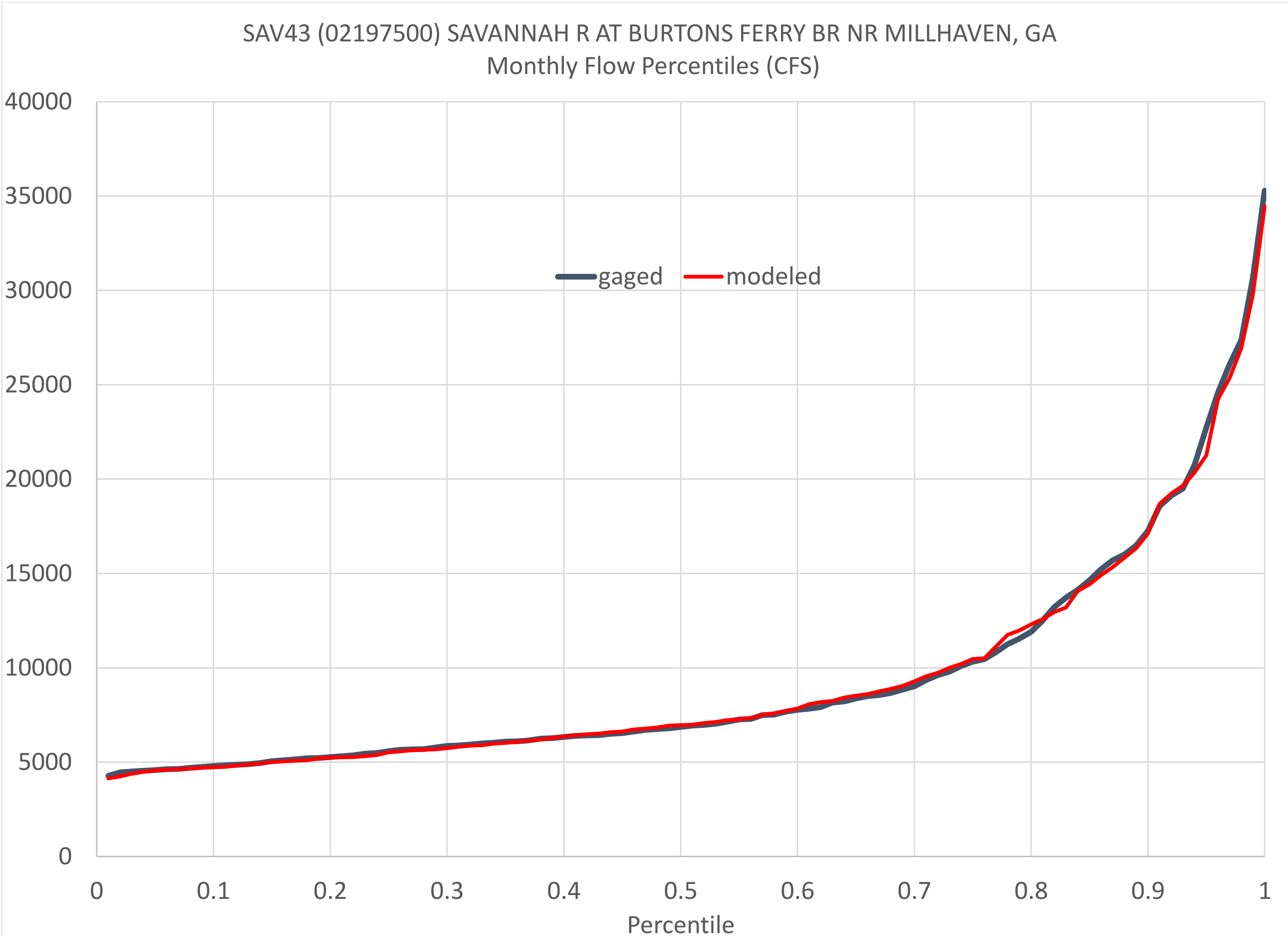
SAV43 (02197500) SAVANNAH R AT BURTONS FERRY BR NR MILLHAVEN, GA (CFS)
modeled
gaged
40,000
35,000
30,000
25,000
20,000
15,000
10,000
5,000
0
Jan-83
Jul-88
Dec-93
Jun-99
Dec-04
Jun-10

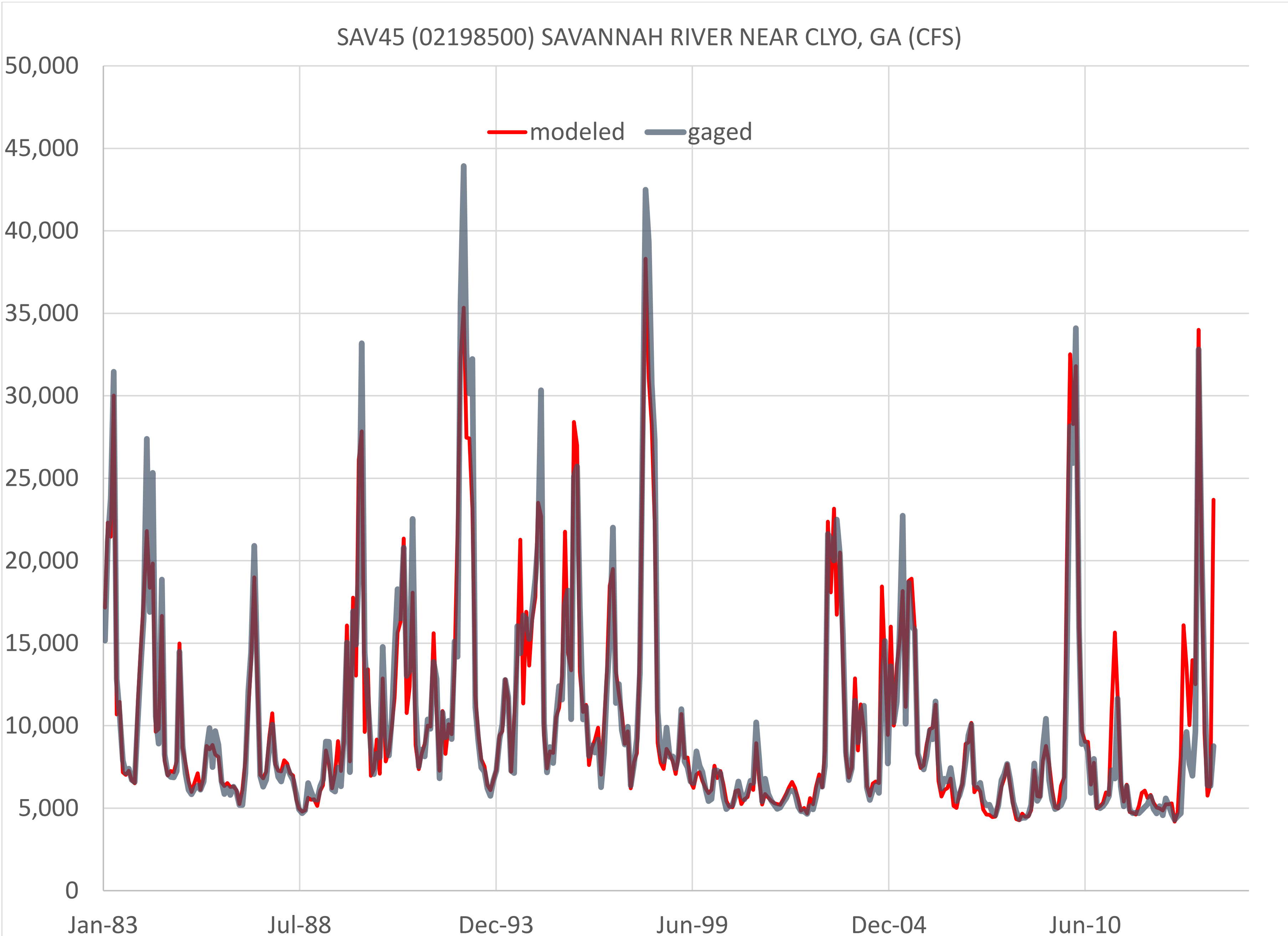

SAV43 (02197500) SAVANNAH R AT BURTONS FERRY BR NR MILLHAVEN, GA
Cumulative Flow (CFS)
modeled
gaged
3,500,000
3,000,000
2,500,000
2,000,000
1,500,000
1,000,000
500,000
0
Jan-83
Jul-88
Dec-93
Jun-99
Dec-04
Jun-10



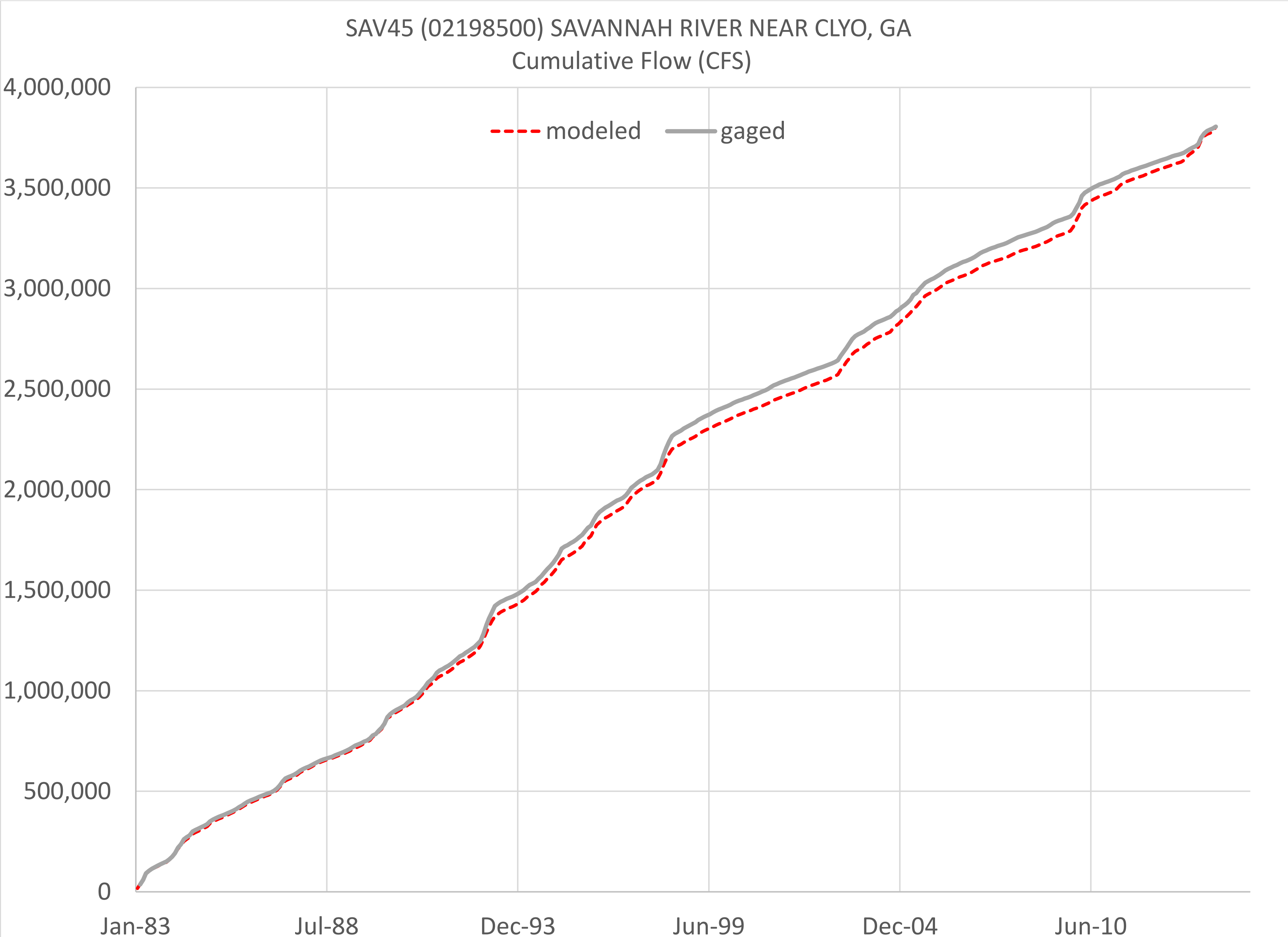
SAV43 (02197500) SAVANNAH R AT BURTONS FERRY BR NR MILLHAVEN, GA (CFS)
Annual Average Flow
gaged
modeled
18,000
16,000
14,000
12,000
10,000
8,000
6,000
4,000
2,000
0
1983
1988
1993
1998
2003
2008
2013


SAV43 (02197500) SAVANNAH R AT BURTONS FERRY BR NR MILLHAVEN, GA
Monthly Mean Flow (CFS)
gaged
modeled
16,000
14,000
12,000
10,000
8,000
6,000
4,000
2,000
0
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec

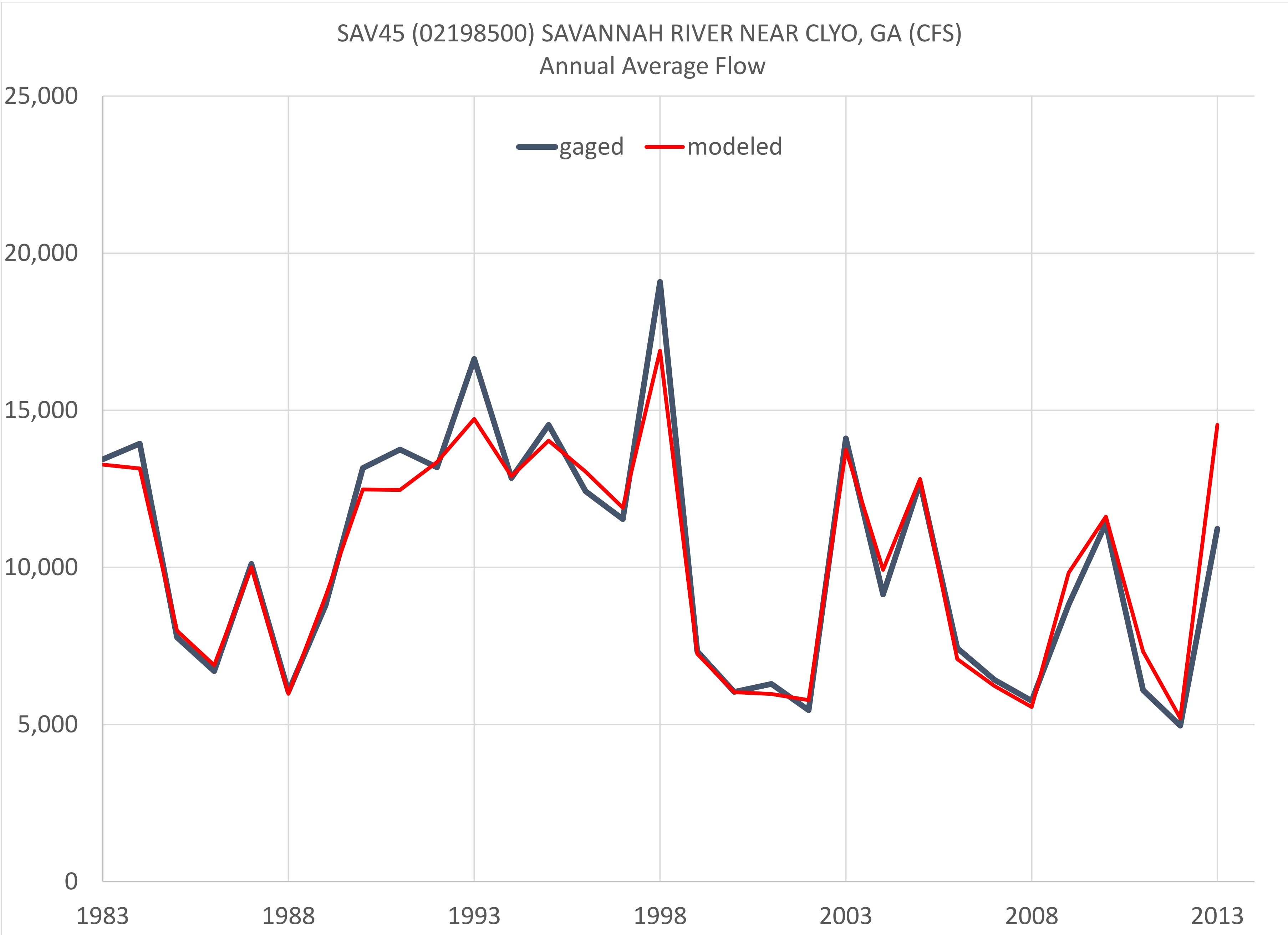

SAV43 (02197500) SAVANNAH R AT BURTONS FERRY BR NR MILLHAVEN, GA
Monthly Flow Percentiles (CFS)
gaged
modeled
40000
35000
30000
25000
20000
15000
10000
5000
0
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
Percentile



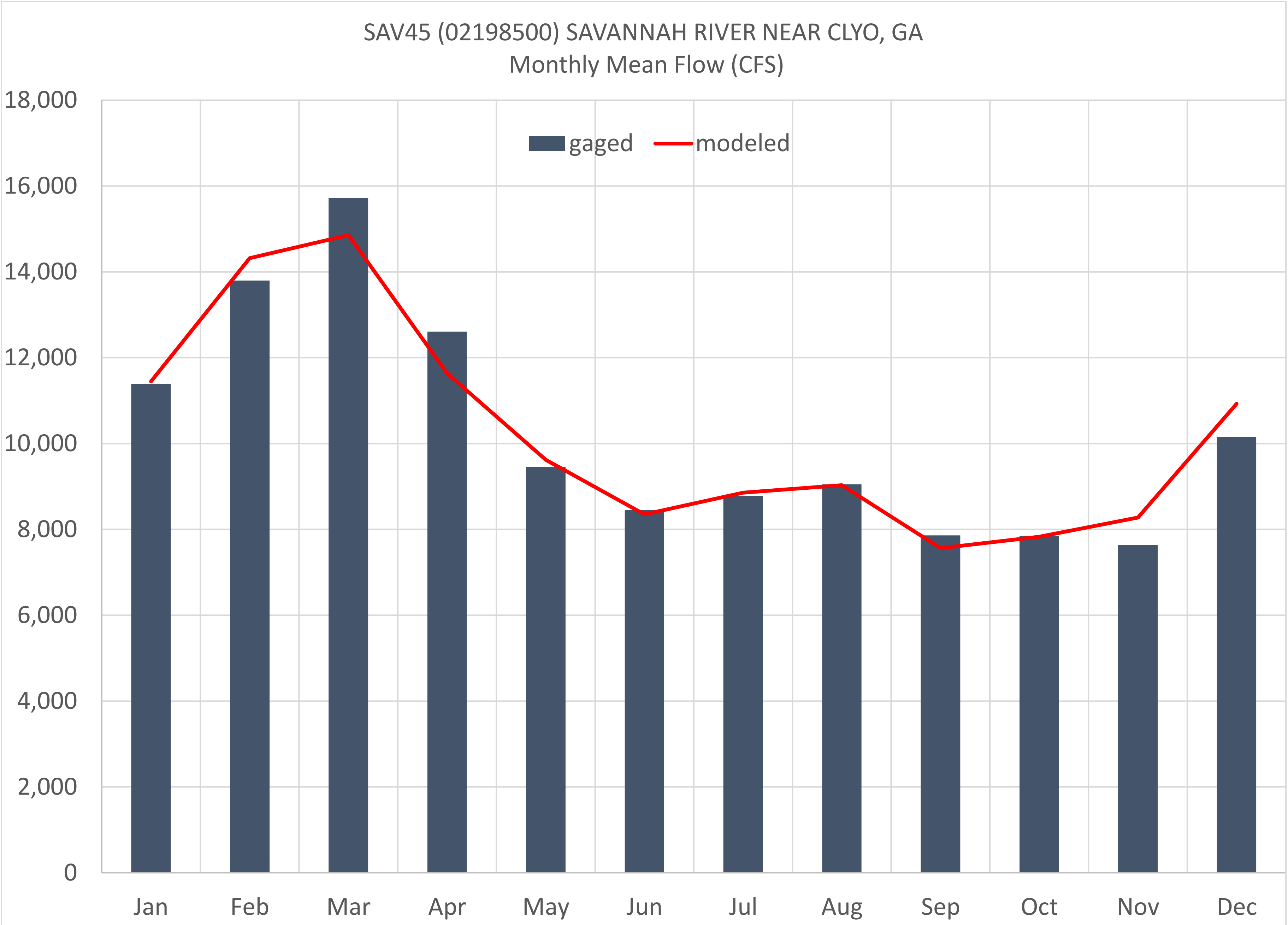
SAV45 (02198500) SAVANNAH RIVER NEAR CLYO, GA (CFS)
modeled
gaged
50,000
45,000
40,000
35,000
30,000
25,000
20,000
15,000
10,000
5,000
0
Jan-83
Jul-88
Dec-93
Jun-99
Dec-04
Jun-10

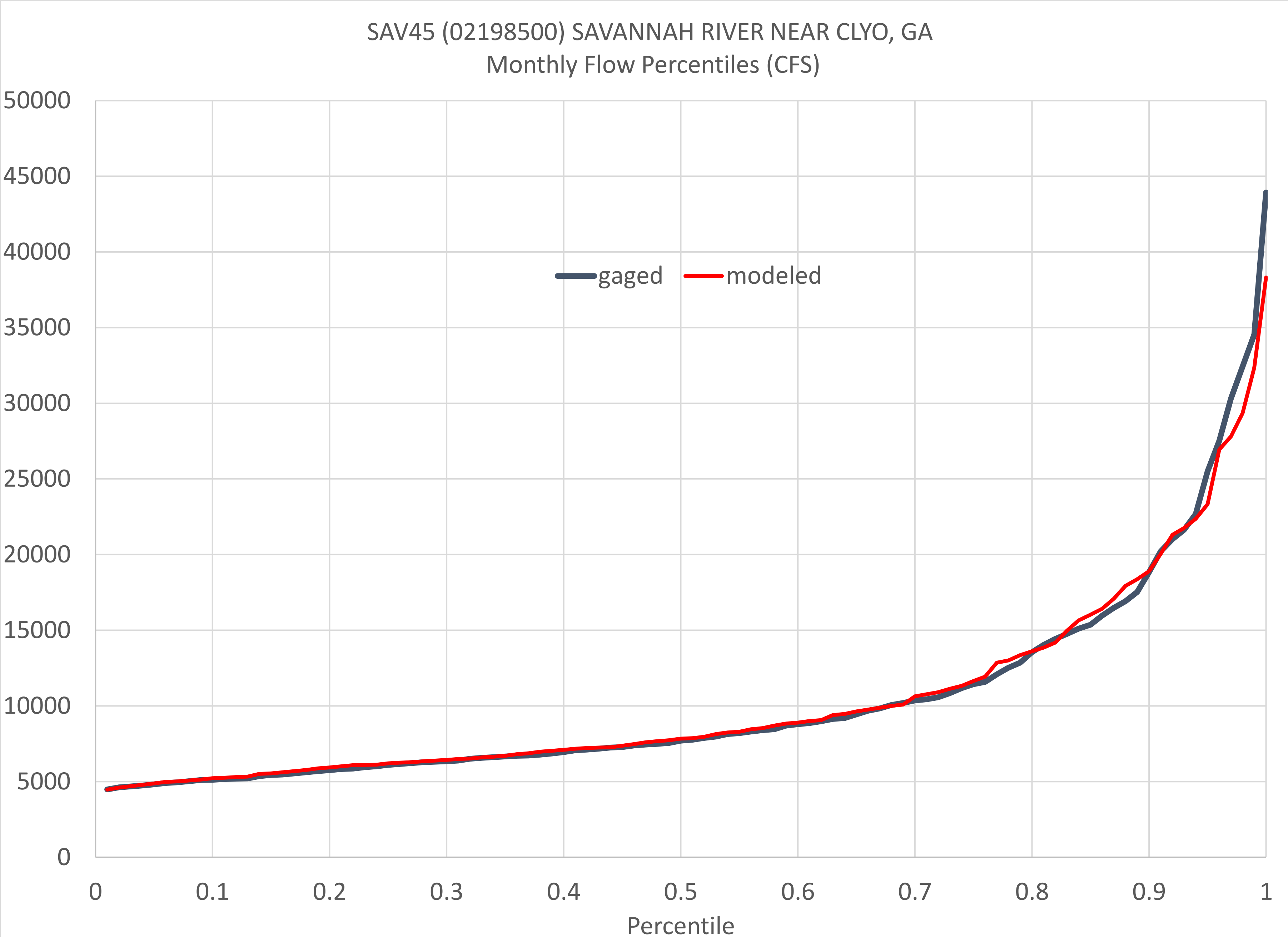


SAV45 (02198500) SAVANNAH RIVER NEAR CLYO, GA
Cumulative Flow (CFS)
modeled
gaged
4,000,000
3,500,000
3,000,000
2,500,000
2,000,000
1,500,000
1,000,000
500,000
0
Jan-83
Jul-88
Dec-93
Jun-99
Dec-04
Jun-10



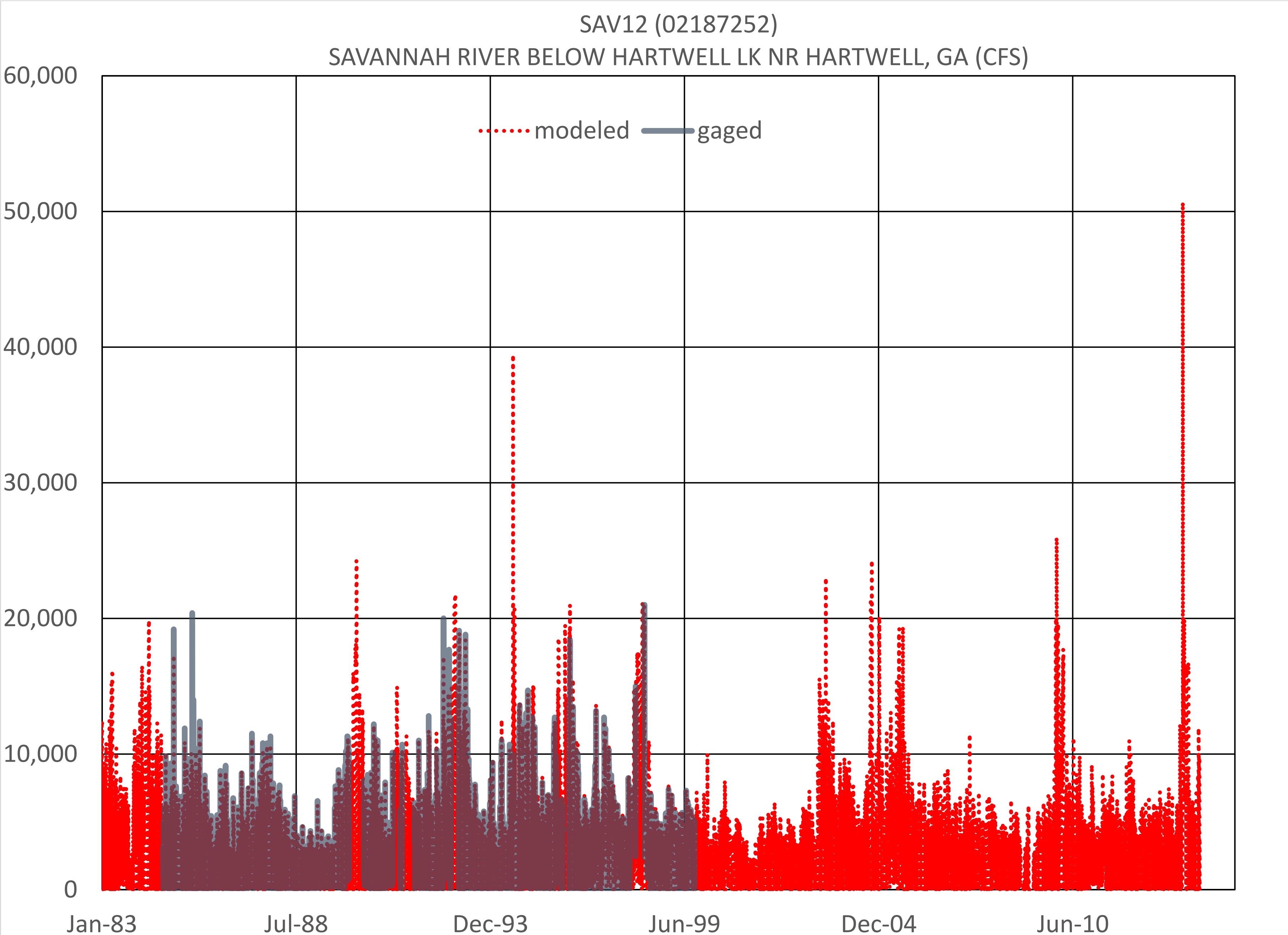
SAV45 (02198500) SAVANNAH RIVER NEAR CLYO, GA (CFS)
Annual Average Flow
gaged
modeled
25,000
20,000
15,000
10,000
5,000
0
1983
1988
1993
1998
2003
2008
2013

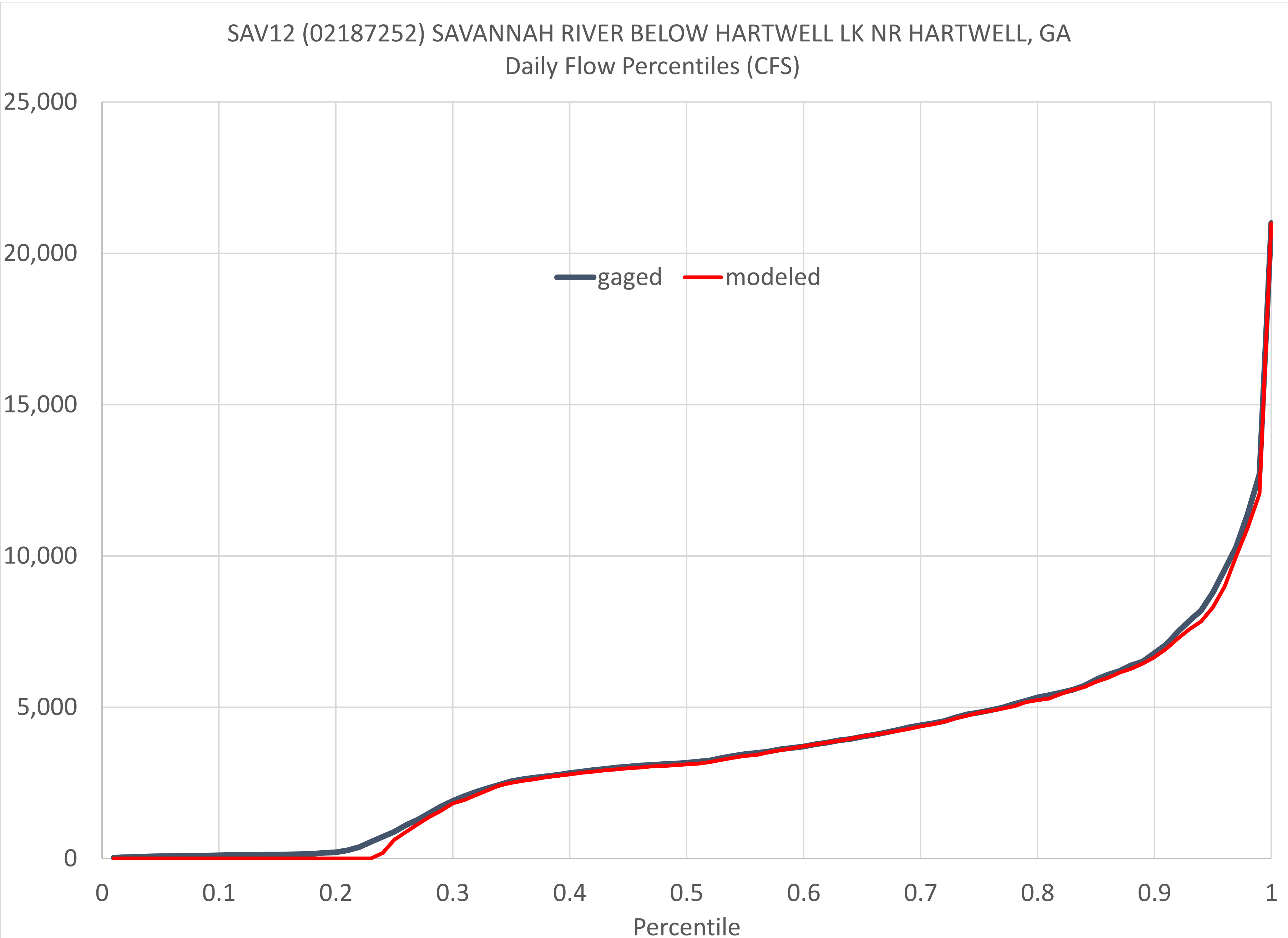

SAV45 (02198500) SAVANNAH RIVER NEAR CLYO, GA
Monthly Mean Flow (CFS)
gaged
modeled
18,000
16,000
14,000
12,000
10,000
8,000
6,000
4,000
2,000
0
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec

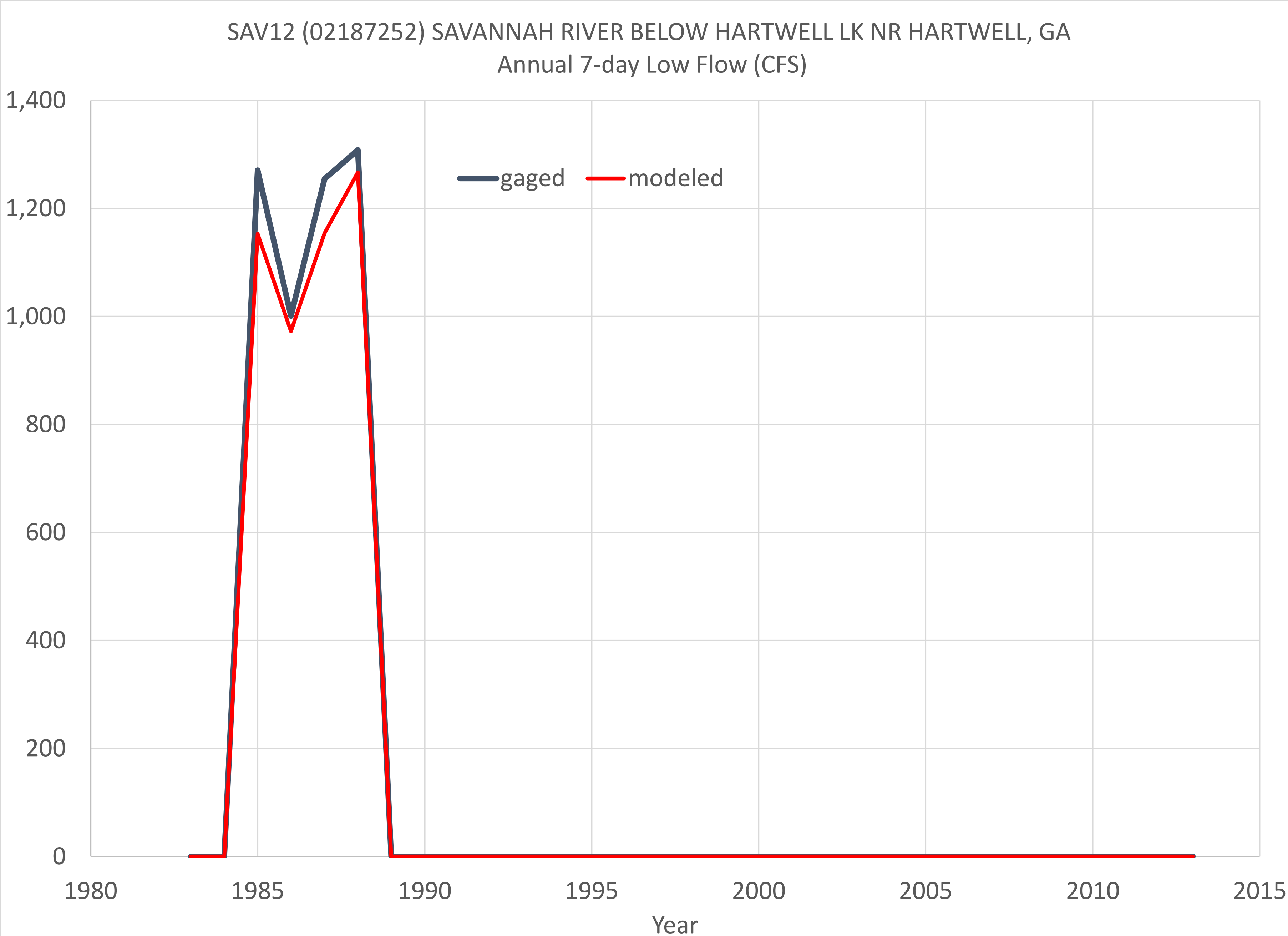

SAV45 (02198500) SAVANNAH RIVER NEAR CLYO, GA
Monthly Flow Percentiles (CFS)
50000
45000
40000
35000
30000
25000
20000
15000
10000
5000
0
gaged
modeled
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
Percentile

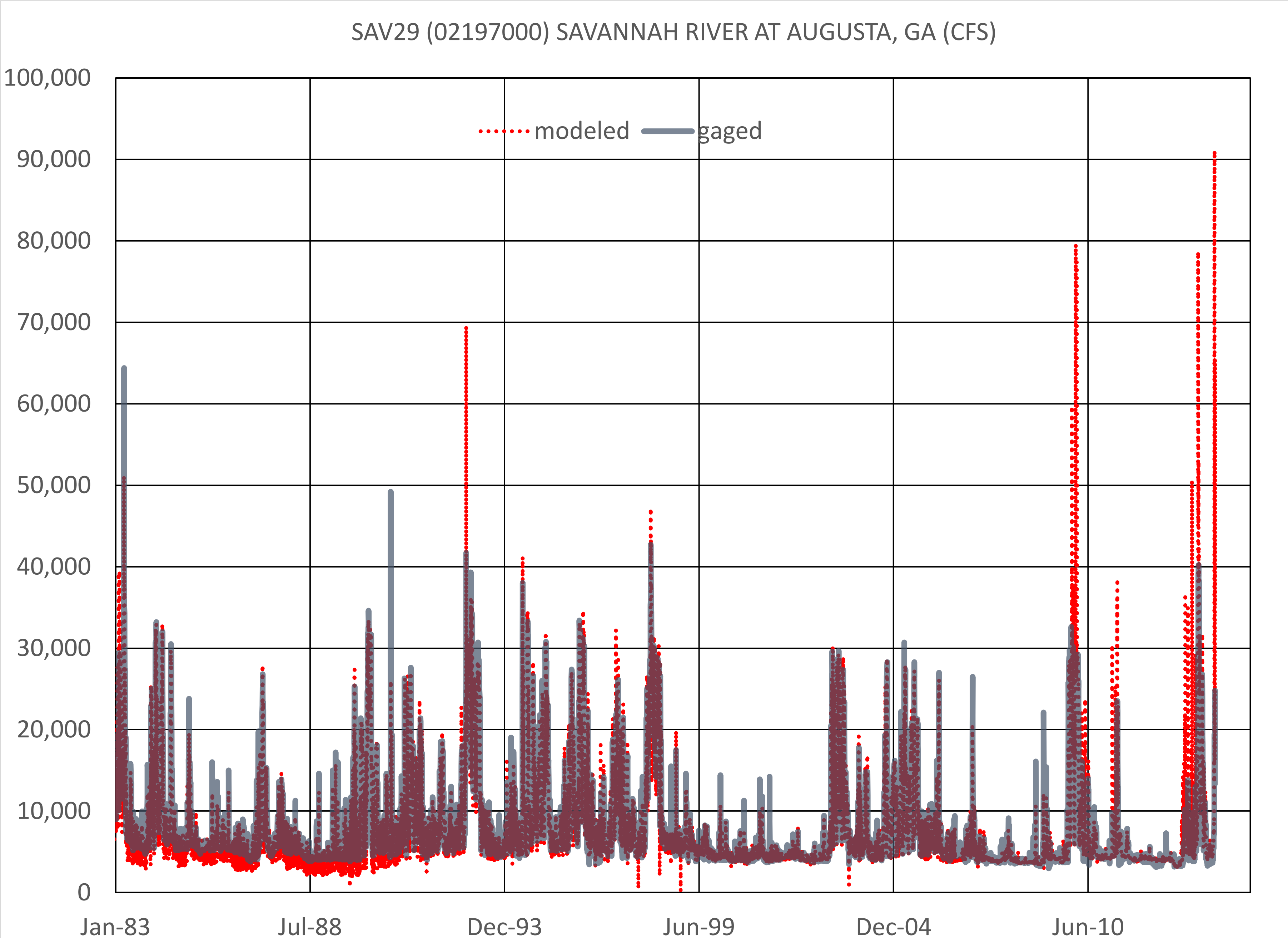
Appendix D

Prescribed Outflows Model Daily Calibration Results

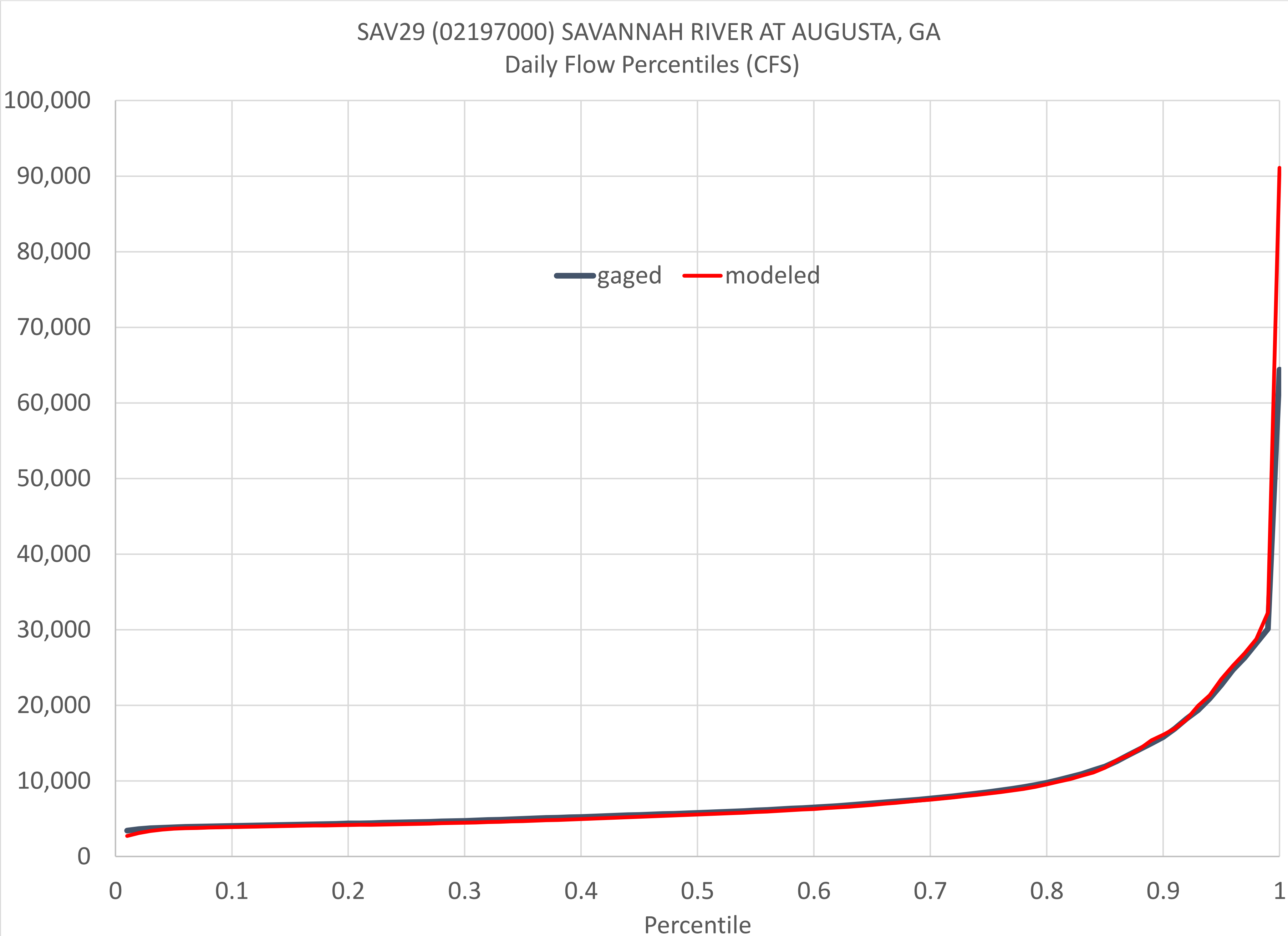

SAV12 (02187252)
SAVANNAH RIVER BELOW HARTWELL LK NR HARTWELL, GA (CFS)
modeled
gaged
60,000
50,000
40,000
30,000
20,000
10,000
0
Jan-83
Jul-88
Dec-93
Jun-99
Dec-04
Jun-10

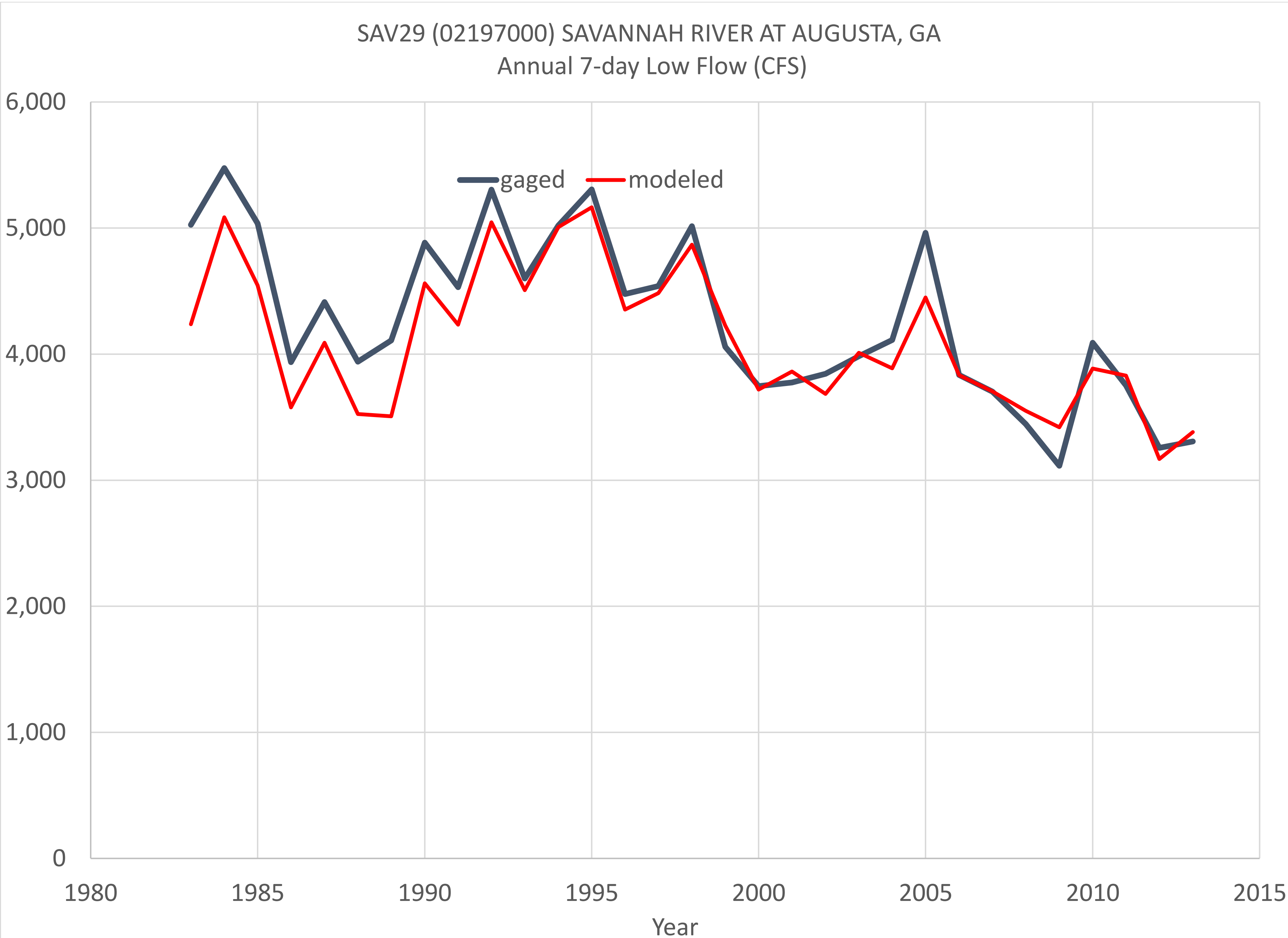

SAV12 (02187252) SAVANNAH RIVER BELOW HARTWELL LK NR HARTWELL, GA
Daily Flow Percentiles (CFS)
gaged
modeled
25,000
20,000
15,000
10,000
5,000
0
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
Percentile

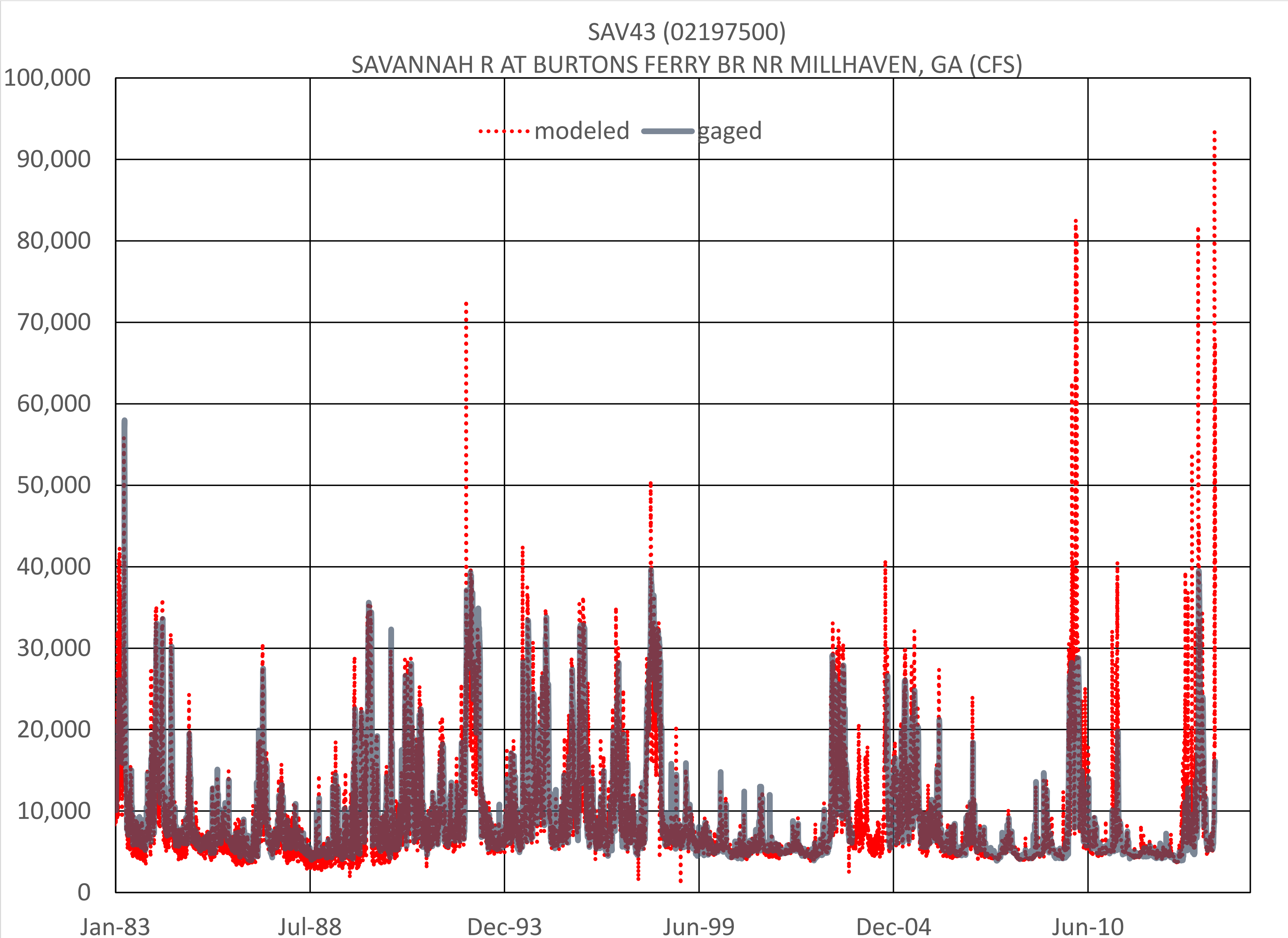

SAV12 (02187252) SAVANNAH RIVER BELOW HARTWELL LK NR HARTWELL, GA
Annual 7-day Low Flow (CFS)
1,400
1,200
1,000
800
600
400
200
0
1980
1985
1990
1995
2000
2005
2010
2015
Year
gaged
modeled

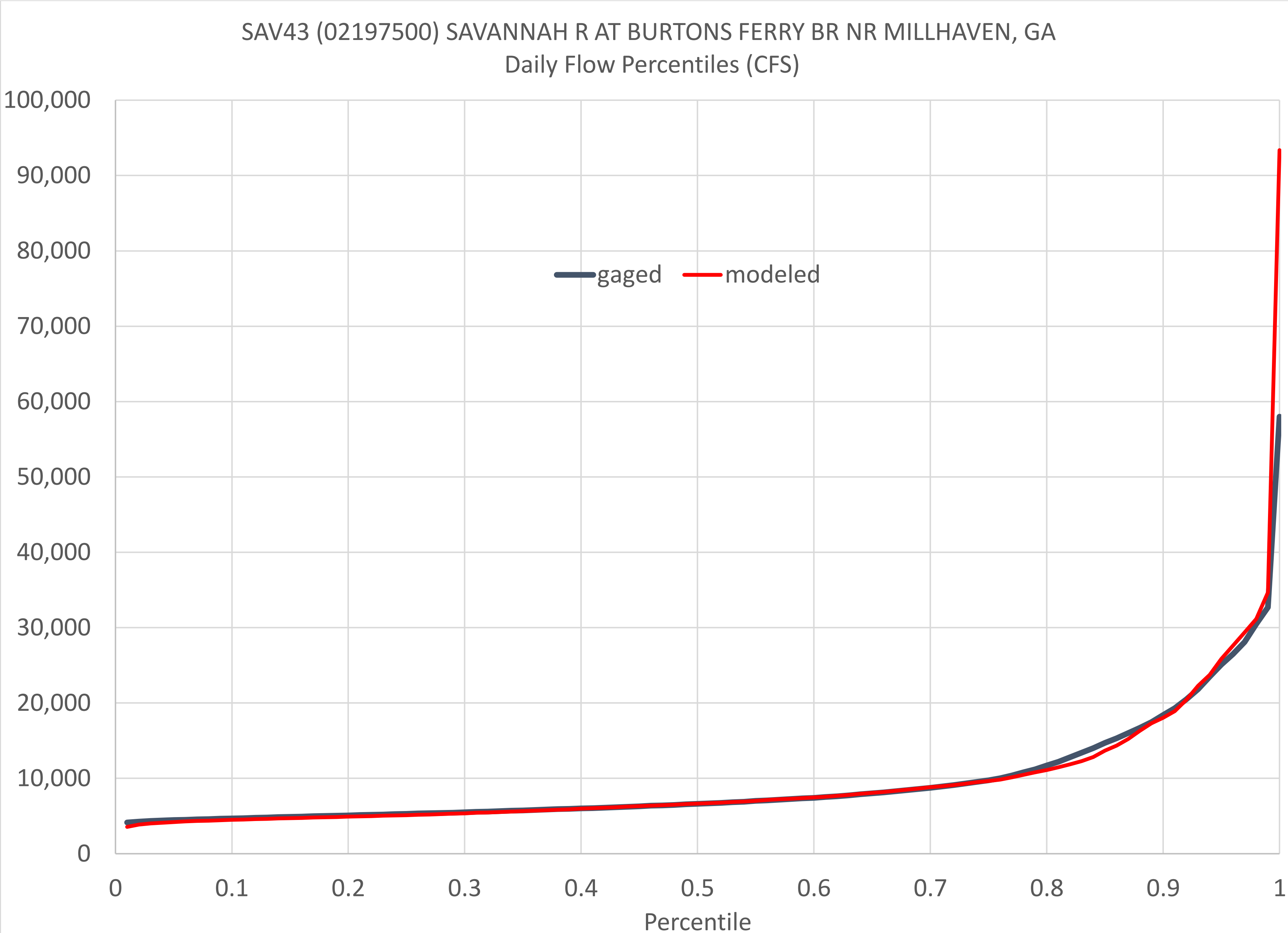


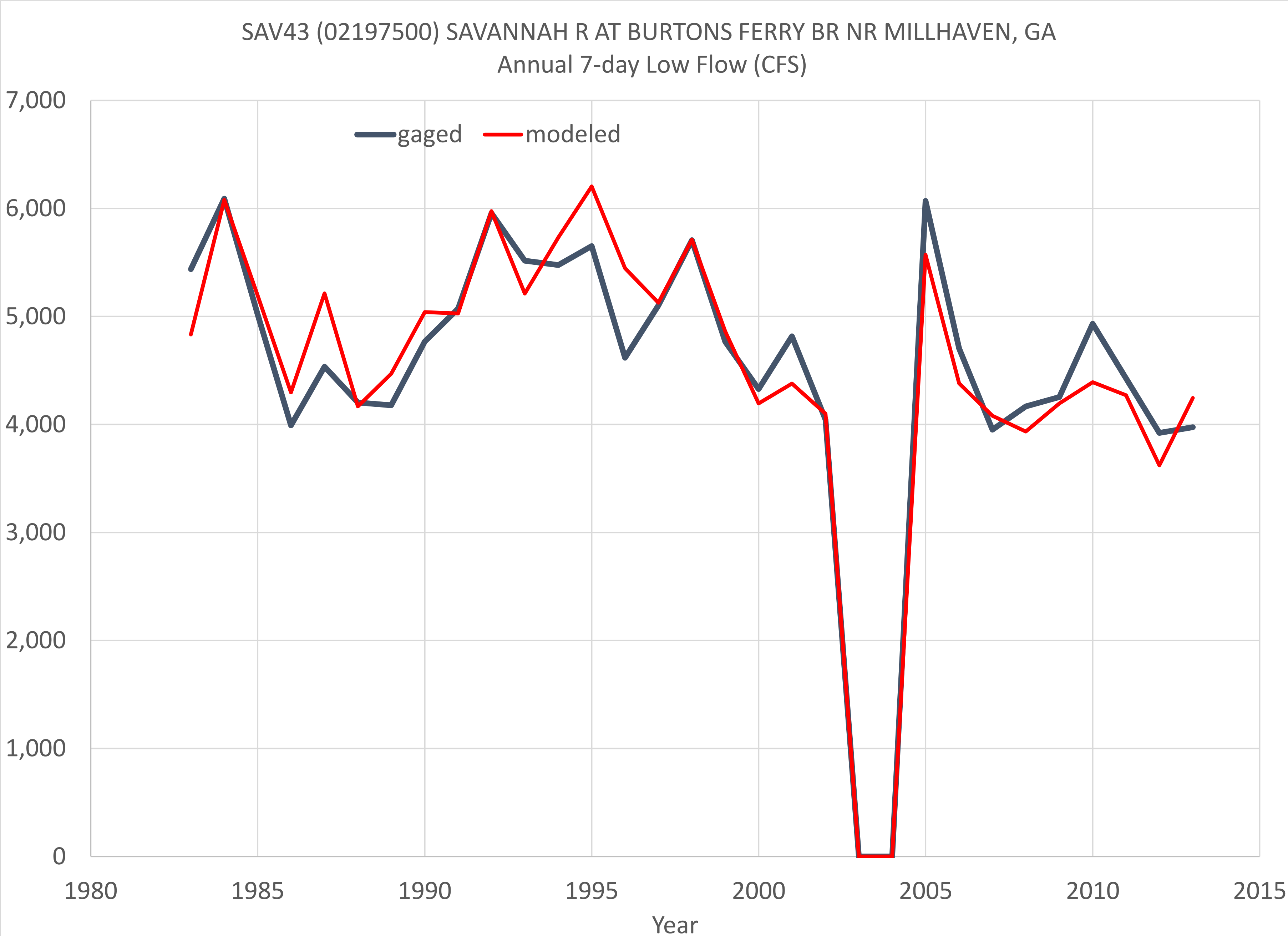
SAV29 (02197000) SAVANNAH RIVER AT AUGUSTA, GA (CFS)
modeled
gaged
100,000
90,000
80,000
70,000
60,000
50,000
40,000
30,000
20,000
10,000
0
Jan-83
Jul-88
Dec-93
Jun-99
Dec-04
Jun-10

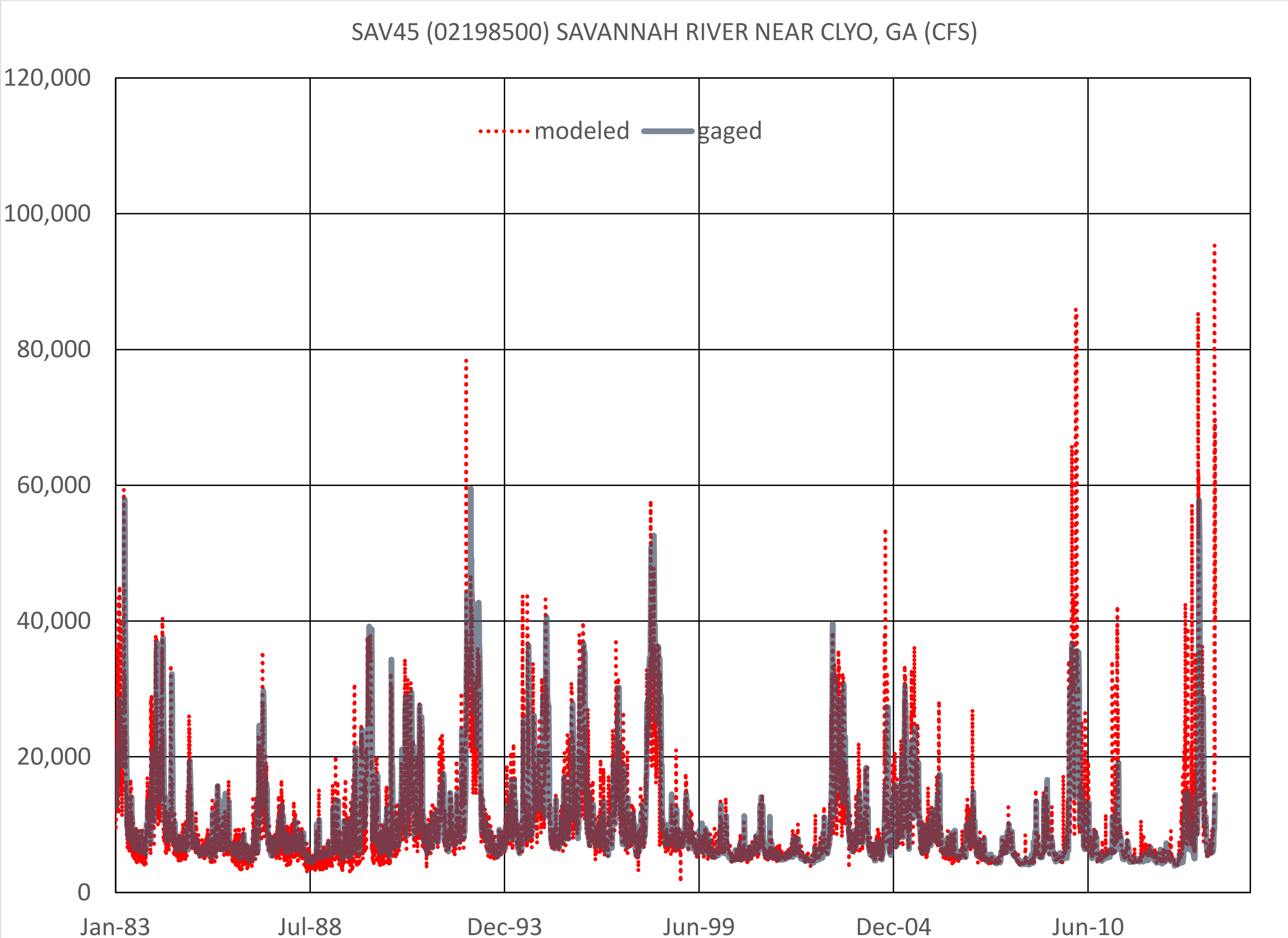

SAV29 (02197000) SAVANNAH RIVER AT AUGUSTA, GA
Daily Flow Percentiles (CFS)
100,000
90,000
80,000
70,000
60,000
50,000
40,000
30,000
20,000
10,000
0
gaged
modeled
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
Percentile


SAV29 (02197000) SAVANNAH RIVER AT AUGUSTA, GA
Annual 7-day Low Flow (CFS)
gaged
modeled
6,000
5,000
4,000
3,000
2,000
1,000
0
1980
1985
1990
1995
2000
2005
2010
2015
Year

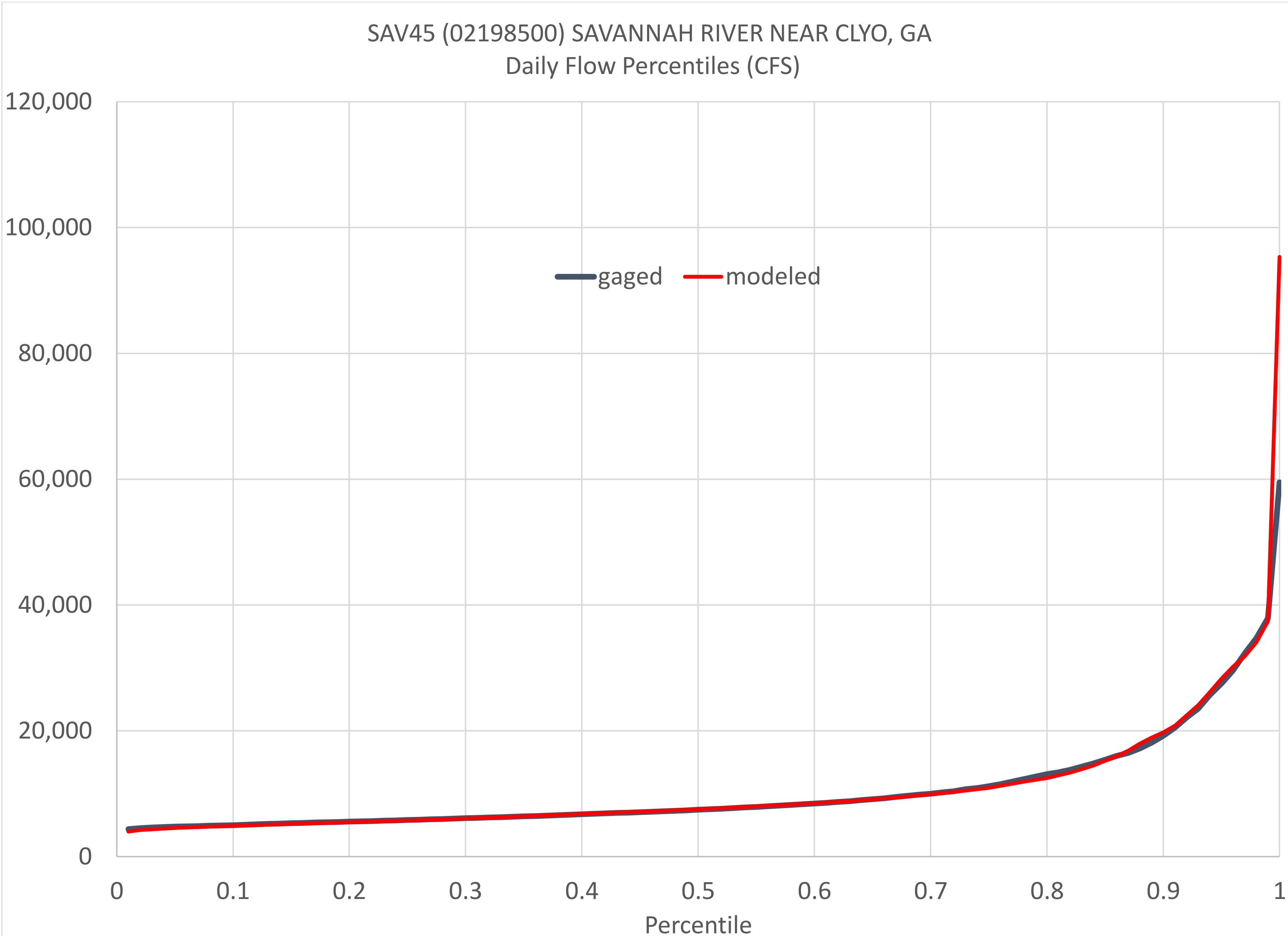

SAV43 (02197500)
SAVANNAH R AT BURTONS FERRY BR NR MILLHAVEN, GA (CFS)
modeled
gaged
100,000
90,000
80,000
70,000
60,000
50,000
40,000
30,000
20,000
10,000
0
Jan-83
Jul-88
Dec-93
Jun-99
Dec-04
Jun-10

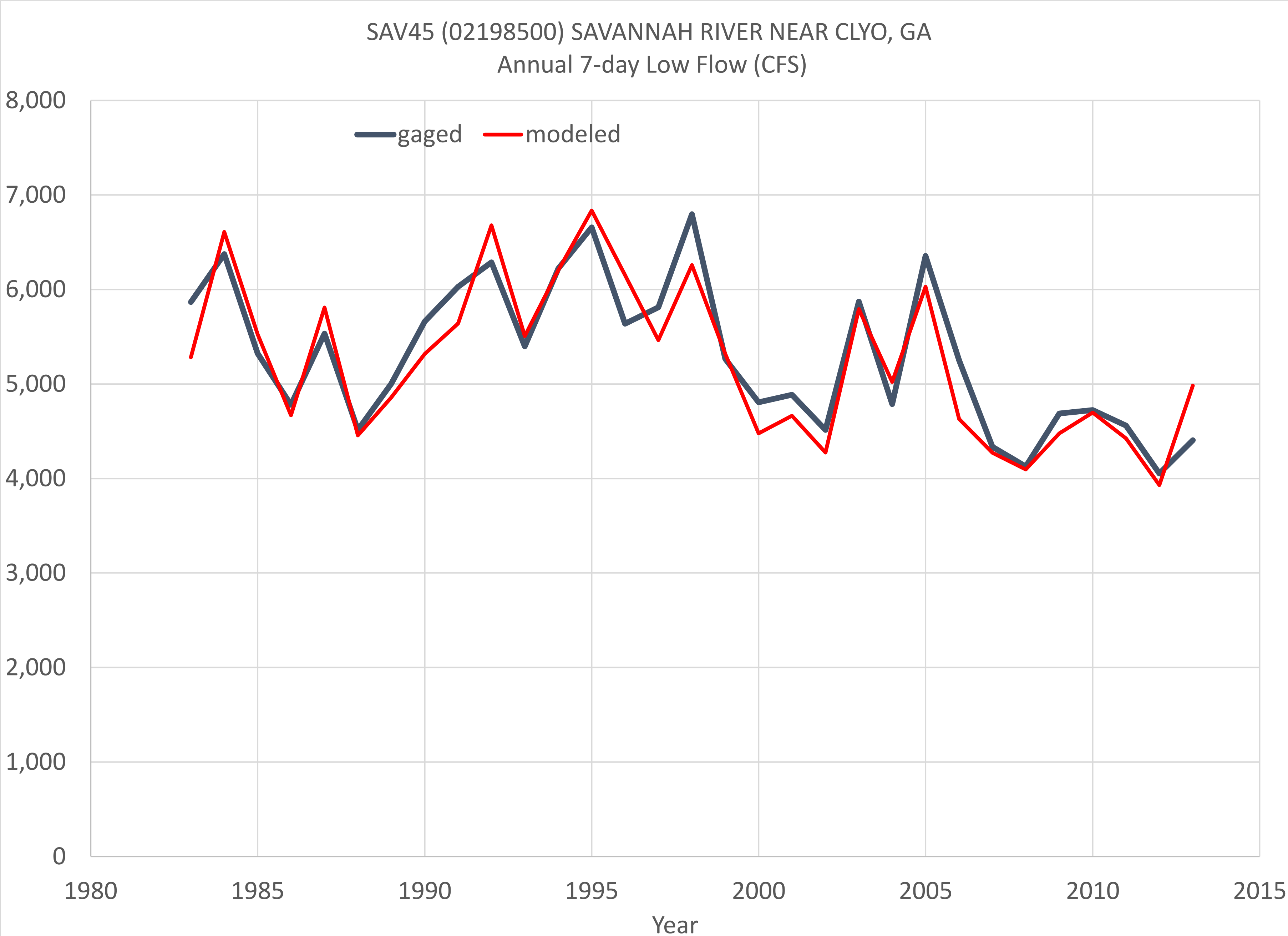

SAV43 (02197500) SAVANNAH R AT BURTONS FERRY BR NR MILLHAVEN, GA
Daily Flow Percentiles (CFS)
100,000
90,000
80,000
70,000
60,000
50,000
40,000
30,000
20,000
10,000
0
gaged
modeled
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
Percentile


SAV43 (02197500) SAVANNAH R AT BURTONS FERRY BR NR MILLHAVEN, GA
Annual 7-day Low Flow (CFS)
7,000
6,000
5,000
4,000
3,000
2,000
1,000
0
gaged
modeled
1980
1985
1990
1995
2000
2005
2010
2015
Year



SAV45 (02198500) SAVANNAH RIVER NEAR CLYO, GA (CFS)
modeled
gaged
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


SAV45 (02198500) SAVANNAH RIVER NEAR CLYO, GA
Daily Flow Percentiles (CFS)
gaged
modeled
120,000
100,000
80,000
60,000
40,000
20,000
0
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
Percentile


SAV45 (02198500) SAVANNAH RIVER NEAR CLYO, GA
Annual 7-day Low Flow (CFS)
gaged
modeled
8,000
7,000
6,000
5,000
4,000
3,000
2,000
1,000
0
1980
1985
1990
1995
2000
2005
2010
2015
Year

Annual 7 day Low Flows: Modeled

Year	SAVANNAH RIVER BELOW HARTWELL LK NR HARTWELL, GA	SAVANNAH RIVER AT AUGUSTA, GA	SAVANNAH R AT BURTONS FERRY BR NR MILLHAVEN, GA	SAVANNAH RIVER NEAR CLYO, GA
ID->	**SAV12**	**SAV29**	**SAV43**	**SAV45**
1983		4,237.3	4,834.0	5,283.1
1984		5,086.3	6,079.6	6,609.0
1985	1,153.3	4,545.5	5,194.9	5,527.3
1986	972.6	3,576.7	4,297.0	4,667.5
1987	1,154.1	4,091.2	5,215.0	5,810.1
1988	1,267.0	3,524.7	4,166.5	4,456.4
1989		3,507.7	4,470.0	4,856.4
1990		4,562.1	5,041.1	5,319.3
1991		4,233.9	5,027.5	5,640.7
1992		5,045.0	5,976.2	6,680.3
1993		4,507.5	5,212.9	5,506.4
1994		5,007.0	5,733.0	6,204.6
1995		5,164.6	6,204.5	6,835.2
1996		4,352.5	5,447.4	6,152.7
1997		4,483.6	5,126.5	5,463.4
1998		4,868.6	5,711.5	6,259.3
1999		4,226.5	4,860.7	5,319.2
2000		3,718.5	4,195.6	4,477.5
2001		3,861.4	4,379.1	4,664.2
2002		3,683.7	4,100.2	4,274.8
2003		4,010.1		5,792.0
2004		3,886.5		5,021.9
2005		4,448.7	5,570.6	6,028.7
2006		3,832.2	4,381.8	4,630.9
2007		3,704.0	4,080.3	4,271.8
2008		3,551.0	3,934.5	4,095.0
2009		3,419.9	4,195.8	4,478.3
2010		3,884.9	4,392.3	4,696.2
2011		3,830.3	4,270.8	4,423.6
2012		3,168.0	3,622.6	3,930.1
2013		3,382.6	4,245.7	4,983.8

Annual 7 day Low Flows: Measured

Year	SAVANNAH RIVER BELOW HARTWELL LK NR HARTWELL, GA	SAVANNAH RIVER AT AUGUSTA, GA	SAVANNAH R AT BURTONS FERRY BR NR MILLHAVEN, GA	SAVANNAH RIVER NEAR CLYO, GA
ID->	**SAV12**	**SAV29**	**SAV43**	**SAV45**
1983		5,025.7	5,438.6	5,867.1
1984		5,475.7	6,091.4	6,374.3
1985	1,270.9	5,037.1	5,018.6	5,324.3
1986	1,000.9	3,935.7	3,991.4	4,780.0
1987	1,254.9	4,412.9	4,535.7	5,532.9
1988	1,308.4	3,940.0	4,204.3	4,512.9
1989		4,108.6	4,178.6	5,002.9
1990		4,884.3	4,768.6	5,662.9
1991		4,531.4	5,071.4	6,030.0
1992		5,304.3	5,955.7	6,287.1
1993		4,600.0	5,517.1	5,398.6
1994		5,020.0	5,477.1	6,221.4
1995		5,307.1	5,651.4	6,657.1
1996		4,477.1	4,618.6	5,637.1
1997		4,540.0	5,102.9	5,811.4
1998		5,014.3	5,707.1	6,797.1
1999		4,057.1	4,765.7	5,264.3
2000		3,745.7	4,328.6	4,807.1
2001		3,775.7	4,817.1	4,885.7
2002		3,844.3	4,044.3	4,512.9
2003		3,982.9		5,871.4
2004		4,112.9		4,787.1
2005		4,961.4	6,070.0	6,355.7
2006		3,835.7	4,704.3	5,251.4
2007		3,702.9	3,951.4	4,335.7
2008		3,444.3	4,167.1	4,127.1
2009		3,114.3	4,254.3	4,688.6
2010		4,090.0	4,932.9	4,722.9
2011		3,751.4	4,427.1	4,558.6
2012		3,257.1	3,921.4	4,052.9
2013		3,307.1	3,974.3	4,405.7

Note: blank cells indicate years when sufficient gaged flows were not availalable for comparison.

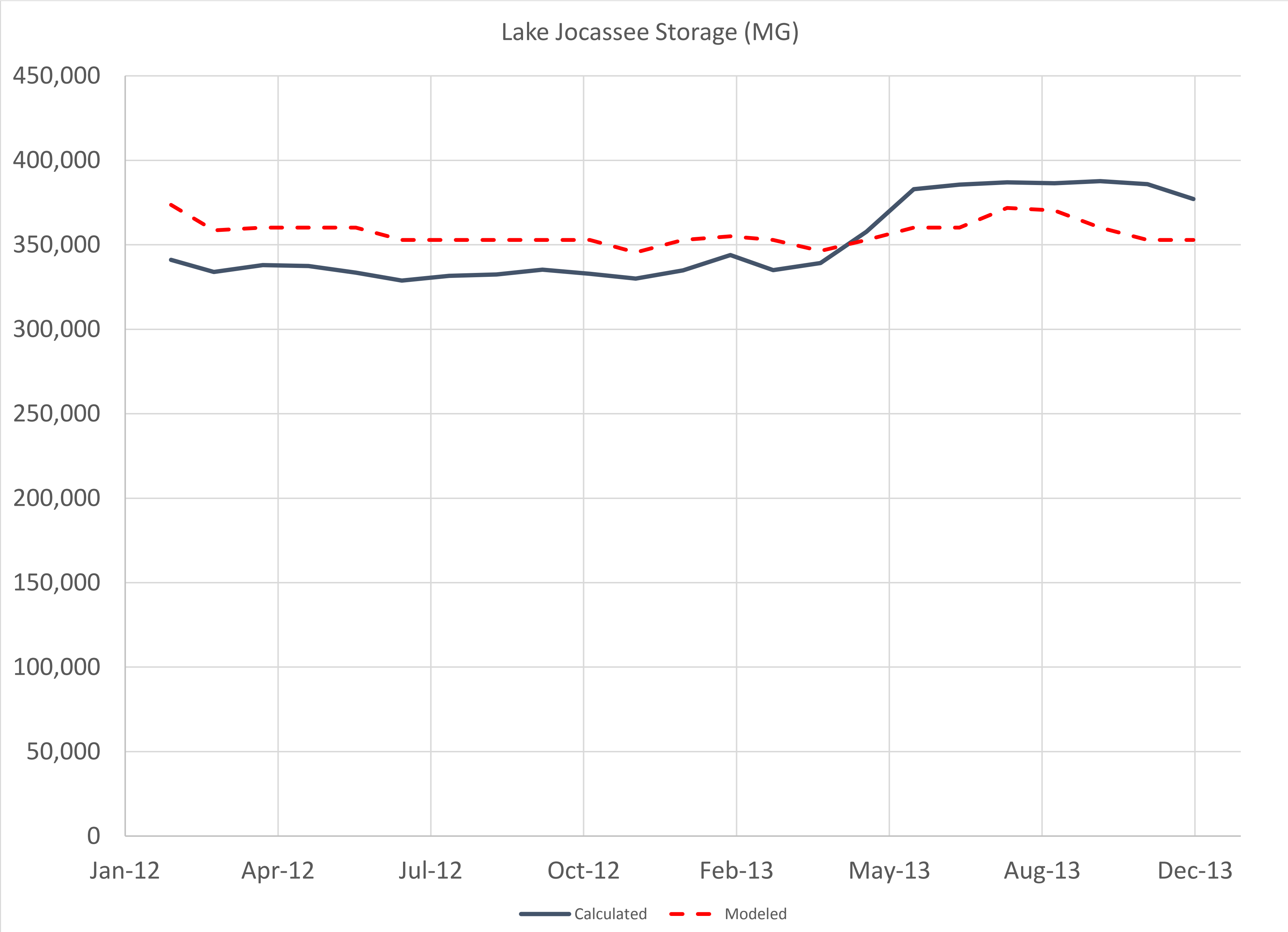
Approximate 7Q10 Comparison - Modeled vs. Measured

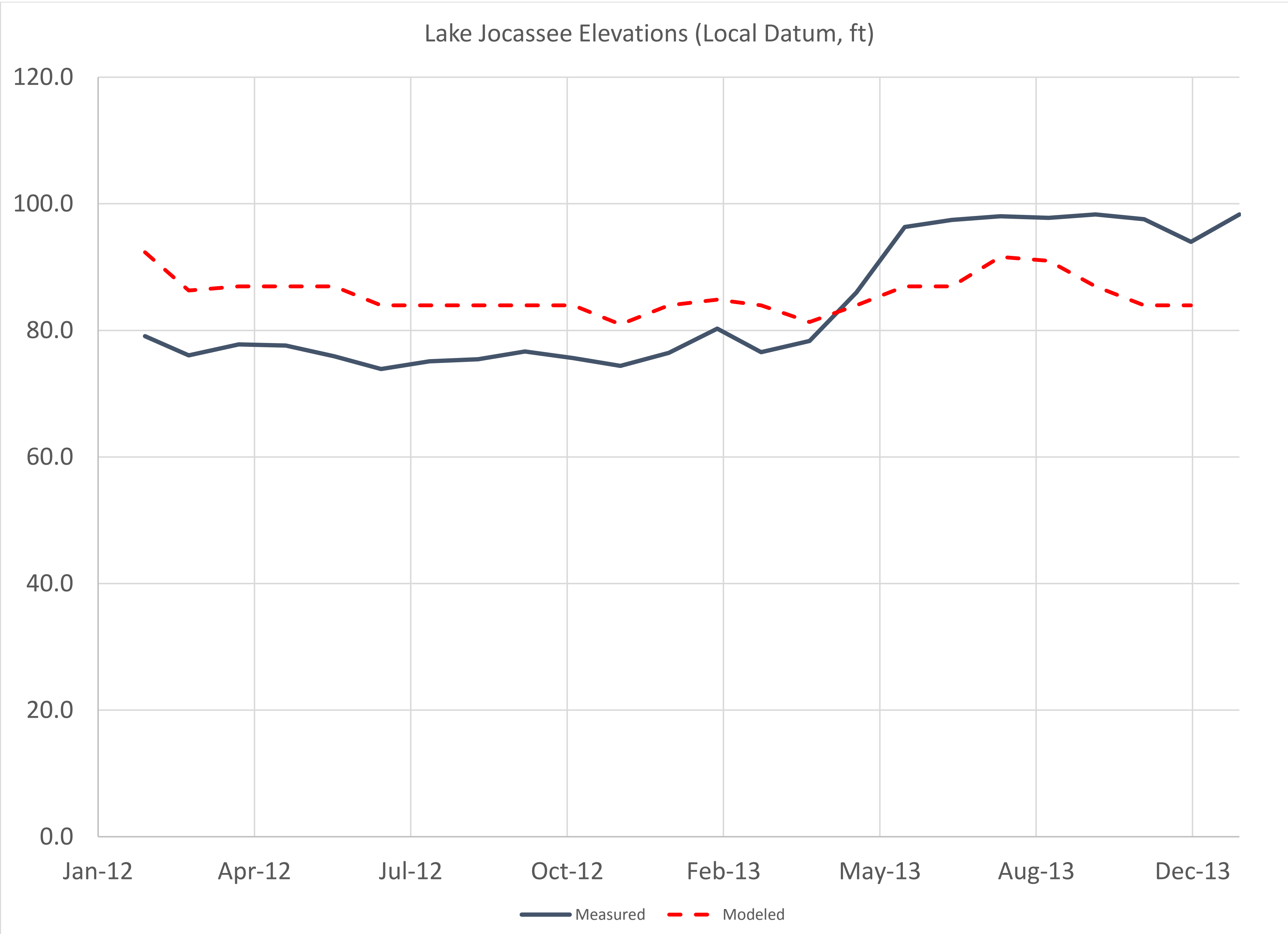
Year	SAVANNAH RIVER BELOW HARTWELL LK NR HARTWELL, GA	SAVANNAH RIVER AT AUGUSTA, GA	SAVANNAH R AT BURTONS FERRY BR NR MILLHAVEN, GA	SAVANNAH RIVER NEAR CLYO, GA
ID->	**SAV12**	**SAV29**	**SAV43**	**SAV45**
Modeled	1,026.8	3,507.7	4,096.2	4,274.8
Measured	1,077.1	3,444.3	3,988.0	4,405.7
% Diff.	-4.7%	1.8%	2.7%	-3.0%

Appendix E

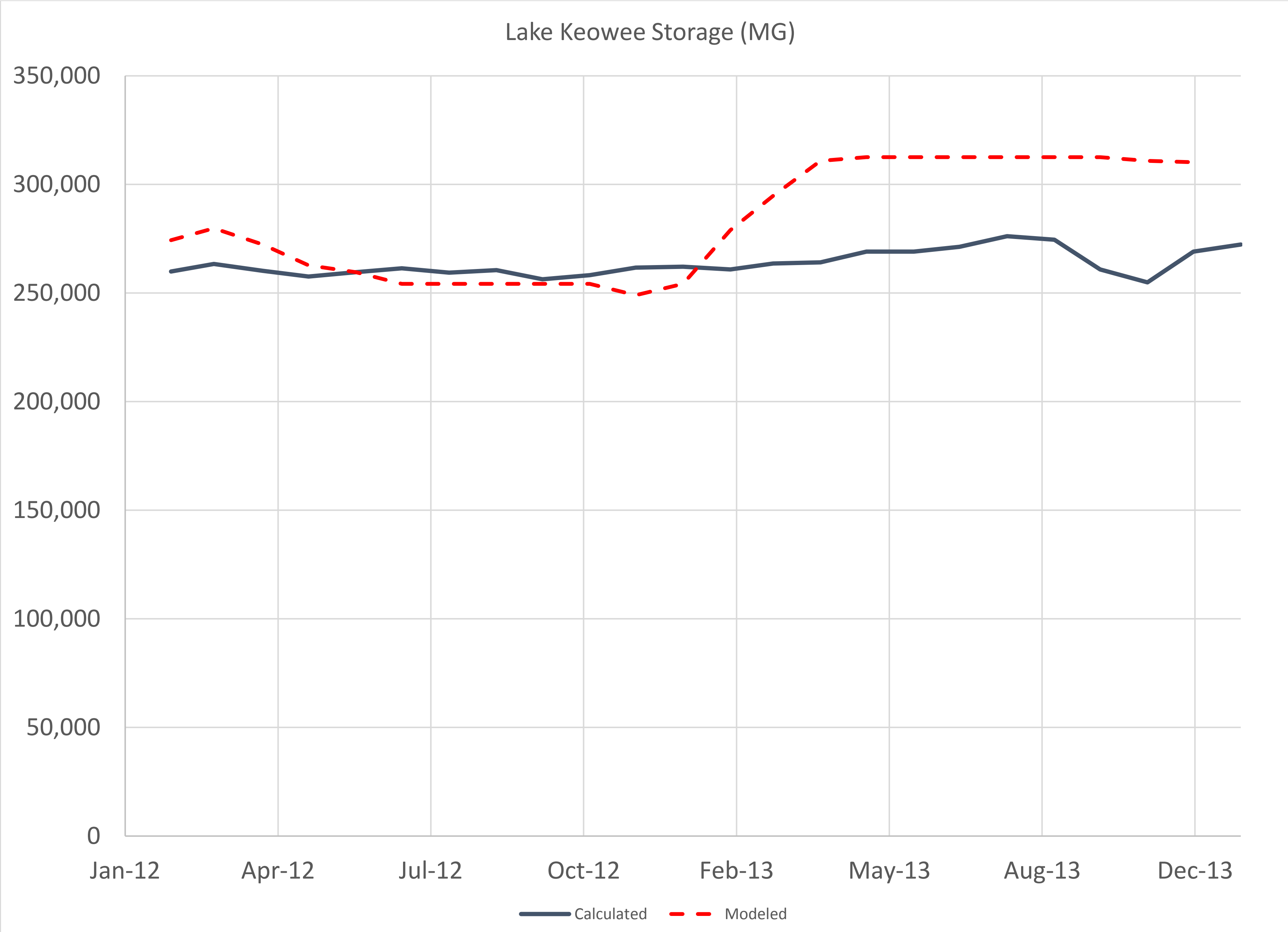
Baseline Validation Model Monthly Calibration Results

CDM Smith

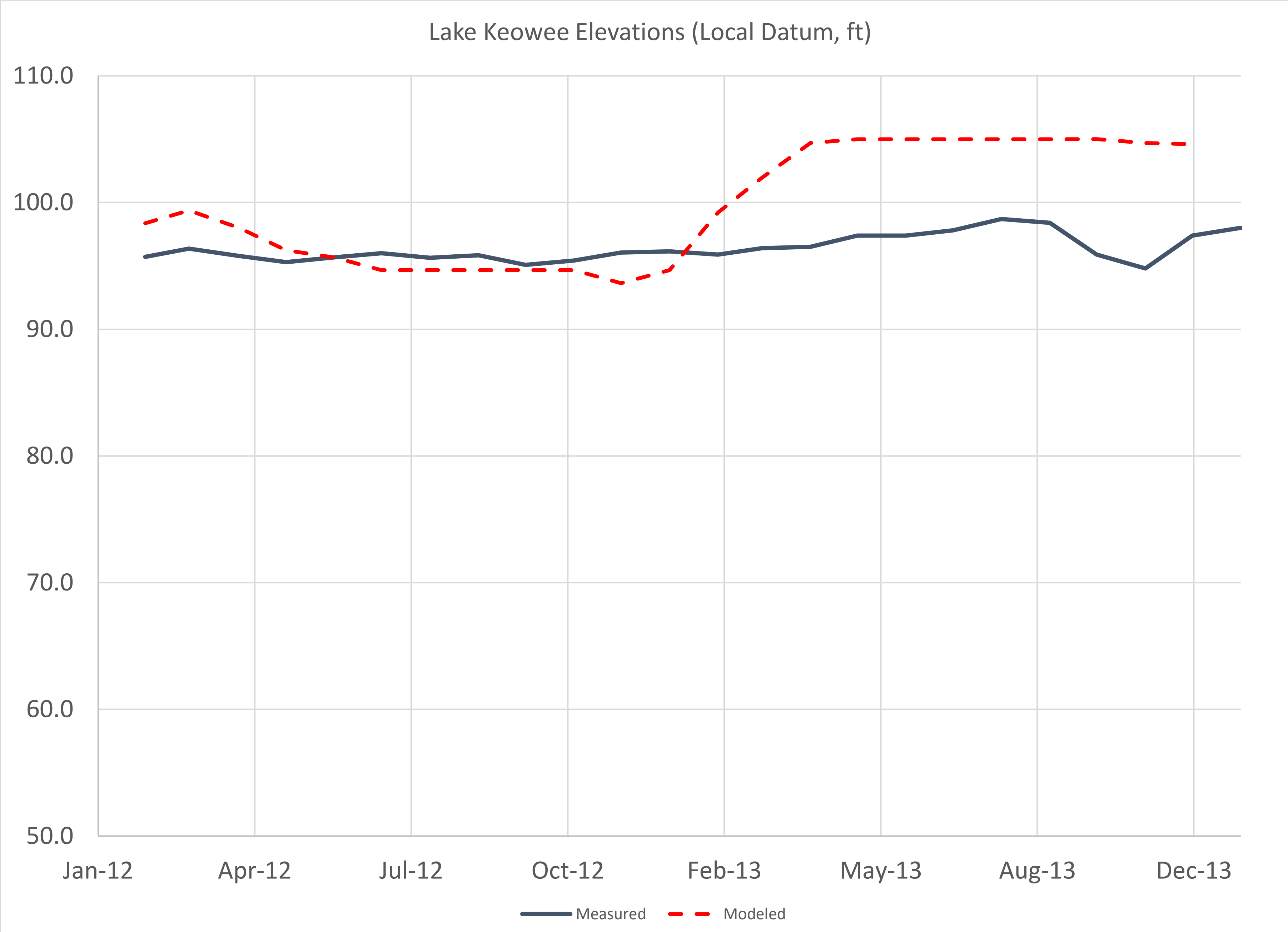

Lake Jocassee Storage (MG)
450,000
400,000
350,000
300,000
250,000
200,000
150,000
100,000
50,000
0
Jan-12
Apr-12
Jul-12
Oct-12
Feb-13
May-13
Aug-13
Dec-13
Calculated
Modeled



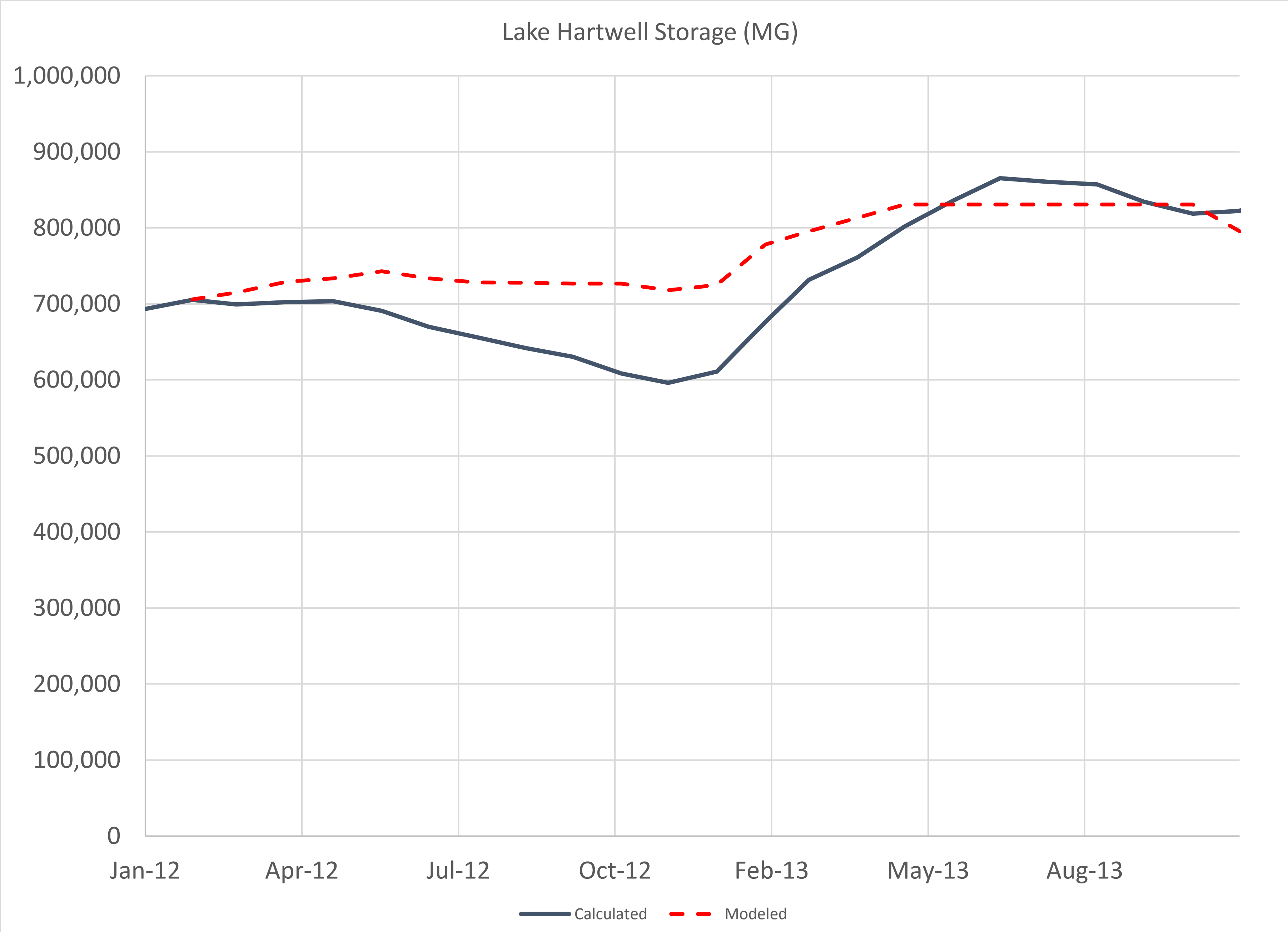
Lake Jocassee Elevations (Local Datum, ft)
120.0
100.0
80.0
60.0
40.0
20.0
0.0
Jan-12
Apr-12
Jul-12
Oct-12
Feb-13
May-13
Aug-13
Dec-13
Measured
Modeled

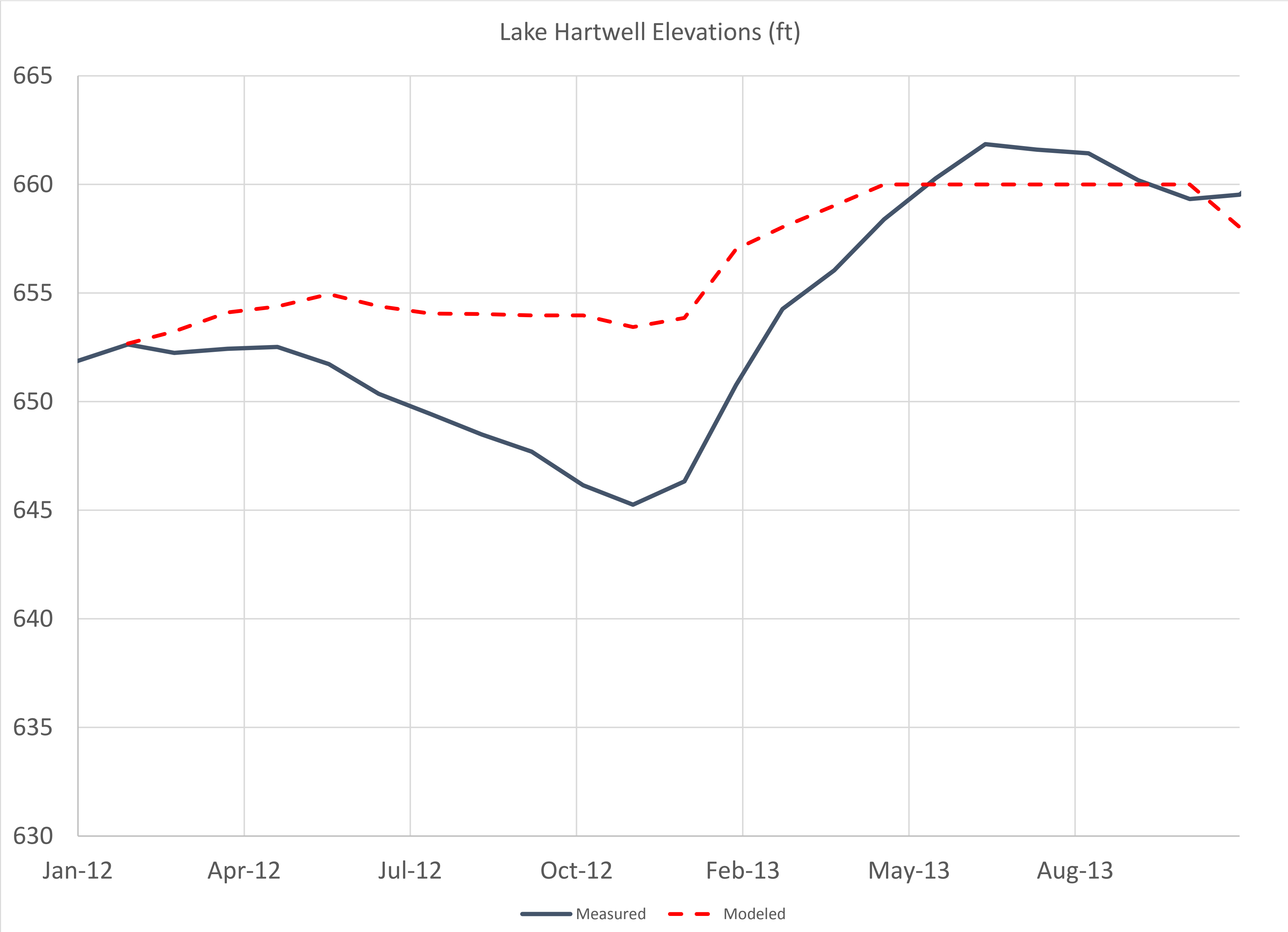


Lake Keowee Storage (MG)
350,000
300,000
250,000
200,000
150,000
100,000
50,000
0
Jan-12
Apr-12
Jul-12
Oct-12
Feb-13
May-13
Aug-13
Dec-13
Calculated
Modeled

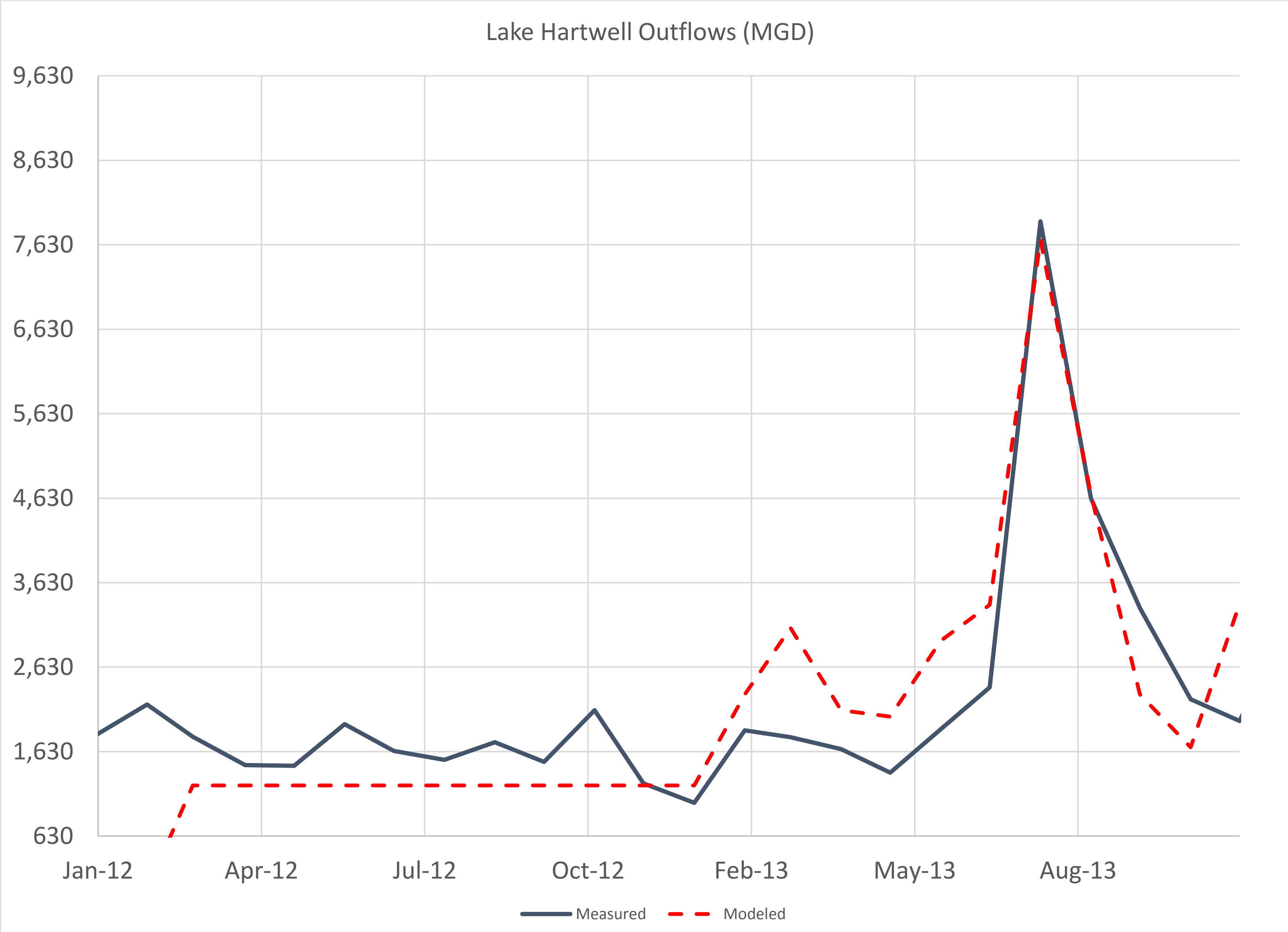


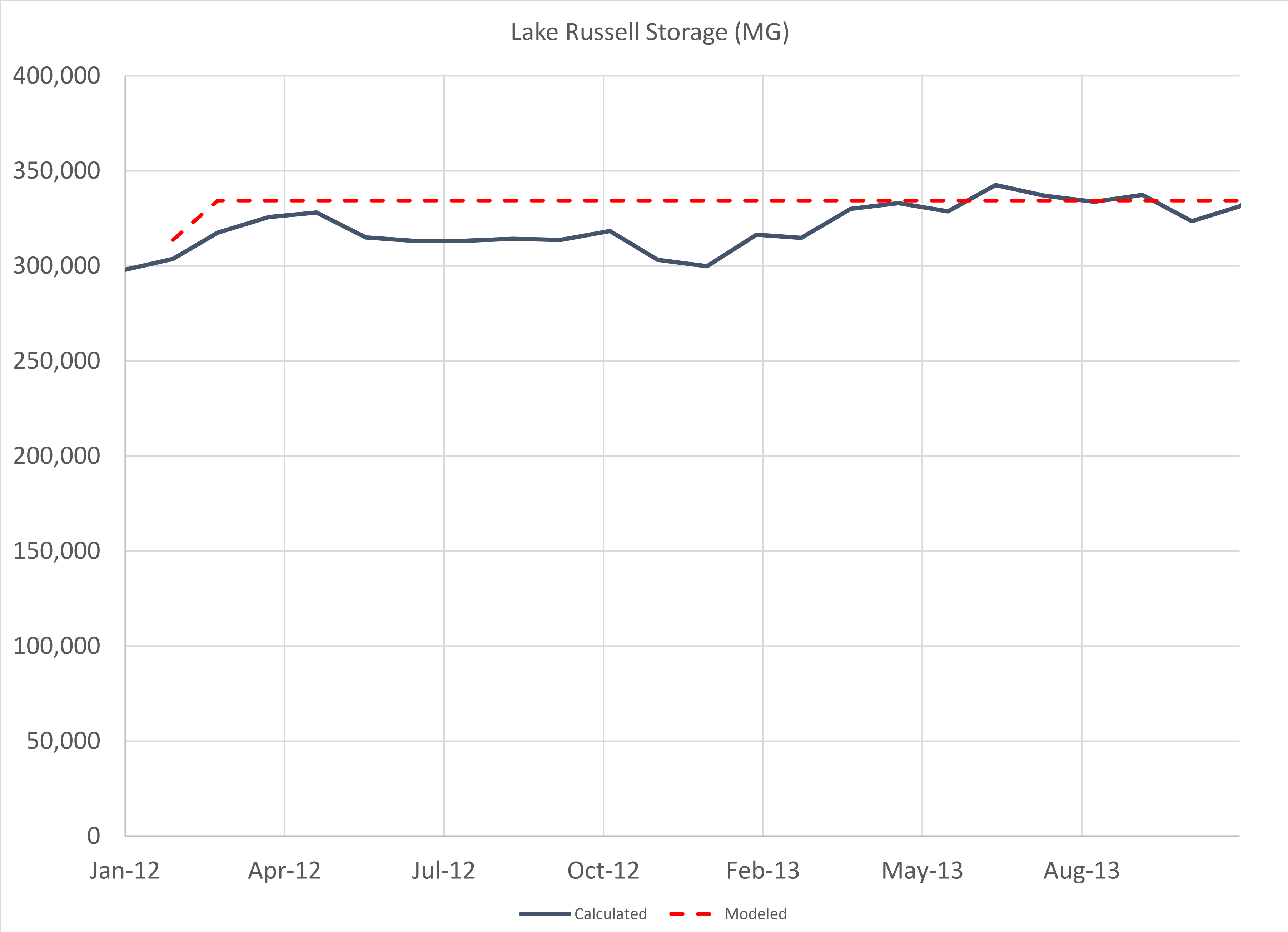
Lake Keowee Elevations (Local Datum, ft)
110.0
100.0
90.0
80.0
70.0
60.0
50.0
Jan-12
Apr-12
Jul-12
Oct-12
Feb-13
May-13
Aug-13
Dec-13
Measured
Modeled

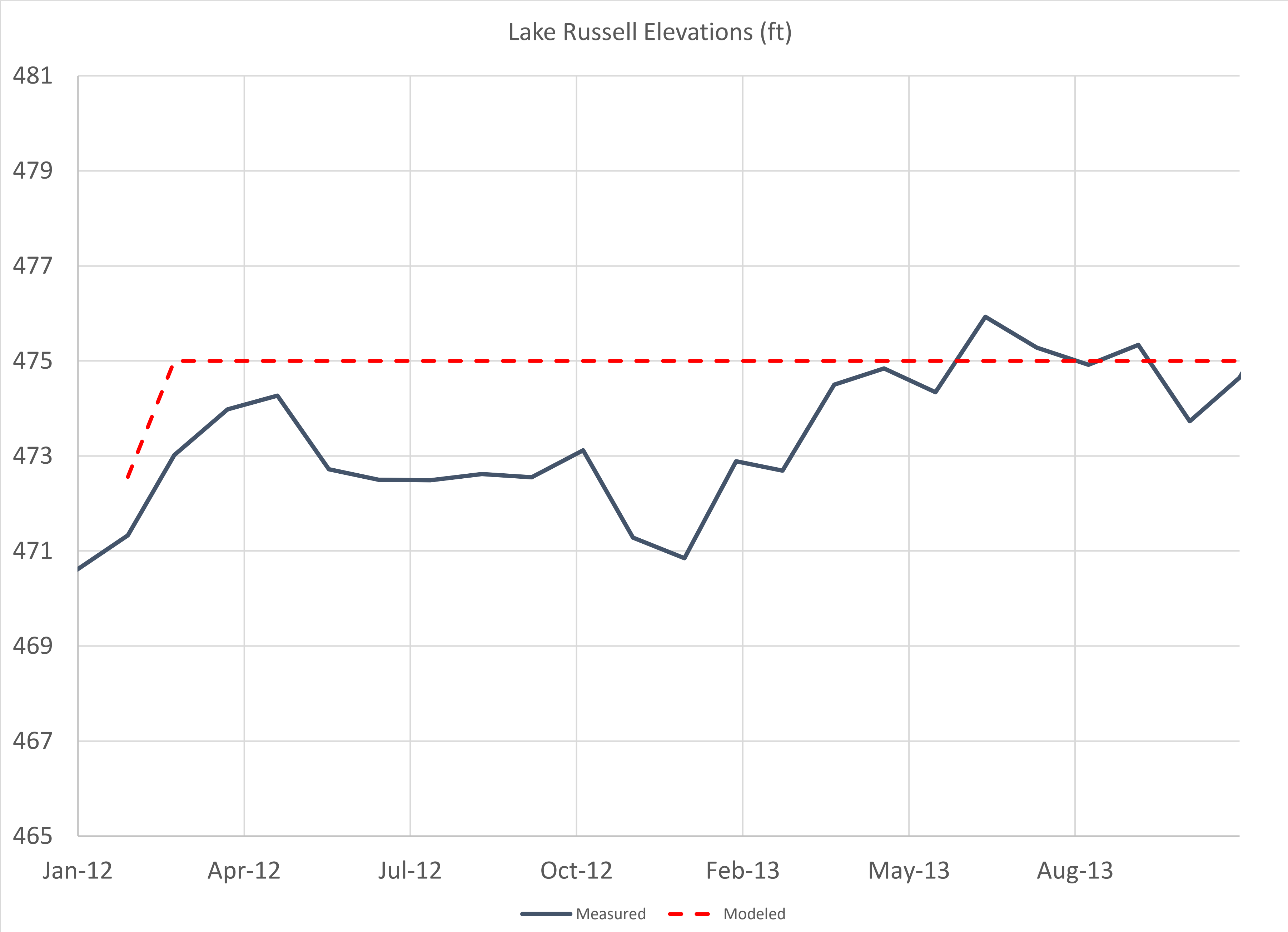

Lake Hartwell Storage (MG)
1,000,000
900,000
800,000
700,000
600,000
500,000
400,000
300,000
200,000
100,000
0
Jan-12
Apr-12
Jul-12
Oct-12
Feb-13
May-13
Aug-13
Calculated
Modeled

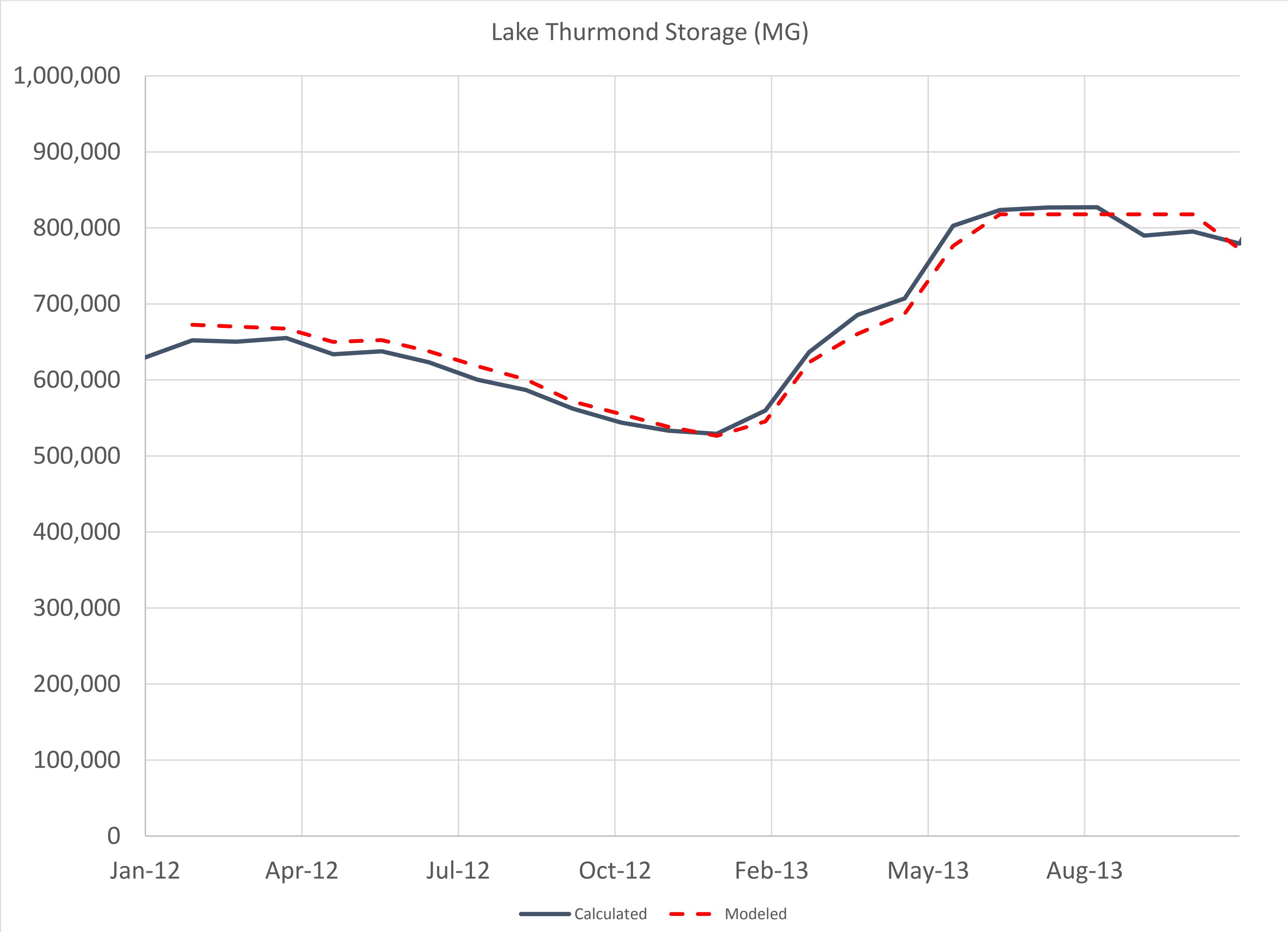


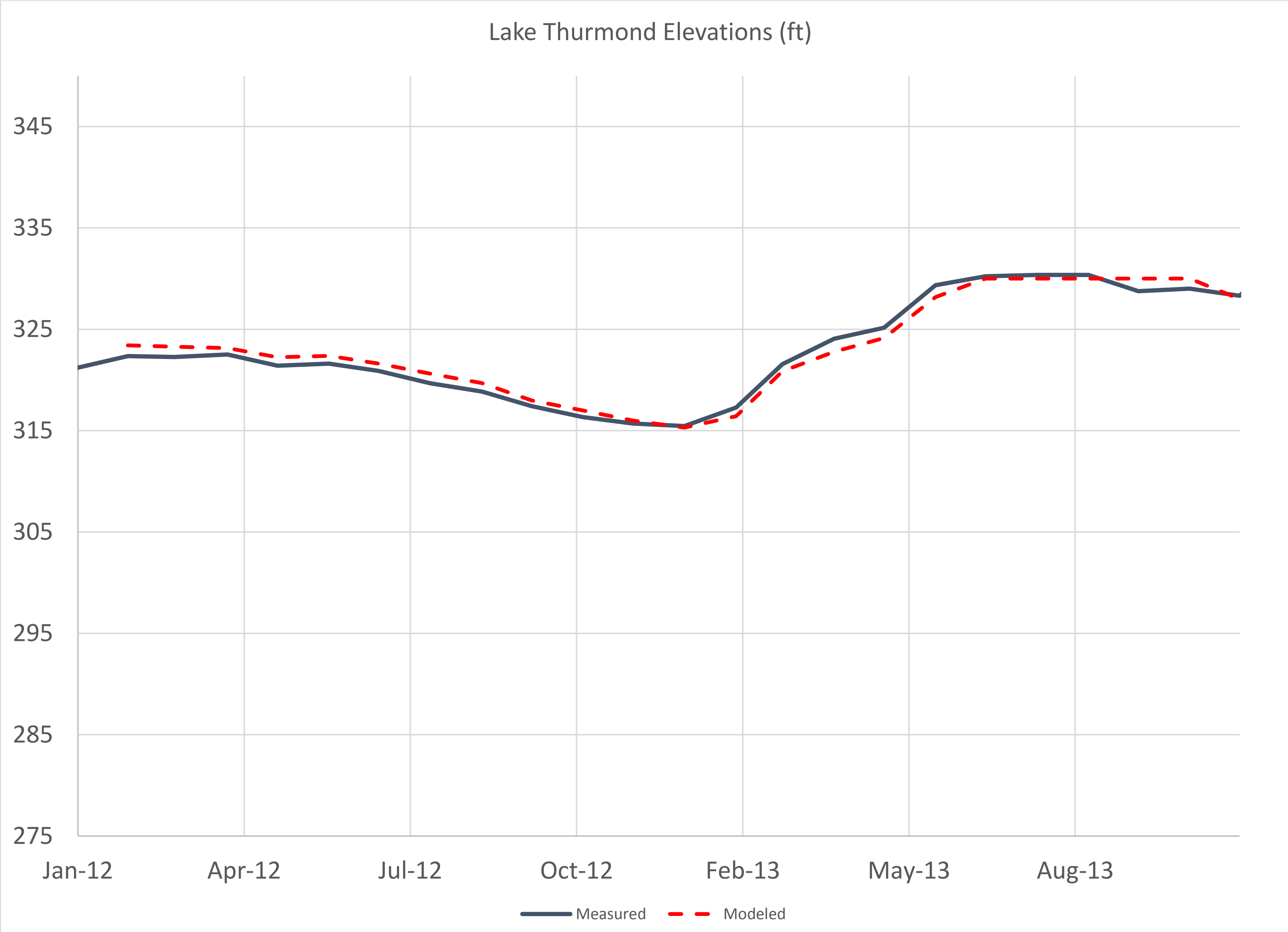
Lake Hartwell Elevations (ft)
665
660
655
650
645
640
635
630
Jan-12
Apr-12
Jul-12
Oct-12
Feb-13
May-13
Aug-13
Measured
Modeled


Lake Hartwell Outflows (MGD)
9,630
8,630
7,630
6,630
5,630
4,630
3,630
2,630
1,630
630
Jan-12
Apr-12
Jul-12
Oct-12
Feb-13
May-13
Aug-13
Measured
Modeled

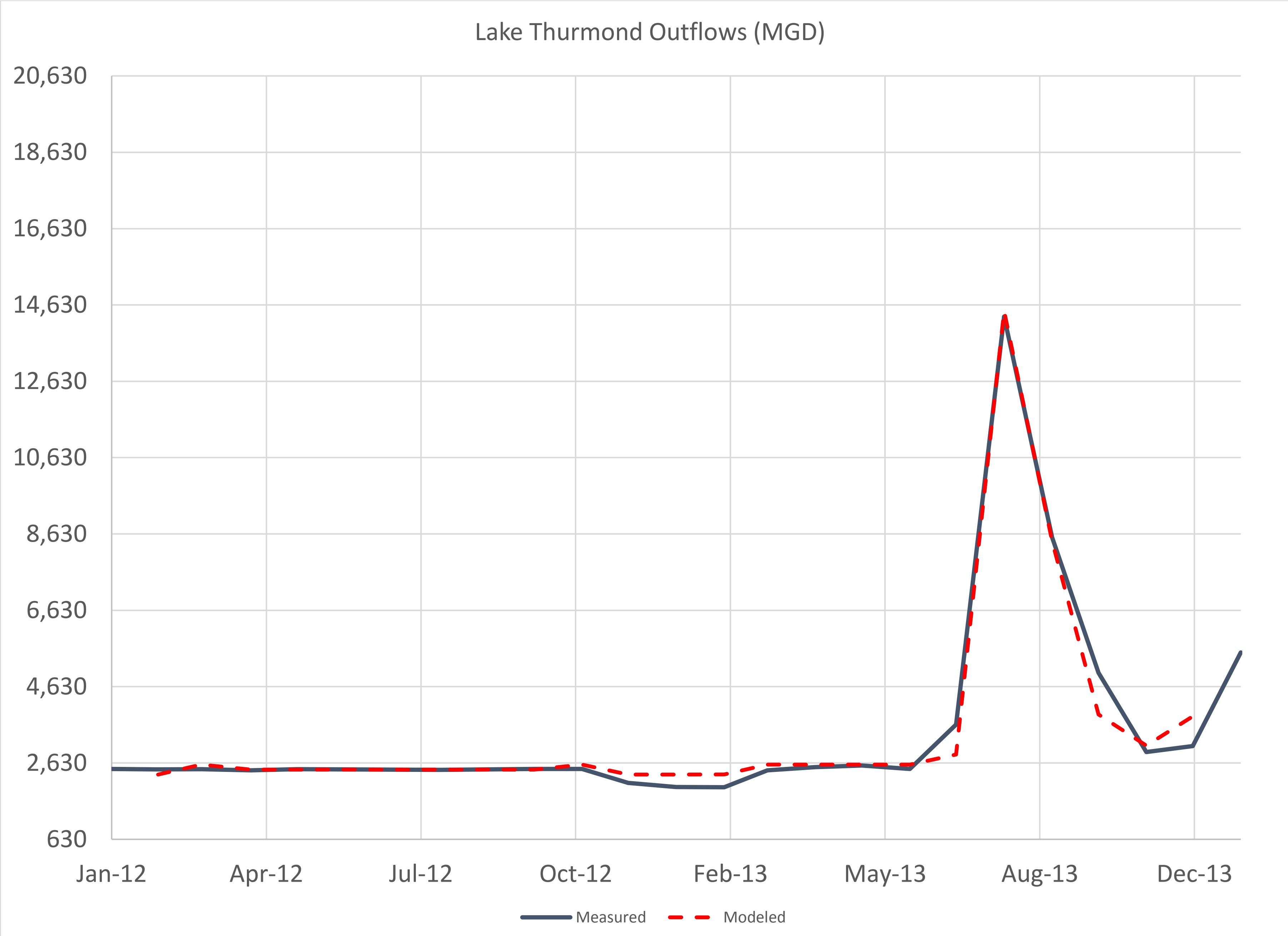

Lake Russell Storage (MG)
400,000
350,000
300,000
250,000
200,000
150,000
100,000
50,000
0
Jan-12
Apr-12
Jul-12
Oct-12
Feb-13
May-13
Aug-13
Calculated
Modeled


Lake Russell Elevations (ft)
481
479
477
475
473
471
469
467
465
Jan-12
Apr-12
Jul-12
Oct-12
Feb-13
May-13
Aug-13
Measured
Modeled


Lake Thurmond Storage (MG)
1,000,000
900,000
800,000
700,000
600,000
500,000
400,000
300,000
200,000
100,000
0
Jan-12
Apr-12
Jul-12
Oct-12
Feb-13
May-13
Aug-13
Calculated
Modeled



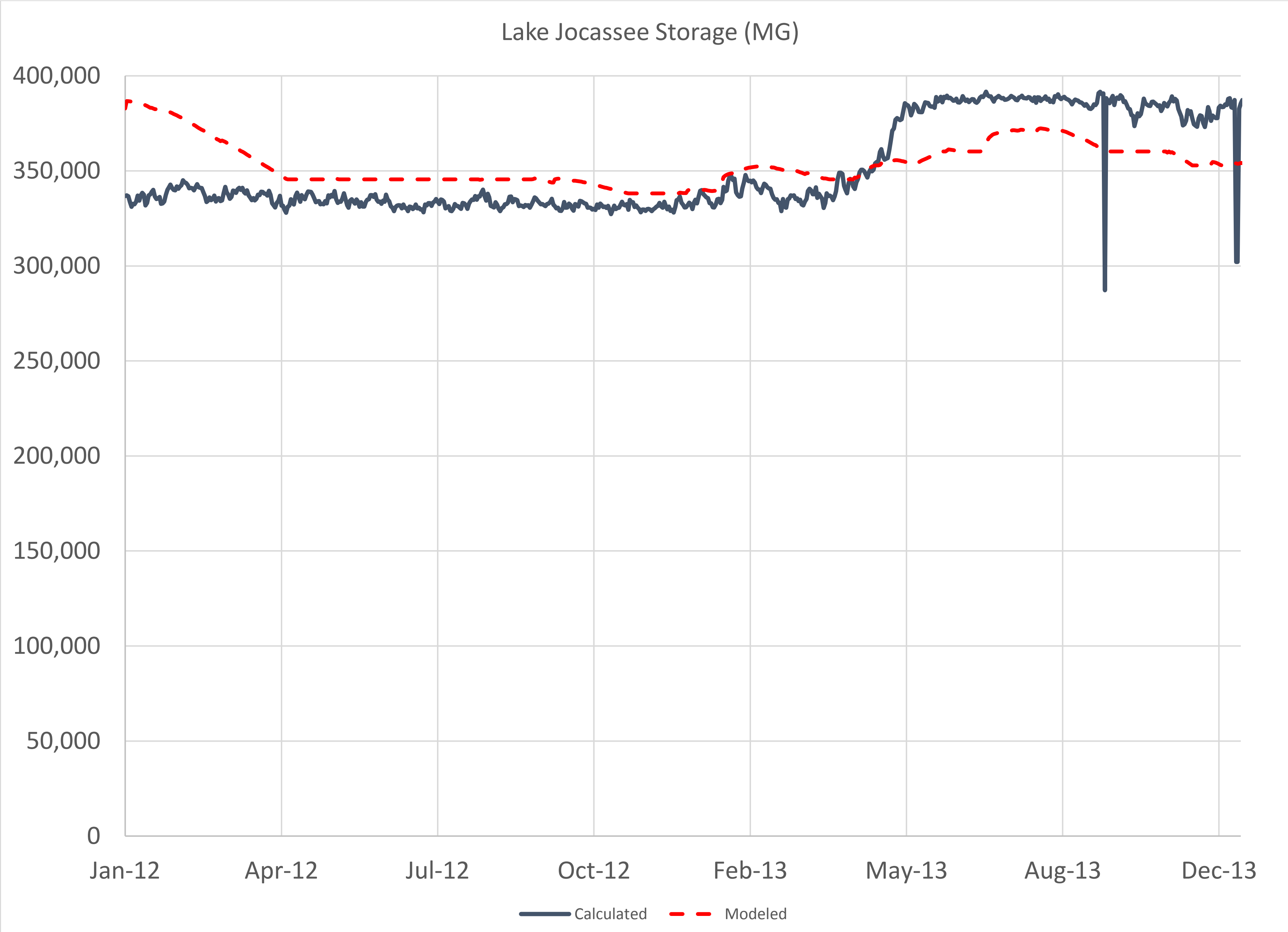
Lake Thurmond Elevations (ft)
345
335
325
315
305
295
285
275
Jan-12
Apr-12
Jul-12
Oct-12
Feb-13
May-13
Aug-13
Measured
Modeled

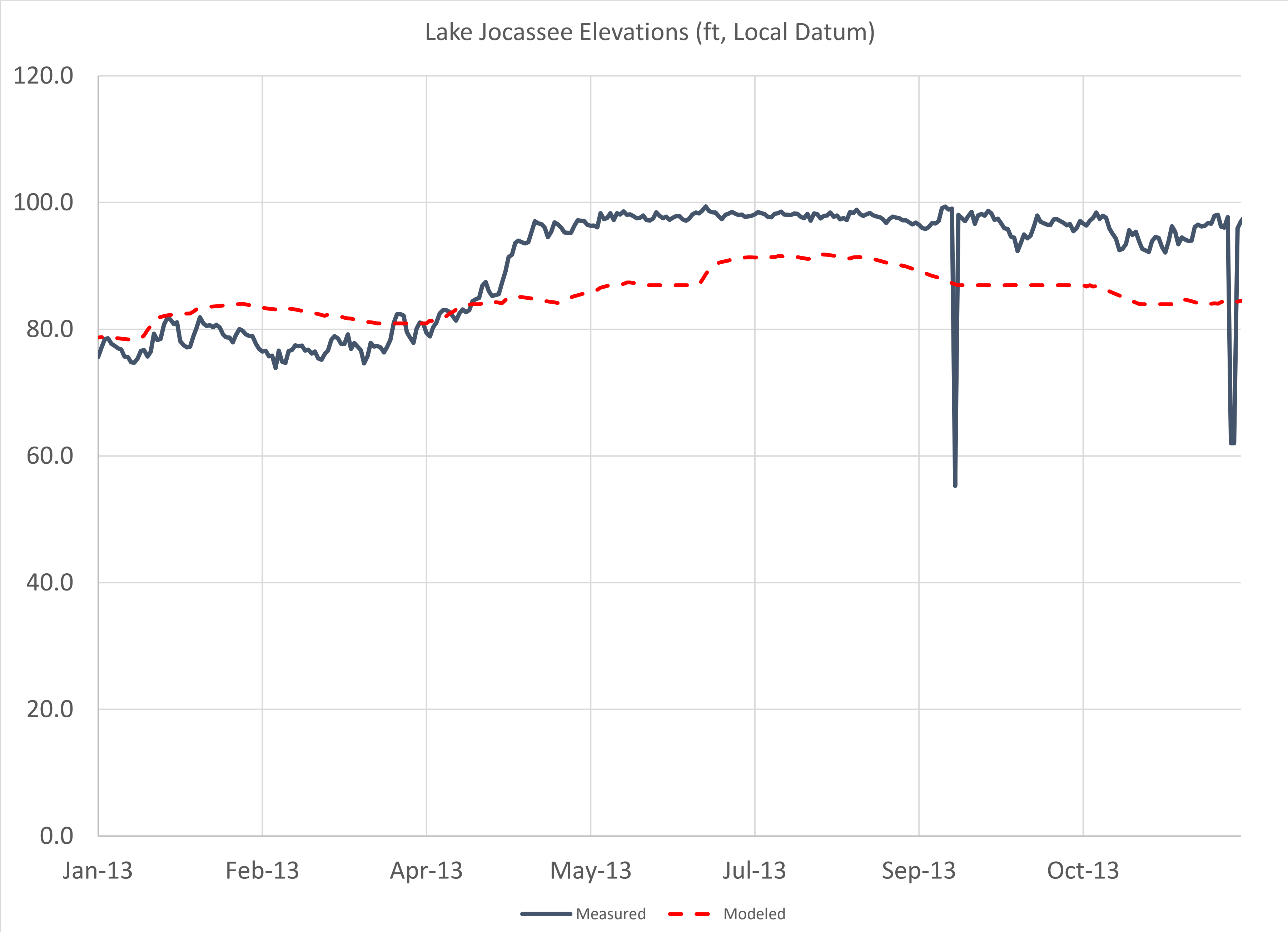

Lake Thurmond Outflows (MGD)
20,630
18,630
16,630
14,630
12,630
10,630
8,630
6,630
4,630
2,630
630
Jan-12
Apr-12
Jul-12
Oct-12
Feb-13
May-13
Aug-13
Dec-13
Measured
Modeled

Appendix F

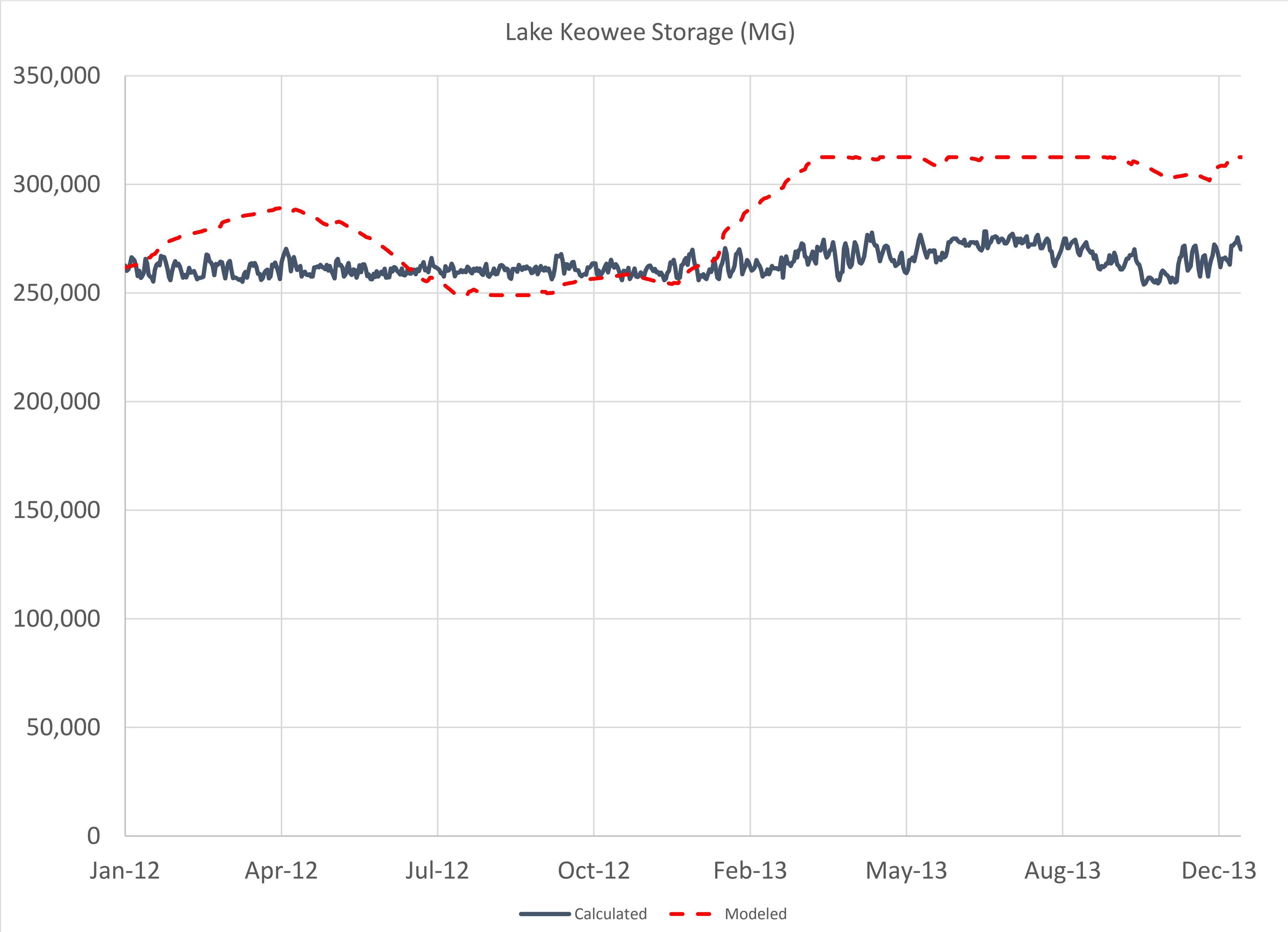
Baseline Validation Model Daily Calibration Results

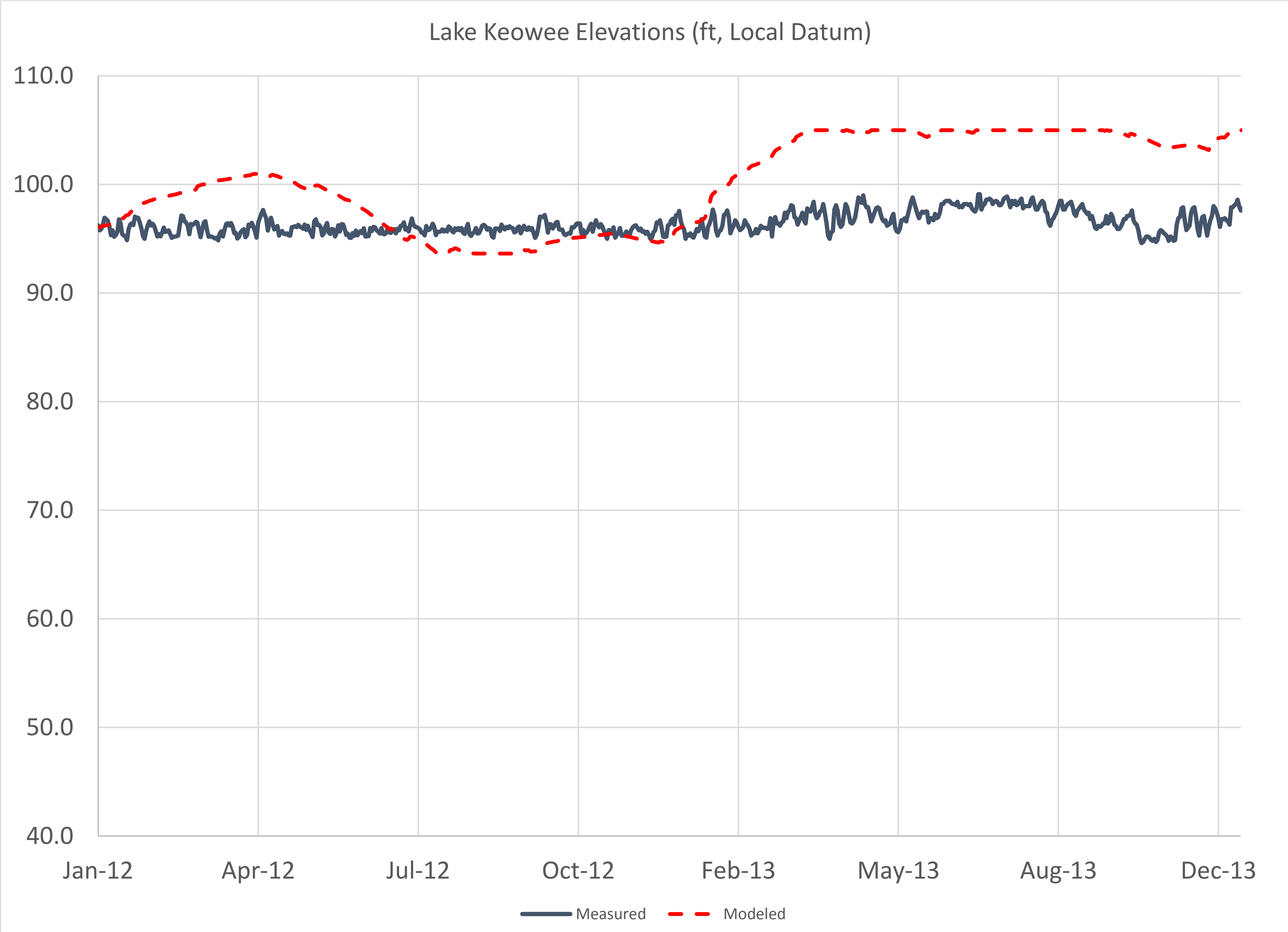
CDM Smith

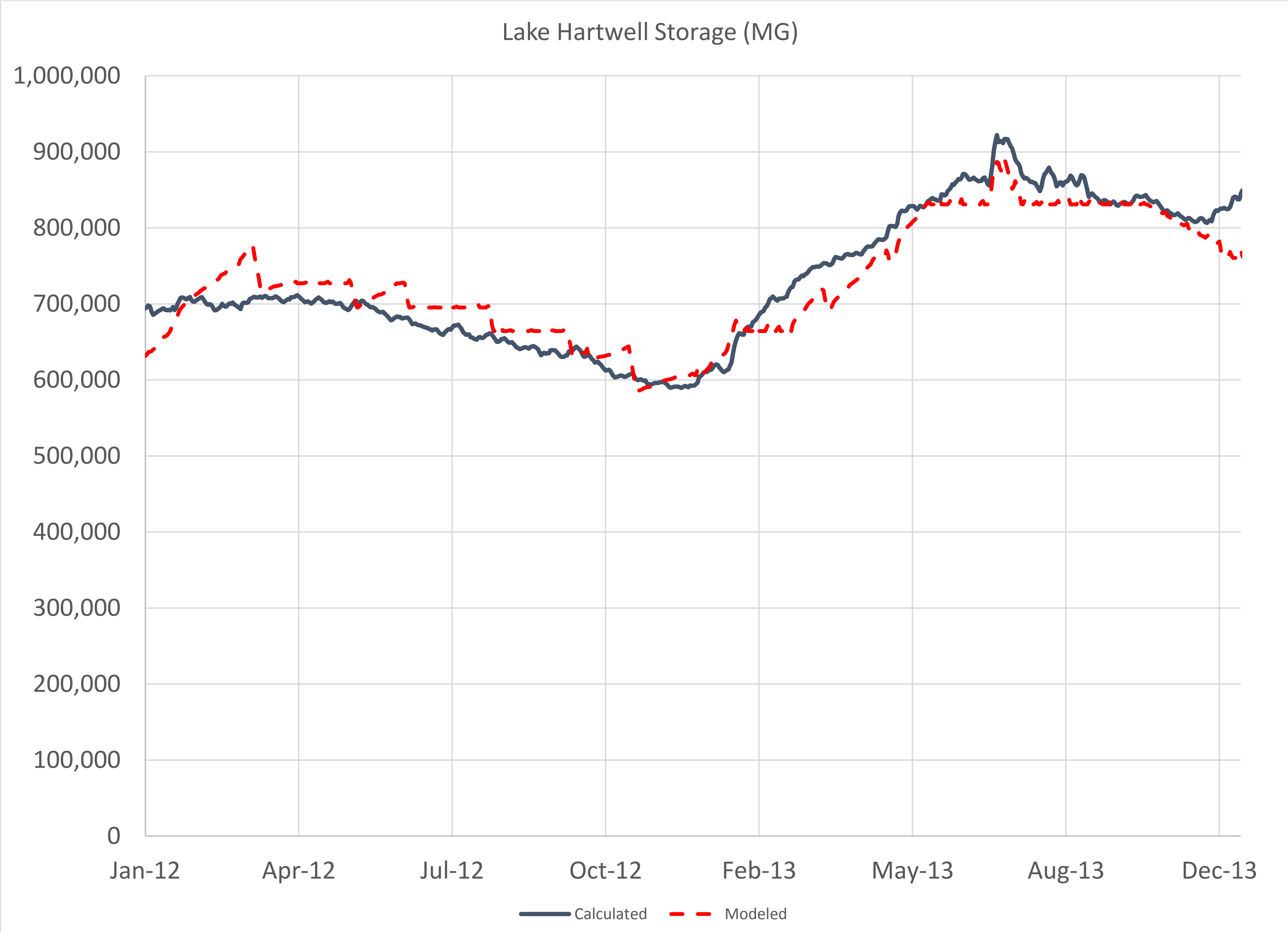

Lake Jocassee Storage (MG)
400,000
350,000
300,000
250,000
200,000
150,000
100,000
50,000
0
Jan-12
Apr-12
Jul-12
Oct-12
Feb-13
May-13
Aug-13
Dec-13
Calculated
Modeled



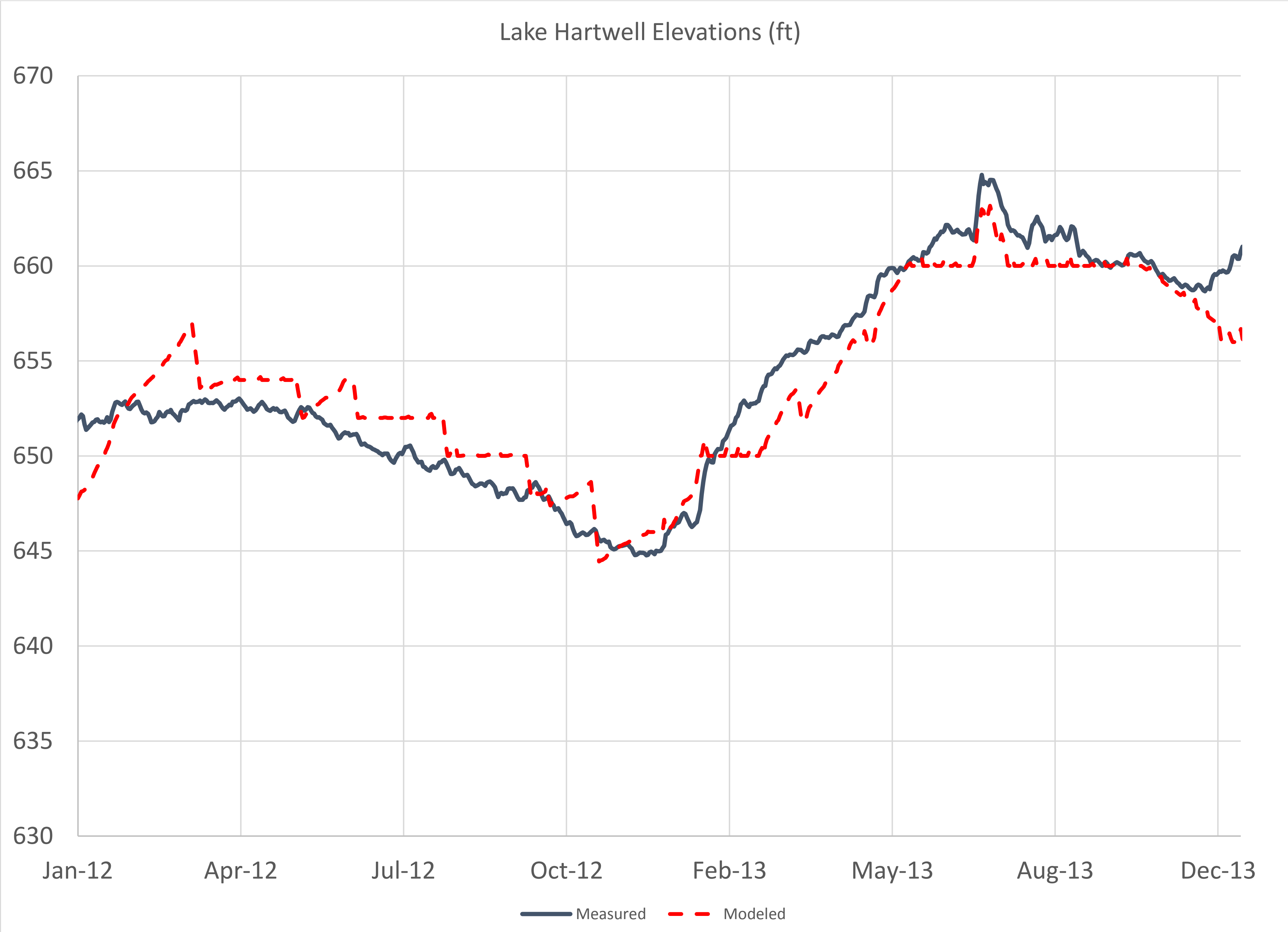
Lake Jocassee Elevations (ft, Local Datum)
120.0
100.0
80.0
60.0
40.0
20.0
0.0
Jan-13
Feb-13
Apr-13
May-13
Jul-13
Sep-13
Oct-13
Measured
Modeled


Lake Keowee Storage (MG)
350,000
300,000
250,000
200,000
150,000
100,000
50,000
0
Jan-12
Apr-12
Jul-12
Oct-12
Feb-13
May-13
Aug-13
Dec-13
Calculated
Modeled

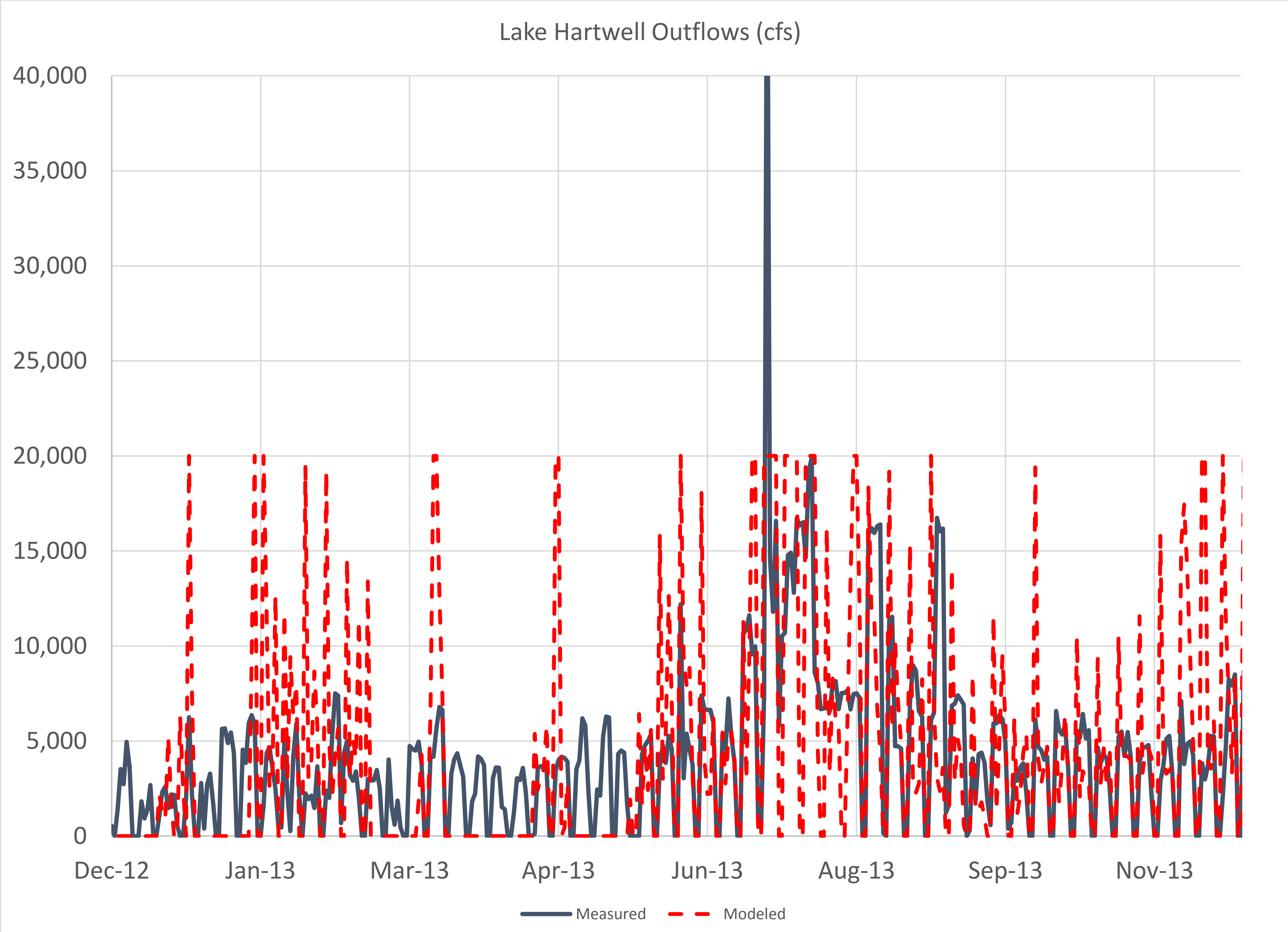

Lake Keowee Elevations (ft, Local Datum)
110.0
100.0
90.0
80.0
70.0
60.0
50.0
40.0
Jan-12
Apr-12
Jul-12
Oct-12
Feb-13
May-13
Aug-13
Dec-13
Measured
Modeled



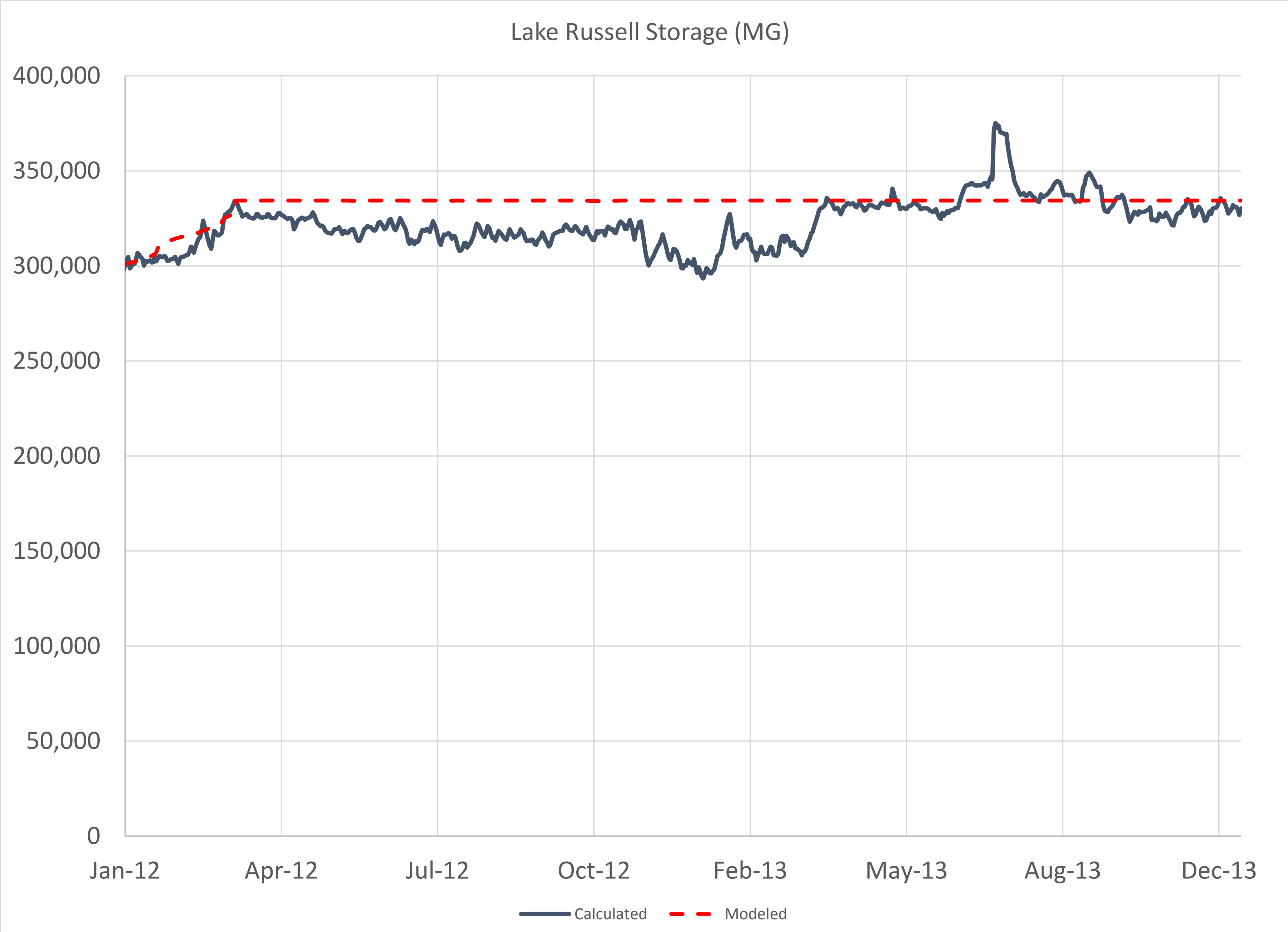
Lake Hartwell Storage (MG)
1,000,000
900,000
800,000
700,000
600,000
500,000
400,000
300,000
200,000
100,000
0
Jan-12
Apr-12
Jul-12
Oct-12
Feb-13
May-13
Aug-13
Dec-13
Calculated
Modeled

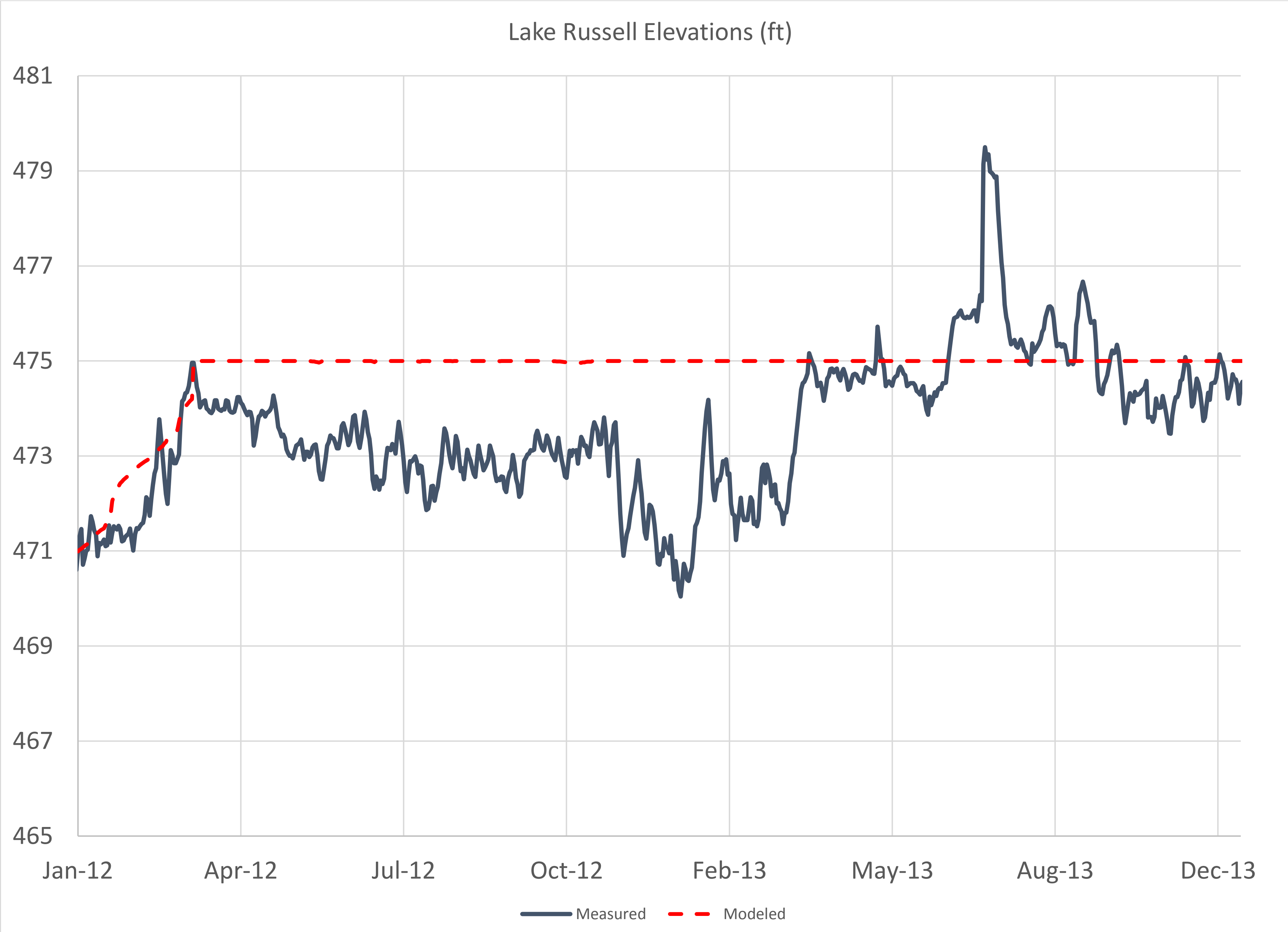


Lake Hartwell Elevations (ft)
670
665
660
655
650
645
640
635
630
Jan-12
Apr-12
Jul-12
Oct-12
Feb-13
May-13
Aug-13
Dec-13
Measured
Modeled

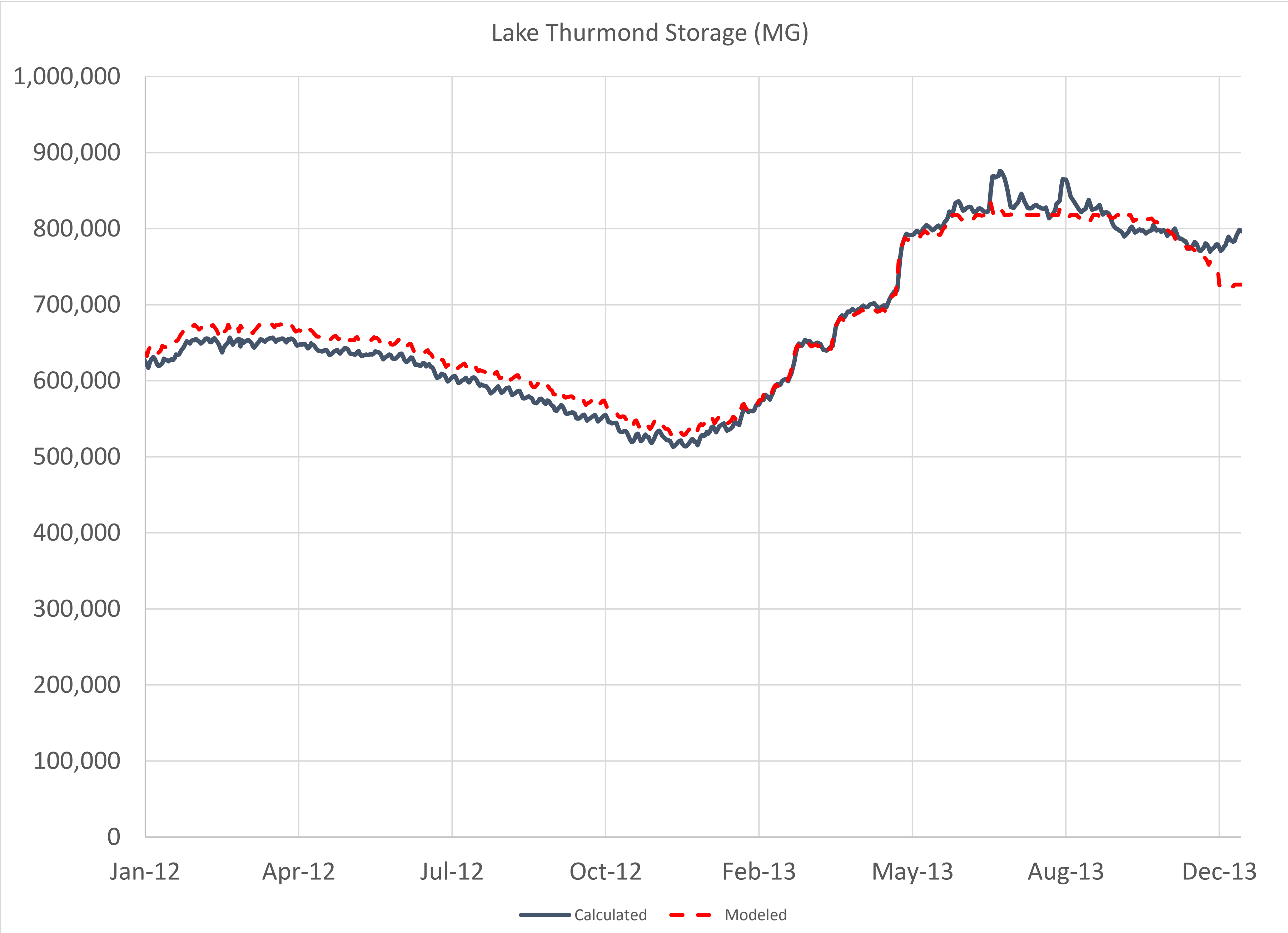


Lake Hartwell Outflows (cfs)
40,000
35,000
30,000
25,000
20,000
15,000
10,000
5,000
0
Dec-12
Jan-13
Mar-13
Apr-13
Jun-13
Aug-13
Sep-13
Nov-13
Measured
Modeled

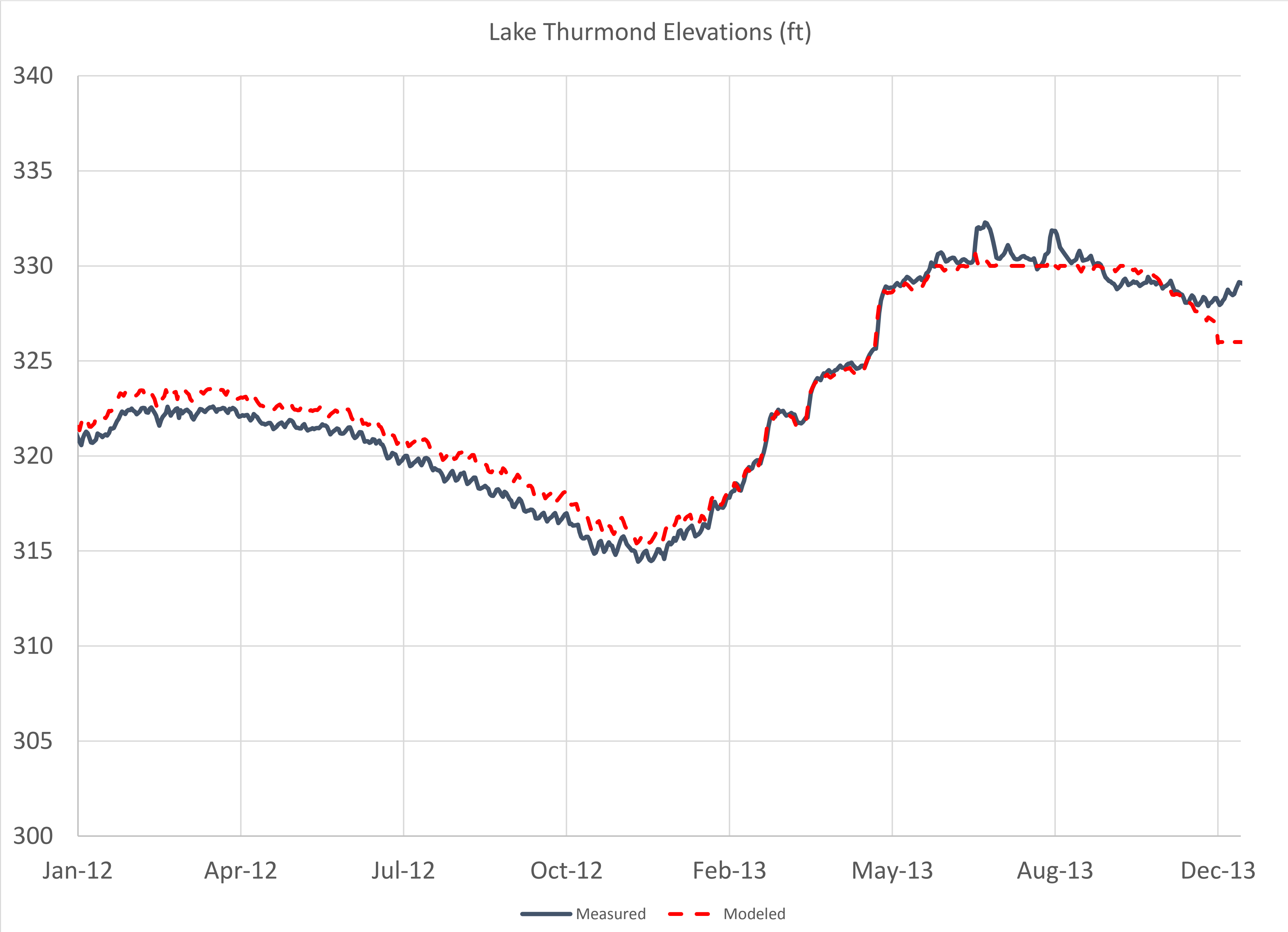

Lake Russell Storage (MG)
400,000
350,000
300,000
250,000
200,000
150,000
100,000
50,000
0
Jan-12
Apr-12
Jul-12
Oct-12
Feb-13
May-13
Aug-13
Dec-13
Calculated
Modeled



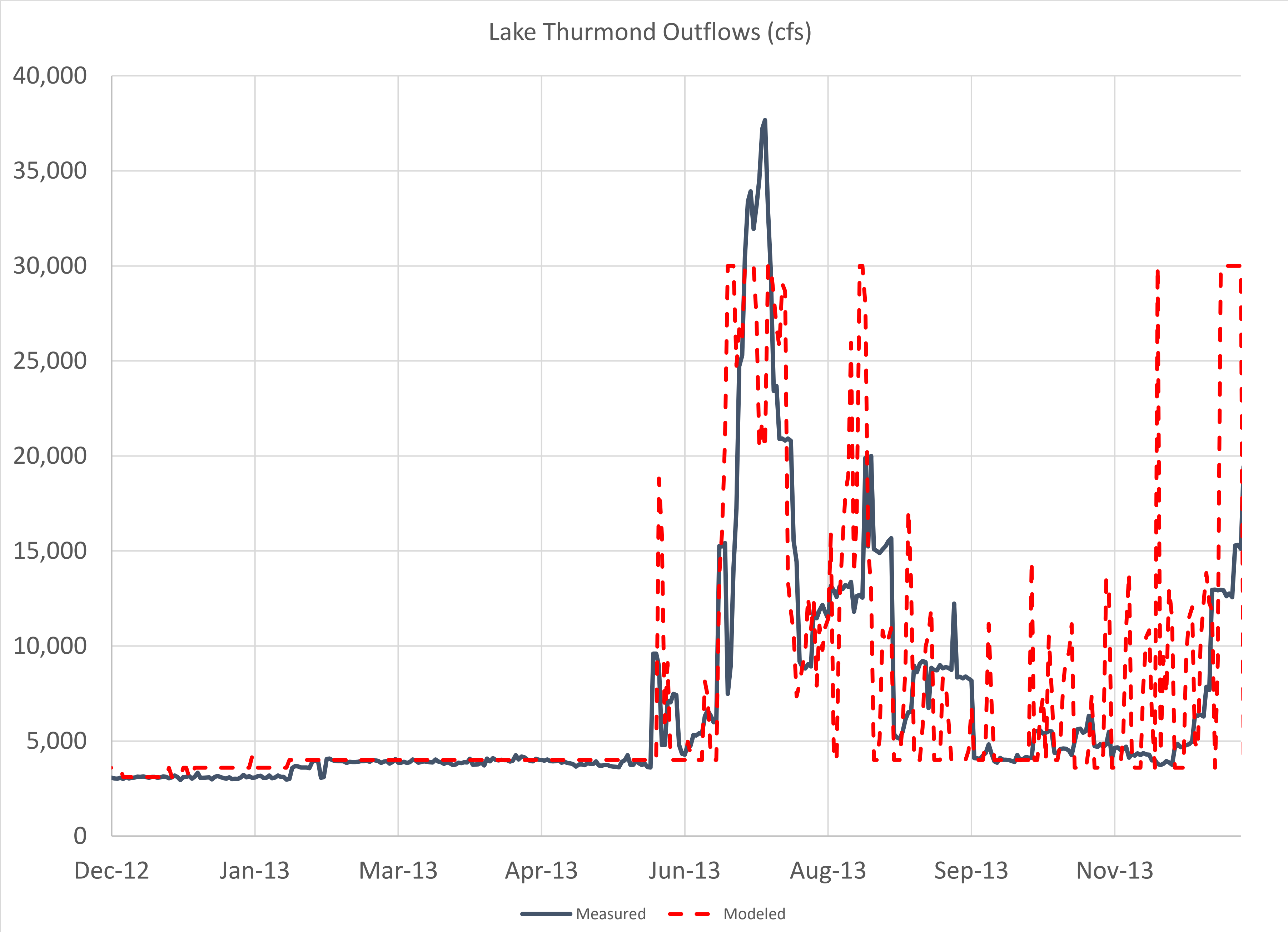
Lake Russell Elevations (ft)
481
479
477
475
473
471
469
467
465
Jan-12
Apr-12
Jul-12
Oct-12
Feb-13
May-13
Aug-13
Dec-13
Measured
Modeled



Lake Thurmond Storage (MG)
1,000,000
900,000
800,000
700,000
600,000
500,000
400,000
300,000
200,000
100,000
0
Jan-12
Apr-12
Jul-12
Oct-12
Feb-13
May-13
Aug-13
Dec-13
Calculated
Modeled



Lake Thurmond Elevations (ft)
340
335
330
325
320
315
310
305
300
Jan-12
Apr-12
Jul-12
Oct-12
Feb-13
May-13
Aug-13
Dec-13
Measured
Modeled



Lake Thurmond Outflows (cfs)
40,000
35,000
30,000
25,000
20,000
15,000
10,000
5,000
0
Dec-12
Jan-13
Mar-13
Apr-13
Jun-13
Aug-13
Sep-13
Nov-13
Measured
Modeled

Appendix G

Guidelines for Representing Multi-Basin Water Users in SWAM

CDM Smith

Appendix G
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.

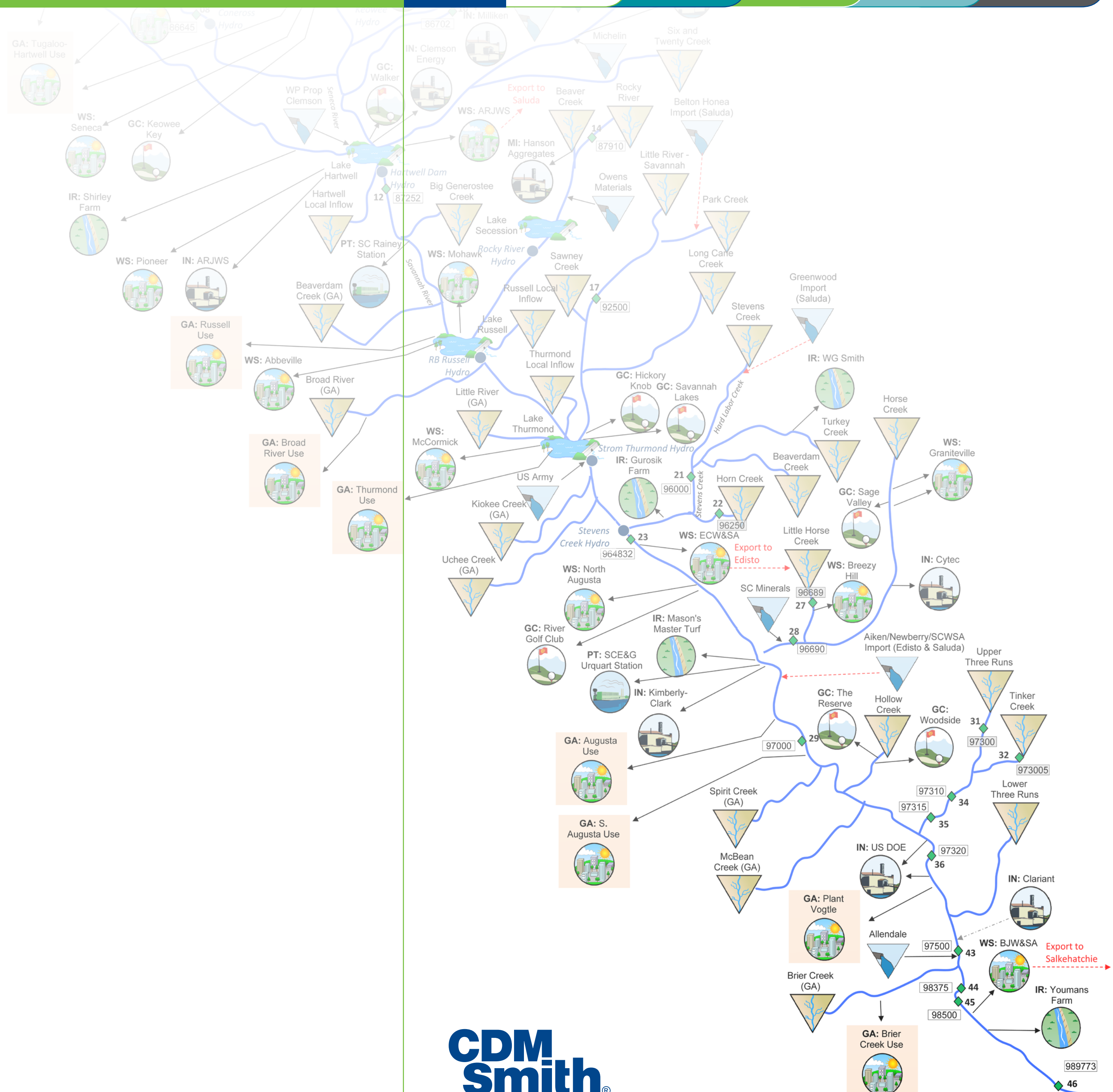
Appendix H

Georgia Permitted Users and Return Flow Locations

Appendix H. Georgia Permitted Users and Return Flow Locations

ID	User Facility Name	Withdrawal Tributary	Model Object ID	River Mile	Permit Limit (MGD)
149-0111-02	J M Huber Corp - Brier Creek	Brier Creek	GA: Brier Creek Use	0.5	3
081-0111-01	J M Huber Corp - Reedy Creek	Brier Creek	GA: Brier Creek Use	0.5	4
149-0111-04	Thiele Kaolin Company	Brier Creek	GA: Brier Creek Use	0.5	1
097-0111-03	Thomson-McDuffie County W/S Commission	Brier Creek	GA: Brier Creek Use	0.5	2
017-0113-01	Waynesboro, City Of	Brier Creek	GA: Brier Creek Use	0.5	1
006-0106-05	Banks County Board Of Commissioners	Broad River	GA: Broad River Use	0.5	1
006-0106-01	Commerce, City Of	Broad River	GA: Broad River Use	0.5	4
109-0105-01	Crawford, City Of	Broad River	GA: Broad River Use	0.5	0
059-0103-01	Royston, City Of	Broad River	GA: Broad River Use	0.5	1
095-0106-03	Turner Concrete Company, Incorporated	Broad River	GA: Broad River Use	0.5	0
119-0101-03	Clayton-Rabun Co. Water & Sewer Authority	Tugaloo River/Lake Yonah	GA: Tugaloo-Hartwell Use	13	4
073-0190-01	Hartwell, City Of	Mainstem/Lake Hartwell	GA: Tugaloo-Hartwell Use	65	4
059-0102-01	Lavonia, City Of	Tugaloo River	GA: Tugaloo-Hartwell Use	26	2
059-0102-04	Lavonia, City Of	Mainstem/Lake Hartwell	GA: Tugaloo-Hartwell Use	65	3
127-0102-05	Toccoa, City of	Tugaloo River/Lake Yonah	GA: Tugaloo-Hartwell Use	13	6
127-0102-02	Toccoa, City Of - Davidson Creek	Tugaloo River	GA: Tugaloo-Hartwell Use	26	9
127-0102-02	Toccoa, City Of - Lake Toccoa	Tugaloo River	GA: Tugaloo-Hartwell Use	26	9
121-0191-06	Augusta-Richmond County	Mainstem	GA: Augusta Use	165	45
121-0191-09	Augusta-Richmond County	Mainstem	GA: Augusta Use	165	15
121-0191-10	Avondale Mills - Augusta Canal	Mainstem	GA: Augusta Use	165	NA
036-0110-01	Columbia County Water System	Mainstem	GA: Augusta Use	165	46
121-0191-07	DSM Chemicals Augusta, Inc.	Mainstem	GA: Augusta Use	165	7
121-0110-03	Fort Gordon - Butler Creek	Mainstem	GA: Augusta Use	165	NA
121-0110-02	Fort Gordon - Cow Branch	Mainstem	GA: Augusta Use	165	1
121-0191-01	General Chemical Corp., Augusta Plant	Mainstem	GA: Augusta Use	165	5
121-0191-03	PCS Nitrogen Fertilizer, L.P.	Mainstem	GA: Augusta Use	165	11
121-0191-02	International Paper Corporation - Augusta Mill	Mainstem	GA: S. Augusta Use	169	72
017-0191-05	Georgia Power Co - Plant Vogtle	Mainstem	GA: Plant Vogtle	199	85
052-0104-01	Elberton, City Of	Mainstem/Lake Russell	GA: Russell Use	94	2
052-0104-04	Elberton, City Of	Mainstem/Lake Russell	GA: Russell Use	94	4
036-0109-04	Columbia County Water System	Mainstem/Lake Thurmond	GA: Thurmond Use	131.5	8
090-0108-01	Lincolnton, City Of	Mainstem/Lake Thurmond	GA: Thurmond Use	131.5	1
097-0109-05	Thomson-McDuffie County W/S Commission	Mainstem/Lake Thurmond	GA: Thurmond Use	131.5	3
066-0109-02	Union Point, City Of	Mainstem/Lake Thurmond	GA: Thurmond Use	131.5	0
157-0109-01	Washington, City Of - Clarks Hill	Mainstem/Lake Thurmond	GA: Thurmond Use	131.5	2
157-0109-03	Washington, City Of - Old Plant	Mainstem/Lake Thurmond	GA: Thurmond Use	131.5	2

ID	Return Facility Name	Discharge Tributary	Model Object ID	River Mile
GA0020974	Thomson WPCP	Brier Creek	GA: Brier Creek Use	0.6
GA0021857	Wrens WPCP	Brier Creek	GA: Brier Creek Use	0.6
GA0032981	Thiele Kaolin - Hobbs	Brier Creek	GA: Brier Creek Use	0.6
GA0038466	Waynesboro WPCP	Brier Creek	GA: Brier Creek Use	0.6
GA0047317	Thiele Kaolin - Wrens	Brier Creek	GA: Brier Creek Use	0.6
GA0048101	ECC International - Wrens	Brier Creek	GA: Brier Creek Use	0.6
GA0021491	Royston WPCP	Broad River	GA: Broad River Use	0.6
GA0022209	Lee Arrendal Correctional Institute WPCP	Broad River	GA: Broad River Use	0.6
GA0025682	Elberton - Falling Creek WPCP	Broad River	GA: Broad River Use	0.6
GA0026247	Commerce - Northside WPCP	Broad River	GA: Broad River Use	0.6
GA0002038-001	Roselane Development Company, Inc.	Tugaloo River	GA: Tugaloo-Hartwell Use	34
GA0002038-010	Roselane Development Company, Inc.	Tugaloo River	GA: Tugaloo-Hartwell Use	34
GA0002038-0A0	Roselane Development Company, Inc.	Tugaloo River	GA: Tugaloo-Hartwell Use	34
GA0020923	Clayton WPCP	Tugaloo River	GA: Tugaloo-Hartwell Use	34
GA0021806	Toccoa - Toccoa Creek WPCP	Tugaloo River	GA: Tugaloo-Hartwell Use	34
GA0021814	Toccoa - Eastanollee Creek WPCP	Tugaloo River	GA: Tugaloo-Hartwell Use	34
GA0002071-010	PCS Nitrogen Fertilizer	Mainstem	GA: Augusta Use	165.1
GA0002160-002	DSM Chemicals Augusta Inc.	Mainstem	GA: Augusta Use	165.1
GA0002160-003	DSM Chemicals Augusta Inc.	Mainstem	GA: Augusta Use	165.1
GA0002488-ALL	Thermal Ceramics Inc.	Mainstem	GA: Augusta Use	165.1
GA0002909	Martin Marietta Aggregates - Augusta Quarry	Mainstem	GA: Augusta Use	165.1
GA0002925	General Chemical Corporation	Mainstem	GA: Augusta Use	165.1
GA0031992	Columbia County - Reed Creek WPCP	Mainstem	GA: Augusta Use	165.1
GA0037621	Augusta Butler Creek - Messerly	Mainstem	GA: Augusta Use	165.1
GA0036790	Rinker Materials	Kiokee Creek	GA: Augusta Use	0.1
GA0036790-001	Rinker Materials	Kiokee Creek	GA: Augusta Use	0.1
GA0036790-002	Rinker Materials	Kiokee Creek	GA: Augusta Use	0.1
GA0047775	Columbia County - Little River WPCP	Uchee Creek	GA: Augusta Use	0.1
GA0020389	Harlem WPCP	Uchee Creek	GA: Augusta Use	0.1
GA0031984	Columbia County - Crawford Creek WPCP	Uchee Creek	GA: Augusta Use	0.1
GA0002470-001	Unimin Corporation	Spirit Creek	GA: S. Augusta Use	0.1
GA0002801	International Paper Company	Spirit Creek	GA: S. Augusta Use	0.1
GA0003484	USA Fort Gordon	Spirit Creek	GA: S. Augusta Use	0.1
GA0003719	Olin Corporation - Augusta	Spirit Creek	GA: S. Augusta Use	0.1
GA0022161	DHR - East Central Regional Hospital	Spirit Creek	GA: S. Augusta Use	0.1
GA0047147	Augusta - Spirit Creek WPCP	Spirit Creek	GA: S. Augusta Use	0.1
GA0025631	Elberton - Fortson Creek WPCP	Beaverdam Creek	GA: Russell Use	0.1
GA0002321-001	Martin Marietta - Camak Quarry	Little River (GA)	GA: Thurmond Use	0.1
GA0031101	Washington WPCP	Little River (GA)	GA: Thurmond Use	0.1
GA0049450	Lincolnton WPCP	Little River (GA)	GA: Thurmond Use	0.1



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