Technical Memorandum

To: *South Carolina Department of Natural Resources (DNR)*
South Carolina Department of Health and Environmental Control (DHEC)

From: *CDM Smith*

Date: *September 2015 (update of July 2015 Draft)*

Subject: *Unimpaired Flow Dataset for the Saluda River Basin*
(Prepared as part of the South Carolina Surface Water Quantity Modeling Program)

1.0 Introduction

Unimpaired Flows (UIFs) represent the theoretical historical rate of flow at a location in the absence of all human activity in the river channel, such as water withdrawals, discharges, and impoundments. They will be used as boundary conditions and calibration targets for natural hydrology in the computer simulation models of the 8 major river basins in South Carolina. As such, they represent an important step in the South Carolina Surface Water Quantity Modeling project.

This technical memorandum (TM) summarizes the completion of the UIF dataset for the Saluda River Basin, to the confluence of the Broad River. Following completion of the Broad River Basin UIF dataset, the Saluda Basin UIF dataset will be extended to include the Congaree River to the confluence of the Wateree River. At that time, this TM will be updated.

This TM references the electronic database which houses the completed UIF dataset for the Saluda Basin, and also summarizes the techniques and decisions pertaining to synthesis of data where it is unavailable, and which may be specific to individual locations.

2.0 Overview of UIF Methodology

Fundamentally, UIFs are calculated by removing known impacts from measured streamflow values at places in which flow has been measured historically. An alternate method sometimes employed utilizes rainfall-runoff modeling to estimate natural runoff tendencies, but this technique is often

uncertain, and its only sure footing is in calibration to measured (and frequently impaired) streamflow records anyway. For the Saluda River Basin, UIFs were calculated at every location in which a USGS gage has recorded historical flow measurements. Measured and estimated impacts of withdrawals, discharges, impoundments were included as linear "debits" or "credits," and the measured flow was adjusted accordingly. Where historical data on river operations did not exist, it was hindcast using various estimation techniques. Once the UIFs were developed for each USGS gage, the Period of Record (POR) for each gage was statistically extended (if necessary) to cover the range of 1925-2013 (coinciding with the longest recorded streamflow in the basin). As a final step, the UIFs in ungaged basins were estimated from UIFs in basins with similar size, land use, and topography.

UIFs are intended to be used for the following purposes:

a) Headwater input to the SWAM models

b) Incremental flow inputs along the mainstem in the SWAM models

c) SWAM model calibration

d) Comparison of simulated managed flows to natural flows

e) Other uses by DNR/DHEC outside of the SWAM models

Figure 2.1 illustrates the step-by-step methodology for computing UIFs. It is supported by the following technical memoranda, which specifically outline the steps and guidelines for UIF computation and decision-making:

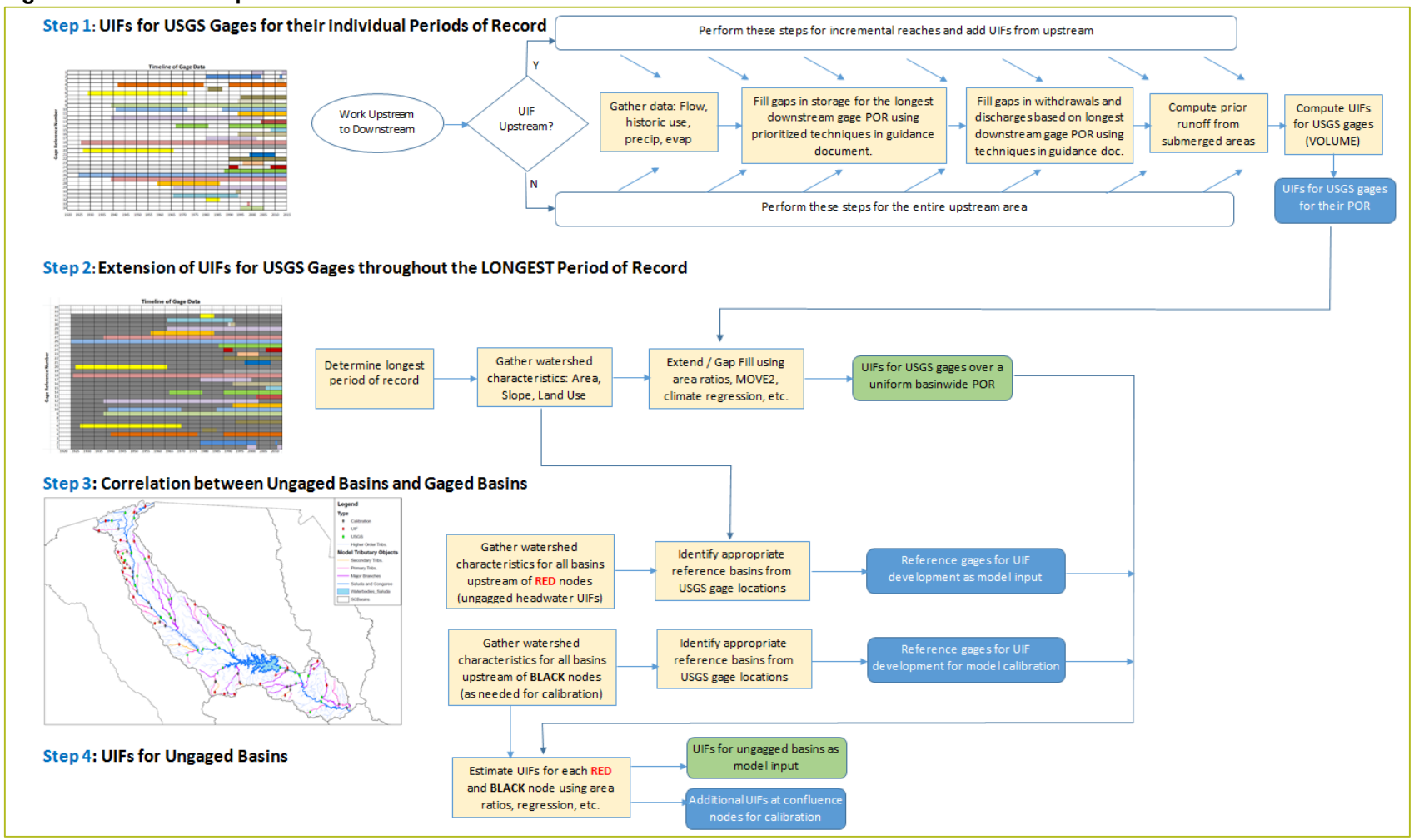
- *Methodology for Unimpaired Flow Development, Saluda River Basin, South Carolina (CDM Smith, January 2015)* – Included as **Attachment A** of this report. This includes a list of all USGS gages in the basin, as well as the documented water users whose data were used in computing the UIFs.
- *Guidelines for Standardizing and Simplifying Operational Record Extension (CDM Smith, March 2015)* – Included as **Attachment B** of this report. This includes guidelines for various techniques for operational gap filling and record extension, and which techniques are most appropriate for various circumstances.
- *Guidelines for Identifying Reference Basins for UIF Extension or Synthesis (CDM Smith, April 2015)* – Included as **Attachment C** of this report.
- *Refinements to the UIF Extension Process, with an Example* – Included as **Attachment E.**

The original guidance document for the UIFs (Attachment A, listed above) distinguished between Unregulated Flows (flows affected by impoundments) and Unimpaired Flows (flows which include the impacts of impoundments in addition to withdrawals and discharges along the river). It was determined that the distinction was not necessary in South Carolina, and so the procedure for computing Unregulated Flows in Section 5.3 of Attachment A was not separated from the rest of the UIF calculation, but rather, included in a single UIF equation represented by Equation 1 in Attachment A. Generally, the methods employed for the South Carolina UIFs are very similar to those employed for UIFs in North Carolina and Georgia, and include the impacts of impoundments, withdrawals, and discharges.

Figure 2.2 illustrates the locations of all UIFs developed for the Saluda River Basin, and distinguishes between those computed by adjusting measured streamflow at USGS gages, and those computed for ungaged basins through area transposition.

Hindcasting of agricultural withdrawals in the Saluda Basin was also required for the UIF calculations. Withdrawal data reported to DHEC from 2002 and 2014 was used directly, and prior to that, values from 1950 through 2001 were hindcasted using irrigated acreage estimation techniques. These estimation techniques are described in the CDM Smith memorandum entitled, "*Methodology for Developing Historical Surface Water Withdrawals for Agriculture Irrigation,"* dated July 2015.

Figure 2.1: UIF Development Process



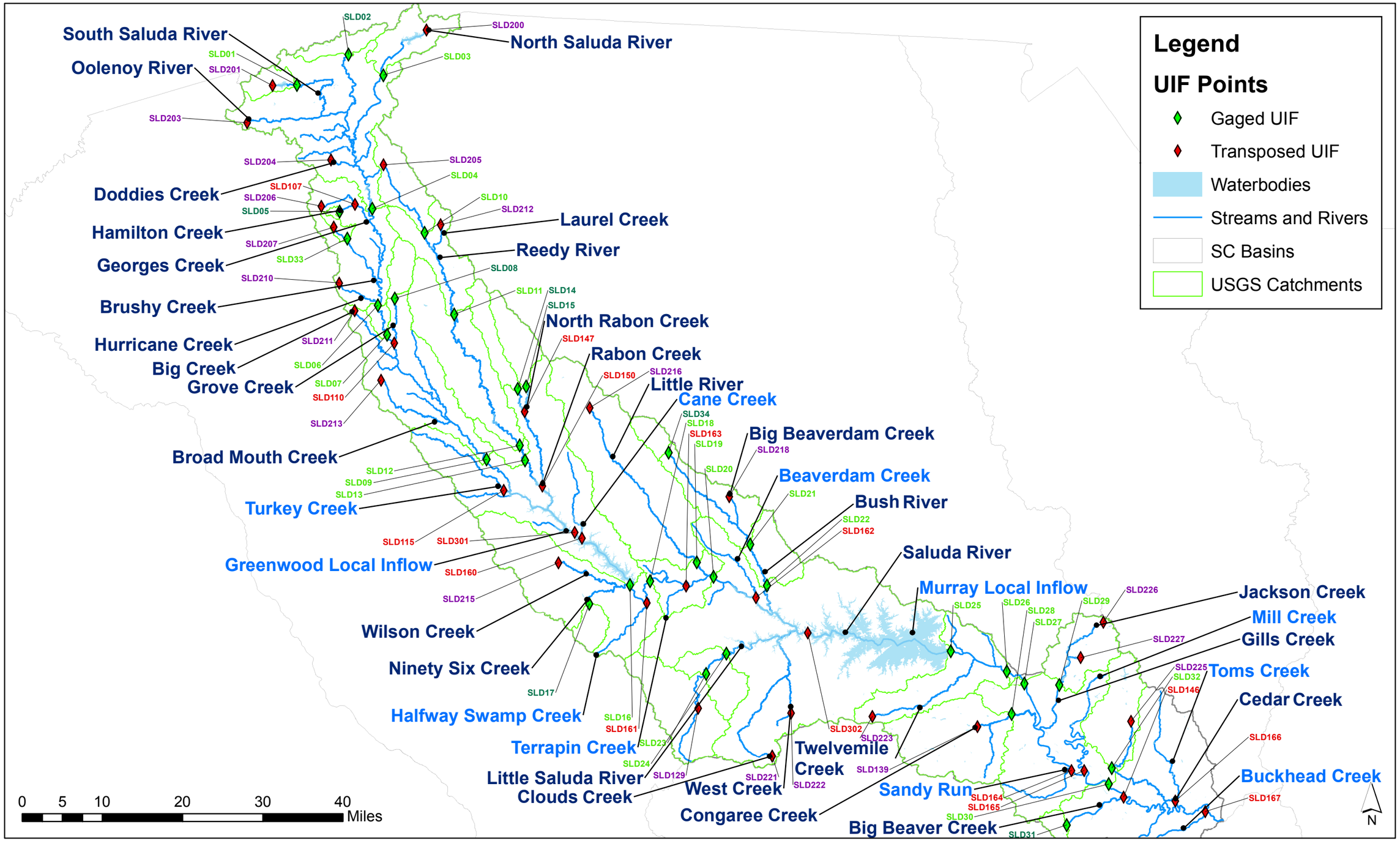


Figure 2.2: Unimpaired Flow Locations in the Saluda River Basin

3.0 Quality Assurance Reviews

Quality Assurance guidelines were developed in an internal CDM Smith memorandum dated April 2015, entitled *"Quality Assurance Guidelines: Unimpaired Flow Calculations (UIFs) for the South Carolina Surface Water Quantity Models."* The document is included in this report as **Attachment D**.

The Quality Assurance results are documented in each UIF workbook in the "QAQC" worksheet. Documentation includes the name of the reviewer, requested changes, and changes made. Some review items in addition to those presented in Attachment D were added to check the UIF extension calculations.

4.0 Summary of Operational Hindcasting

Unique circumstances involving data availability, observable trends, etc. required decisions about how to develop representative hindcast values for each individual user. A summary of hindcasting methods used for withdrawals, discharges, and storage are presented in **Table 4.1**, **Table 4.2**, and **Table 4.3**, respectively. Reference **Attachments A** and **B** for details on the listed methodologies.

Table 4.1: Summary of Methods Used for Hindcasting Withdrawals

Project Gage ID	USGS Number	Stream	Withdrawal Hindcasting			
			User ID	User Name	Time Periods	Method Used
SLD01	2162290	SOUTH SALUDA RIVER	23WS002S03	Greenville WS	Jan 1930 - Dec 1931	Anecdotal information
			23WS002S02	Greenville WS	none	none
SLD03	2162350	MIDDLE SALUDA RIVER	23GC013S01	Cliffs Club at Valley	Jan 1996 - Dec 2000	Anecdotal information
			23WS002S01	Greenville WS	none	none
SLD04	2162500	SALUDA RIVER	39GC002S01	Rolling Green GC	Jan 1955 - Dec 1985	Anecdotal information
			39GC006S01	The Rock at Jocassee GC	none	none
			39WS001S01	EASLEY COMBINED UTILITIES	Jan 1958 - Dec 1969	Annual data
SLD06	2163000	SALUDA RIVER	04MI001S01	VULCAN CONSTRUCTION MATERIALS LP	none	None
SLD07	2163001	SALUDA RIVER	04IN019S01	GERBER CHILDRENSWEAR INC	none	None
			04IN019S02	GERBER CHILDRENSWEAR INC	none	None
			04IN020S01	SOFT CARE APPAREL	none	None

Project Gage ID	USGS Number	Stream	Withdrawal Hindcasting			
			User ID	User Name	Time Periods	Method Used
			04IN020S02	SOFT CARE APPAREL	none	None
SLD09	2163500	SALUDA RIVER	04WS005S01	Belton Honea Path WA	Jan 1962 - Dec 1982	Anecdotal information
			04WS011S01	Town of Williamston	Jan 1935 - Dec 1982	Anecdotal information
			04PT001S01	DUKE ENERGY CAROLINAS LLC	Jan 1951 - Dec 1983	Monthly averages
SLD10	2164000	REEDY RIVER	23GC004S01	Furman Univ GC	Oct 1996 - Dec 1998	Short-term gap filling
			23GC004S02	Furman Univ GC	none	none
			23IN033S01	US FINISHING	none	none
SLD11	2164110	REEDY RIVER	23GC014S01	The Preserve at Verdae	Jan 1991 - Dec 2000	Anecdotal information
SLD16	2166501	SALUDA RIVER	City Pond/Coronaca Creek	Greenwood CPW	Jan 1935 - Dec 1954	Anecdotal information
			24WS001S02	Greenwood CPW	none	None
			24WS001S03	Greenwood CPW	Jan 1955 - Dec 1994	Anecdotal information
			24WS001S01	Greenwood CPW	Jan 1960 - Dec 1982	Anecdotal information
			30WS002S01	Laurens CPW	Jan 1928 - Dec 1982	Anecdotal information
			30WS002S02	Laurens CPW	Jan 1948 - Dec 1982	Anecdotal information
			30WS002S03	Laurens CPW	Jan 1989 - Dec 1995	Anecdotal information
			24IN007S01	GREENWOOD MILLS INC ADAMS PLANT	none	none
			24IN003S01	GREENWOOD MILLS INC CHALMERS PLANT	none	none
			24IN004S01	GREENWOOD MILLS INC DURST PLANT	none	none
			24IN009S01	GREENWOOD MILLS INC NINETY SIX PLANT	none	none
			24IN006S01	GREENWOOD MILLS INC SLOAN PLANT	none	none
			24IN052S01	GREENWOOD MILLS INC HARRIS PLANT	none	none

Project Gage ID	USGS Number	Stream	Withdrawal Hindcasting			
			User ID	User Name	Time Periods	Method Used
SLD20	2167500	SALUDA RIVER	36WS001S01	NEWBERRY CITY OF	Jan 1962 - Dec 1982	Annual data
SLD25	2168504	SALUDA RIVER	32GC010S01	Ponderosa CC	Jan 1965 - Dec 2000	Anecdotal information
			32WS052S01	City of W. Columbia	Jan 1990 - May 1991; May 1993 - Dec 1993	Short-term gap filling
			32PT001S01	SCE&G	Dec 1958 - Jun 1983	Monthly averages
			36WS002S01	NEWBERRY COUNTY WATER & SEWER AUTHORITY	none	None
			40WS002S02	COLUMBIA CITY OF	none	None
			41WS003S01	SALUDA COUNTY WATER AND SEWER AUTHORITY	none	None
SLD26	2168504	SALUDA RIVER	32GC004S01	CC of Lexington	Jan 1966 - Dec 1984	Anecdotal information
			32GC004S01	CC of Lexington	Jul 1997 - Dec 2000	Anecdotal information
			32IN006S01	Shaw Industries	Jan 1961 - Jun 1983	Anecdotal information
			32WS001S01	Town of Lexington	Aug 1925 - Dec 1982	Regional population trends
			32GC007S01	GOLDEN HILLS INC	none	None
			32IN001S01	BC COMPONENTS INC	none	none
SLD33	2162700	MIDDLE BRANCH	39GC003S01	Smithfields CC	Jan 1983 - Dec 2001	Anecdotal information

Table 4.2: Summary of Methods Used for Hindcasting Discharges

Project Gage ID	USGS Number	Stream	Discharge Hindcasting			
			Facility Name	ID	Time Periods	Method Used
SLD04	2162500	Saluda River	MILLIKEN/GAYLEY PLANT	SC0003191-001	7/1978-12/1988	Industrial discharge
			MILLIKEN/GAYLEY PLANT	SC0003191-T11	none	Short-term gap filling
			WCRSA/MARIETTA WWTP	SC0026883-001	1/1972-12/1988	Correlated with monthly withdrawal (Greenville)
			WCRSA/SALUDA RIVER PLANT	SC0034568-001	1/1975-12/1988	Correlated with monthly withdrawal (Greenville)
			GREENVILLE/N SALUDA & TABLE ROCK WTP	SCG646033-001	1/1930-12/2013	Permit estimates (Greenville)
SLD06	2163000	Saluda River	WCRSA/PIEDMONT REGIONAL WWTP	SC0048470-001	none	none
			WCRSA/PIEDMONT PLANT	SC0023906-001	1/1965-12/1988	Correlated with monthly withdrawal (Greenville)
			EASLEY/MIDDLE BRANCH WWTP	SC0039853-001	1/1958-12/1988	Correlated with monthly withdrawal (Easley)
			WCRSA/GEORGES CREEK	SC0047309-001	none	none
			EASLEY/GEORGES CREEK LAGOON	SC0023043-001	1/1958-12/1988	Correlated with monthly withdrawal (Easley)
			WCRSA/LAKESIDE PLANT	SC0037460-001	1/1975-12/1988	Correlated with monthly withdrawal (Greenville)
			WCRSA/PARKER PLANT	SC0037451-001	1/1975-12/1988	Correlated with monthly withdrawal (Greenville)
			WCRSA/GROVE CREEK WWTP	SC0024317-001	1/1972-12/1988	Correlated with monthly withdrawal (Greenville)
			AIR PRODUCTS & CHEMICALS, INC	SC0048429-001	none	Short-term gap filling
			VULCAN CONST MAT/LAKESIDE	SCG730245-000	6/2008-8/2008	Permit estimates (Vulcan)

Project Gage ID	USGS Number	Stream	Discharge Hindcasting			
			Facility Name	ID	Time Periods	Method Used
SLD07	2163001	Saluda River	PELZER, TOWN OF	SC0040797-001	1/1960-12/1988	Correlated with monthly withdrawal (Greenville)
			WEST PELZER WWTF	SC0025194-001	1/1960-12/1988	Correlated with monthly withdrawal (Greenville)
SLD09	2163500	Saluda River	WARE SHOALS/DAIRY STREET	SC0020214-001	1/1962-12/1988	Correlated with monthly withdrawal (Belton Honea)
			HONEA PATH/CHIQUOLA MILL	SC0020672-001	1/1962-12/1988	Correlated with monthly withdrawal (Belton Honea)
			BELTON/DUCWORTH PLANT	SC0020745-001	1/1962-12/1988	Correlated with monthly withdrawal (Belton Honea)
			BELTON/DUCWORTH (SALUDA)	SC0045896-002	none	Short-term gap filling
			BELTON/DUCWORTH (SALUDA)	SC0045896-003	none	Short-term gap filling
			BELTON/DUCWORTH (SALUDA)	SC0045896-001	none	Short-term gap filling
			WILLIAMSTON/BIG CRK EAST WWTP	SC0046841-001	none	Short-term gap filling
			DUKE ENERGY/LEE STEAM STATION	SC0002291-001	1/1951-12/1988	Monthly estimates from user
			DUKE ENERGY/LEE STEAM STATION	SC0002291-004	1/1951-12/1988	Monthly estimates from user
			WILLIAMSTON/BIG CREEK EAST	SC0025976-001	1/1935-12/1988	Extended from anecdotal info
SLD11	2164110	Reedy River	WCRSA/LOWER REEDY RIVER PLANT	SC0024261-001	11/1985-12/1988	Correlated with monthly withdrawal (Greenville)
			WCRSA/MAULDIN ROAD	SC0041211-001	1/1930-12/1988	Correlated with monthly withdrawal (Greenville)
SLD12	2165000	Reedy River	SC DEPT CORR/PERRY CORR INST	SC0029343-001	none	Short-term gap filling
SLD18	2167000	Saluda River	NINETY SIX WWTF	SC0036048-001	1/1935-12/1988	Correlated with monthly withdrawal (Greenwood)
			GREENWOOD/WILSON CREEK WWTF	SC0021709-001	1/1935-12/1988	Correlated with monthly withdrawal (Greenwood)

Project Gage ID	USGS Number	Stream	Discharge Hindcasting			
			Facility Name	ID	Time Periods	Method Used
SLD19	2167450	Little River	LAURENS COMM OF PW/LAURENS	SC0020702-001	1/1928-12/1988	Correlated with monthly withdrawal (Laurens)
			INGERSOLL RAND/G.W. RECOVERY SYS	SC0048534-001	none	none
			LAURENS WTP	SCG646028-001	1/1928-12/2013	Permit estimates (Laurens)
SLD20	2167500	Saluda River	NEWBERRY WTP	SCG646047-001	1/1926-12/2013	Permit estimates (Newberry)
SLD21	2167563	BUSH RIVER	LAURENS CO W&S/CLINTON-JOANNA	SC0037974-001	2/1930-12/1988	Extended from regional population trends
SLD22	2167582	BUSH RIVER	NEWBERRY CO W&SA/PLANT #1	SC0040860-001	1/1926-12/1988	Correlated with monthly withdrawal (Newberry)
			NEWBERRY/BUSH RIVER WWTF	SC0024490-001	1/1926-12/1988	Correlated with monthly withdrawal (Newberry)
SLD23	21677037	LITTLE SALUDA RIVER	SALUDA, TOWN OF	SC0022381-001	1/1926-12/1988	Correlated with monthly withdrawal (Newberry)
SLD25	2168504	SALUDA RIVER	AMICK PROCESSING INC	SC0025585-001	none	Short-term gap filling
			SCE&G/MCMEEKIN STEAM STATION	SC0002046 (lumped)	6/1958-12/2013	Permit estimates (SCE&G)
SLD26	2169000	SALUDA RIVER	LEXINGTON/COVENTRY WOODS SD	SC0026735-001	8/1925-12/1988	Correlated with monthly withdrawal (W. Columbia)
			CWS/WATERGATE DEVELOPMENT	SC0027162-001	6/1978-12/1988	Industrial discharge
			VANARSDALE SD/MIDLANDS UTILITY	SC0030945-001	none	Short-term gap filling
			LEXINGTON/WHITEFORD SD WWTP	SC0043541-001	none	Short-term gap filling
			BUSH RIVER UTILITIES	SC0032743-001	none	Short-term gap filling
			CWS/I-20 REGIONAL	SC0035564-001	2/1985-12/1988	Industrial discharge
			WOODLAND HILLS WEST SD	SC0029475-001	none	none

Project Gage ID	USGS Number	Stream	Discharge Hindcasting			
			Facility Name	ID	Time Periods	Method Used
			ALPINE UTILITIES/STOOP CREEK	SC0029483-001	none	Short-term gap filling
			SHAW INDUSTRIES GROUP/COLUMBIA	SC0003557 (lumped)	1/1961-12/1988	Correlated with monthly withdrawal (Shaw)
			BC COMPONENTS INC	SC0003425 (lumped)	1/1983-12/1988	Correlated with monthly withdrawal (BC Components)
			CWS/FRIARSGATE SD	SC0036137-001	2/1982-12/1988	Industrial discharge

Table 4.3: Summary of Methods Used for Hindcasting Storage

Project Gage ID	USGS Number	Stream	Storage Hindcasting		
			Reservoir Name	Time Periods	Method Used
SLD01	2162290	SOUTH SALUDA RIVER	Table Rock	1/1930-12/1999	Hindcast Method #3 adjusted for variable historic withdrawals
SLD03	21623975	NORTH SALUDA RIVER	North Saluda	1/1961-12/1999	Hindcast Method #2 adjusted for variable historic withdrawals
SLD04	2162500	SALUDA RIVER	Saluda Lake	none	Assumed run-of-river
SLD12	2165000	REEDY RIVER	Boyd Mill Pond	none	Assumed run-of-river
SLD16	2166501	SALUDA RIVER	Lake Rabon	1/1989-11/2011	Hindcast Method #1
			Lake Greenwood	10/1960-9/1966	Multi-year gap filled with Method #1, small gaps with interpolation
SLD25	2168504	SALUDA RIVER	Lake Murray	none	Filled small gaps with interpolation

An example of one of the withdrawal hindcasting methods is shown in **Figure 4.1,** which shows discharges extended for Belton Honea Path Water Authority based on anecdotal information provided by the user prior to 1983.

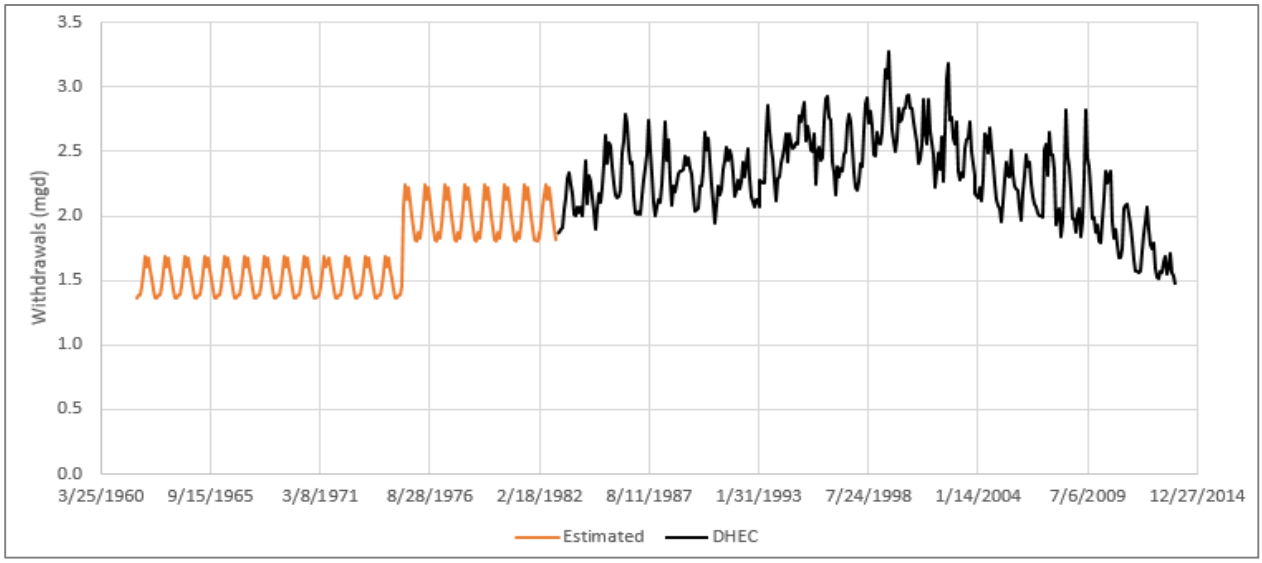


Figure 4.1: Hindcasting Using Anecdotal Information for Belton Honea Path Water Authority

An example of one of the discharge hindcasting methods is shown in **Figure 4.2,** which shows discharges extended based on withdrawals for Easley.

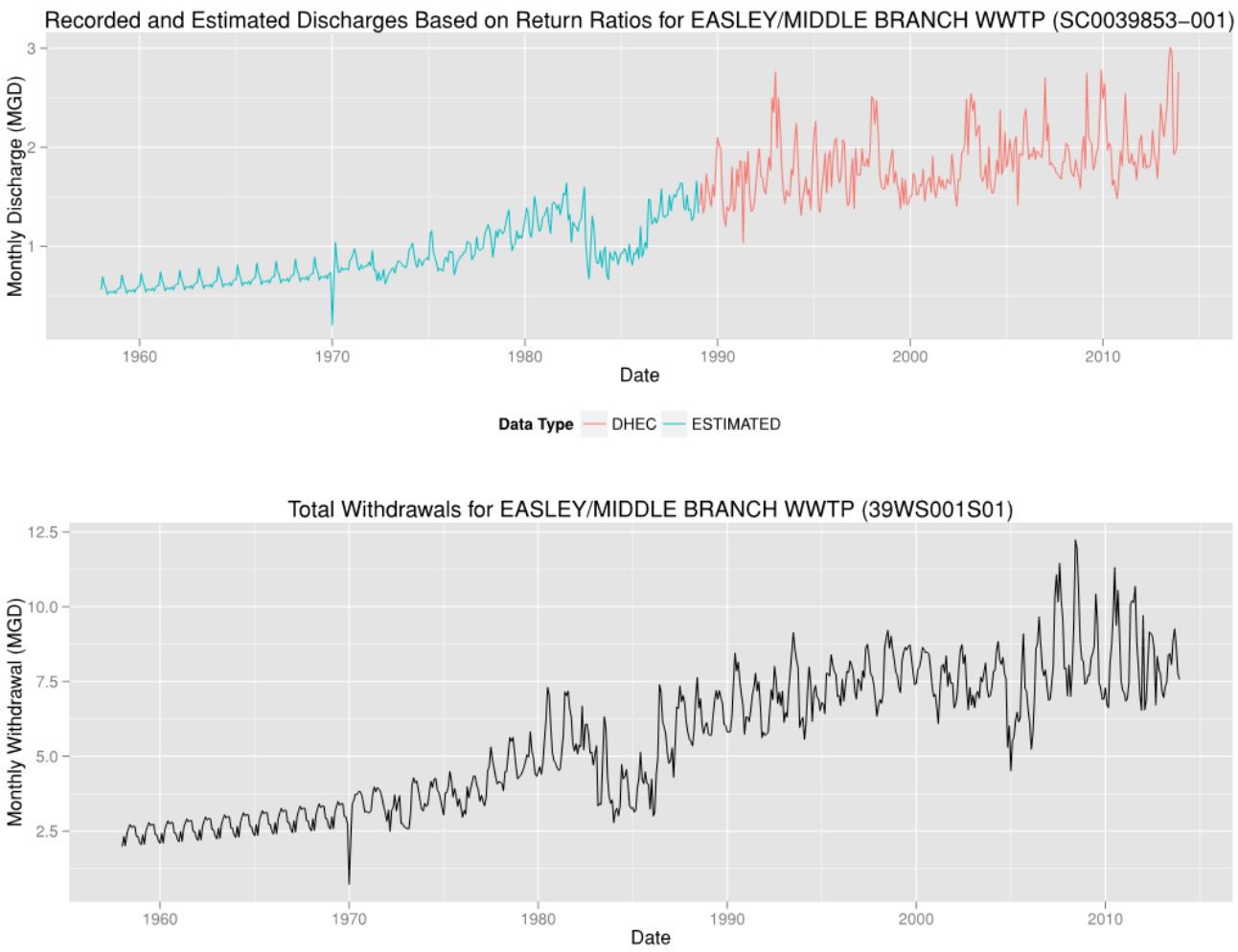


Figure 4.2: (TOP) DHEC Provided and Estimated Monthly Discharge. (BOTTOM) Monthly Withdrawals Used for Hindcasting

In the absence of simulation models of specific reservoirs, historical reservoir dynamics had to be estimated with simple predictive variables, such as cumulative rainfall and estimated historical withdrawals. An example validation graph for storage hindcasting is shown for Table Rock reservoir in **Figures 4.3a and 4.3b** (Methods are explained in Attachment B). The complete timeseries for Table Rock, with estimated and observed portions indicated, is then shown in **Figure 4.4**.

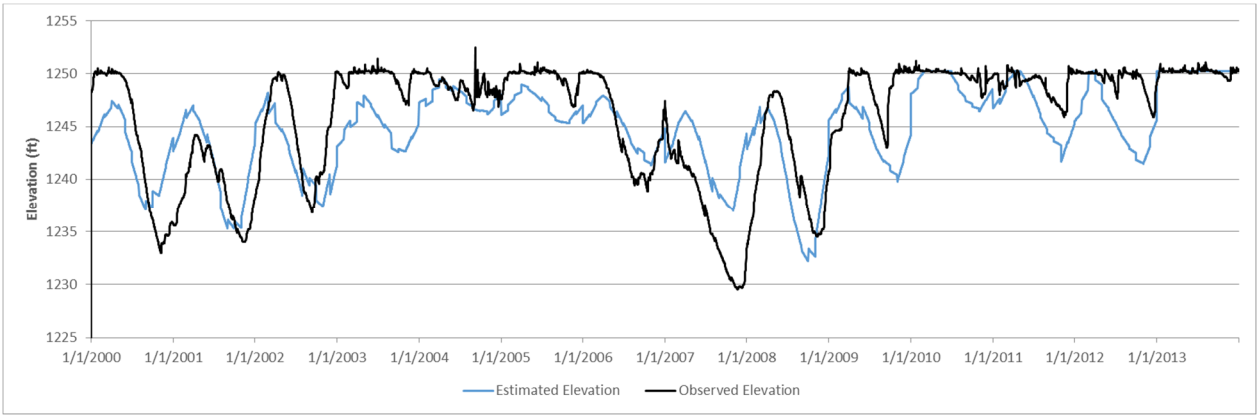


Figure 4.3a: Validation of Hindcasting Method 3 for Table Rock Reservoir (daily observed elevations)

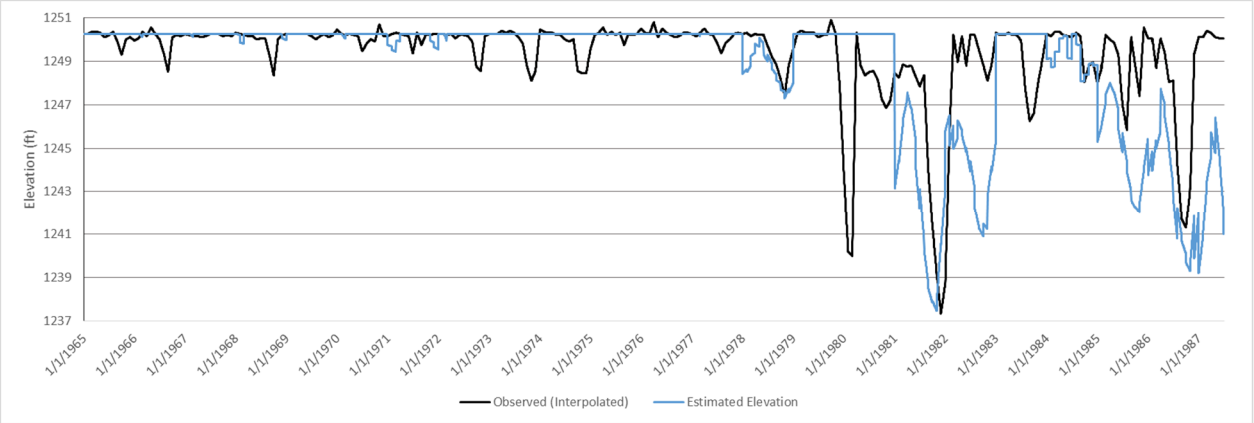


Figure 4.3b: Validation of Hindcasting Method 3 for Table Rock Reservoir (monthly observed elevations)

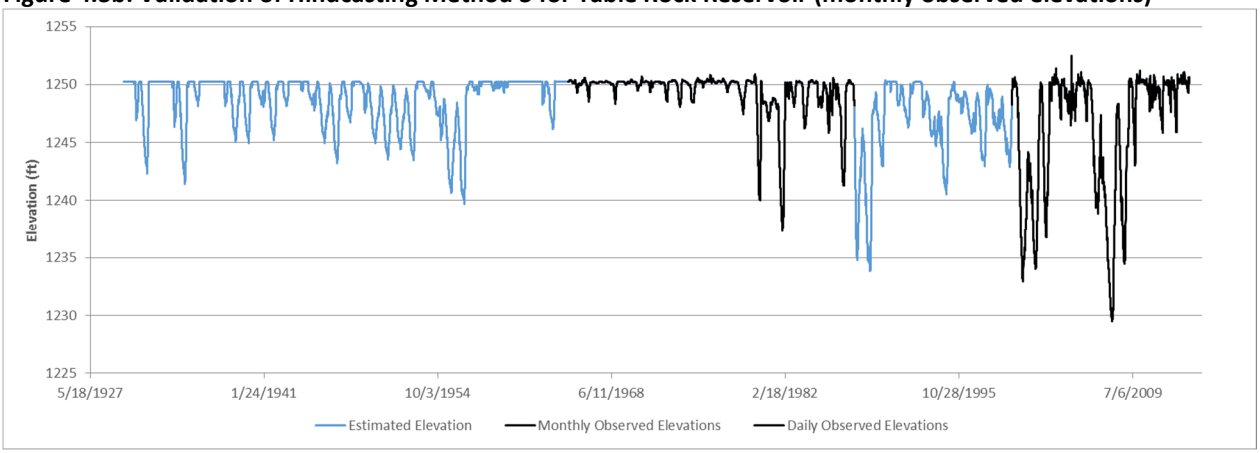


Figure 4.4: Complete Timeseries (Estimated and Observed) for Table Rock

5.0 Summary of Gaged UIF Flow Record Extension

A summary of the reference gages and methods used to extend the UIFs with partial periods of record is provided in **Table 5.1**. Initial candidates of reference gages are selected following guidelines outlined in **Attachment C.** See **Attachment E** for details pertaining to the decision-making process. As MOVE.1 without an initial log transform may produce negative or near-zero values, area proration replaces values below the overlapping minimum between the partial and extension gage. Four gages are italicized: SLD28, SL29, SLD31, and SLD32. These four are tributaries to the Congaree and needed extension to 1983 for SWAM calibration. Once Broad UIFs have been developed, these will be fully extended to the full period of record. Also of note, one Broad gage, BRD11 (USGS number 02154790 on South Pacolet River) was brought in to further improve SLD03.

Table 5.1: Summary of Extending UIFs with Partial Periods of Record

USGS Gage with Partial Record					USGS Reference Gage(s)			Method of Extension
Project Gage ID	USGS Number	Stream	Periods of Record	Basin Area (mi^2)	Project Gage ID	Stream	Basin Area (mi^2)	
SLD01	2162290	SOUTH SALUDA RIVER	02/2000 - 09/2005 07/2012 - 01/2014	17.2	SLD02	MIDDLE SALUDA RIVER	20.9	MOVE.1 (log transform)
					SLD04	SALUDA RIVER	295.0	MOVE.1 (log transform)
					SLD18	SALUDA RIVER	1354.8	MOVE.1 (log transform)
					SLD26	SALUDA RIVER	2517.2	MOVE.1 (log transform)
SLD02	2162350	MIDDLE SALUDA RIVER	10/1980 - 09/2003 07/2012 - 10/2013	20.9	SLD01	SOUTH SALUDA RIVER	17.2	MOVE.1: no transform, Area Ratio if MOVE.1 < 6.6 cfs
					SLD04	SALUDA RIVER	295.0	MOVE.1 (log transform)
					SLD18	SALUDA RIVER	1354.8	MOVE.1: no transform, Area Ratio if MOVE.1 < 6.6 cfs
					SLD26	SALUDA RIVER	2517.2	MOVE.1: no transform, Area Ratio if MOVE.1 < 6.6 cfs
SLD03	21623975	NORTH SALUDA RIVER	01/2011 - 01/2013	44.2	SLD02	MIDDLE SALUDA RIVER	20.9	MOVE.1: no transform, Area Ratio if MOVE.1 < 26.3 cfs
					BRD11	SOUTH PACOLET RIVER	55.4	MOVE.1 (log transform)
					SLD04	SALUDA RIVER	295.0	MOVE.1: no transform, Area Ratio if MOVE.1 < 9.3 cfs
					SLD18	SALUDA RIVER	1354.8	MOVE.1: no transform, Area Ratio if MOVE.1 < 9.3 cfs

USGS Gage with Partial Record					USGS Reference Gage(s)			Method of Extension
Project Gage ID	USGS Number	Stream	Periods of Record	Basin Area (mi^2)	Project Gage ID	Stream	Basin Area (mi^2)	
					SLD26	SALUDA RIVER	2517.2	MOVE.1: no transform, Area Ratio if MOVE.1 < 9.3 cfs
SLD04	2162500	SALUDA RIVER	01/1942 - 10/1978 02/1990 - current	295.0	SLD06	SALUDA RIVER	410.0	MOVE.1 (log transform)
					SLD09	SALUDA RIVER	580.2	MOVE.1 (log transform)
					SLD18	SALUDA RIVER	1354.8	MOVE.1 (log transform)
					SLD26	SALUDA RIVER	2517.2	MOVE.1 (log transform)
SLD05	2162525	HAMILTON CREEK	01/1981 - 09/1986	1.6	SLD18	SALUDA RIVER	1354.8	MOVE.1 (log transform)
					SLD26	SALUDA RIVER	2517.2	MOVE.1 (log transform)
SLD06	2163000	SALUDA RIVER	10/1929 - 09/1971	410.0	SLD04	SALUDA RIVER	295.0	MOVE.1 (log transform)
					SLD09	SALUDA RIVER	580.2	MOVE.1 (log transform)
					SLD18	SALUDA RIVER	1354.8	MOVE.1 (log transform)
					SLD26	SALUDA RIVER	2517.2	MOVE.1 (log transform)
SLD07	2163001	SALUDA RIVER	04/1995 - current	418.8	SLD09	SALUDA RIVER	580.2	MOVE.1: no transform, Area Ratio if MOVE.1 < 58.2 cfs
					SLD18	SALUDA RIVER	1354.8	MOVE.1 (log transform)
					SLD26	SALUDA RIVER	2517.2	MOVE.1 (log transform)
SLD08	21630967	GROVE CREEK	07/1994 - 11/2008	19.2	SLD11	REEDY RIVER	110.0	MOVE.1: no transform, Area Ratio if MOVE.1 < 0 cfs
					SLD10	REEDY RIVER	48.5	MOVE.1: no transform, Area Ratio if MOVE.1 < 0 cfs
					SLD14	SOUTH RABON CREEK	29.9	MOVE.1 (log transform)
					SLD18	SALUDA RIVER	1354.8	MOVE.1 (log transform)
					SLD26	SALUDA RIVER	2517.2	MOVE.1 (log transform)
SLD09	2163500	SALUDA RIVER	03/1939 - current	580.2	SLD06	SALUDA RIVER	410.0	MOVE.1 (log transform)
					SLD18	SALUDA RIVER	1354.8	MOVE.1 (log transform)
					SLD26	SALUDA RIVER	2517.2	MOVE.1 (log transform)
SLD10	2164000	REEDY RIVER	11/1941 - 09/1971 06/1987 - current	48.5	SLD06	SALUDA RIVER	410.0	MOVE.1 (log transform)
					SLD14	SOUTH RABON CREEK	29.9	MOVE.1: no transform, Area Ratio if MOVE.1 < 5.2 cfs
					SLD18	SALUDA RIVER	1354.8	MOVE.1: no transform, Area Ratio if MOVE.1 < 5.2 cfs
					SLD26	SALUDA RIVER	2517.2	MOVE.1 (log transform)
SLD11	2164110	REEDY RIVER	09/1993 - current	110.0	SLD10	REEDY RIVER	48.5	MOVE.1 (log transform)
					SLD18	SALUDA RIVER	1354.8	MOVE.1 (log transform)
					SLD26	SALUDA RIVER	2517.2	MOVE.1 (log transform)
SLD12	2165000	REEDY RIVER	04/1939 - 09/2004	236.2	SLD13	REEDY RIVER	251.3	Area Ratio
					SLD18	SALUDA RIVER	1354.8	Area Ratio
					SLD26	SALUDA RIVER	2517.2	Area Ratio

USGS Gage with Partial Record					USGS Reference Gage(s)			Method of Extension
Project Gage ID	USGS Number	Stream	Periods of Record	Basin Area (mi^2)	Project Gage ID	Stream	Basin Area (mi^2)	
SLD13	21650905	REEDY RIVER	11/2004 - current	251.3	SLD18	SALUDA RIVER	1354.8	MOVE.1: no transform, Area Ratio if MOVE.1 < 5 cfs
					SLD26	SALUDA RIVER	2517.2	Area Ratio
SLD14	2165200	SOUTH RABON CREEK	01/1967 - 09/1981 05/1990 - current	29.9	SLD10	REEDY RIVER	48.5	MOVE.1 (log transform)
					SLD18	SALUDA RIVER	1354.8	MOVE.1 (log transform)
					SLD26	SALUDA RIVER	2517.2	MOVE.1 (log transform)
SLD15	21652801	NORTH RABON CREEK	08/2008 - current	36.7	SLD14	SOUTH RABON CREEK	29.9	Area Ratio
					SLD18	SALUDA RIVER	1354.8	MOVE.1: no transform, Area Ratio if MOVE.1 < 0 cfs
					SLD26	SALUDA RIVER	2517.2	MOVE.1: no transform, Area Ratio if MOVE.1 < 0 cfs
SLD16	2166501	SALUDA RIVER	10/1994 - 09/1995 10/1996 - current	1165.0	SLD18	SALUDA RIVER	1354.8	MOVE.1 (log transform)
					SLD26	SALUDA RIVER	2517.2	MOVE.1: no transform, Area Ratio if MOVE.1 < 125 cfs
SLD17	2166970	NINETY-SIX CREEK	10/1980 - 09/2001	17.8	SLD22	BUSH RIVER	114.4	MOVE.1 (log transform)
					SLD18	SALUDA RIVER	1354.8	MOVE.1 (log transform)
					SLD26	SALUDA RIVER	2517.2	MOVE.1 (log transform)
SLD18	2167000	SALUDA RIVER	10/1926 - current	1354.8	SLD26	SALUDA RIVER	2517.2	MOVE.1: no transform, Area Ratio if MOVE.1 < 119 cfs
SLD19	2167450	LITTLE RIVER	03/1990 - current	223.6	SLD18	SALUDA RIVER	1354.8	MOVE.1: no transform, Area Ratio if MOVE.1 < 0.02 cfs
					SLD26	SALUDA RIVER	2517.2	MOVE.1: no transform, Area Ratio if MOVE.1 < 0.02 cfs
SLD20	2167500	SALUDA RIVER	01/1927 - 09/1965	1624.7	SLD18	SALUDA RIVER	1354.8	MOVE.1 (log transform)
					SLD26	SALUDA RIVER	2517.2	Area Ratio
SLD21	2167563	BUSH RIVER	03/1999 - 06/2009	73.7	SLD22	BUSH RIVER	114.4	MOVE.1 (log transform)
					SLD26	SALUDA RIVER	2517.2	MOVE.1 (log transform)
SLD22	2167582	BUSH RIVER	02/1990 - current	114.4	SLD26	SALUDA RIVER	2517.2	MOVE.1 (log transform)
SLD23	21677037	LITTLE SALUDA RIVER	10/1996 - 09/2001 11/2001 - 05/2002 10/2002 - 09/2004	90.4	SLD17	NINETY-SIX CREEK	17.8	Area Ratio
					SLD22	BUSH RIVER	114.4	Area Ratio
					SLD18	SALUDA RIVER	1354.8	Area Ratio
					SLD26	SALUDA RIVER	2517.2	Area Ratio
SLD25	2168504	SALUDA RIVER	10/1988 - current	2417.6	SLD26	SALUDA RIVER	2517.2	MOVE.1: no transform, Area Ratio if MOVE.1 < 185 cfs

USGS Gage with Partial Record					USGS Reference Gage(s)			Method of Extension
Project Gage ID	USGS Number	Stream	Periods of Record	Basin Area (mi^2)	Project Gage ID	Stream	Basin Area (mi^2)	
SLD26	2169000	SALUDA RIVER	08/1925 - current	2517.2	NONE (complete record)			
SLD28	*2169550*	*CONGAREE CREEK*	*10/1959 - 09/1980*	*119.2*	*SLD29*	*GILLS CREEK*	*58.7*	*Area Ratio*
SLD29	*2169570*	*GILLS CREEK*	*10/1966 - current*	*58.7*	*NONE (complete to 1983)*			
SLD31	*2169630*	*BIG BEAVER CREEK*	*07/1966 - 09/1993*	*9.9*	*SLD32*	*CEDAR CREEK*	*67.9*	*Area Ratio*
					SLD29	*GILLS CREEK*	*58.7*	*Area Ratio*
SLD32	*2169670*	*CEDAR CREEK*	*11/1980-09/1985*	*67.9*	*SLD31*	*BIG BEAVER CREEK*	*9.9*	*Area Ratio*
					SLD29	*GILLS CREEK*	*58.7*	*Area Ratio*
SLD33	2162700	MIDDLE BRANCH	05/1998 - 09/1998	6.5	SLD08	GROVE CREEK	19.2	Area Ratio
					SLD10	REEDY RIVER	48.5	Area Ratio
					SLD18	SALUDA RIVER	1354.8	Area Ratio
					SLD26	SALUDA RIVER	2517.2	Area Ratio
SLD34	2167557	BUSH RIVER	06/1995 - 09/2005	15.5	SLD17	NINETY-SIX CREEK	17.8	MOVE.1: no transform, Area Ratio if MOVE.1 < 0 cfs
					SLD22	BUSH RIVER	114.4	MOVE.1: no transform, Area Ratio if MOVE.1 < 0 cfs
					SLD18	SALUDA RIVER	1354.8	MOVE.1: no transform, Area Ratio if MOVE.1 < 0 cfs
					SLD26	SALUDA RIVER	2517.2	MOVE.1: no transform, Area Ratio if MOVE.1 < 0 cfs

Note: SLD28, SL29, SLD31, and SLD32 are tributaries to the Congaree and needed extension to 1983 for SWAM calibration. Once Broad River Basin UIFs have been developed, these will be fully extended to the full period of record.

One way to evaluate selection of extension method is comparing frequency curves with flows of the partial record needing extending. A sample plot for SLD20 is shown in **Figure 5.1**.

Validation graphs are available for each USGS gage. Each validation graph show the period of record for a computed UIF and the predicted flows from reference gages during that same period of record. A sample validation graph is shown in **Figure 5.2**. The usage of each reference gage over different ungaged periods for the target gage (prioritized by hydrologic similarity and available record) is illustrated in **Figure 5.3**. Graphs for each UIF timeseries developed at a USGS gage site are presented in **Attachment F**.

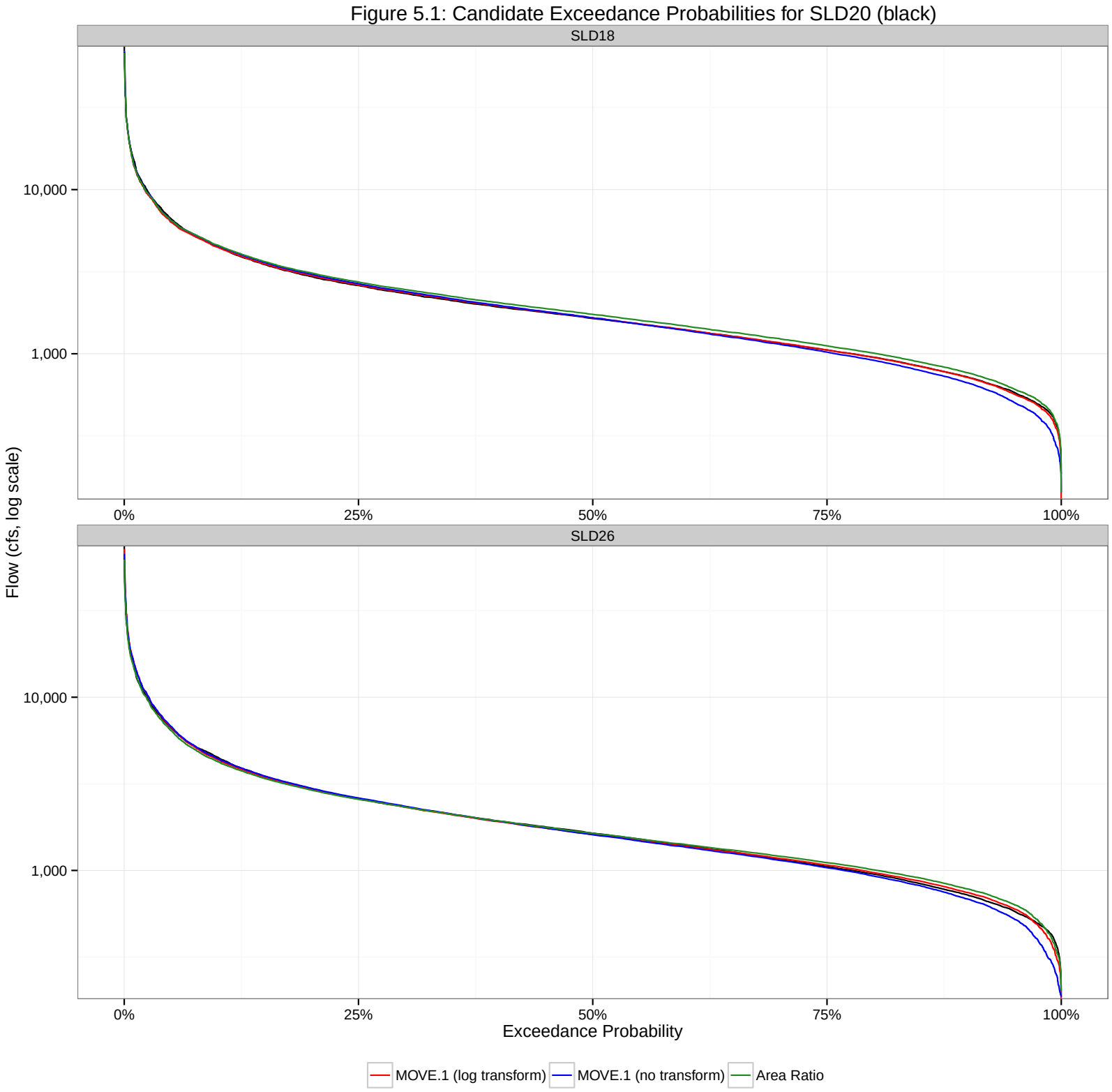


Figure 5.1: Candidate Exceedance Probabilities for SLD20 (black)
SLD18
SLD26
10,000
1,000
0%
25%
50%
75%
100%
Flow (cfs, log scale)
Exceedance Probability
MOVE.1 (log transform)
MOVE.1 (no transform)
Area Ratio

Figure 5.2: Final Verification Timeseries for SLD20 (black)

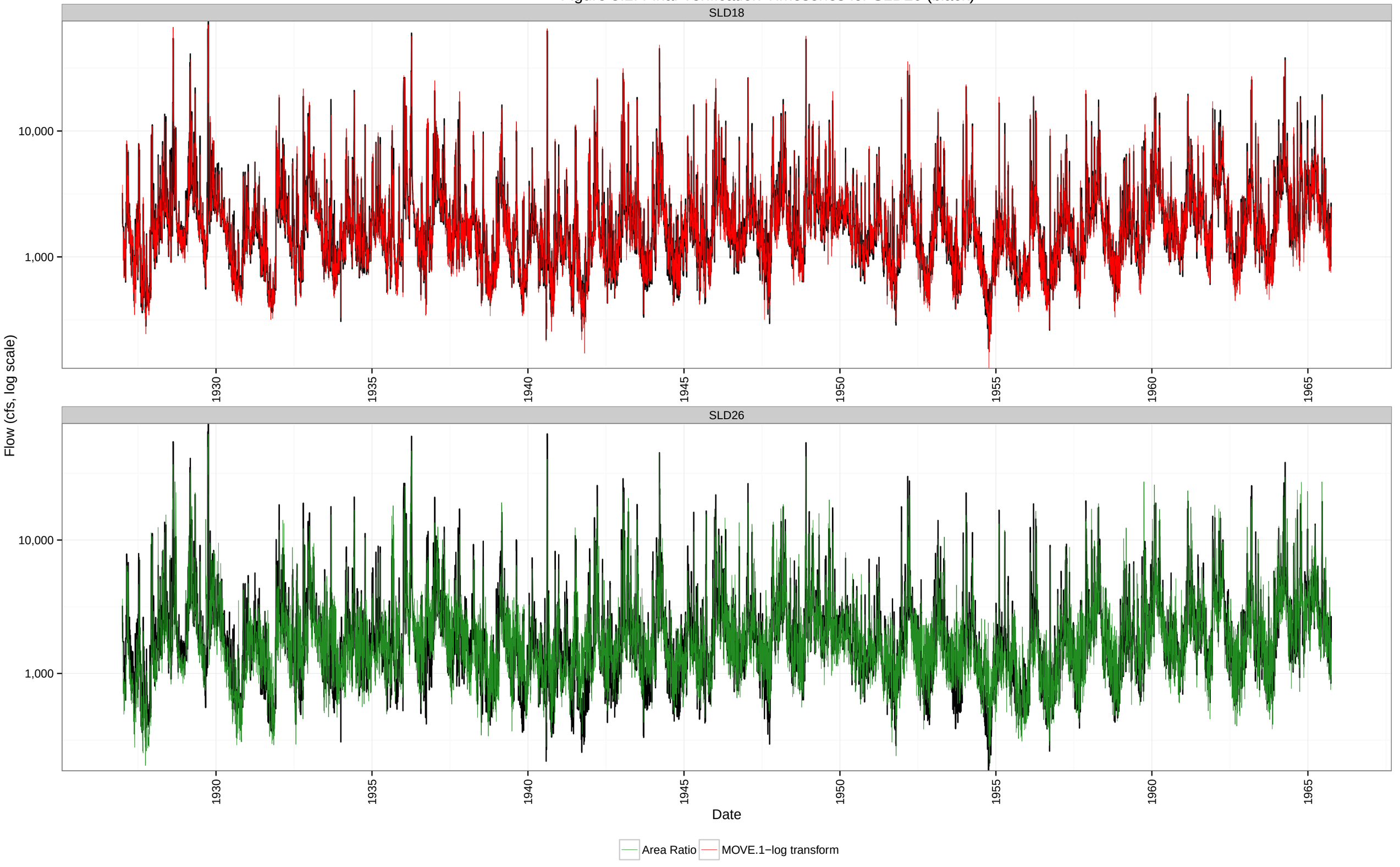
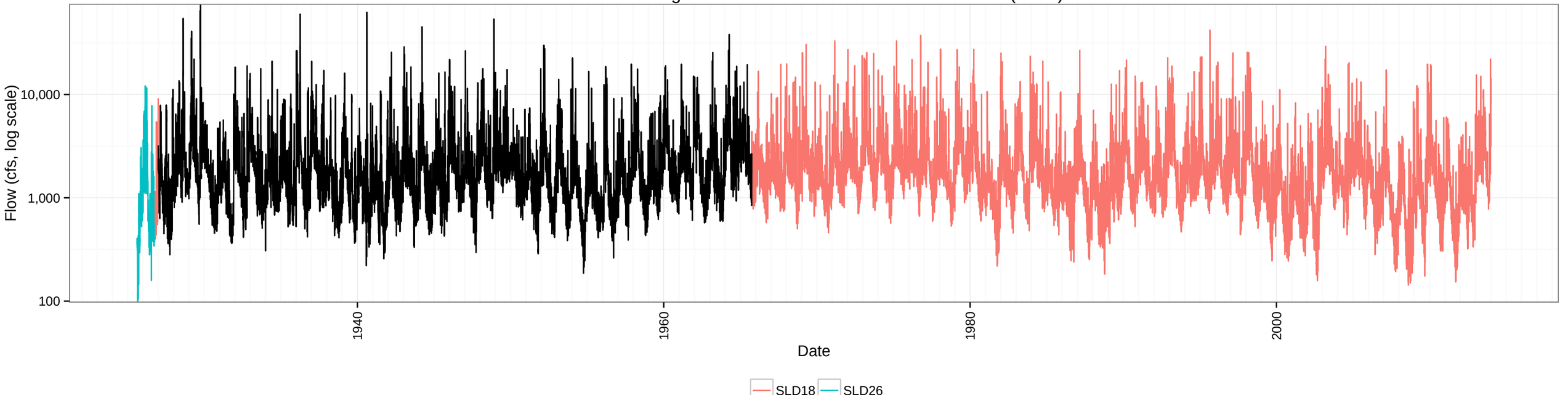


Figure 5.3: Extended Timeseries for SLD20 (black)



6.0 Summary of Ungaged UIF Transposition

Area proration was used to transpose the UIF timeseries from gaged basins to ungaged basins. Selection of reference gages follows guidelines established in Attachment C. **Table 6.1** summarizes the information for the ungaged basins and the gaged basins used as reference. Headwater flows are used as input for each explicitly modeled tributary in SWAM whereas confluence flows are needed for implicit tributaries needed for model calibration.

Table 6.1: UIFs in Ungaged Basins (Area Ratio Method Only)

	Ungaged Basin				USGS Reference Gage[1]				
Project ID	SWAM Usage	Location	Basin Area (mi^2)	% Developed / % Forest	Project Gage ID	USGS Number	Stream	Basin Area (mi^2)	% Developed / % Forest
SLD129	Headwater Flow	Little Saluda River	18.1	6.6 / 72.1	SLD23	21677037	LITTLE SALUDA RIVER	90.4	7.4 / 59.0
SLD200	Headwater Flow	North Saluda Res	5.8	0.3 / 99.7	SLD03	21623975	NORTH SALUDA RIVER	44.2	5.2 / 87.3
SLD139	Headwater Flow	Lexington Landfill	35.32	16.2/39.1	SLD28	2169500	CONGAREE CREEK	119	28.7/35.2
SLD201	Headwater Flow	Table Rock Res	8.1	0.0 / 99.4	SLD01	2162290	SOUTH SALUDA RIVER	17.2	0.6 / 93.5
SLD203	Headwater Flow	The Rock GC	4.2	10.7 / 86.6	SLD04	2162500	SALUDA RIVER	295.0	8.3 / 77.7
SLD204	Headwater Flow	Rolling Green GC	1.6	11.6 / 39.2	SLD04	2162500	SALUDA RIVER	295.0	8.3 / 77.7
SLD205	Headwater Flow	Furham U. GC	9.4	37.9 / 41.5	SLD10	2164000	REEDY RIVER	48.5	68.5 / 23.8
SLD206	Headwater Flow	Easley Discharge	3.1	58.7 / 28.4	SLD06	2163000	SALUDA RIVER	410.0	16.3 / 66.5
SLD207	Headwater Flow	Smithfields GC	2.0	84.1 / 13.8	SLD33	2162700	MIDDLE BRANCH	6.5	70.0 / 20.4
SLD210	Headwater Flow	Merrit Bros	1.0	17.8 / 25.1	SLD06	2163000	SALUDA RIVER	410.0	16.3 / 66.5
SLD211	Headwater Flow	Stoneybrook	1.1	20.5 / 29.1	SLD09	2163500	SALUDA RIVER	580.2	16.1 / 61.5
SLD212	Headwater Flow	The Preserve at Verdae	3.1	80.9 / 16.0	SLD11	2164110	REEDY RIVER	110.0	63.3 / 25.4
SLD213	Headwater Flow	Belton Honea Discharge	4.1	24.5 / 33.2	SLD09	2163500	SALUDA RIVER	580.2	16.1 / 61.5

[1] Ungaged flows are synthesized from UIFs, not original USGS gage flows.

	Ungaged Basin				USGS Reference Gage[1]				
Project ID	SWAM Usage	Location	Basin Area (mi^2)	% Developed / % Forest	Project Gage ID	USGS Number	Stream	Basin Area (mi^2)	% Developed / % Forest
SLD215	Headwater Flow	Greenwood Discharge	52.6	32.7 / 44.6	SLD18	2167000	SALUDA RIVER	1354.8	17.9 / 55.3
SLD216	Headwater Flow	Laurens Discharge	26.3	22.1 / 44.9	SLD19	2167450	LITTLE RIVER	223.6	9.2 / 60.0
SLD218	Headwater Flow	Overbridge	3.2	5.7 / 33.1	SLD21	2167563	BUSH RIVER	73.7	13.6 / 45.0
SLD221	Headwater Flow	Watson Jerrold	1.9	11.3 / 27.1	SLD25	2168504	SALUDA RIVER	2417.6	14.0 / 54.9
SLD222	Headwater Flow	Ponderosa GC	6.2	17.6/49.4	SLD23	21677037	LITTLE SALUDA RIVER	90.4	7.4 / 59.0
SLD223	Headwater Flow	Multiple Ag	4.2	11.8 / 40.8	SLD26	2169000	SALUDA RIVER	2517.2	15.4 / 54.0
SLD225	Headwater Flow	Walker Farm	25.4	8.3 / 42.4	SLD32	2169670	CEDAR CREEK	67.9	10.6 / 45.7
SLD226	Headwater Flow	Members GC	1.5	78.9 / 15.2	SLD29	2169570	GILLS CREEK	58.7	55.7 / 32.5
SLD227	Headwater Flow	Forest Lake GC	19.3	20.1 / 56.6	SLD29	2169570	GILLS CREEK	58.7	55.7 / 32.5
SLD115	Confluence Flow	Turkey Creek	45.3	8.1 / 56.7	SLD16	2166501	SALUDA RIVER	1165.0	18.4 / 55.0
SLD301	Confluence Flow	Lake Greenwood Inflow	92.2	12/60.5	SLD16	2166501	SALUDA RIVER	1165.0	18.4 / 55.0
SLD161	Confluence Flow	Halfway Swamp Creek	35.2	4.7/68	SLD17	2166970	NINETY-SIX CREEK	17.8	4.8/53.8
SLD163	Confluence Flow	Terrapin Creek	10.5	3.8/76.1	SLD17	2166970	NINETY-SIX CREEK	17.8	4.8/53.8
SLD160	Confluence Flow	Cane Creek	31.9	10.5/60.4	SLD19	2167450	LITTLE RIVER	223.6	9.2 / 60.0
SLD162	Confluence Flow	Beaverdam Creek	28.4	5.1/53.3	SLD21	2167563	BUSH RIVER	73.7	13.6 / 45.0
SLD302	Confluence Flow	Lake Murray Inflow	239.4	13/59.4	SLD25	2168504	SALUDA RIVER	2417.6	14.0 / 54.9
SLD164	Confluence Flow	Sandy Run	39.9	8.9 / 54.5	SLD32	2169670	CEDAR CREEK	67.9	10.6 / 45.7
SLD165	Confluence Flow	Mill Creek	42.6	27.8 / 54.3	SLD32	2169670	CEDAR CREEK	67.9	10.6 / 45.7

	Ungaged Basin				USGS Reference Gage[1]				
Project ID	**SWAM Usage**	**Location**	**Basin Area (mi^2)**	**% Developed / % Forest**	**Project Gage ID**	**USGS Number**	**Stream**	**Basin Area (mi^2)**	**% Developed / % Forest**
SLD166	Confluence Flow	Toms Creek	50.3	6.2 / 53.4	SLD32	2169670	CEDAR CREEK	67.9	10.6 / 45.7
SLD167	Confluence Flow	Buckhead Creek	19.6	3.0 / 60.5	SLD31	2169630	BIG BEAVER CREEK	9.9	3.8 / 60.0

List of Attachments

A. *Methodology for Unimpaired Flow Development, Saluda River Basin, South Carolina* (CDM Smith, January 2015)

B. *Guidelines for Standardizing and Simplifying Operational Record Extension* (CDM Smith, March 2015)

C. *Guidelines for Identifying Reference Basins for UIF Extension or Synthesis* (CDM Smith, April 2015)

D. *Quality Assurance Guidelines: Unimpaired Flow Calculations (UIFs) for the South Carolina Surface Water Quantity Models* (CDM Smith, April 2015)

E. *Refinements to the UIF Extension Process, with an Example* (CDM Smith, September 2015)

F. UIF Timeseries Graphs at USGS Gage Locations

ATTACHMENT A

Methodology for Unimpaired Flow Development, Saluda River Basin, South Carolina

(CDM Smith, January 2015) – *See draft memo*

ATTACHMENT B

Guidelines for Standardizing and Simplifying Operational Record Extension

(CDM Smith, March 2015) – *See draft memo*

ATTACHMENT C

Guidelines for Identifying Reference Basins for UIF Extension or Synthesis

(CDM Smith, April 2015) – *See draft memo*

ATTACHMENT D

Quality Assurance Guidelines: UIFs for the South Carolina Surface Water Quantity Models

(CDM Smith, April 2015)

Quality Assurance Guidelines

Unimpaired Flow Calculations (UIFs) for the South Carolina Surface Water Quantity Models

Prepared by CDM Smith, April 2015, Adjusted September 2015

Procedural Review

What to Review	How Many UIF Workbooks	How Much Within Each UIF Workbook
Operational Hindcasting and Gap Filling – Appropriate Method?	All	N/A
Approach for negative flow resulting from storage calculations – Major or Minor impact, and Appropriate?	All	Review all UIF entries and required conversions
Overall UIF Equation Correct and Complete	~25%	N/A

Detailed Review

What to Review	How Many UIF Workbooks	How Much Within Each UIF Workbook
All uses included (active and inactive)?	All	N/A
Operational Hindcasting calculations – check math	~50%	Spot check
Operational Hindcasting calculations – visual timeseries evaluation	All	N/A
Hindcast data color-coded through all workbooks and worksheets?	All	Entire workbook
Upstream UIFs (if applicable) accounted for accurately?	All	N/A
Units consistent and accurate?	~25%	Spot check
Overall Mass Balance for reservoirs, if applicable (per example in SLD01 and SLD19)	All	Each Reservoir
Visual comparison of UIF timeseries vs. Gage timeseries	All	N/A

Extension Review

What to Review	R Output Per UIF
DNR recommendations for reference gages applied or justification provided for use of others?	All
All graphs created, labeled correctly, contain correct methods?	All
Any issues regarding noise or minimum values?	All
Selection of UIF Extension Method – Appropriate and Documented?	All
Visual check of final flows graph	All

ATTACHMENT E

Refinements to the UIF Extension Process, with an Example

(CDM Smith, September 2015)

Refinements to the UIF Extension Process, with an Example

South Carolina Surface Water Quantity Modeling

September 2015

The following demonstrates an update to the previously-submitted UIF extension process. Previously, all calculations were performed in Excel, but given a need to accelerate the decision process (e.g. reduce time spent making plots by hand), R codes now automate calculations and plot creation. To demonstrate the reliability of the R code, we present an example of the full UIF extension process via Excel for comparison. For the example, we chose SLD15 on North Rabon Creek (USGS gage 2165280). SLD15 provides a solid example as 1) the gage flows required no unimpairing, 2) the best candidate for extension, SLD14, also required no unimpairing, and 3) it has the same overlapping period of record for all candidate extension gages.

Three methods of extension are considered:

1) Standard MOVE.1 – Flow data is transformed into log (base 10) space, mean and standard deviation are determined from this, and the MOVE.1 equation is applied.

2) Untransformed MOVE.1 – Flow data remains untransformed, mean and standard deviation are determined from this, and the MOVE.1 equation is applied.

3) Area proration – Flow is estimated using a simple ratio of areas.

Two main questions arose in prior investigations: 1) Whether mean and standard deviation should be strictly contained to the overlapping record only and 2) Whether flows should be transformed into log space. To adhere to the strict definition of MOVE.1, for current purposes mean and standard deviation are held to the overlapping record. As the choice of using a log transform or not can produce appreciable differences in estimated flows, both options are still considered. In the table below, the first nine rows (excluding overlapping minimum) represent the necessary distributional statistics for performing MOVE.1 in transformed and untransformed space. The following two rows demonstrate initial suitability of candidacy through correlation. To fulfill assumptions of linearity, candidate flows are first transformed into log space before calculating Pearson's correlation coefficient. The rank-based Kendall's Tau is performed on untransformed flows and can provide a more robust standard of correlation given no assumptions of linearity. However, both coefficients typically trend in the same direction in assessing suitability of candidate reference gages.

	SLD14	SLD18	SLD26
Overlapping Mean (Gage)	27.63	27.63	27.63
Overlapping Log Mean (Gage)	1.18	1.18	1.18
Overlapping St. Dev (Gage)	48.99	48.99	48.99
Overlapping Log St. Dev (Gage)	0.47	0.47	0.47
Overlapping Minimum (Gage)	0	0	0
Overlapping Mean (Ref)	21.90	1514.91	2707.93
Overlapping Log Mean (Ref)	1.08	3.03	3.29

Overlapping St. Dev (Ref)	35.79	1687.60	3034.92
Overlapping Log St. Dev (Ref)	0.46	0.35	0.32
Flow Correlation (Kendall's Tau)	0.83	0.61	0.54
Log Flow Correlation (Pearson)	0.94	0.77	0.71
RMSE (MOVE.1-log transform)	15.78	28.10	38.35
RMSE (MOVE.1-no transform)	16.07	27.78	30.32
RMSE (Area Ratio)	16.07	30.66	31.86
PRESS (MOVE.1-log transform)	1.81	16.93	12.15
PRESS (MOVE-no transform)	0.83	12.53	6.14
PRESS (Area Ratio)	0.72	42.37	28.34

A valid concern arising from untransformed MOVE.1 is the possible existence of negative or unrealistically-low flows. In the previous UIF dataset, we offered a hybrid approach where values from area proration substitute these negative values or values below a certain threshold. In Excel, these thresholds were found through trial and error. This threshold is now strictly defined by the overlapping minimum between the partial gage and candidate gage. As SLD15 naturally runs dry, in this example, all untransformed MOVE.1 values that fall below zero are replaced with those from area proration.

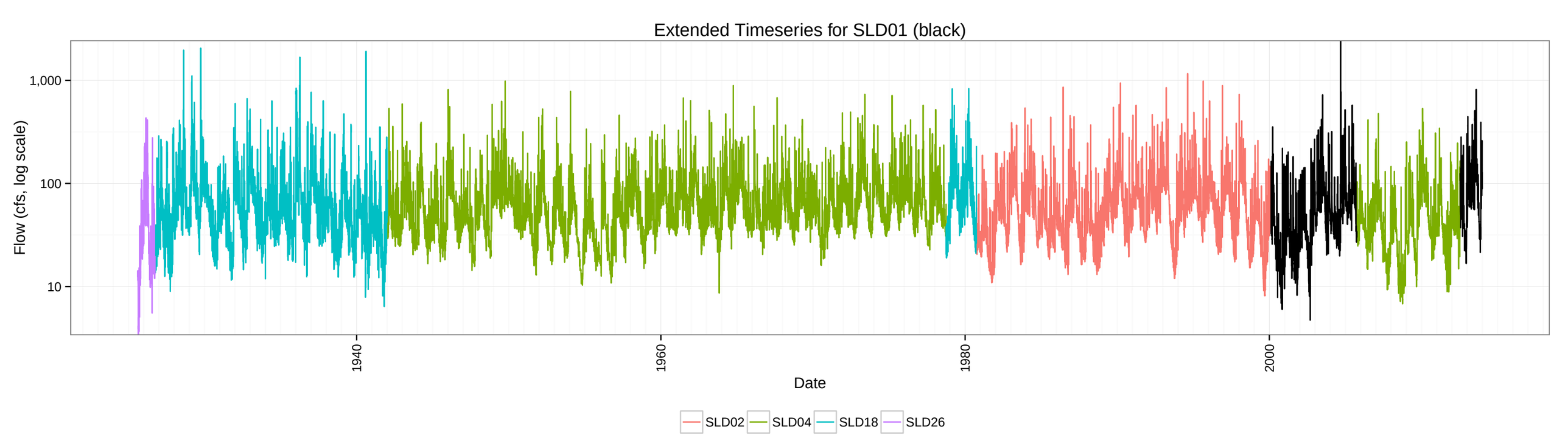
Two quantitative metrics aid the selection of reference gages and methods: root mean square error (RMSE) and predicted residual sum of squares (PRESS). RMSE compares estimated daily values and must be interpreted cautiously as this can be skewed by under or over-predicted flows. As an additional standard, the PRESS metric evaluates *yearly* error. To perform this statistic, one year is iteratively dropped, mean and standard deviation are found from the remaining years, and the dropped year is evaluated from the resulting extension. The values in the table above correspond to total yearly squared error of total volume of water in 1000 acre-ft. While dropping years does not affect the performance of area proration, the final PRESS value is useful in the overall comparison between methods as part of the decision process.

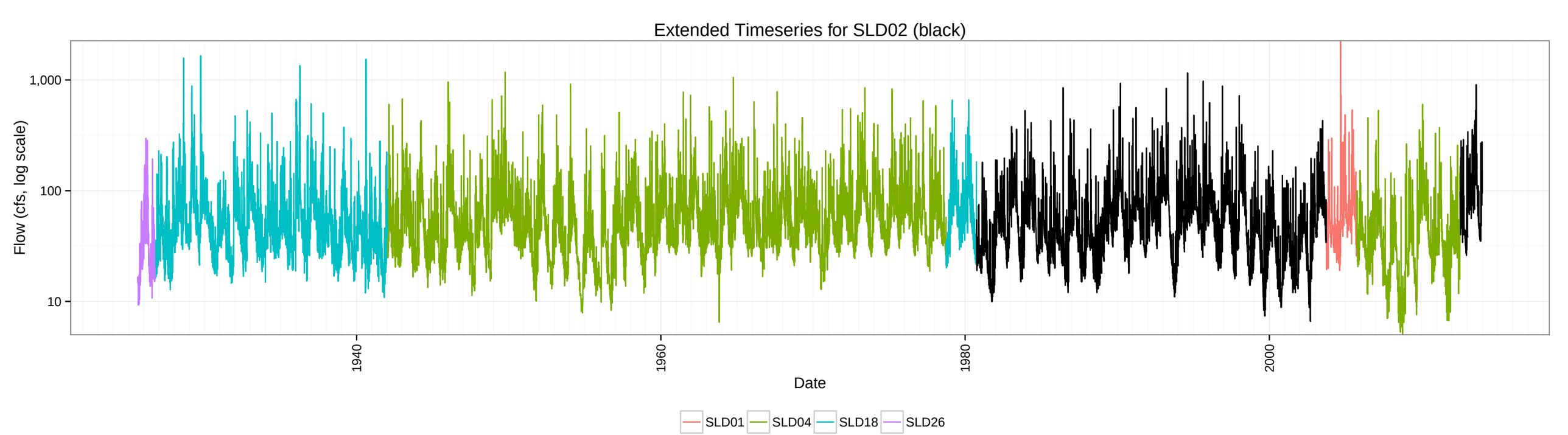
In addition to summary statistics, there are four plots to support to decision-making process: 1) an initial comparison of the original timeseries, 2) timeseries plots of the overlapping record for all methods, 3) scatterplots of the observed versus estimated flows and 4) exceedance frequency curves of the observed and estimated flows. After the first plot, with the y-axis in log-scale, the remaining plots have alternate versions in square root scale. This scale allows for examining low flows without diminishing too much the behavior of higher flows.

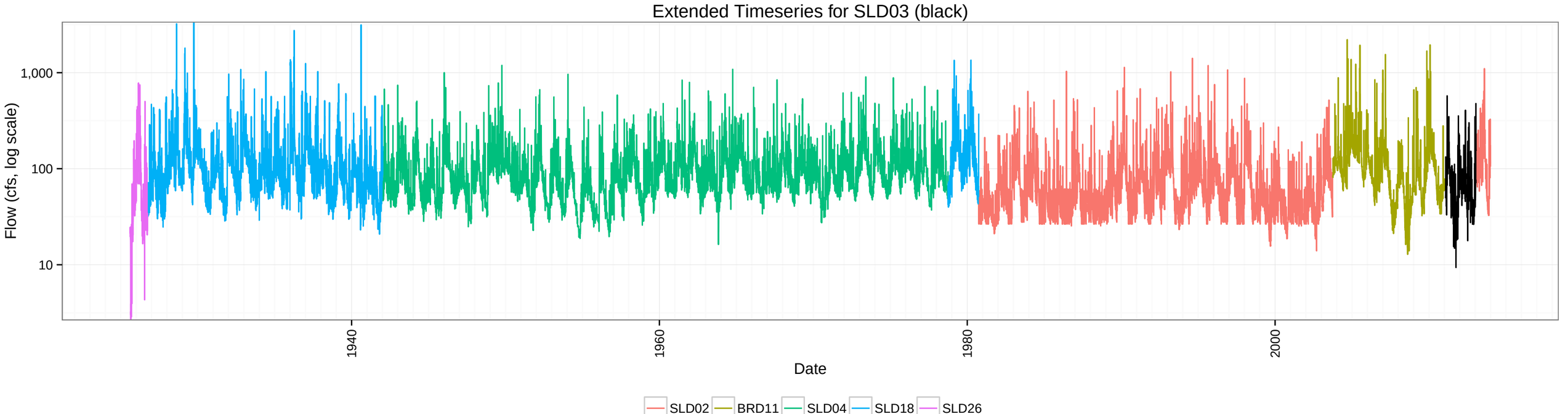
After examining the table and these performance plots, a final decision table is created and fed into another R script that creates the fully-extended record and makes two more plots: 5) verification showing the estimated values for the overlapping record and 6) final flows timeseries for the entire period of record with the use of each reference gage indicated by color. However, this may be an iterative process. The final flow timeseries is still examined and if problems, such as an obvious bias, are evident, the decision table is changed to explore alternate options for problem areas. Lastly, there are timeseries plots contrasting the behavior of immediate upstream/downstream gages.

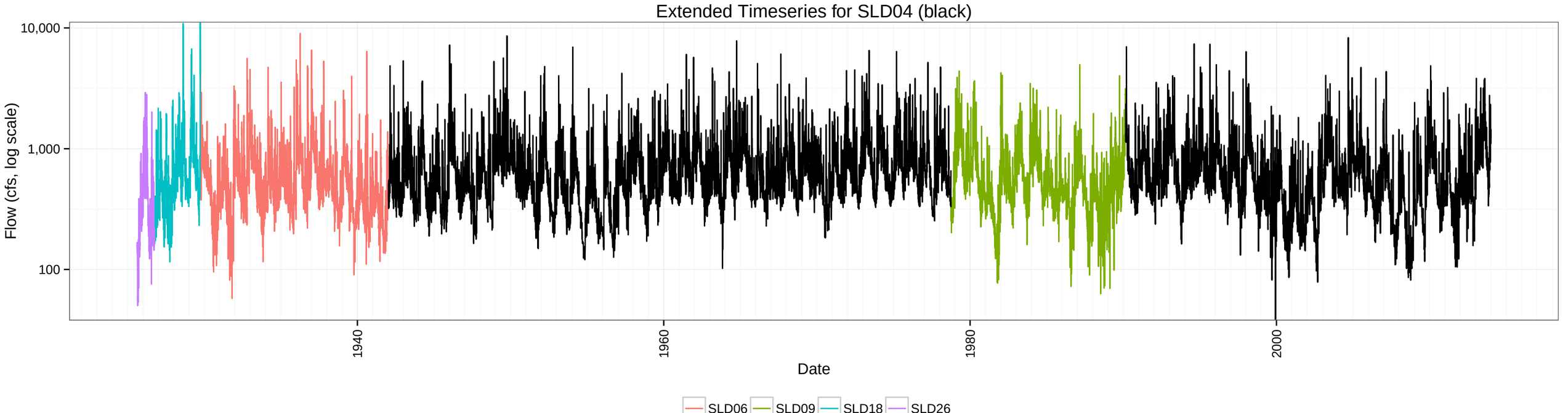
ATTACHMENT F

UIF Timeseries Graphs at USGS Gage Locations

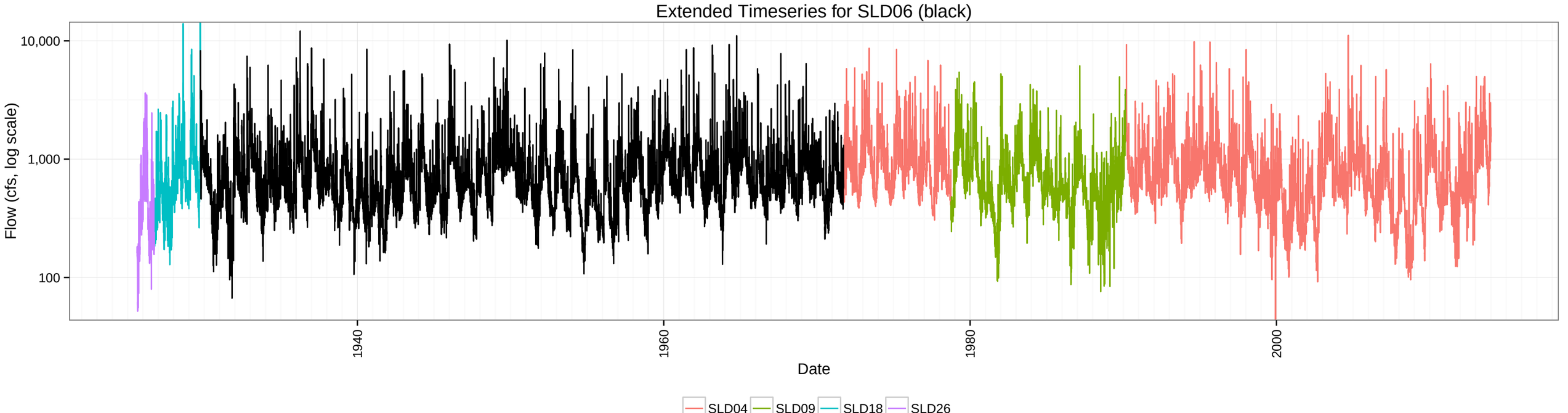

Extended Timeseries for SLD01 (black)
Flow (cfs, log scale)
1,000
100
10
1940
1960
1980
2000
Date
SLD02
SLD04
SLD18
SLD26


Extended Timeseries for SLD02 (black)
Flow (cfs, log scale)
1,000
100
10
1940
1960
1980
2000
Date
SLD01
SLD04
SLD18
SLD26

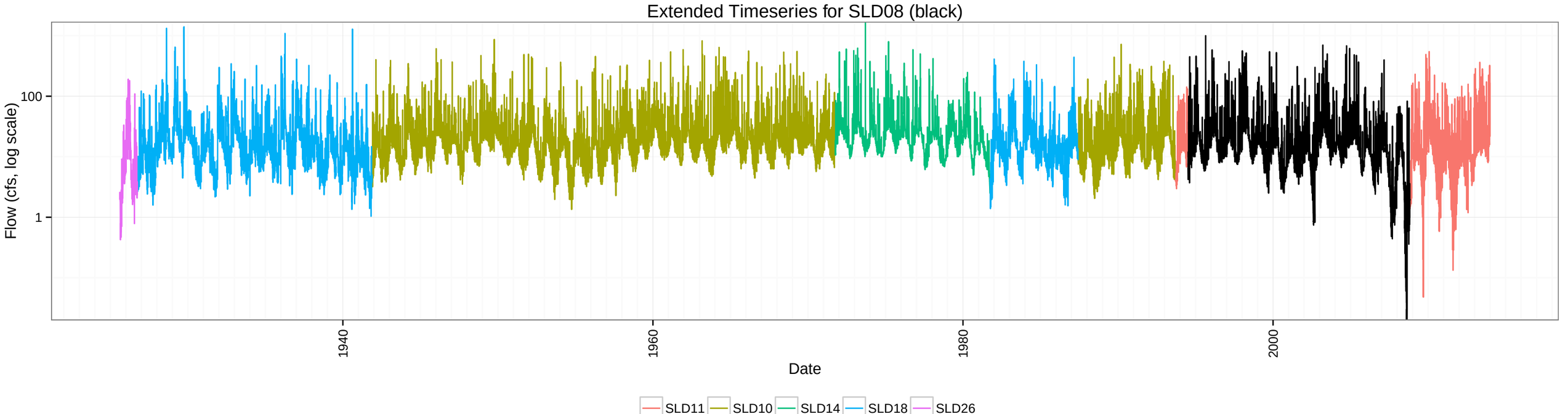

Extended Timeseries for SLD03 (black)
Flow (cfs, log scale)
1,000
100
10
1940
1960
1980
2000
Date
SLD02
BRD11
SLD04
SLD18
SLD26

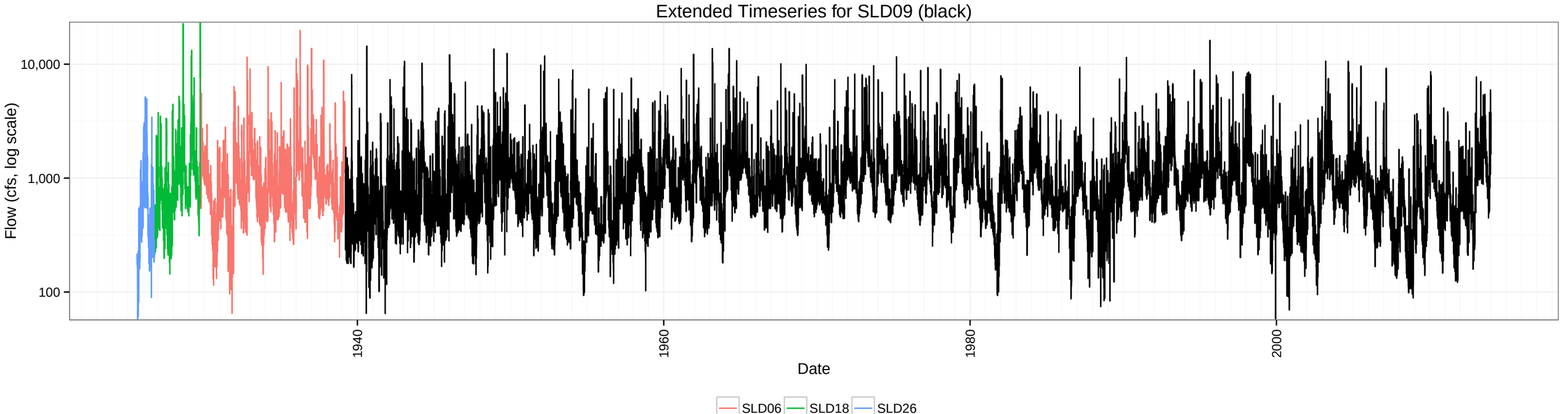

Extended Timeseries for SLD04 (black)
10,000
1,000
100
Flow (cfs, log scale)
1940
1960
1980
2000
Date
SLD06
SLD09
SLD18
SLD26

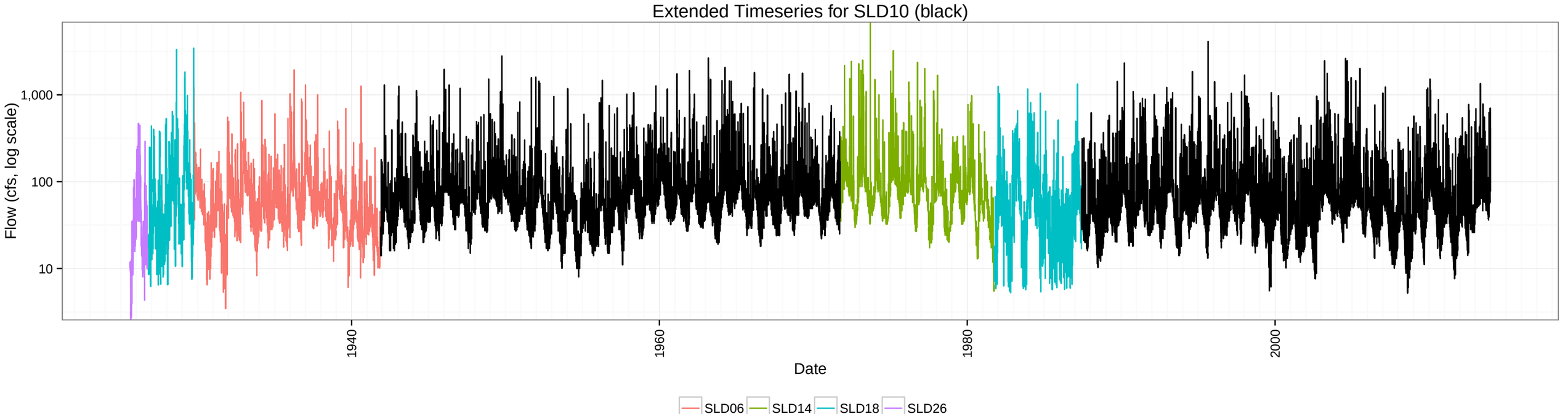

Extended Timeseries for SLD05 (black)
Flow (cfs, log scale)
10.0
1.0
0.1
1940
1960
1980
2000
Date
SLD18
SLD26

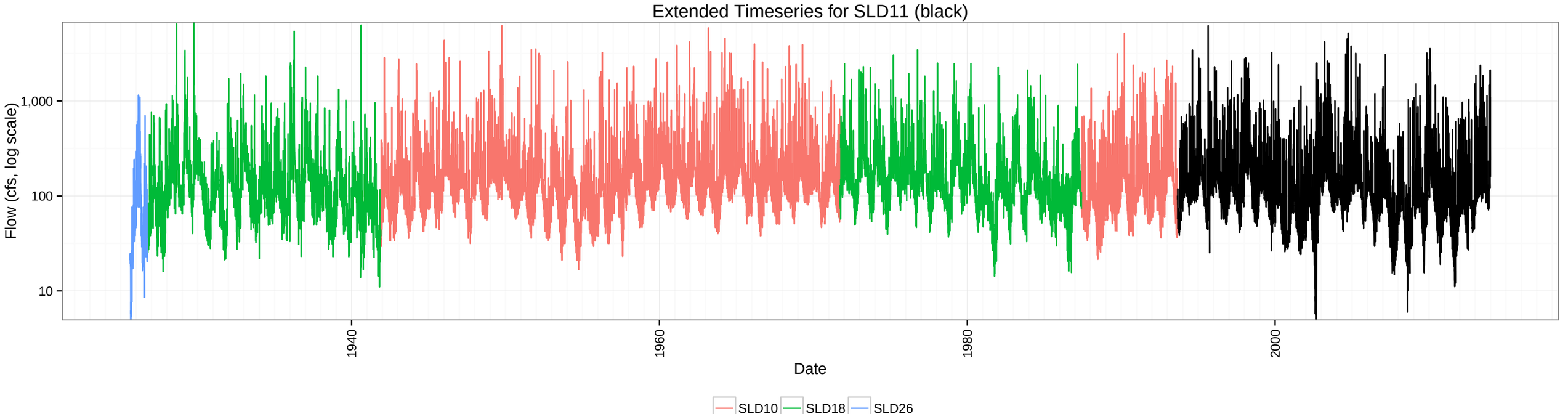

Extended Timeseries for SLD06 (black)
10,000
1,000
100
Flow (cfs, log scale)
1940
1960
1980
2000
Date
SLD04
SLD09
SLD18
SLD26

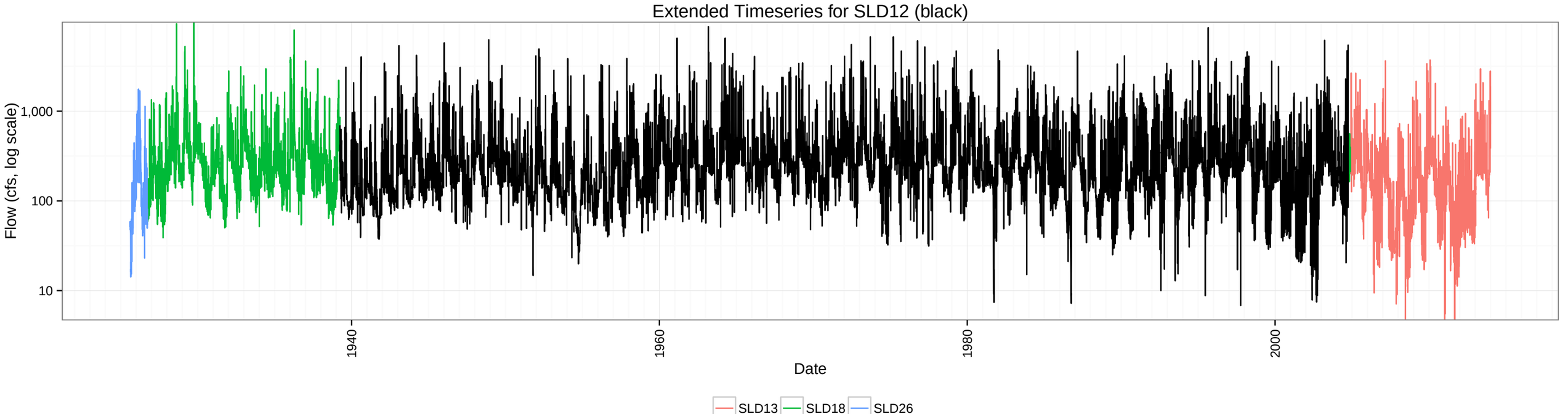

Extended Timeseries for SLD07 (black)
10,000
1,000
100
Flow (cfs, log scale)
1940
1960
1980
2000
Date
SLD09
SLD18
SLD26


Extended Timeseries for SLD08 (black)
Flow (cfs, log scale)
100
1
1940
1960
1980
2000
Date
SLD11
SLD10
SLD14
SLD18
SLD26

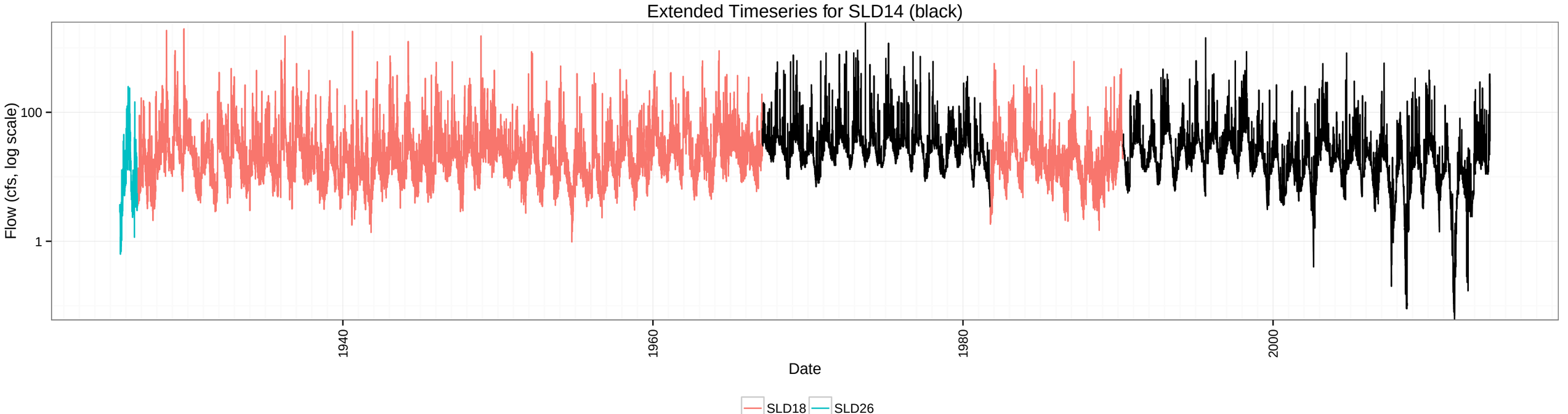

Extended Timeseries for SLD09 (black)
Flow (cfs, log scale)
10,000
1,000
100
1940
1960
1980
2000
Date
SLD06
SLD18
SLD26


Extended Timeseries for SLD10 (black)
Flow (cfs, log scale)
1,000
100
10
1940
1960
1980
2000
Date
SLD06
SLD14
SLD18
SLD26

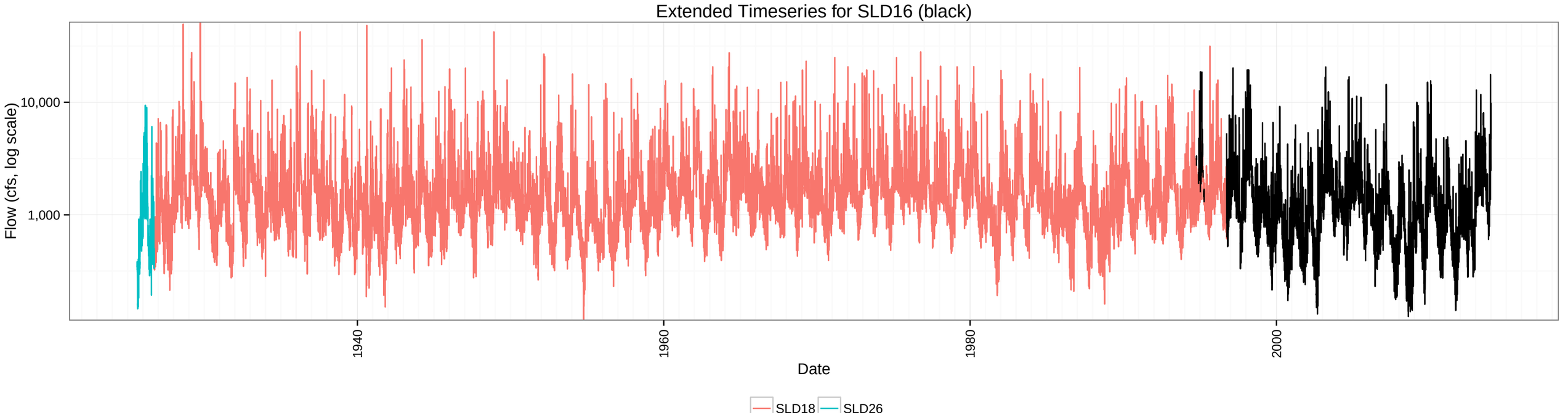

Extended Timeseries for SLD11 (black)
Flow (cfs, log scale)
1,000
100
10
1940
1960
1980
2000
Date
SLD10
SLD18
SLD26

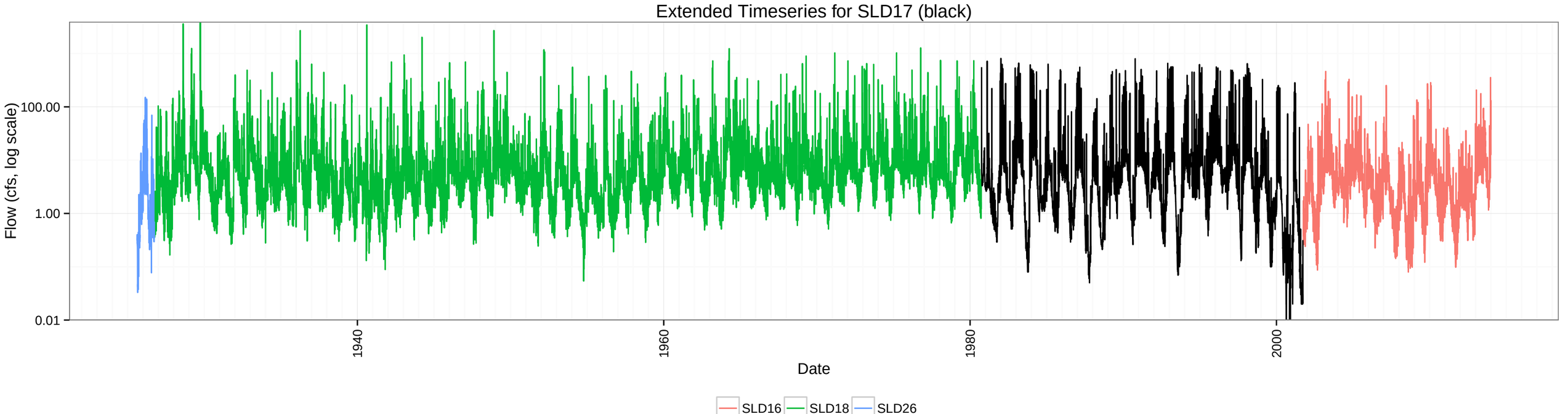

Extended Timeseries for SLD12 (black)
Flow (cfs, log scale)
1,000
100
10
1940
1960
1980
2000
Date
SLD13
SLD18
SLD26

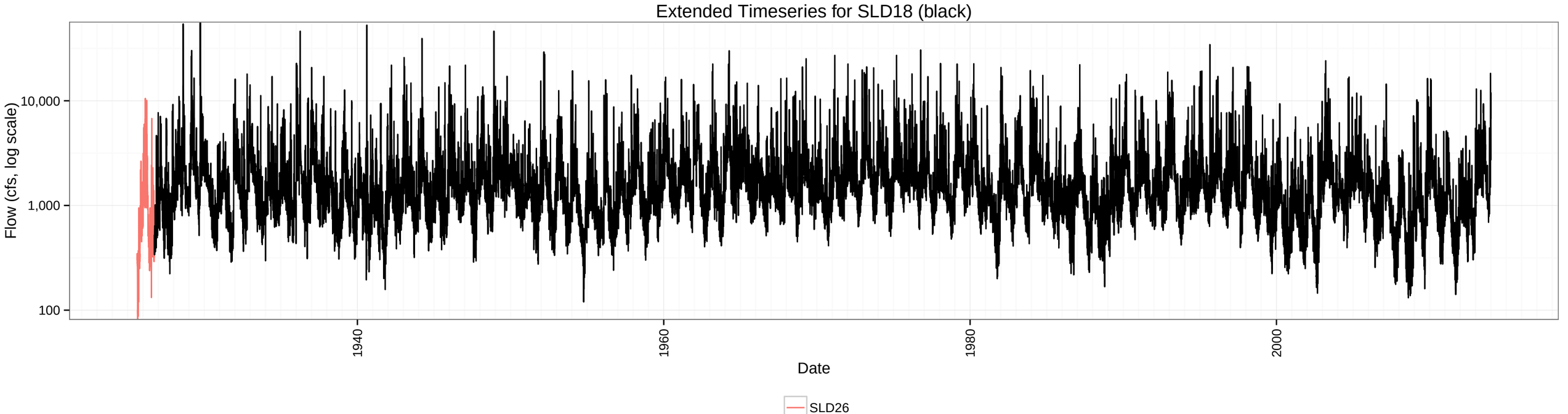

Extended Timeseries for SLD13 (black)
10,000
100
Flow (cfs, log scale)
1940
1960
1980
2000
Date
SLD18
SLD26

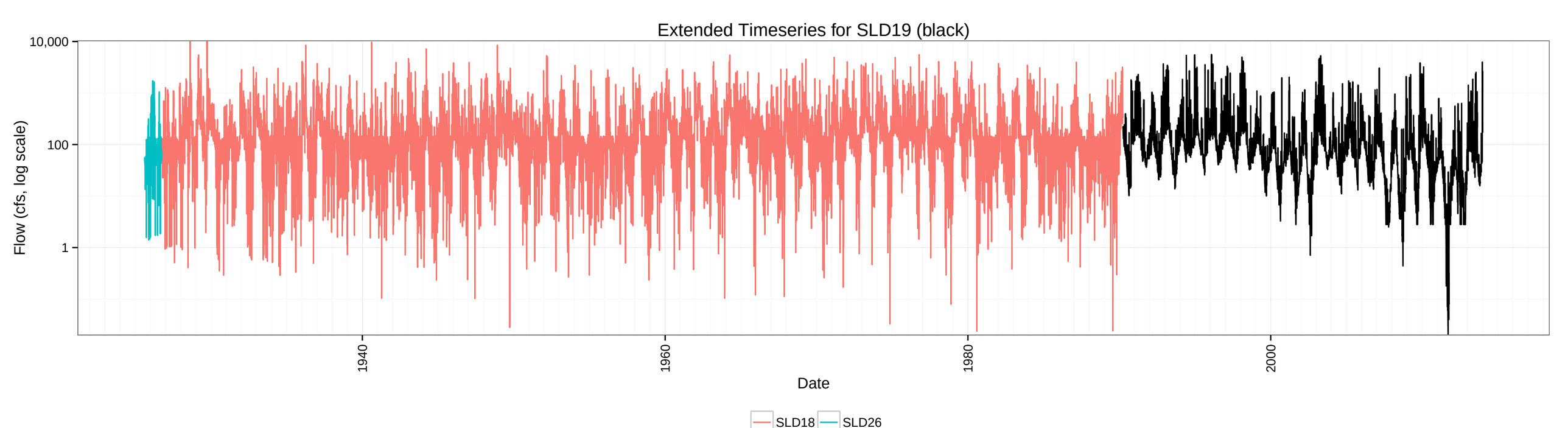

Extended Timeseries for SLD14 (black)
Flow (cfs, log scale)
100
1
1940
1960
1980
2000
Date
SLD18
SLD26

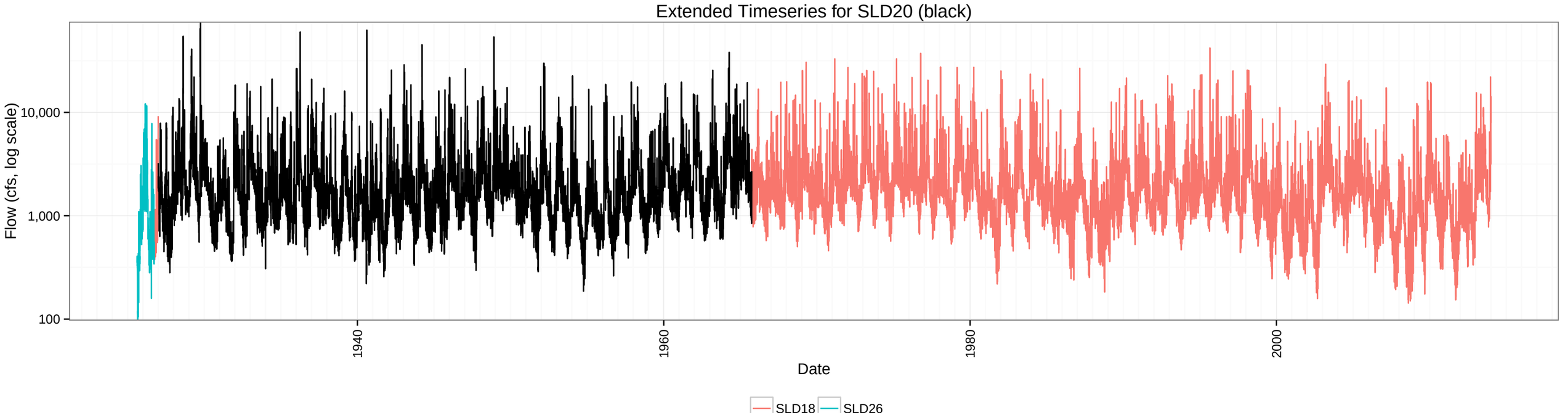

Extended Timeseries for SLD15 (black)
Flow (cfs, log scale)
100.00
1.00
0.01
1940
1960
1980
2000
Date
SLD14
SLD18
SLD26


Extended Timeseries for SLD16 (black)
Flow (cfs, log scale)
10,000
1,000
1940
1960
1980
2000
Date
SLD18
SLD26


Extended Timeseries for SLD17 (black)
Flow (cfs, log scale)
100.00
1.00
0.01
1940
1960
1980
2000
Date
SLD16
SLD18
SLD26

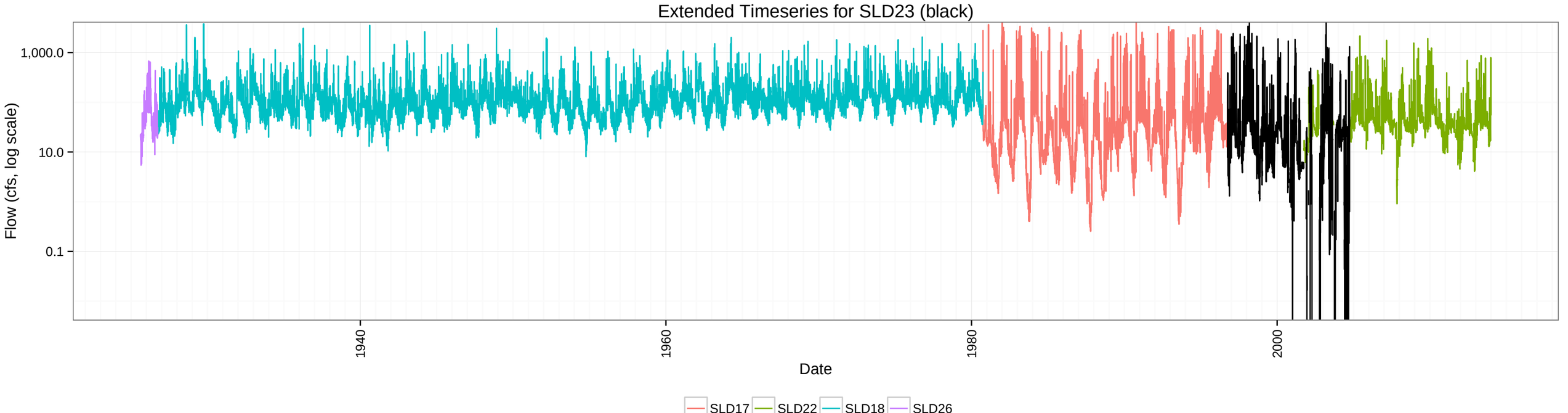

Extended Timeseries for SLD18 (black)
Flow (cfs, log scale)
10,000
1,000
100
1940
1960
1980
2000
Date
SLD26

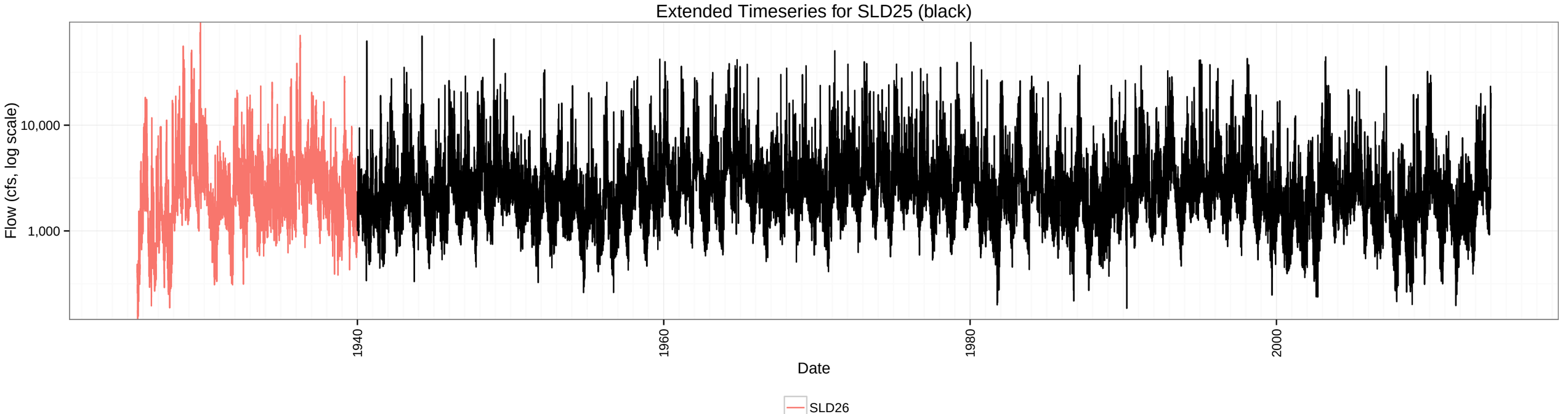

Extended Timeseries for SLD19 (black)
10,000
100
1
Flow (cfs, log scale)
1940
1960
1980
2000
Date
SLD18
SLD26

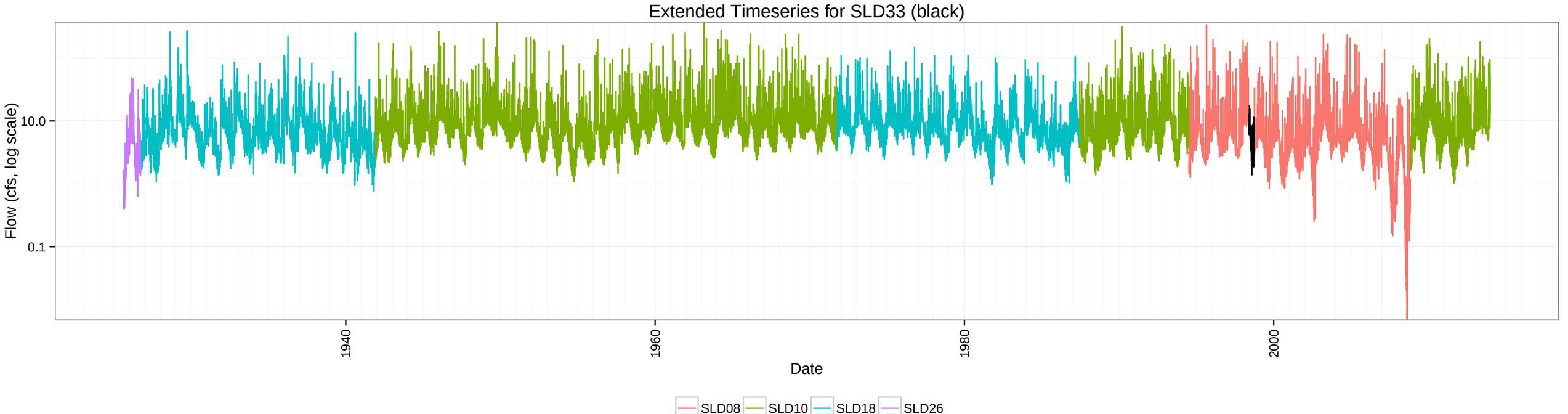

Extended Timeseries for SLD20 (black)
Flow (cfs, log scale)
10,000
1,000
100
1940
1960
1980
2000
Date
SLD18
SLD26


Extended Timeseries for SLD21 (black)
Flow (cfs, log scale)
1,000
10
1940
1960
1980
2000
Date
SLD22
SLD26


Extended Timeseries for SLD22 (black)
Flow (cfs, log scale)
1,000
100
10
1940
1960
1980
2000
Date
SLD26


Extended Timeseries for SLD23 (black)
Flow (cfs, log scale)
1,000.0
10.0
0.1
1940
1960
1980
2000
Date
SLD17
SLD22
SLD18
SLD26


Extended Timeseries for SLD25 (black)
Flow (cfs, log scale)
10,000
1,000
1940
1960
1980
2000
Date
SLD26


Extended Timeseries for SLD33 (black)
Flow (cfs, log scale)
10.0
0.1
1940
1960
1980
2000
Date
SLD08
SLD10
SLD18
SLD26


Extended Timeseries for SLD34 (black)
1,000.0
10.0
0.1
Flow (cfs, log scale)
1940
1960
1980
2000
Date
SLD17
SLD22
SLD18
SLD26