State of California **The Resources Agency**

M e m o r a n d u m

Date: March 18, 2005

To: Mark Holderman, Chief
Temporary Barriers and Lower San Joaquin

Bob Suits, Senior Engineer
Michael Mierzwa, Engineer, WR;
Delta Modeling Section

From: **Department of Water Resources**

Subject: Modeling Simulation of 2004 South Delta Hydrodynamics

This report describes the details of the simulation of historical 2004 Delta hydrodynamic conditions as requested by the Temporary Barriers and Lower San Joaquin Section in DWR's Bay-Delta Office. The period of simulation extends from January 1, 2004 to December 31, 2004.

To simulate the hydrodynamics, the Delta Modeling Section used DSM2-Hydro which is a one-dimensional open channel unsteady flow model based on a four-point finite difference solution of equations of momentum and continuity. The solution scheme has proven to be stable. The model network extends north to Sacramento River at I street, south to San Joaquin River at Vernalis, and west to Martinez where a 15-minute time history of stage input governs how the tide signal propagates into the Delta.

Boundary conditions

Flow and stage information required at model boundaries were downloaded from the IEP web site (www.iep.water.ca.gov) and from the California Data Exchange Center web site (cdec.water.ca.gov). The IEP database includes data collected by various agencies including DWR and USGS. When duplicate data from more than one agency was available, they were assigned a priority order. As the first option, DSM2 uses data ranked at the highest priority, and then proceeds to those of lower priority if necessary. Priority was assigned based on data availability, quality of the data, and past experience. Input data, visually examined using plotting routines, was occasionally missing. In most cases, alternate sources of data filled any gaps.

The levee break on Lower Jones Tract and subsequent flooding was simulated by DSM2 based upon an assumed opening in the levee. The simulation matched the observed time to fill of approximately three days. The later pumpout rates from Jones Tract were determined from the estimated maximum volume of water in Jones Tract and the reported duration of pumping.

Resulting key boundary conditions for 2004 are shown in Figures 1 through 6.

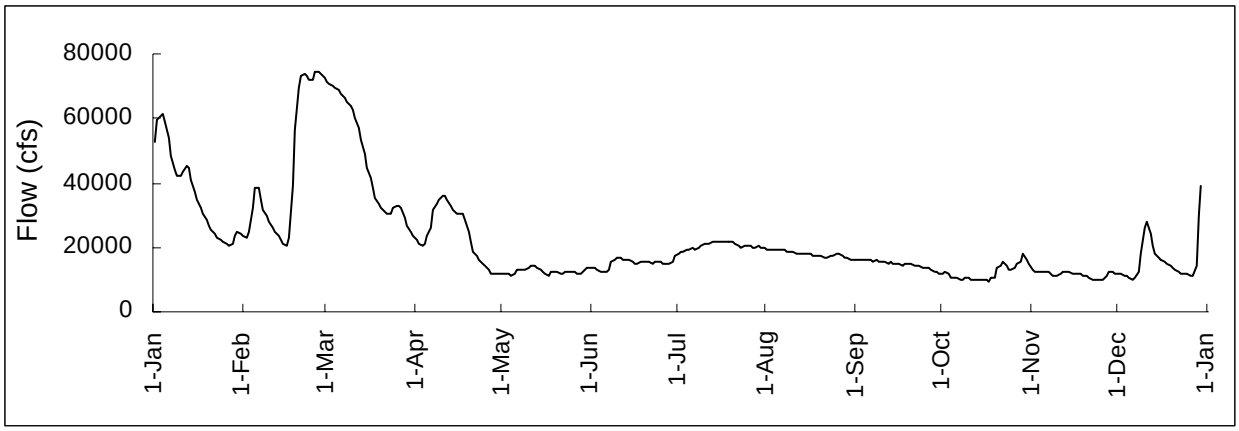


Figure 1. Daily average historical inflow from the Sacramento River, 2004.

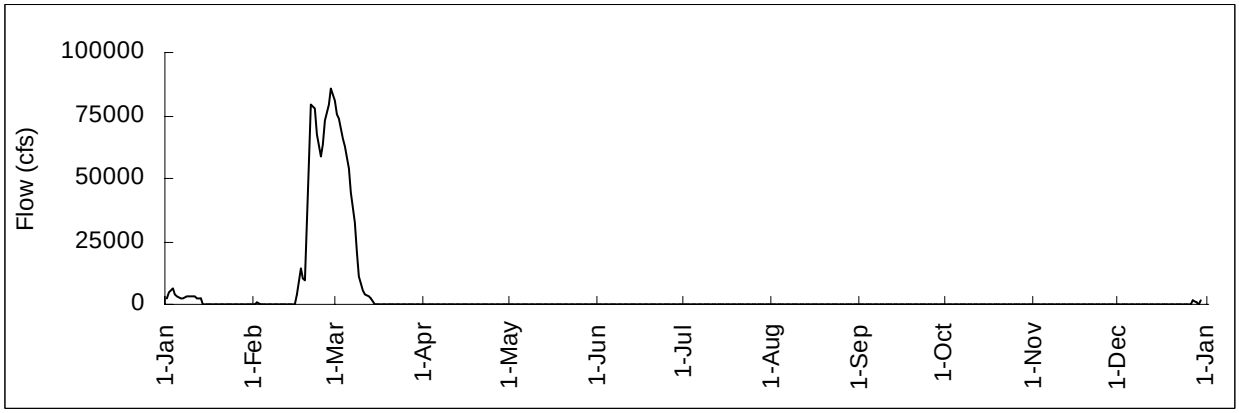


Figure 2. Daily average historical inflow from the Yolo Bypass, 2004.

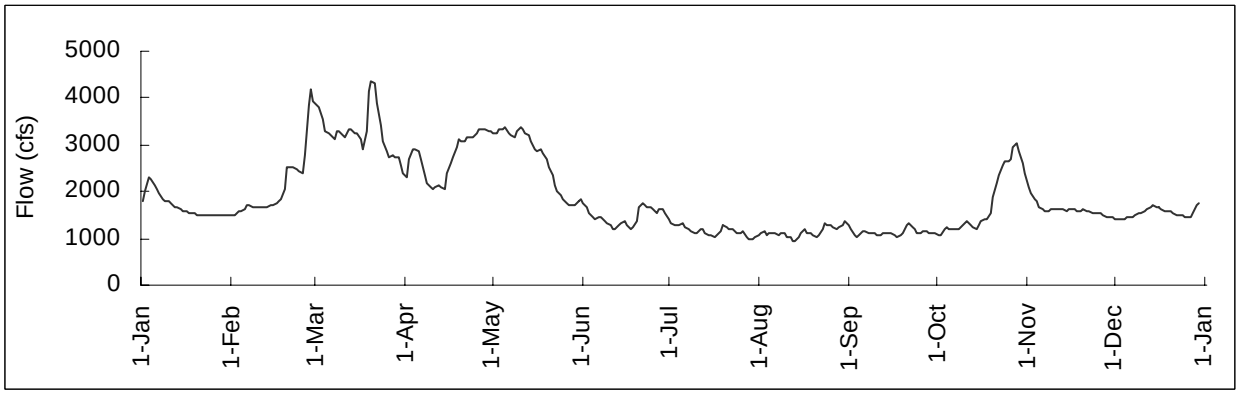


Figure 3. Daily average historical inflow from the San Joaquin River, 2004.

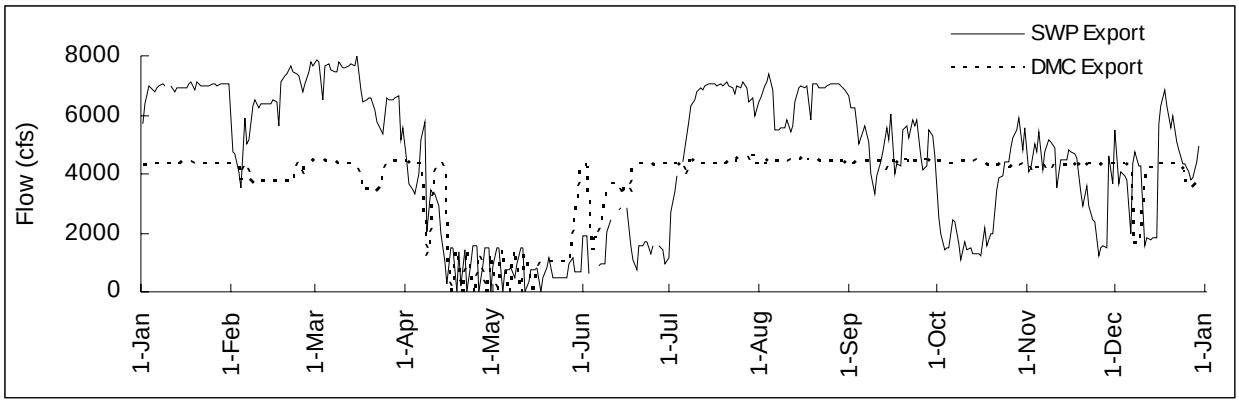


Figure 4. Daily average historical pumping at Banks and Delta Pumping plants, 2004.

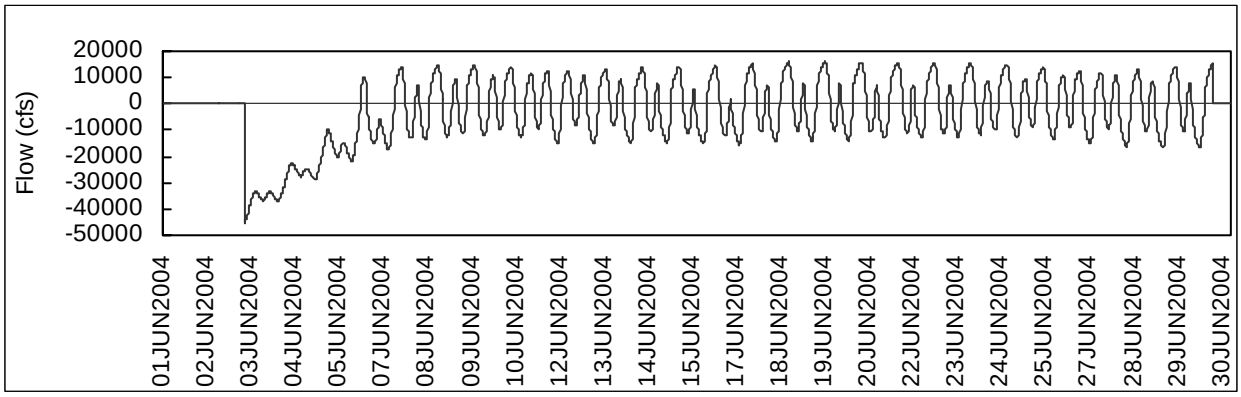


Figure 5. Fifteen-minute flow into and out of Jones Tract as modeled by DSM2.

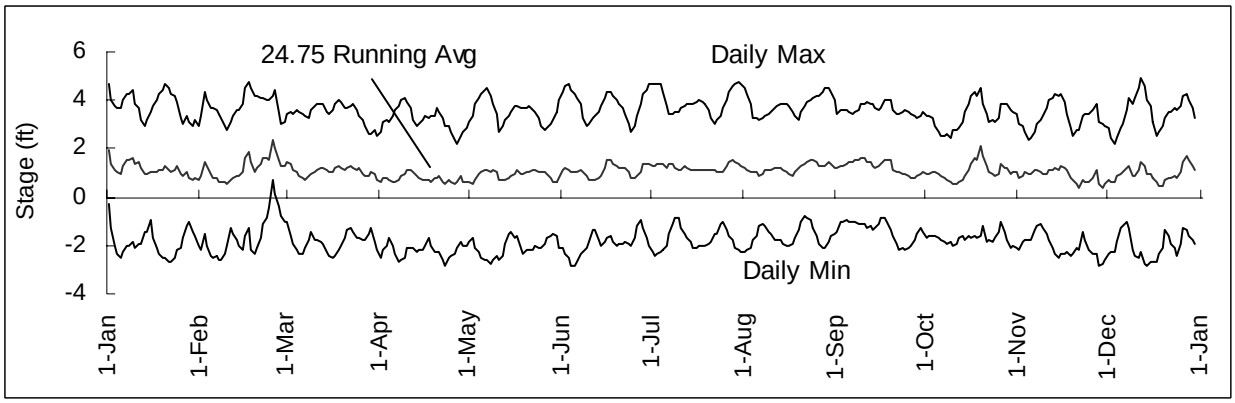


Figure 6. Daily maximum, minimum, and 24.75 hour running average of the historical stage at Martinez, 2004.

Consumptive use

The Delta Island Consumptive Use (DICU) model provided an estimate of the amount of water diverted from and returned to Delta channels due to agriculture activities. Input to DICU model includes precipitation and pan evaporation data and water year types. The water year type determines which of two possible cropping patterns in the Delta is assumed, which in turn contributes to the estimation of agricultural water needs.

Delta Structures

All three temporary agricultural barriers were installed in 2004 in addition to the spring and fall barriers at the head of Old River. The fall barrier at the head of Old River varied from the spring barrier by being notched at 0.0 mean sea level. While installation and removal of the temporary barriers may have taken days or weeks, the DSM2 simulation timed the actual installation and removal to effective dates and times, as inferred from 15-minute observed water levels. The table below describes the historical and DSM2-assumed operation of all the South Delta Barriers.

	Installation			Removal		
Barrier	Started	Ended	DSM2	Started	Ended	DSM2
Middle River	4/12/04	4/15/04	4/12/04	11/10/04	11/10/04	11/10/04
Old River near DMC	4/9/04	4/15/04	4/15/04	11/8/04	11/8/04	11/8/04
Grant Line Canal	4/9/04	6/05/04	6/4/04	11/11/04	11/12/04	11/11/04
Old River @ Head (spring)	4/9/04	4/15/04	4/15/04	5/21/04	5/24/04	5/21/04
Old River @ Head (fall)	9/17/04	9/28/04	9/27/04	11/2/04	11/7/04	11/2/04

Table1. Historical and DSM2-assumed south Delta barriers installation and removal, 2004.

The Delta Cross Channel gates were operated in 2004 as according to the table below.

Time Interval					
Date	Time		Date	Time	Status
1/1/2004	0000	-	5/28/2004	0900	closed
5/28/2004	0900	-	6/1/2004	0900	open
6/1/2004	0900	-	6/3/2004	0930	closed
6/3/2004	0930	-	12/5/2004	1200	open
12/5/2004	1200	-	12/28/2004	1000	closed
12/28/2004	1000	-	12/29/2004	1700	open
12/29/2004	1700	-	12/31/2004	2400	closed

Table 2. Historical Delta Cross Channel operation for 2004.

Accuracy of DSM2 Simulation of 2002 Delta Hydrodynamics

DSM2-simulated stages and flows have been compared to historical data at several locations in the south Delta (Figure 7). Much of the flow and stage data were obtained from DWR's California Data Exchange Center (CDEC) and have not yet been officially screened. For the purpose of this report, obvious errors in the CDEC data were removed. Measured flow through the Old River at Head structure was based upon

readings from an acoustic doppler current profiler installed in one of the culverts. Figure 8 shows the historical and DSM2-simulated daily maximum and minimum stages at 14 locations in the south Delta. DSM2-simulated stages generally followed measured stage, with the most notable exceptions occurring inside Clifton Court Forebay from mid April through June and inside Tom Paine Slough from mid October through December when DSM2 failed to reproduce significant decreases in water levels. In addition, DSM2 consistently modeled the minimum stages in Old River at ROLD024, Coney Island (CIS), and West Canal (CHWST000) about one foot below gage readings. The DSM2-generated minimum water levels just downstream of the Grant Line Canal barrier were also about one foot too low when the barrier was installed, a trend noted in previous years.

The poor matching of minimum water levels in Tom Paine Slough may be to inaccuracies in the bathymetry data, agricultural pumping patterns, or calculated flow through the Tom Paine Slough siphons. Each possibility is currently being investigated.

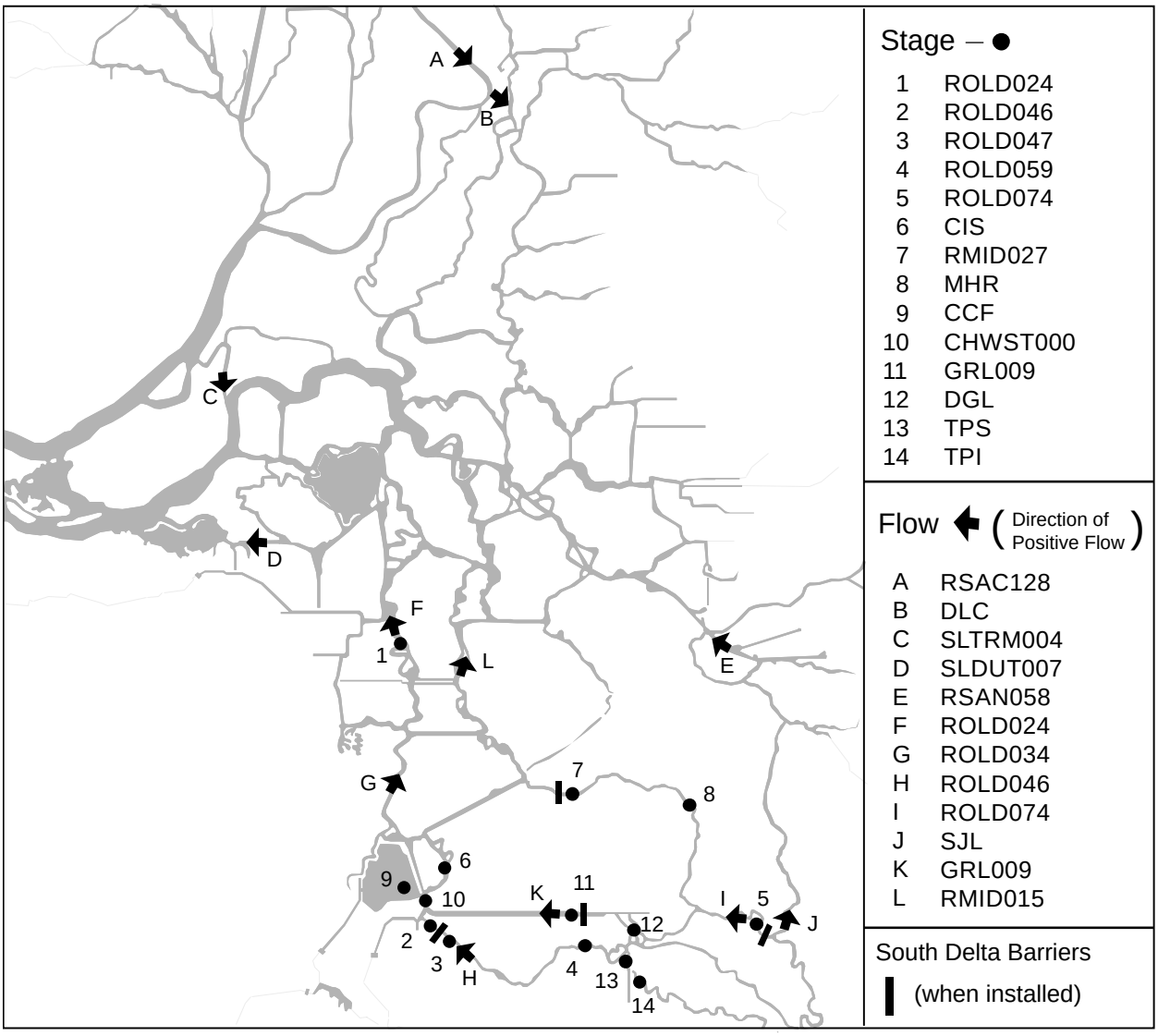


Figure 7. Locations where 2004 historical and DSM2-simulated hydrodynamics are compared.

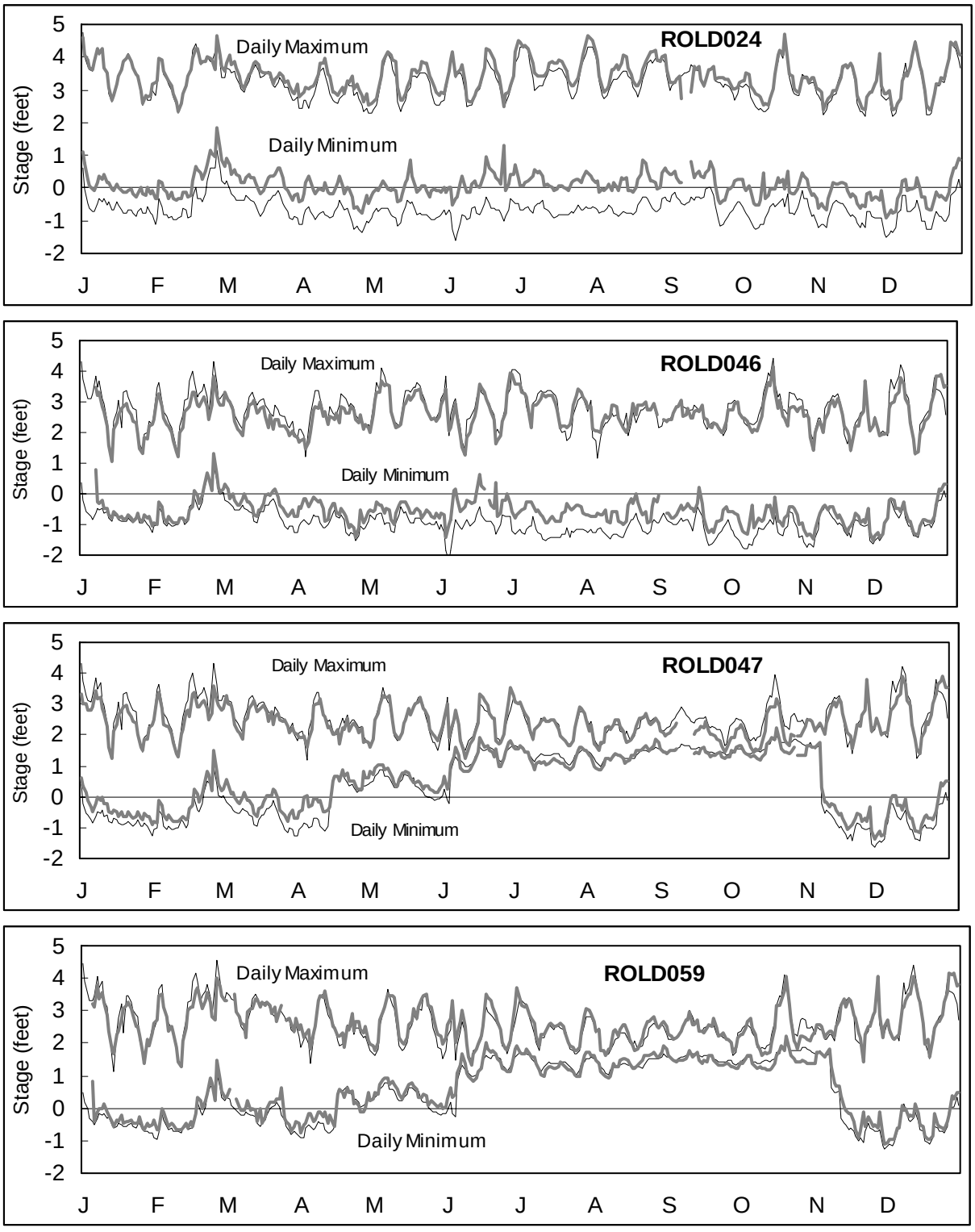


Figure 8. Daily maximum and minimum historical and DSM2-simulated stage, 2004.

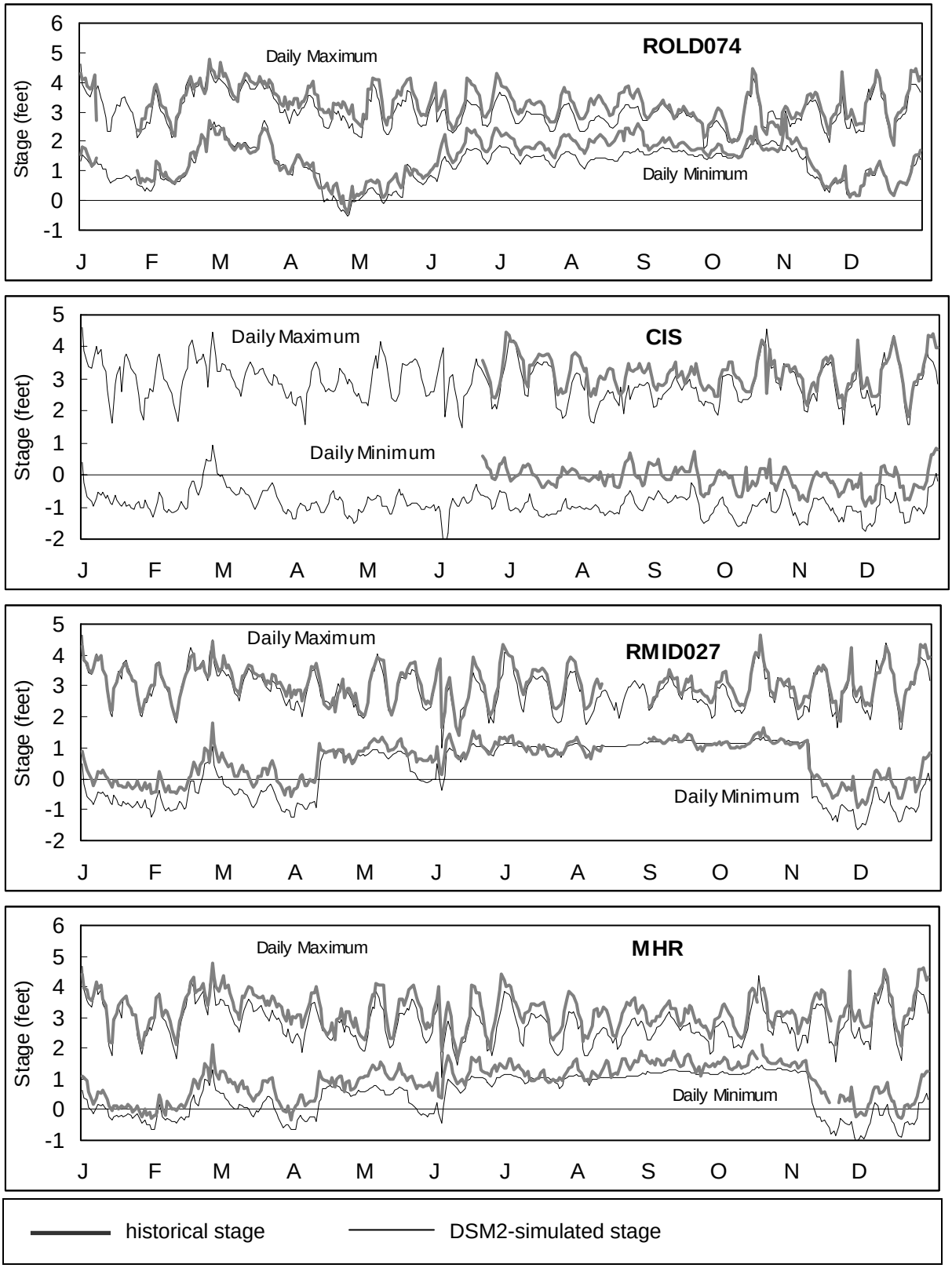


Figure 8-cont. Daily maximum and minimum historical and DSM2-simulated stage, 2004.

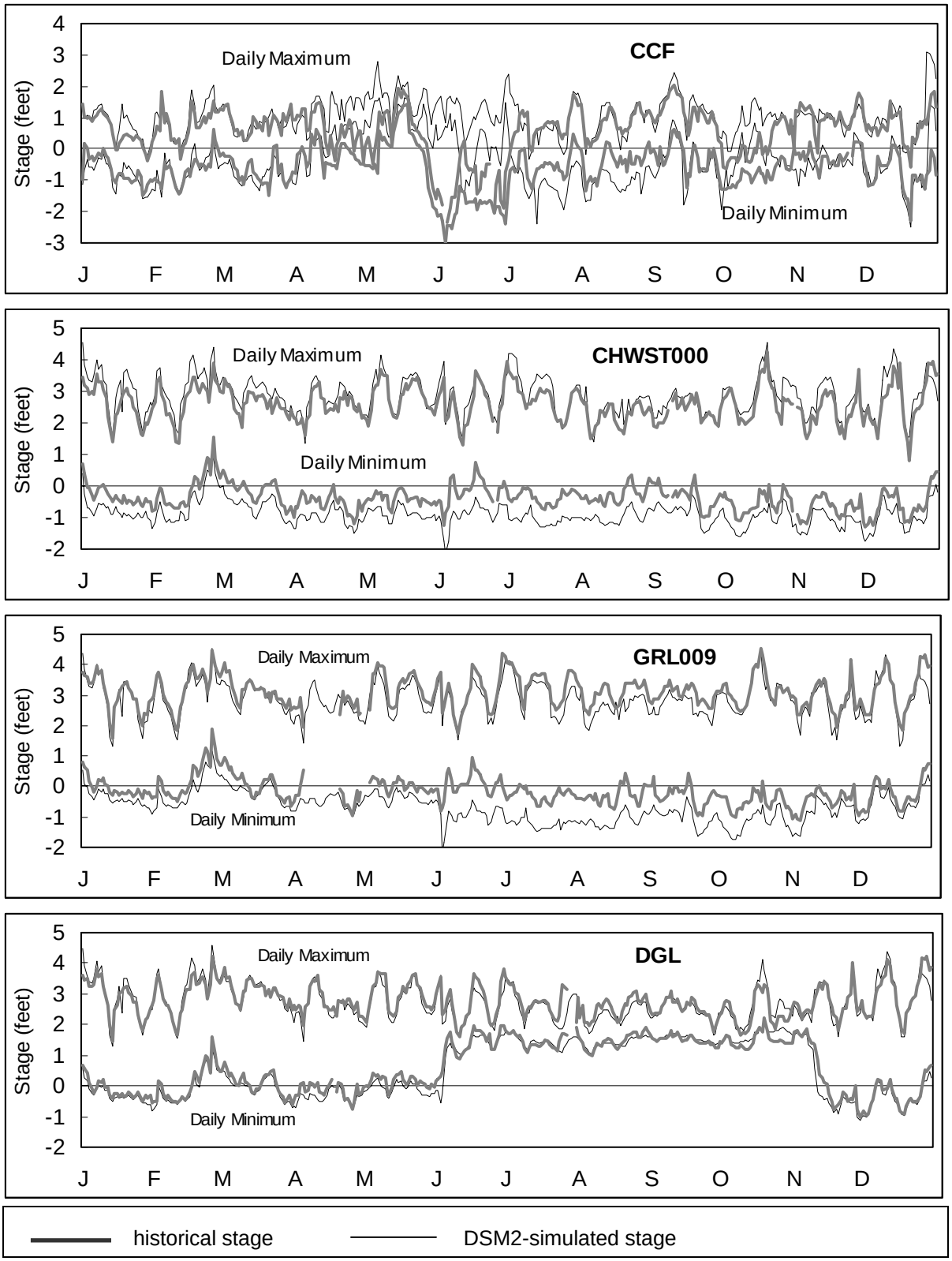


Figure 8-cont. Daily maximum and minimum historical and DSM2-simulated stage, 2004.

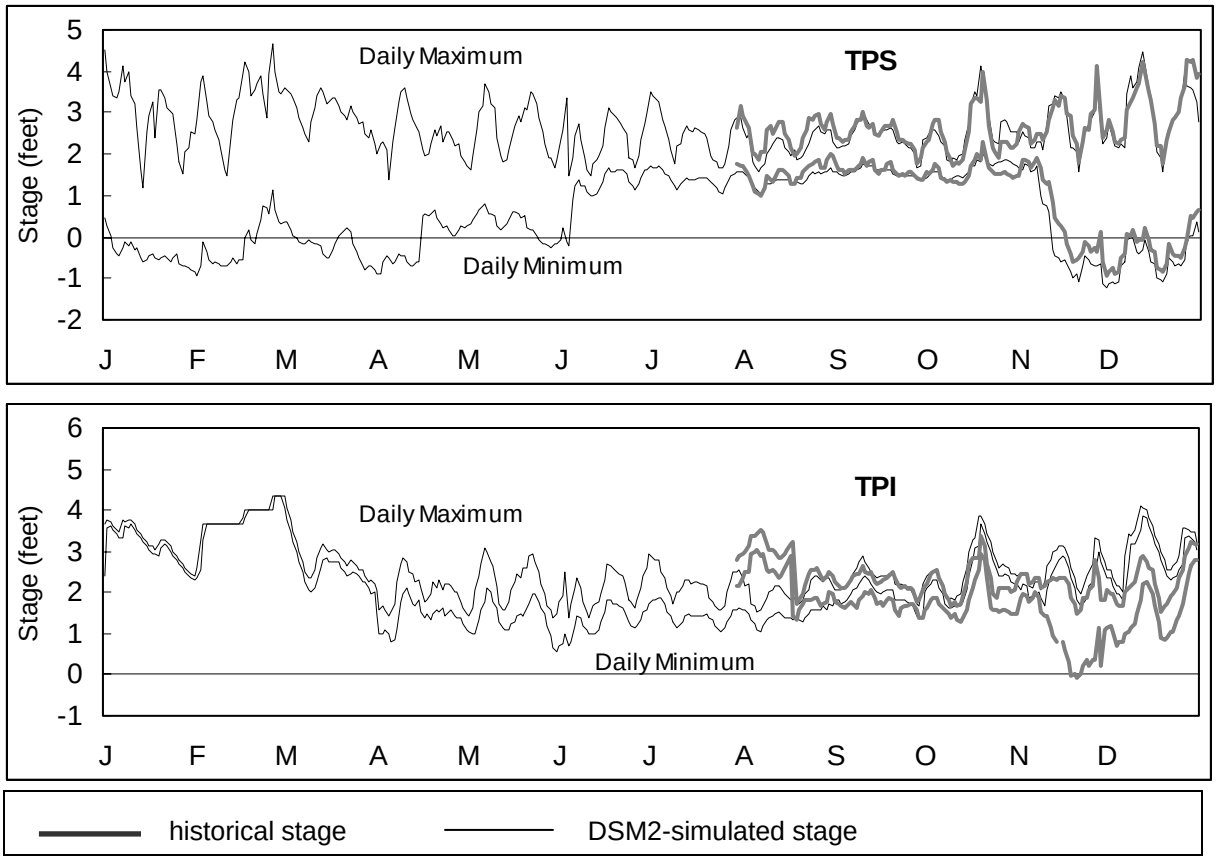


Figure 8-cont. Daily maximum and minimum historical and DSM2-simulated stage, 2004.

Figure 9 shows the historical and DSM2-simulated daily average flows at 12 locations in the Delta. By common sign convention, positive flows refer to downstream flow while negative flow corresponds to upstream flow (see Figure 7). The average flows simulated by DSM2 generally matched measured data. A notable exception is in Grant Line Canal during the periods the barrier was not installed, when average DSM2-generated flow, always in a downstream direction, was from 1,000 cfs to 2,500 cfs less than that estimated from field data. This discrepancy infers that DSM2's calculated flow down Old River at Head may be persistently too low when no barriers are in place. However, when the flow down Old River as calculated by DSM2 is compared to measured flow as estimated by the difference between measured flow at Vernalis and measured flow immediately downstream of the Old River Head (SJL), no large error is evident (Figure 10). When the measured flow in Grant Line Canal is superimposed on the graph, it becomes clear that at times the reported measured flow in Grant Line Canal substantially exceeds the flow down Old River at estimated by field data. This may bring into question the field data reported for Grant Line Canal, but more investigation is needed. The recorded flow at ROLD046 was clearly in error for the October through December period with the recorded flow direction apparently reversed.

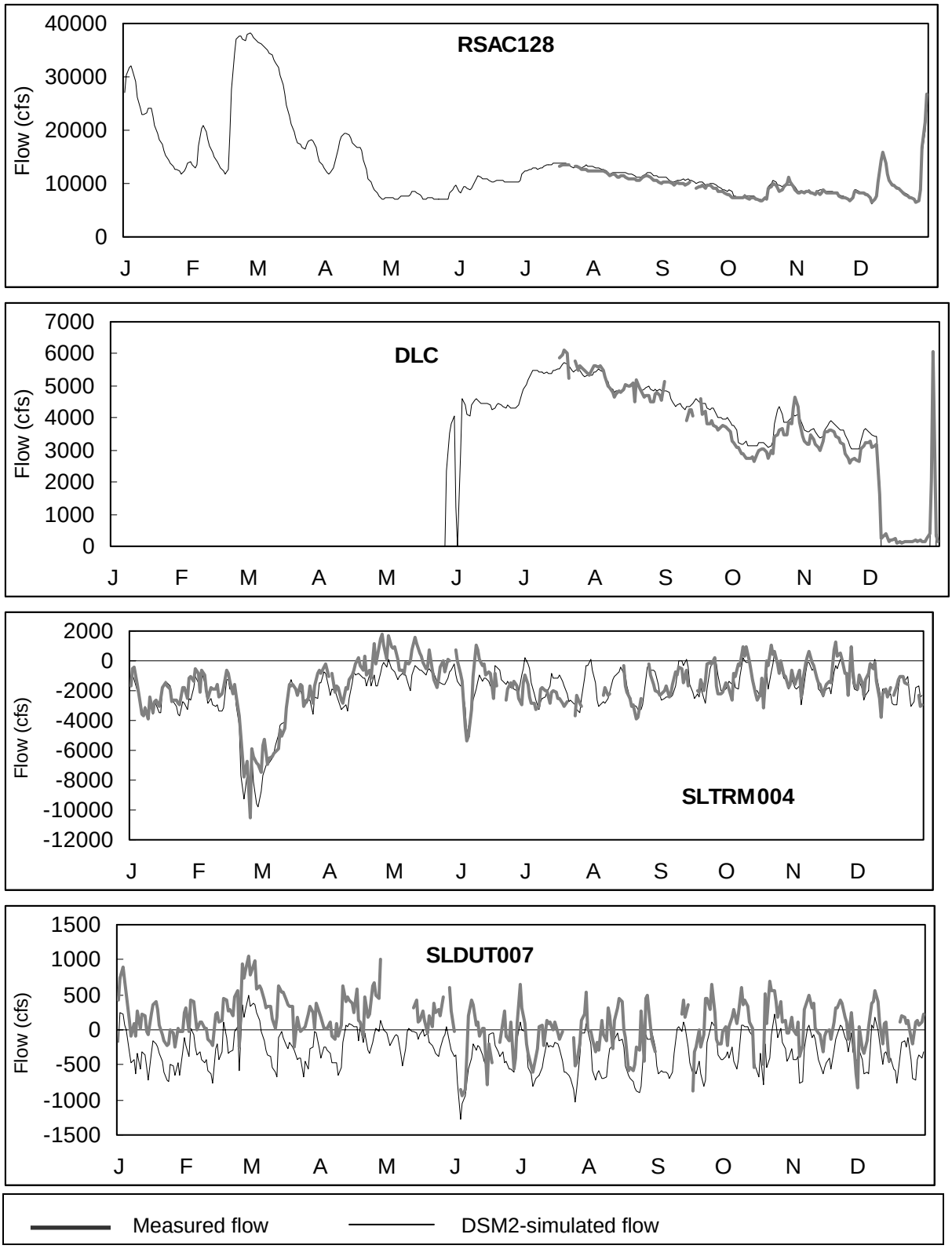


Figure 9. Daily maximum and minimum historical and DSM2-simulated flow, 2004.

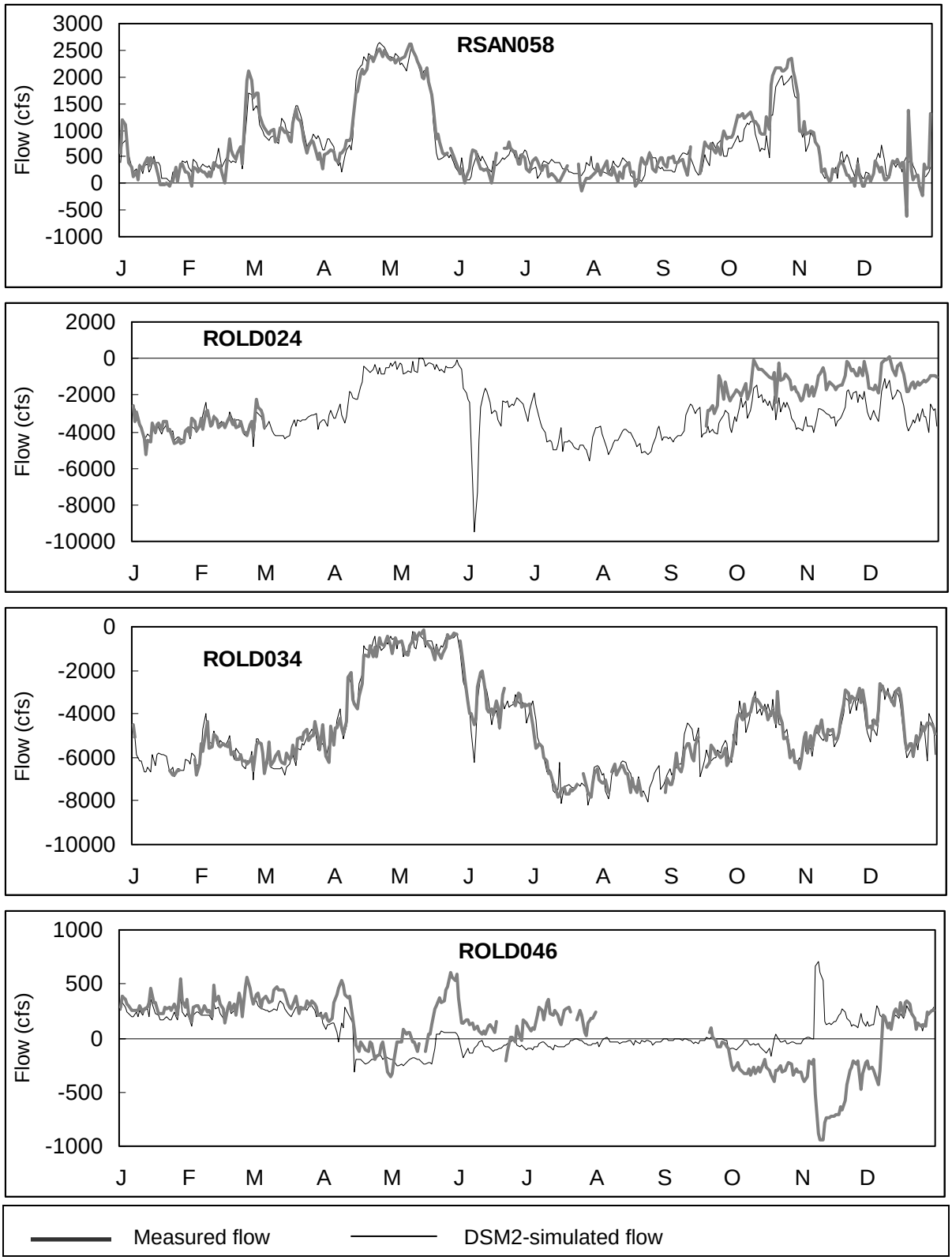


Figure 9 – cont. Daily maximum and minimum historical and DSM2-simulated flow, 2004.

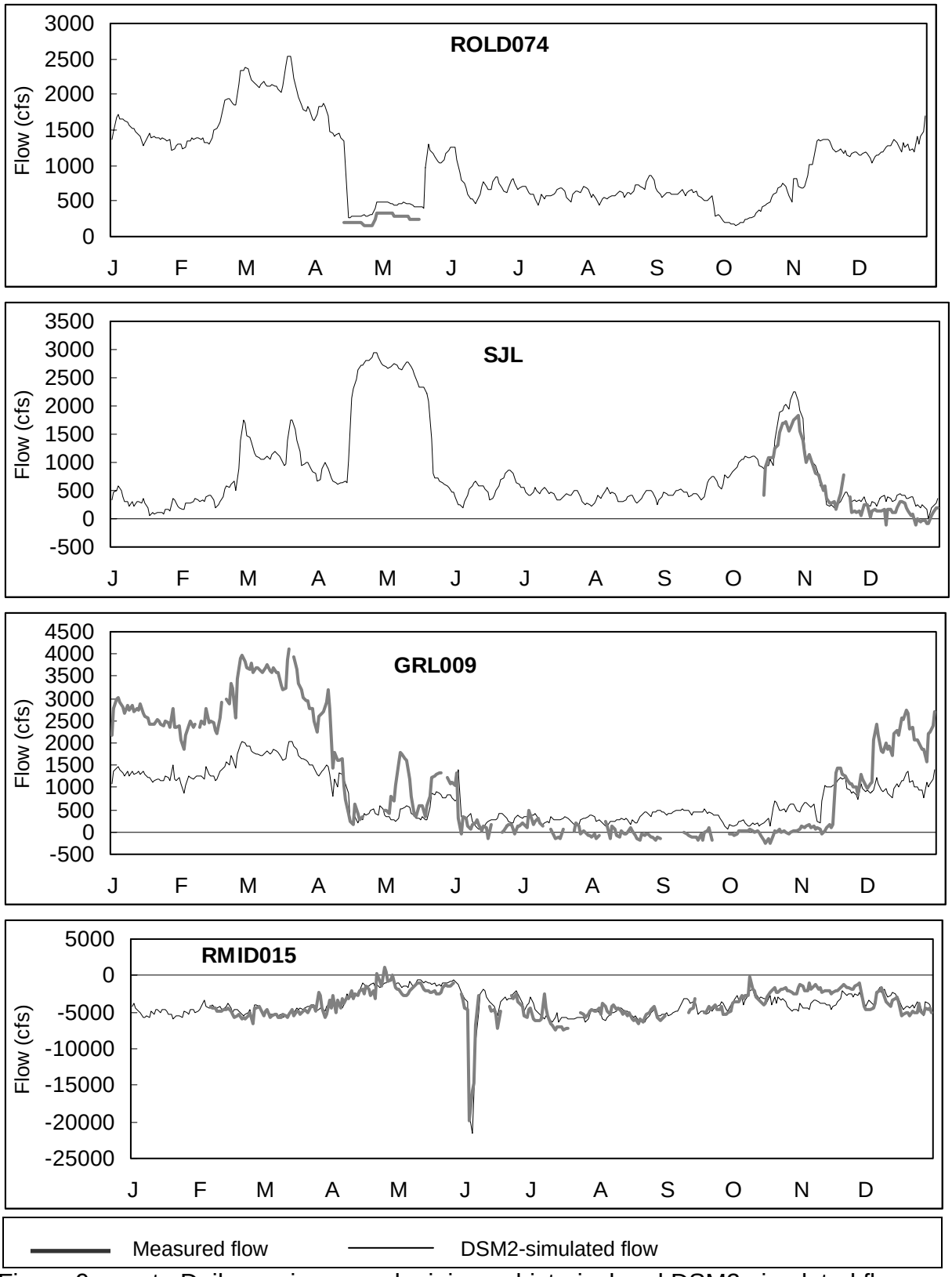


Figure 9 - cont. Daily maximum and minimum historical and DSM2-simulated flow, 2004.

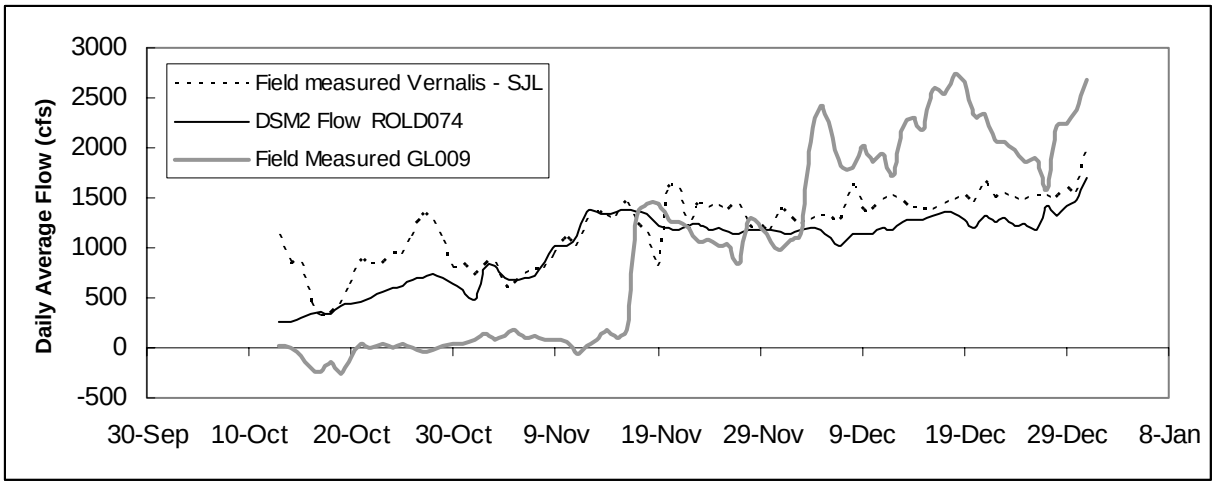


Figure 10. Field measured flow down Grant Line Canal compared to flow down Old River at Head based upon measured data and DSM2.

DSM2 Simulation of 2004 Hydrodynamics

In order to aid the interpretation of DSM2-simulated hydrodynamics, 2004 was partitioned into 28 periods. These periods primarily correspond to times for which significant Delta inflows and exports were fairly constant and south Delta barrier configurations were unchanging. The 28 periods and their characteristics are shown in the table below. The Delta hydrodynamics, as modeled by DSM2, are presented for each of the periods, excluding the periods of November 1-2 and November 8-11 which experienced transitions of multiple barrier installation or removal.

Period		Period Average Flows					Period Barrier Status			
		Sac R. + Yolo Bypass (cfs)	SJR (cfs)	DMC Pumping (cfs)	SWP Pumping (cfs)	Jones Tract Floodflow/ Pumpout (cfs)	MR	OR	GLC	ORH
JAN	1 - 31	38,175	1,685	4,350	6,920	0	--	--	--	--
FEB	1 - 18	29,663	1,662	3,880	5,741	0	--	--	--	--
	19 - 29	137,947	2,873	4,093	7,393	0	--	--	--	--
MAR	1 - 15	93,073	3,345	4,376	7,604	0	--	--	--	--
	16 - 31	31,729	3,209	3,908	6,205	0	--	--	--	--
APR	1 - 12	27,891	2,474	3,424	3,809	0	--	--	--	--
	12 - 15	33,111	2,096	4,238	1,968	0	IN	--	--	--
	15 - 30	19,192	3,077	523	888	0	IN	IN	--	IN
MAY	1 - 21	12,563	3,123	557	780	0	IN	IN	--	IN
	21 - 31	12,350	1,884	1,692	646	0	IN	IN	--	--
JUN	1 - 3	13,788	1,710	4,302	1,904	0	IN	IN	--	--
	3 - 4	13,197	1,551	2,223	637	-25,922	IN	IN	--	--
	4 - 6	12,631	1,438	1,853	910	-16,109	IN	IN	IN	--
	6 - 30	15,666	1,447	3,936	1,669	-100	IN	IN	IN	--
JUL	1 - 11	19,550	1,220	4,302	5,153	0	IN	IN	IN	--
	12 - 31	20,839	1,108	4,417	6,851	630	IN	IN	IN	--
AUG	1 - 31	17,865	1,135	4,429	6,593	750	IN	IN	IN	--
SEP	1 - 27	15,025	1,126	4,381	5,049	638	IN	IN	IN	IN
	28 - 30	12,402	1,117	4,410	4,907	500	IN	IN	IN	IN
OCT	1 - 20	10,672	1,296	4,373	1,687	500	IN	IN	IN	IN
	21 - 31	14,809	2,628	4,308	4,725	500	IN	IN	IN	IN
NOV	1	13,135	2,108	4,360	4,035	500	IN	IN	IN	IN
	2 - 8	12,280	1,754	4,277	4,713	500	IN	IN	IN	--
	8 - 9	11,193	1,595	4,164	5,117	500	IN	--	IN/--	--
	10 - 11	11,544	1,609	4,326	4,229	500	--	--	--	--
	12 - 30	11,270	1,562	4,305	3,357	421	--	--	--	--
DEC	1 - 4	11,362	1,422	4,331	4,288	400	--	--	--	--
	5 - 27	15,399	1,545	3,704	4,147	207	--	--	--	--
	28 - 31	32,963	1,802	3,775	5,070	0	--	--	--	--

Table 3. Characteristics of intervals during 2004 for presentation of simulation results.

Hourly simulated stage and flow data for each period were used to generate data for box plots which graphically show period minimum, maximum, 25% quartile, 75% quartile, and average values. By typical sign convention, negative flow values correspond to upstream flow. The locations where box plots of stage and flow are presented are shown in Figure 11 with arrows indicating assumed positive flow direction. The numerical values these graphs are based upon are presented in the appendix to this report.

The distributions of simulated stages and flow for each of the 26 intervals are shown in Figures 12 and 13. Stage results are presented upstream and downstream of each barrier location and flows are presented throughout the south Delta in order to convey the general circulation patterns. The minimum stages and the average flows from the distributions of data in Figures 12 and 13 are shown in Figure 14 which graphically presents the flow circulation and minimum water levels caused by the installation of the south Delta barriers in 2004.

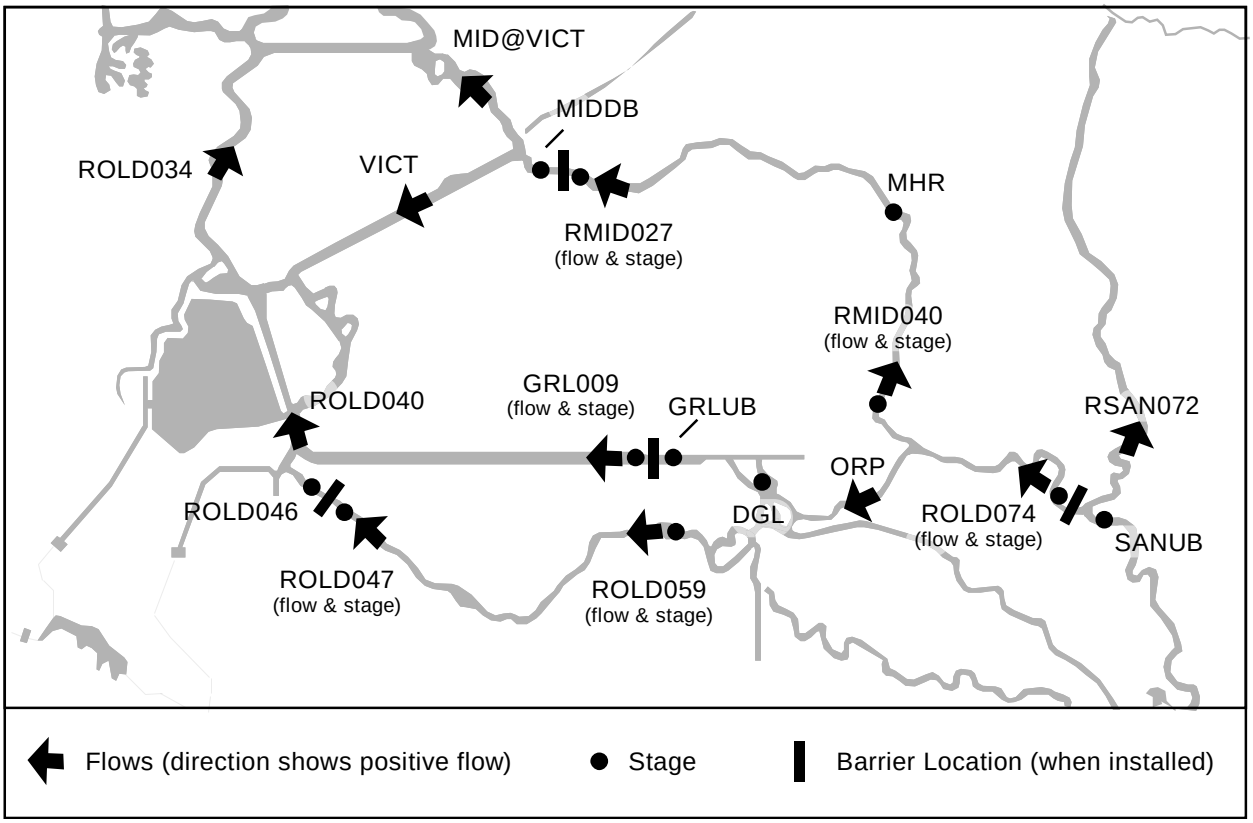


Figure 11. Locations where simulated Delta stages and flows for 2004 are presented.

Discussion

The levee break on Middle River and the subsequent filling of lower Jones Tract temporarily affected water levels and flow patterns in Victoria Canal and Old and Middle rivers downstream of the sites of the temporary barriers. However, by June 6, the Delta hydrodynamics in the south and central Delta had returned to more typical patterns. The installation of the temporary barriers in 2004 significantly altered stages and flows in the south Delta. Minimum water levels tended to be raised 1 to 1-½ feet in April and May in Middle and Old rivers upstream of the barriers, while minimum water levels immediately downstream of the barrier at the head of Old River fell about ½ foot due to the barrier here. Minimum water levels upstream of GRL009 did not improve until the full barrier was installed here in June. Once all three agriculture barriers (Old River, Grant Line Canal, and Middle River) were installed, minimum stages upstream of the barriers further improved about ½ foot. These increases in minimum stage were consistent from June 4 through October, even when the barrier at the head of Old River was in place. This was probably due to a combination of the Grant Line Canal barrier

remaining in place, raising water levels in the reaches of channels bounded by the barriers, and because the fall barrier at the head of Old River was notched at 0.0 msl. In general, the installation of the temporary barriers also resulted in reduced tidal variation in flows near the barriers, a trend once again made more pronounced in Old and Middle River with the installation of the barrier in Grant Line Canal. Each of the barriers still allowed some downstream flow, while both upstream and downstream flow was suppressed at each barrier site.

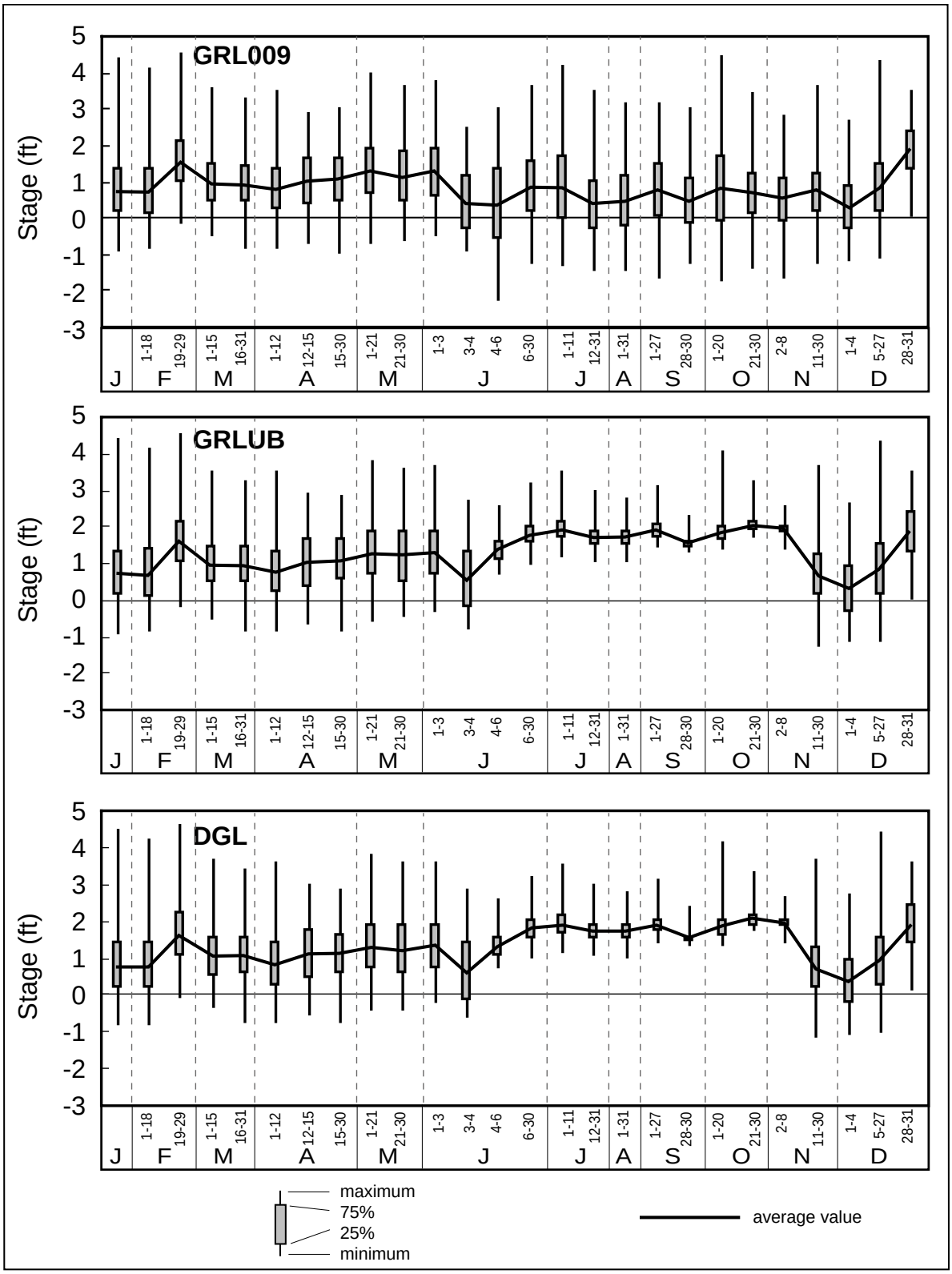


Figure 12. Box Plots showing distribution of DSM2-simulated stages for various periods during 2004.

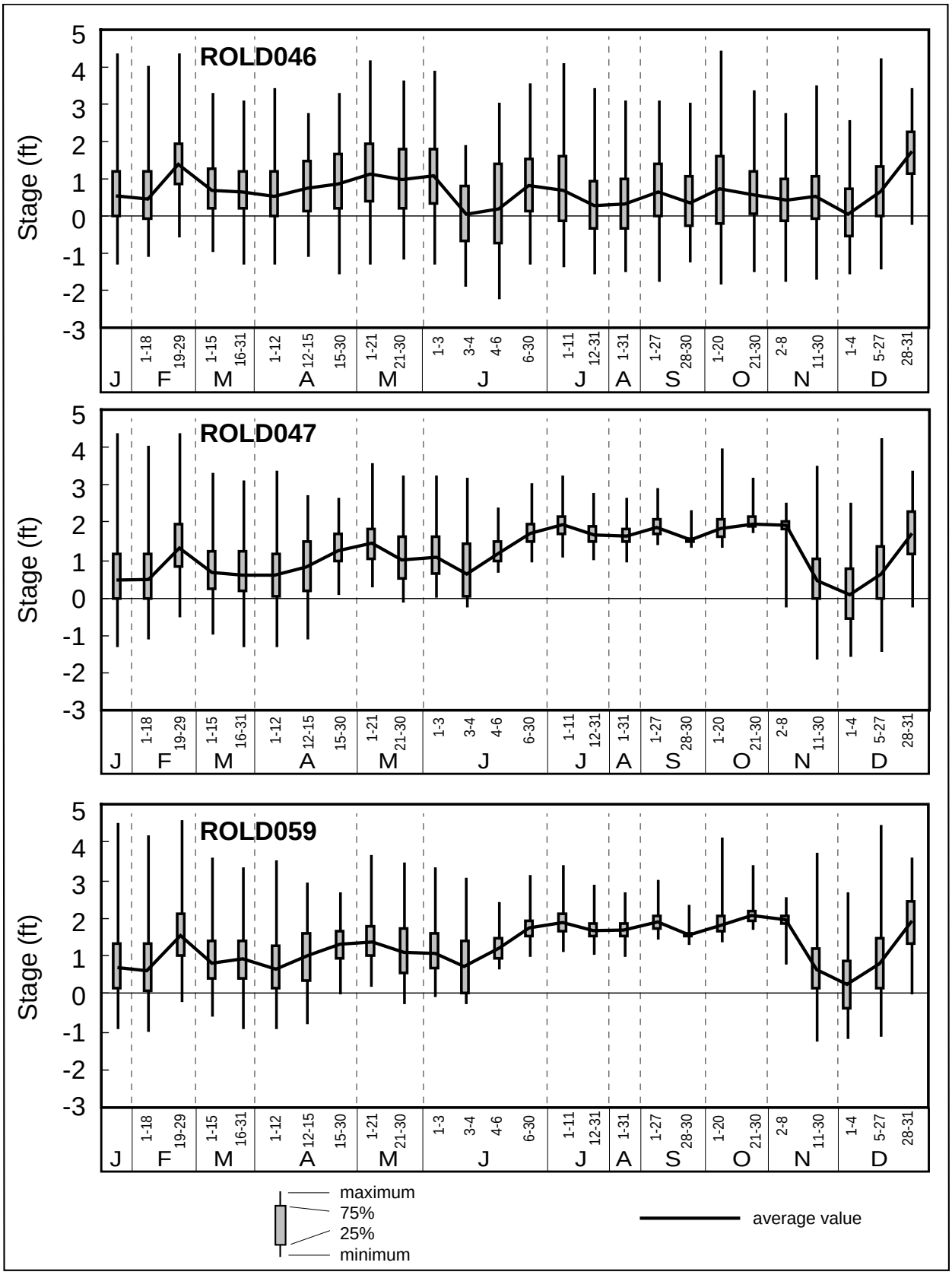


Figure 12 – cont. Box Plots showing distribution of DSM2-simulated stages for various periods during 2004.

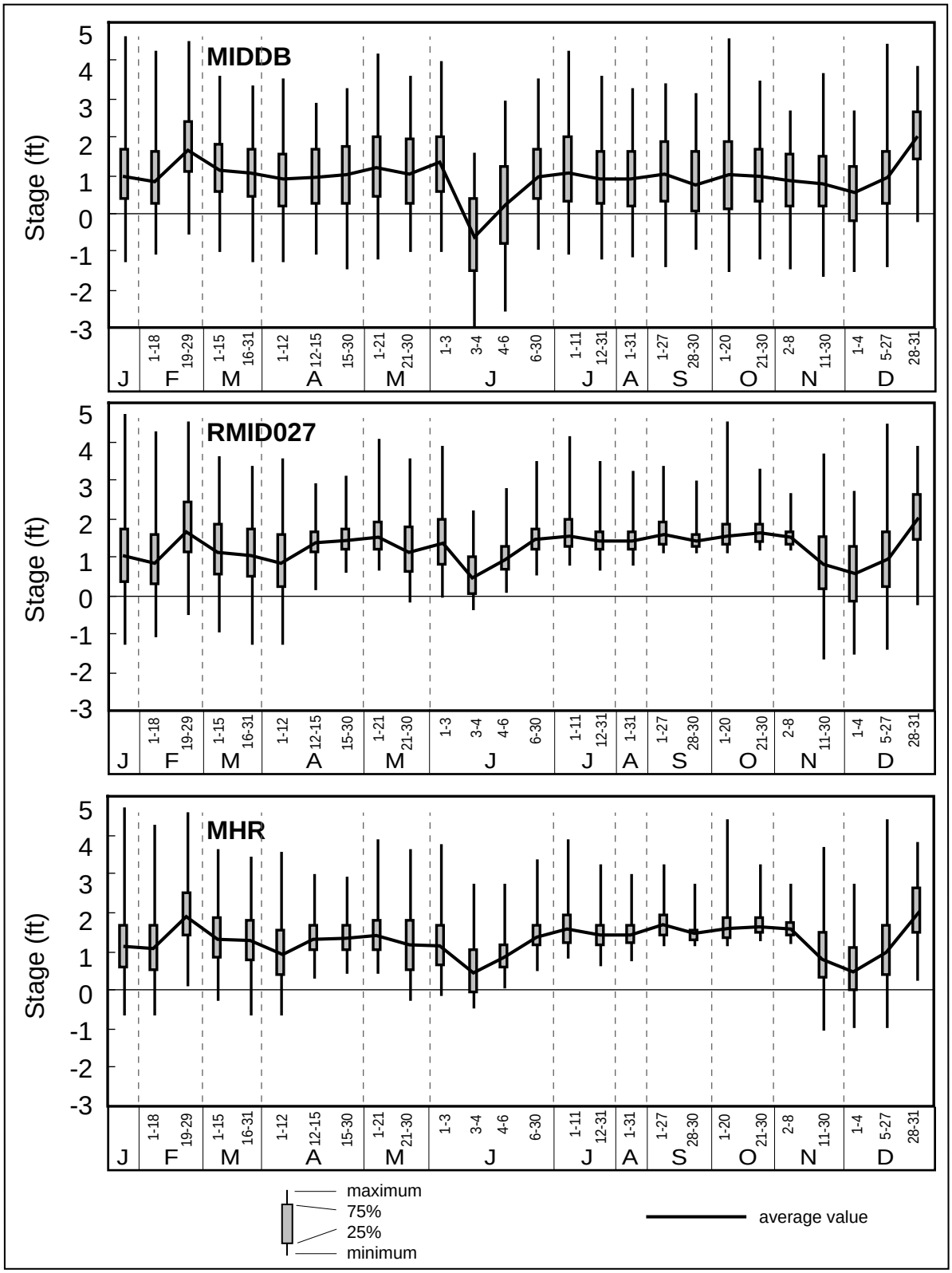


Figure 12 – cont. Box Plots showing distribution of DSM2-simulated stages for various periods during 2004.

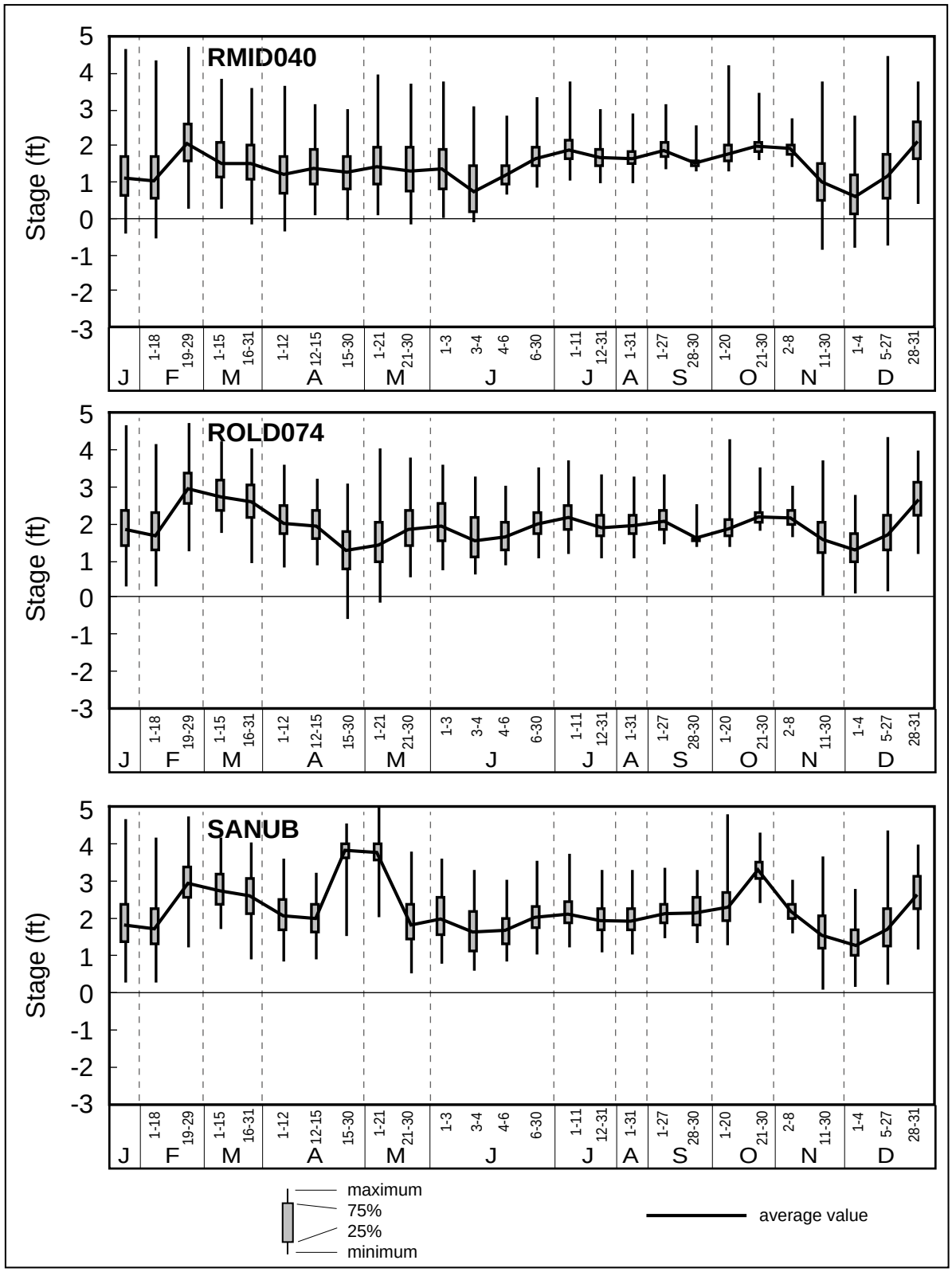


Figure 12 – cont. Box Plots showing distribution of DSM2-simulated stages for various periods during 2004.

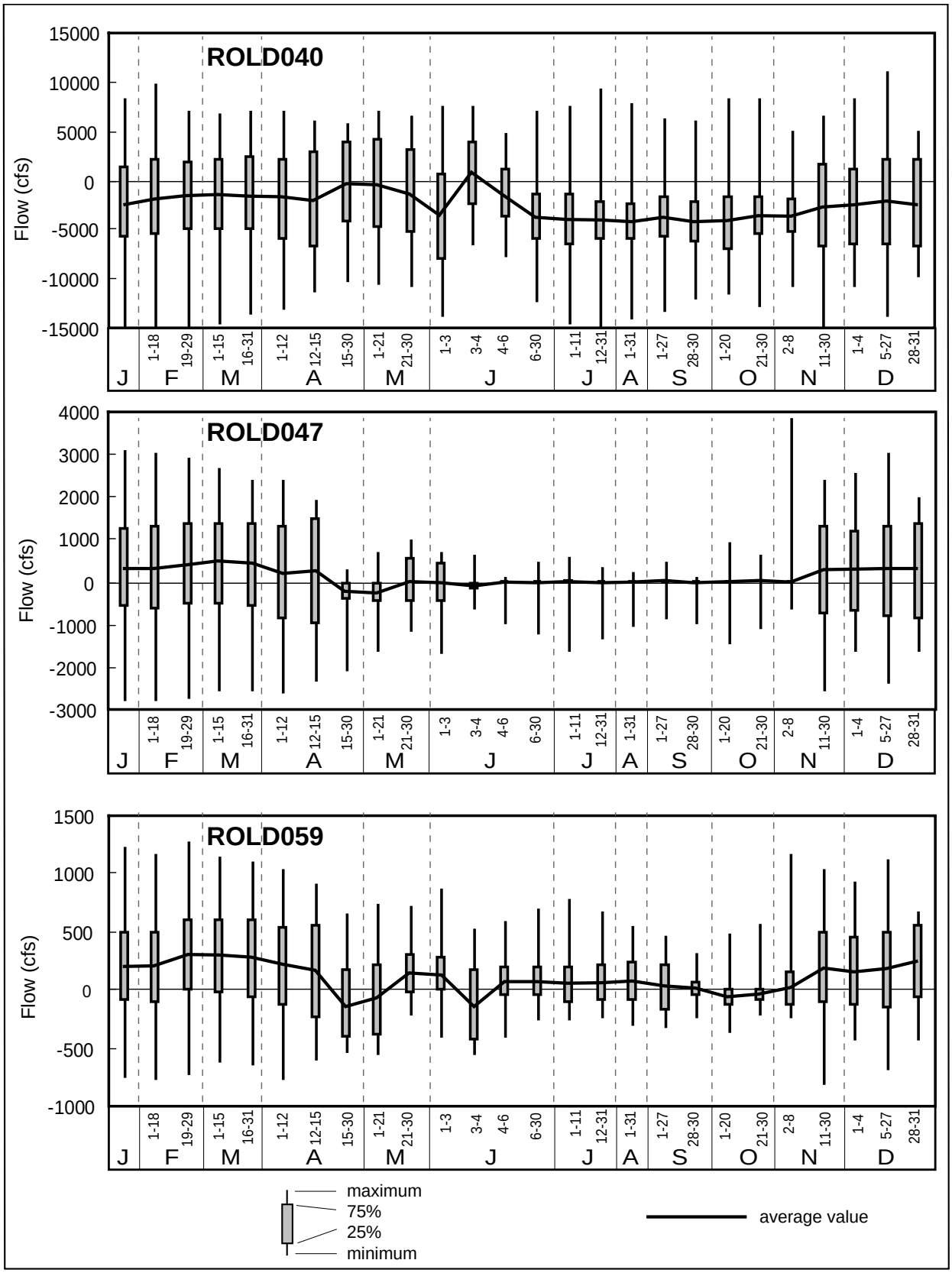


Figure 13. Box Plots showing distribution of DSM2-simulated flows for various periods during 2004.

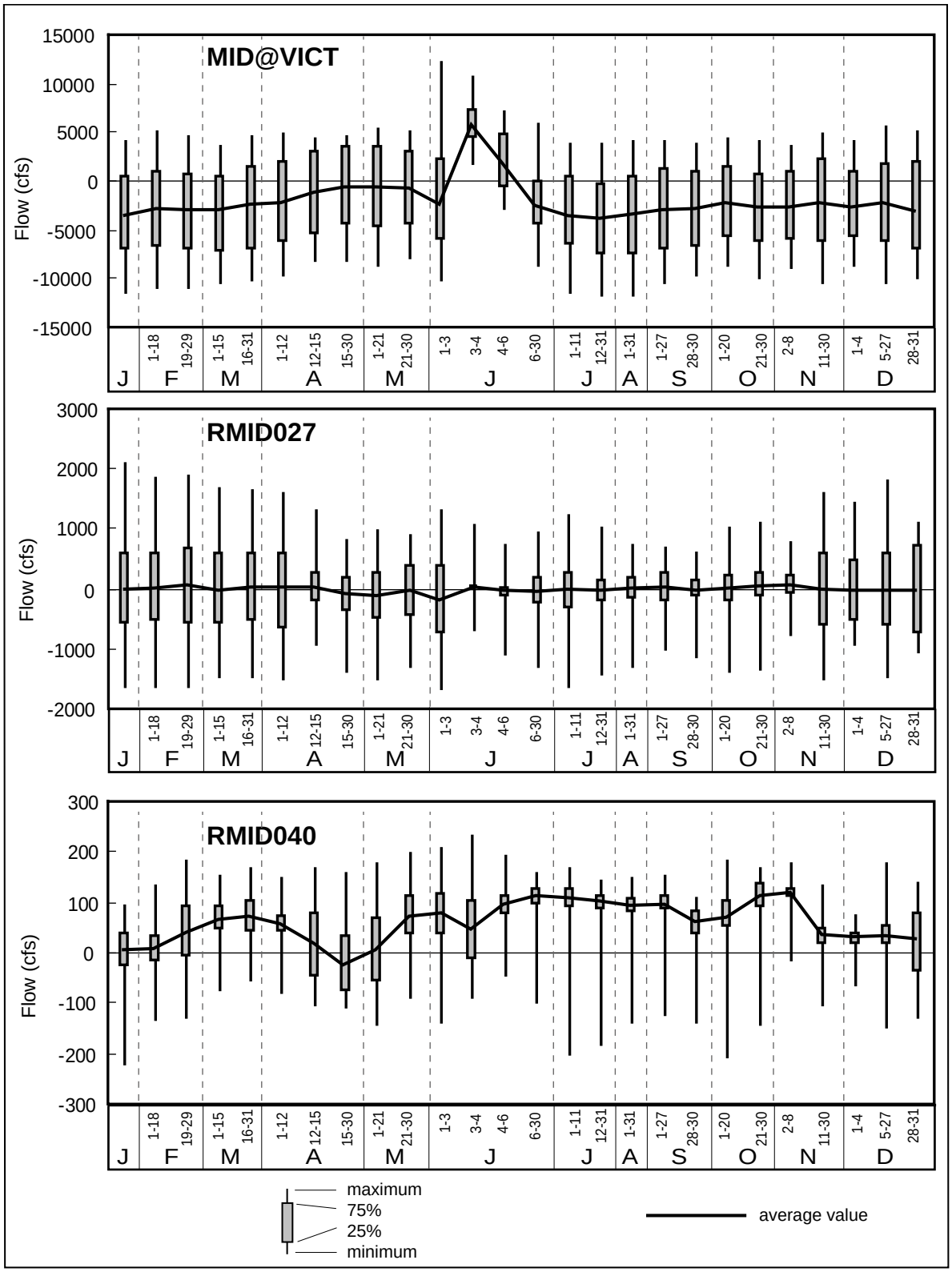


Figure 13 – cont. Box Plots showing distribution of DSM2-simulated flows for various periods during 2004.

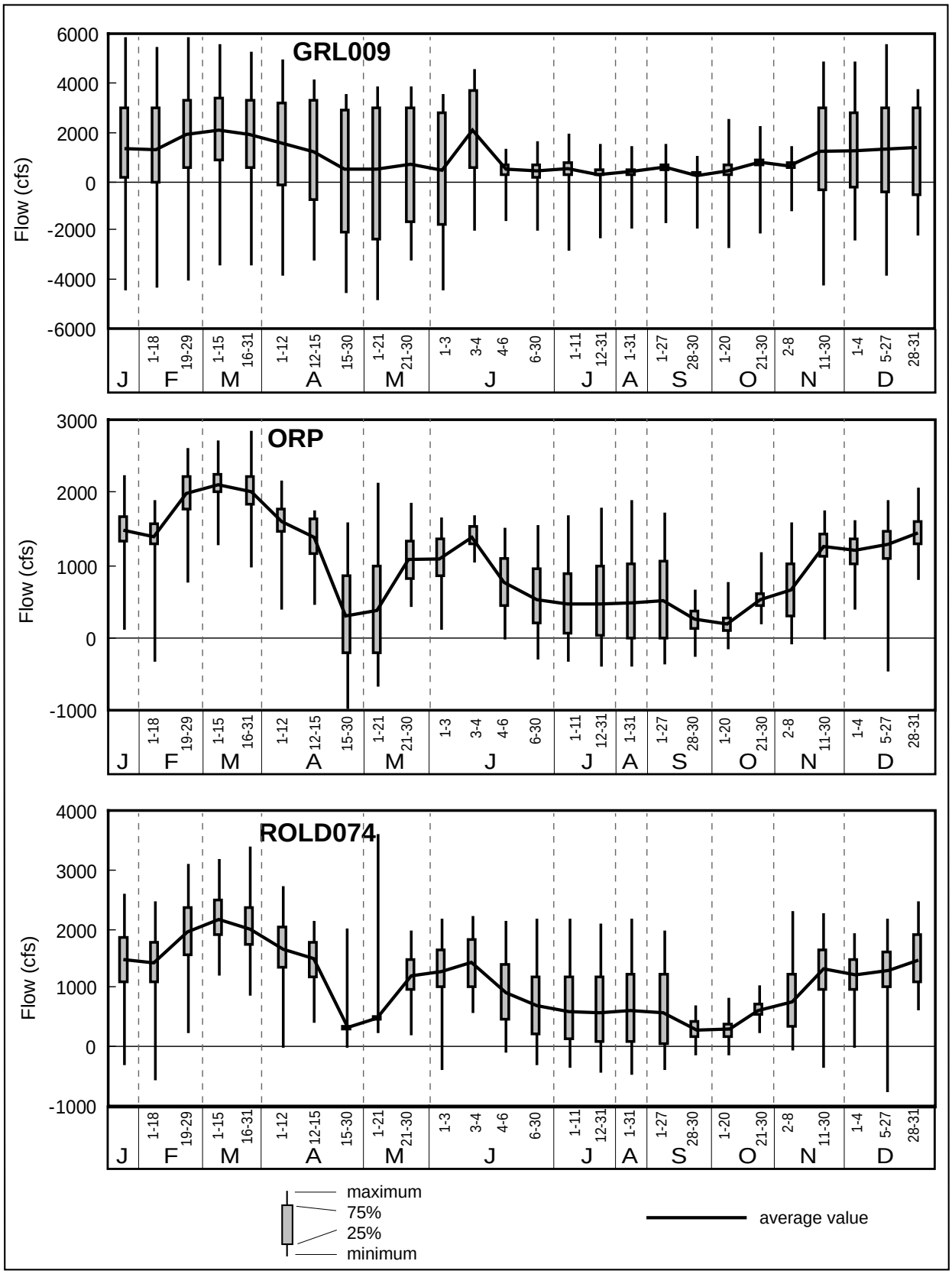


Figure 13 – cont. Box Plots showing distribution of DSM2-simulated flows for various periods during 2004.

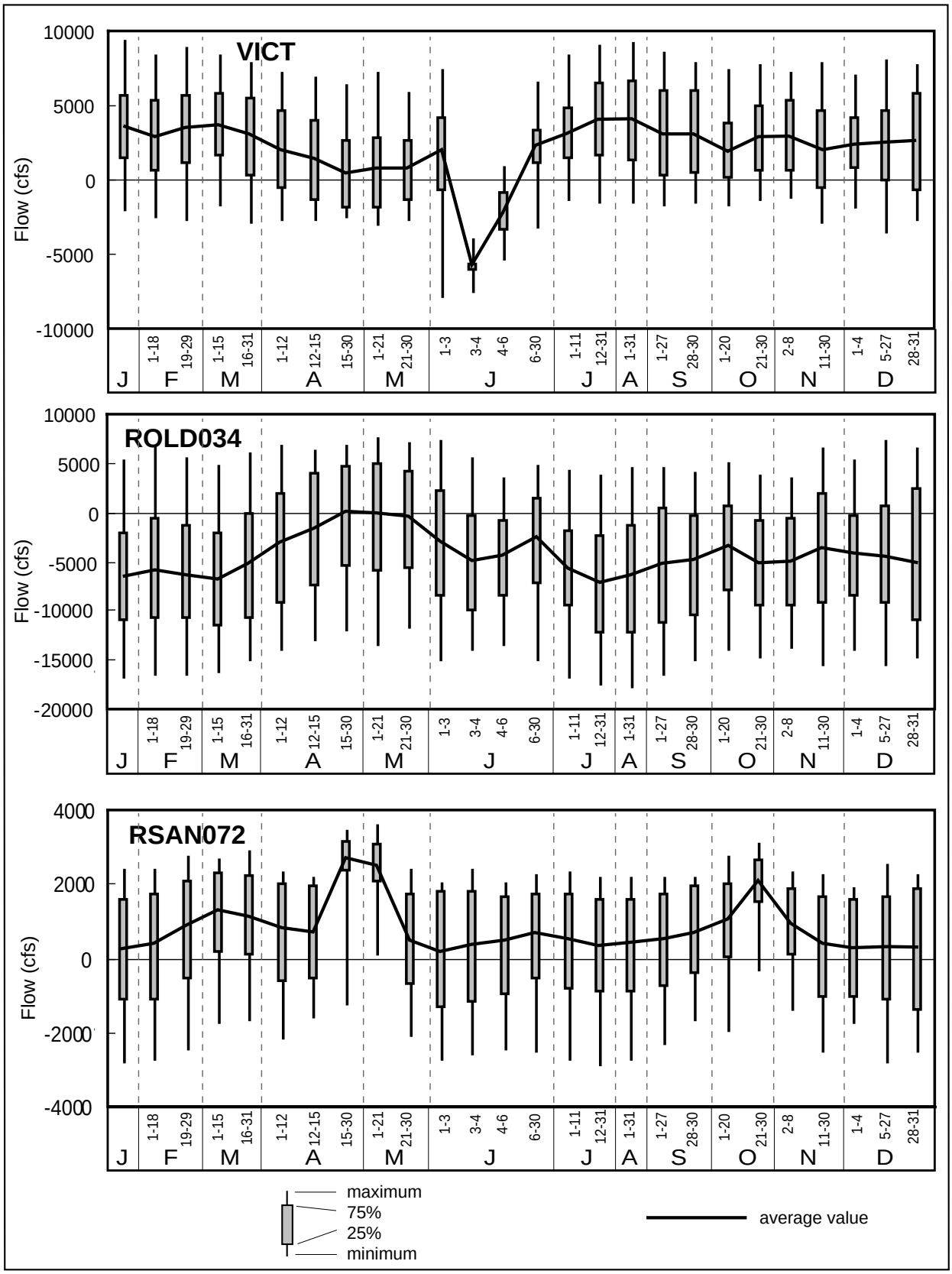


Figure 13 – cont. Box Plots showing distribution of DSM2-simulated flows for various periods during 2004.

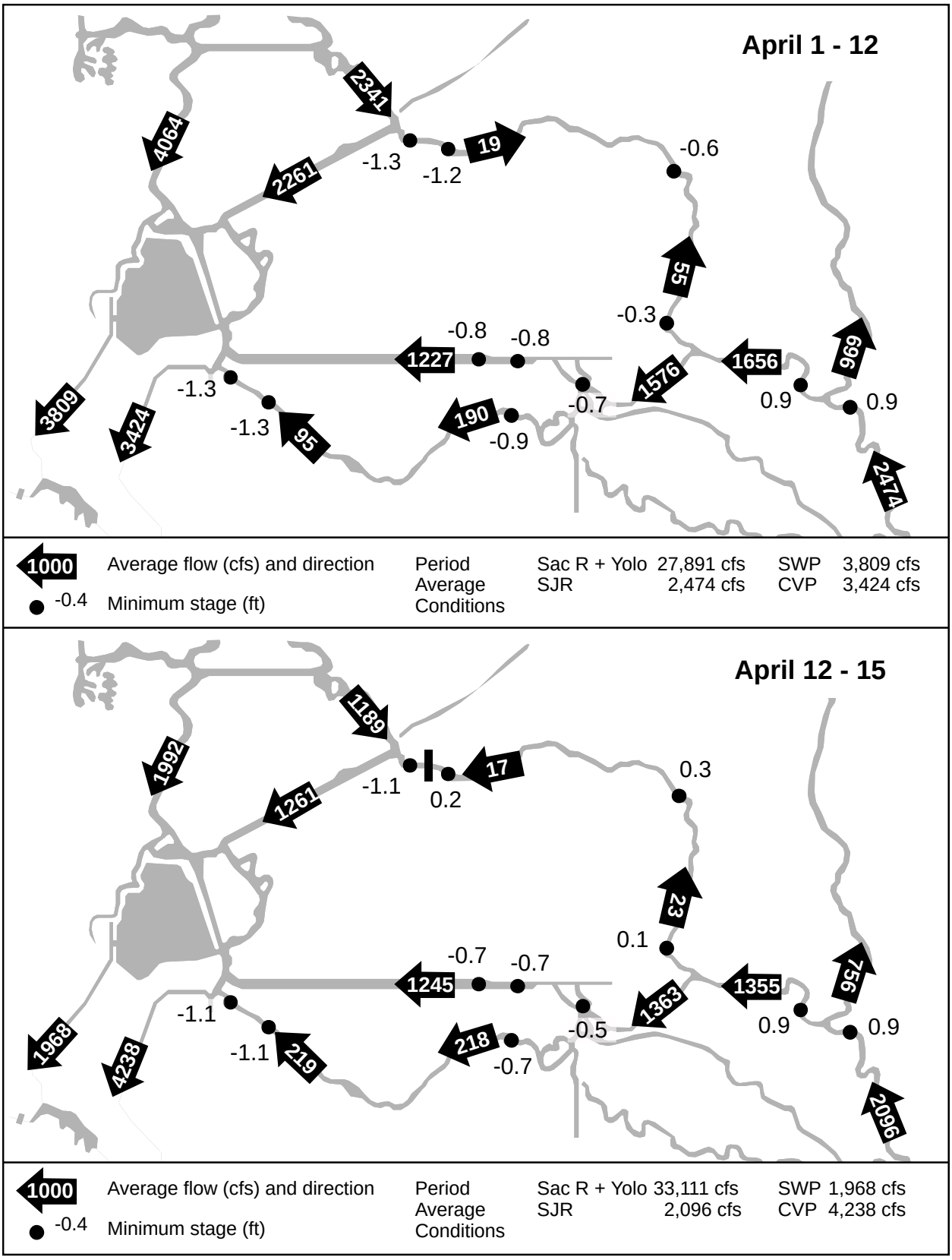
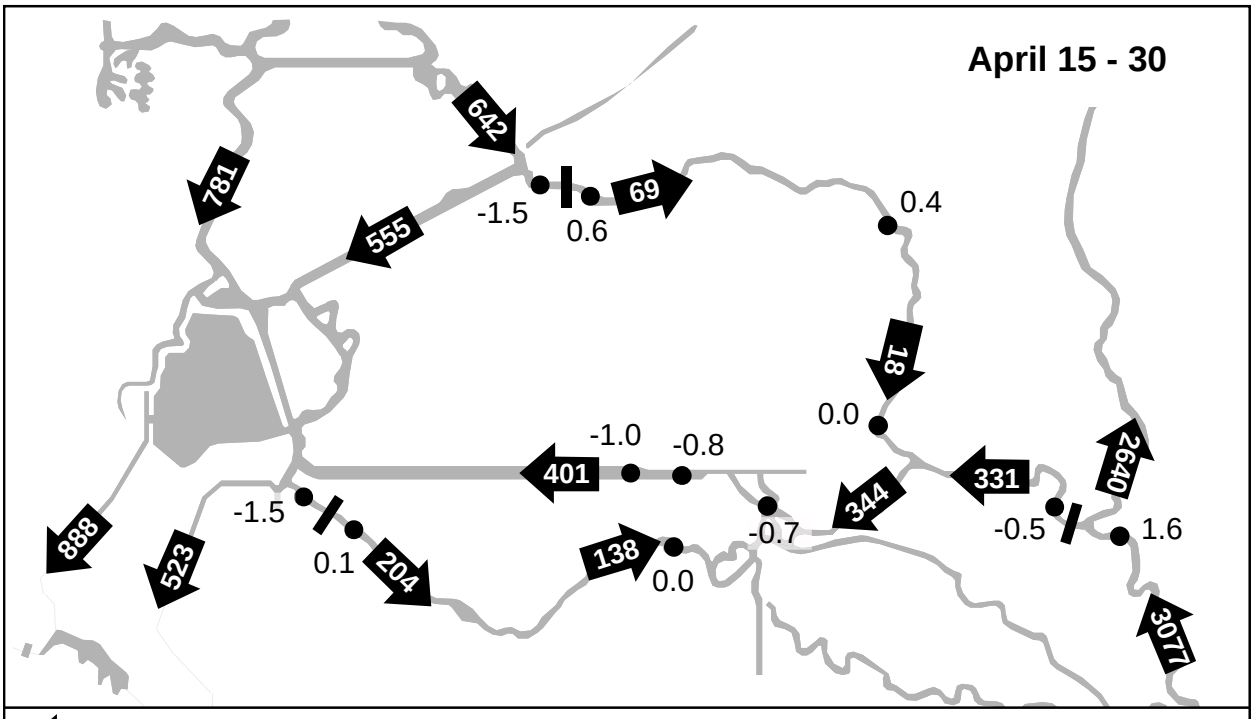


Figure 14. DSM2-simulated average flow patterns and minimum stages for 2004.



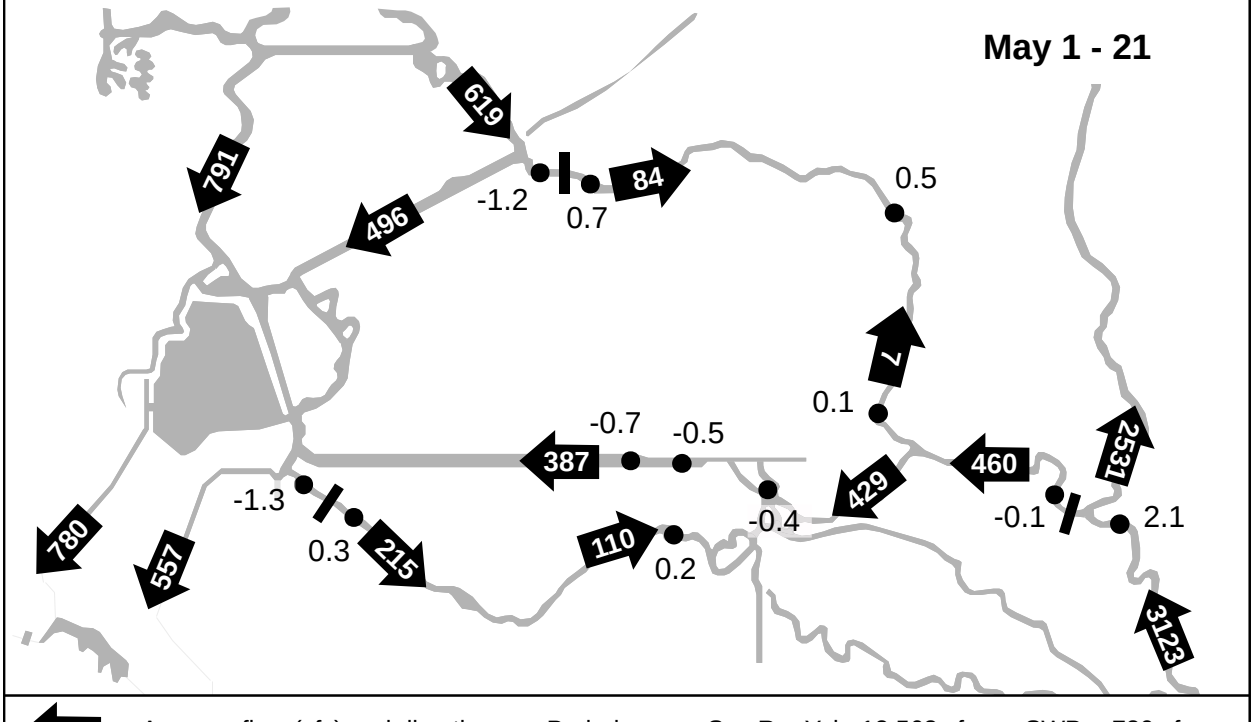
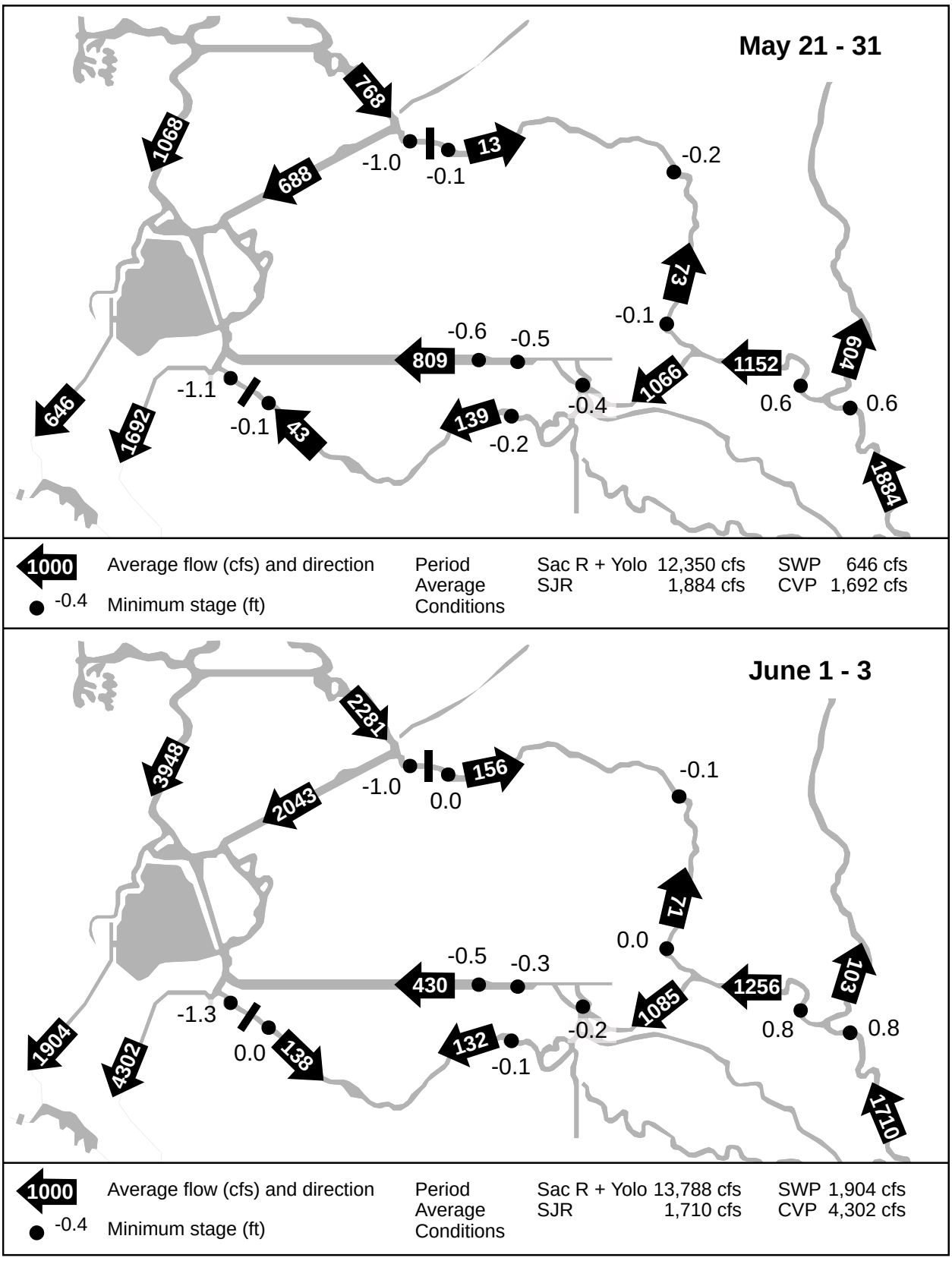


Figure 14 – cont. DSM2-simulated average flow patterns and minimum stages for 2004.



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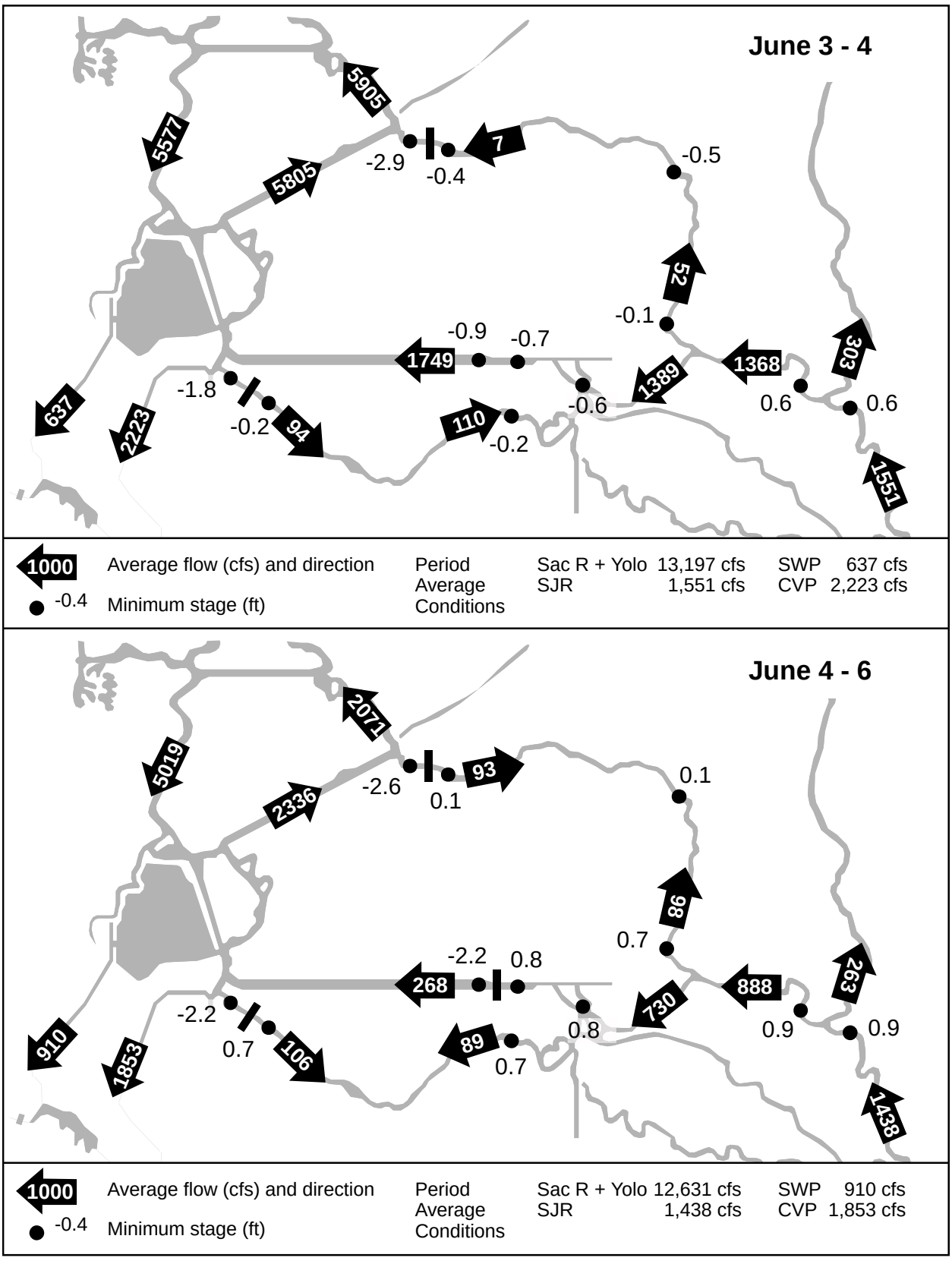

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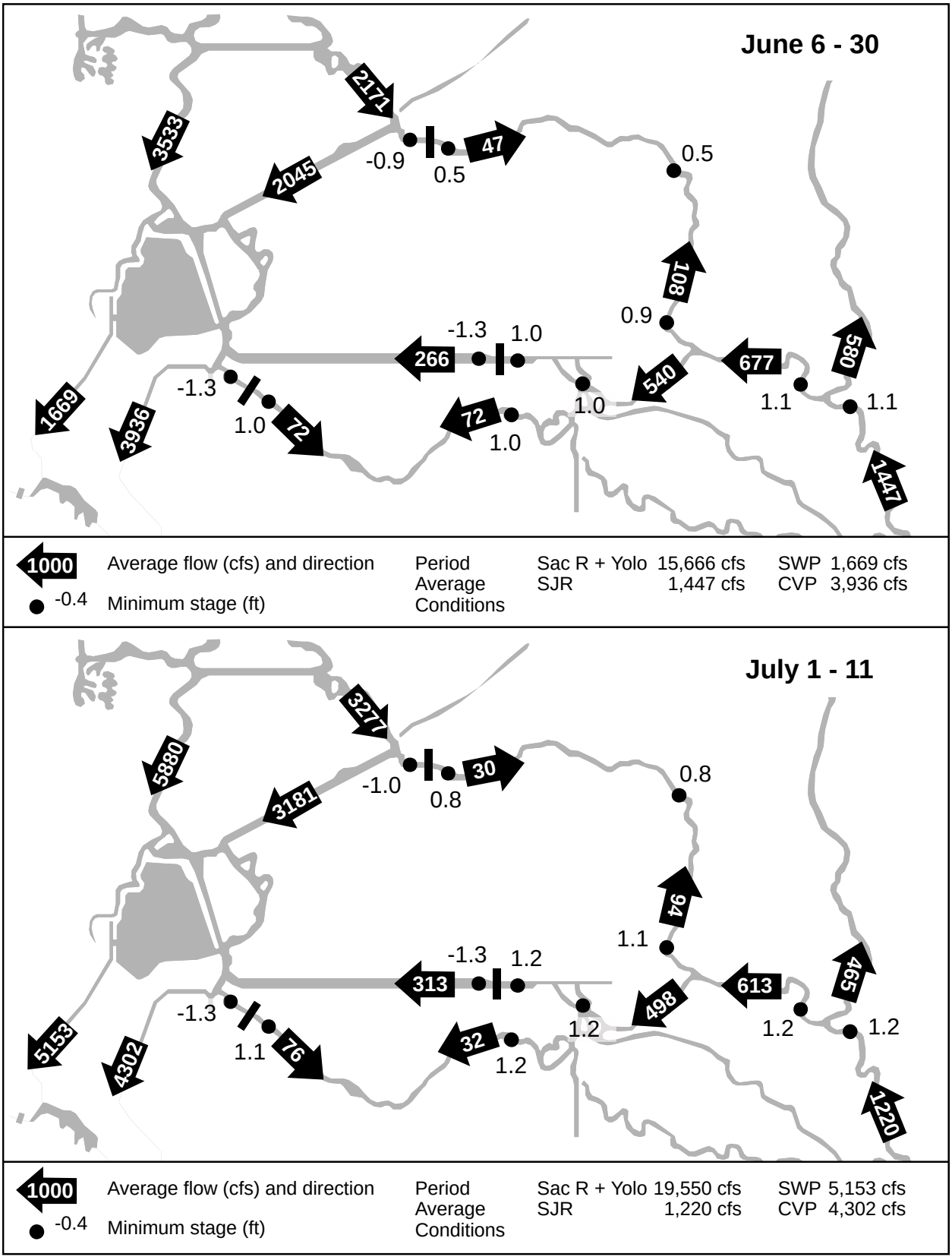

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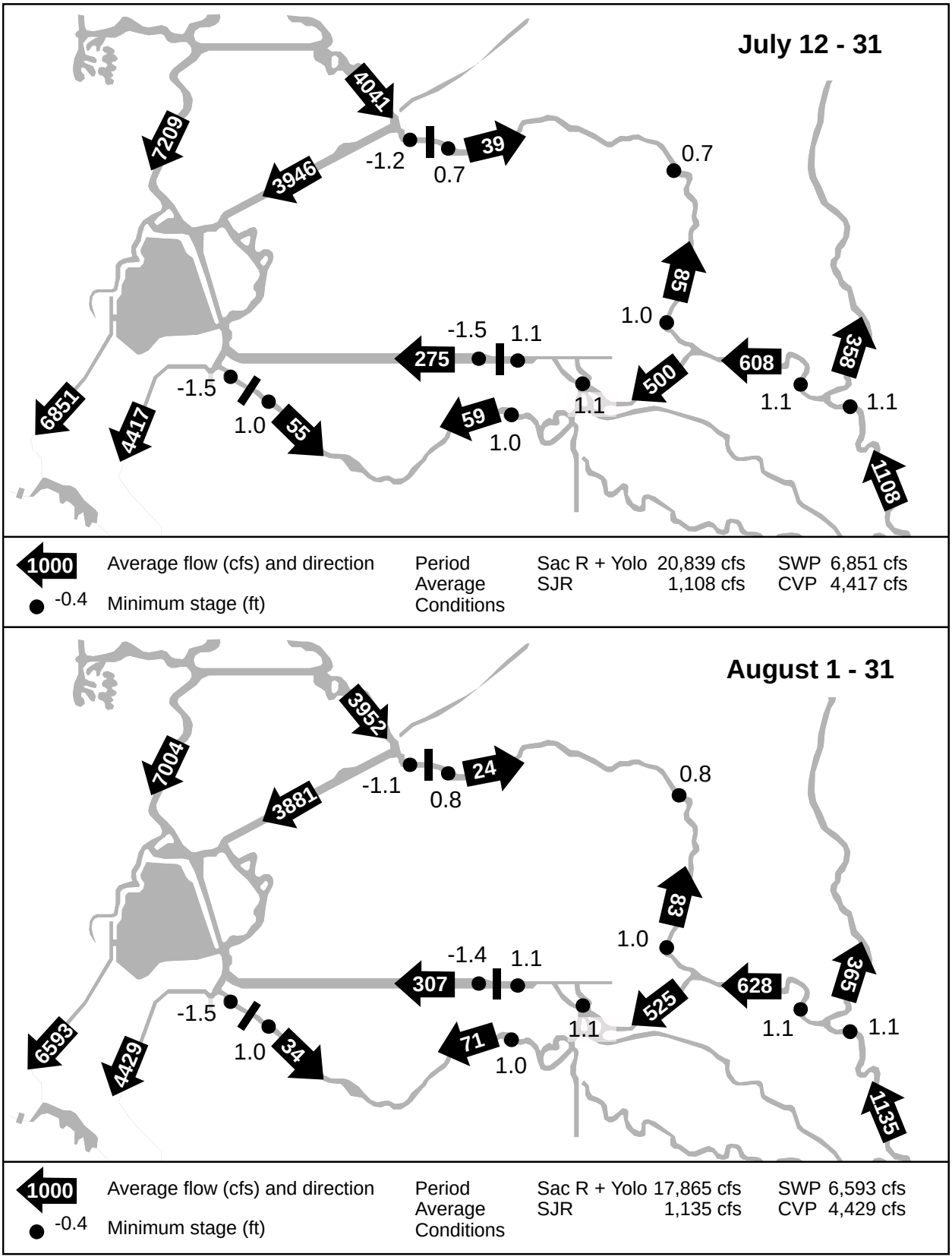

Figure 14 – cont. DSM2-simulated average flow patterns and minimum stages for 2004.

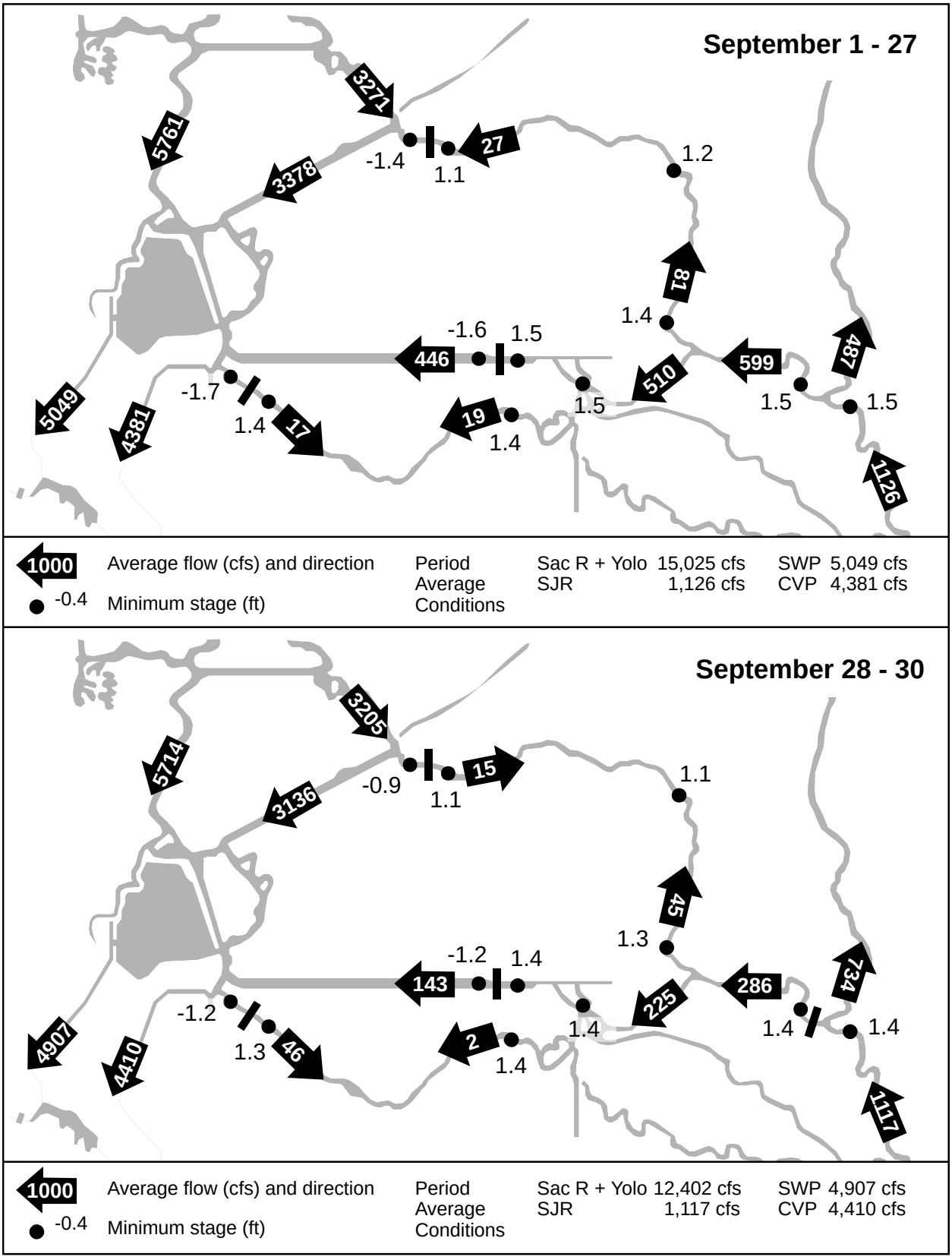

Figure 14 – cont. DSM2-simulated average flow patterns and minimum stages for 2004.

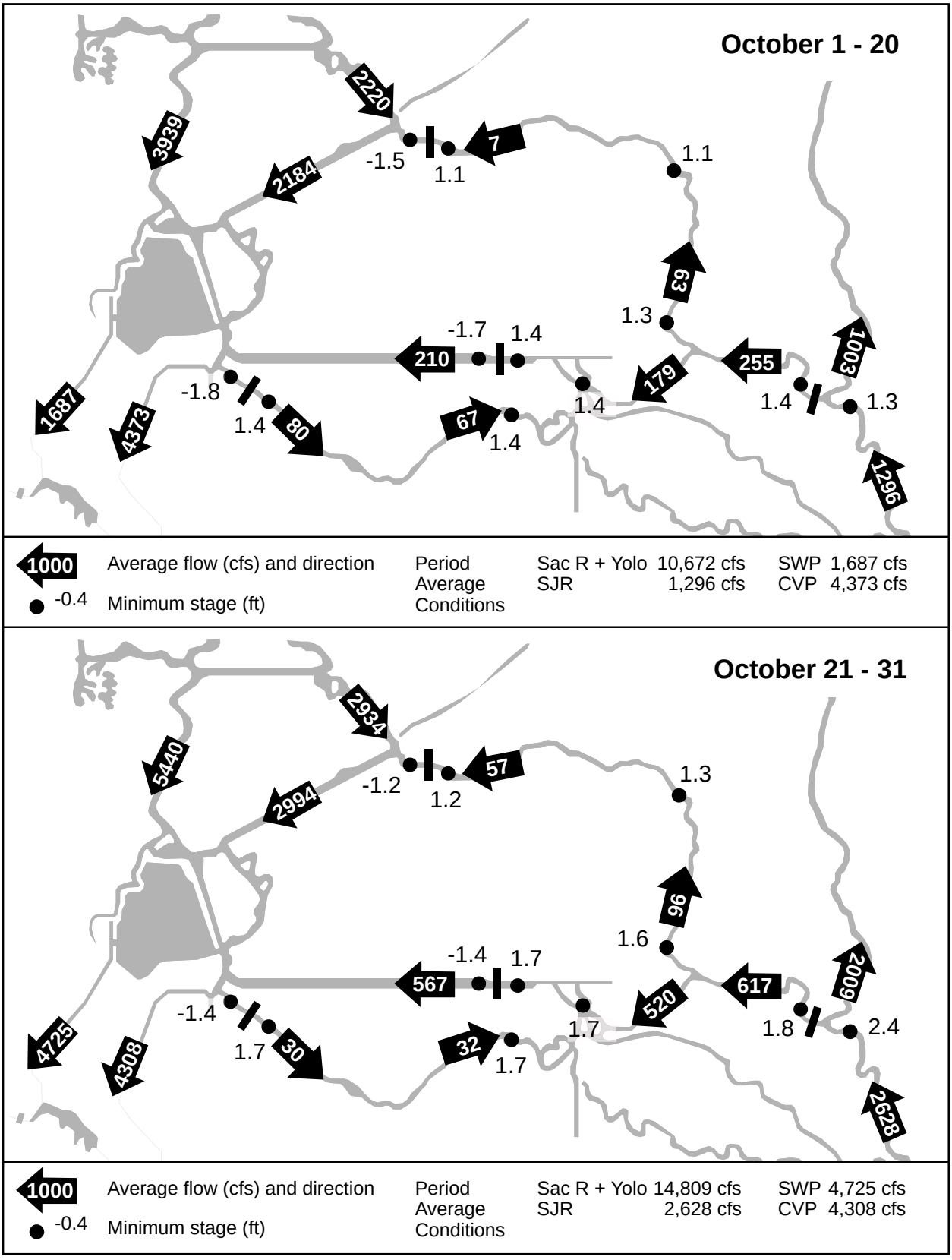

Figure 14 – cont. DSM2-simulated average flow patterns and minimum stages for 2004.

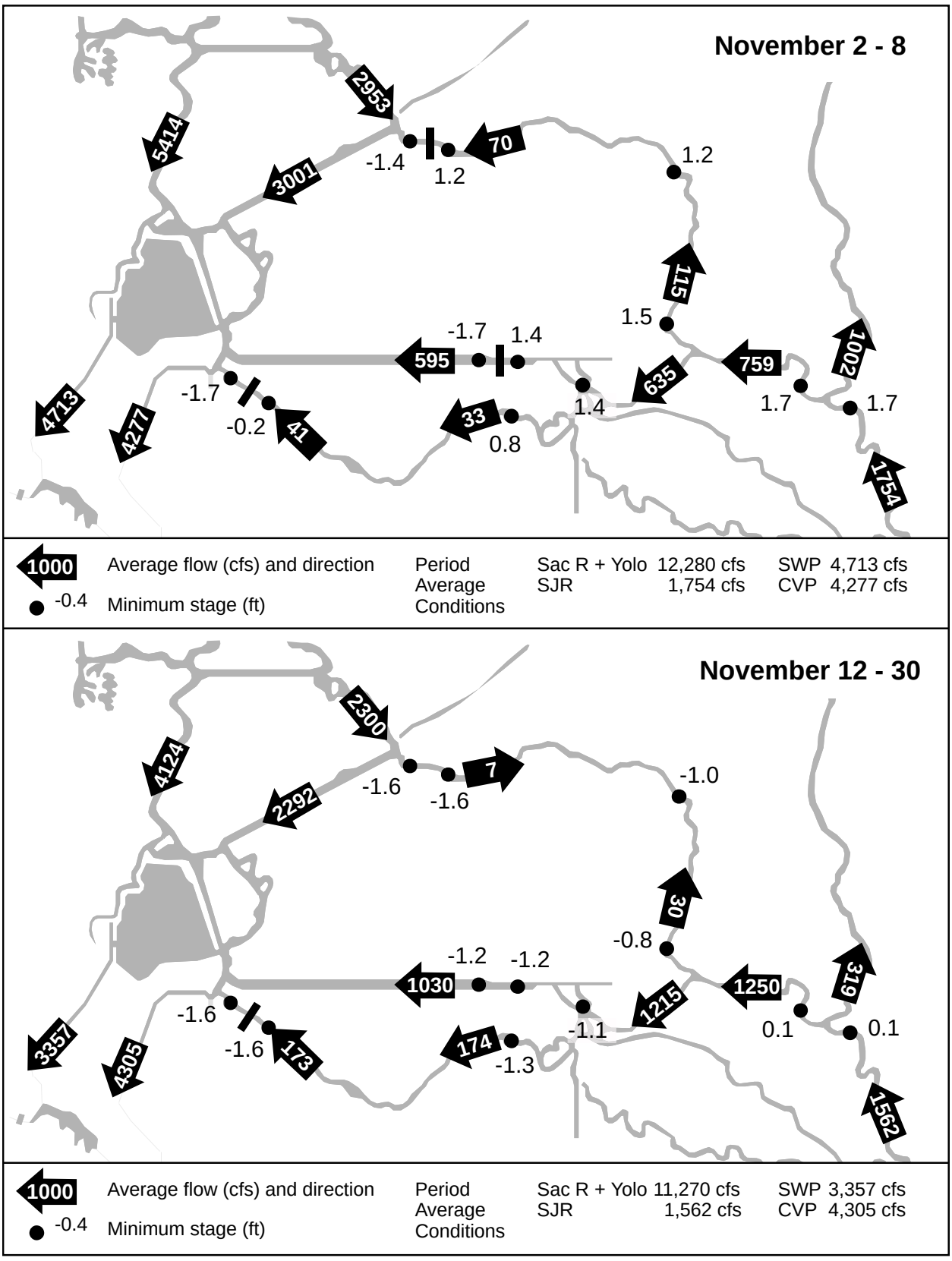

Figure 14 – cont. DSM2-simulated average flow patterns and minimum stages for 2004.

Appendix

This appendix consists of the stage and flow data that is presented graphically in this report via box plots. The values are derived from 15-minute simulated stage and flow over each of the 26 time periods in 2004 presented in Table 3.

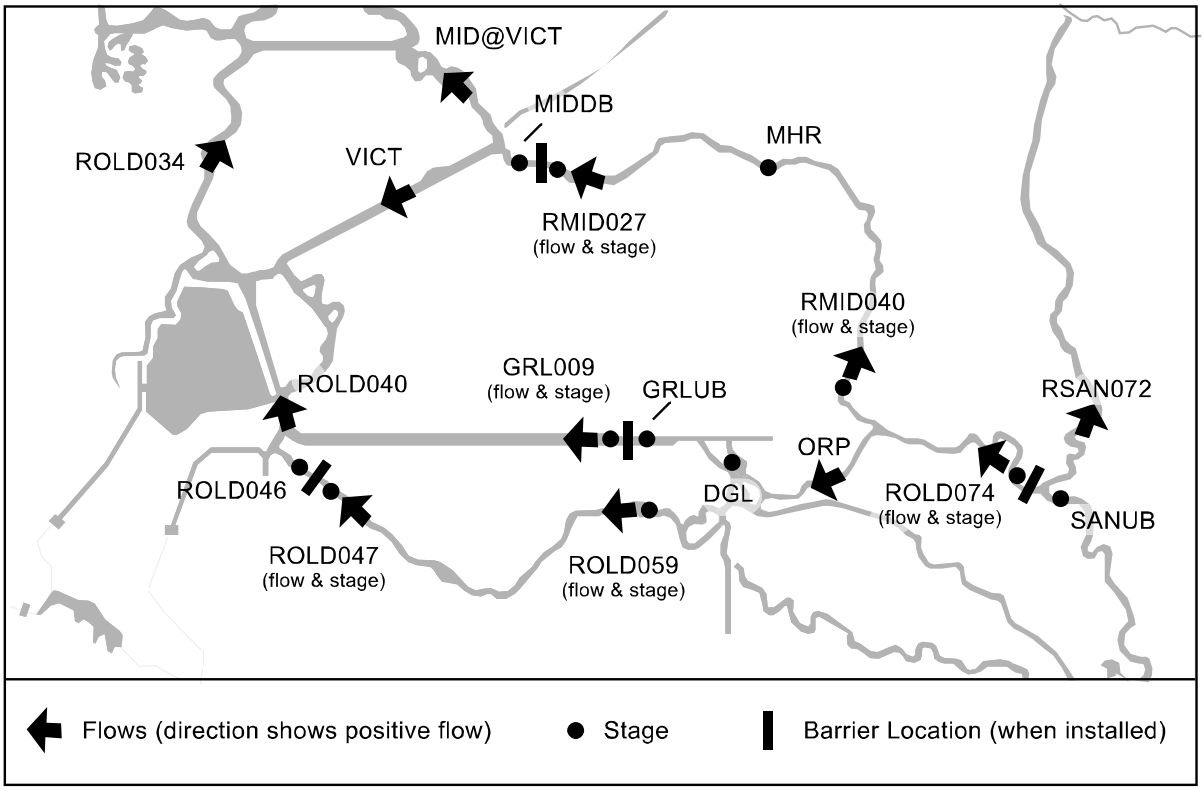

Figure A-1. Locations stage and flow data presented for the simulation of 2003 hydrodynamics.

		GRL009					GRLUB					DGL				
		Min	0.25	Avg	0.75	Max	Min	0.25	Avg	0.75	Max	Min	0.25	Avg	0.75	Max
Jan	1 - 31	-0.91	0.12	0.86	1.35	4.40	-0.91	0.12	0.86	1.35	4.40	-0.81	0.18	0.93	1.42	4.46
Feb	1 - 18	-0.83	0.08	0.82	1.38	4.09	-0.83	0.08	0.82	1.38	4.09	-0.79	0.14	0.89	1.45	4.18
	19 - 29	-0.16	0.98	1.61	2.14	4.51	-0.16	0.98	1.61	2.14	4.51	-0.05	1.06	1.69	2.22	4.61
Mar	1 - 15	-0.46	0.43	1.06	1.49	3.53	-0.46	0.43	1.06	1.49	3.53	-0.30	0.52	1.16	1.57	3.63
	16 -31	-0.83	0.43	0.96	1.46	3.27	-0.83	0.43	0.96	1.46	3.27	-0.70	0.54	1.05	1.55	3.38
Apr	1 - 12	-0.83	0.19	0.84	1.37	3.51	-0.83	0.19	0.84	1.37	3.51	-0.71	0.26	0.91	1.42	3.58
	12 - 15	-0.65	0.34	1.01	1.66	2.89	-0.65	0.34	1.01	1.66	2.89	-0.53	0.42	1.09	1.74	2.98
	15 - 30	-0.98	0.42	1.05	1.67	3.04	-0.82	0.51	1.09	1.65	2.83	-0.71	0.56	1.12	1.67	2.83
May	1 - 21	-0.69	0.60	1.29	1.92	3.96	-0.53	0.69	1.32	1.88	3.78	-0.41	0.73	1.36	1.88	3.79
	21 - 31	-0.60	0.39	1.19	1.87	3.63	-0.45	0.49	1.25	1.89	3.58	-0.35	0.57	1.30	1.91	3.62
Jun	1 - 3	-0.49	0.56	1.31	1.89	3.78	-0.29	0.64	1.35	1.90	3.62	-0.15	0.72	1.39	1.93	3.62
	3 - 4	-0.90	-0.31	0.37	1.14	2.48	-0.73	-0.24	0.49	1.31	2.69	-0.57	-0.18	0.61	1.42	2.85
	4 - 6	-2.22	-0.63	0.36	1.41	3.05	0.76	1.04	1.36	1.62	2.56	0.76	1.03	1.36	1.60	2.59
	6 - 30	-1.25	0.12	0.89	1.59	3.60	1.03	1.52	1.80	2.00	3.16	1.04	1.52	1.80	2.01	3.21
Jul	1 - 11	-1.29	-0.08	0.83	1.73	4.15	1.18	1.66	1.97	2.17	3.49	1.18	1.66	1.97	2.18	3.53
	12 - 31	-1.46	-0.31	0.48	1.05	3.48	1.07	1.50	1.74	1.90	2.97	1.07	1.50	1.75	1.90	2.99
Aug	1 - 31	-1.41	-0.28	0.48	1.14	3.16	1.05	1.50	1.72	1.88	2.77	1.06	1.50	1.72	1.88	2.78
Sep	1 - 27	-1.64	0.03	0.77	1.53	3.17	1.46	1.68	1.90	2.07	3.07	1.46	1.69	1.90	2.07	3.09
	27 - 30	-1.19	-0.21	0.48	1.13	3.05	1.37	1.44	1.55	1.59	2.30	1.37	1.44	1.55	1.59	2.35
Oct	1 - 20	-1.72	-0.13	0.83	1.70	4.48	1.38	1.60	1.89	2.05	4.05	1.38	1.59	1.89	2.05	4.11
	21 - 31	-1.35	0.09	0.75	1.25	3.40	1.74	1.85	2.04	2.16	3.21	1.74	1.85	2.04	2.17	3.30
Nov	2 - 8	-1.66	-0.12	0.51	1.08	2.83	1.44	1.81	1.93	2.04	2.57	1.44	1.81	1.93	2.04	2.63
	11 - 30	-1.23	0.12	0.77	1.24	3.62	-1.23	0.12	0.77	1.24	3.62	-1.12	0.19	0.84	1.30	3.68
Dec	1 - 4	-1.13	-0.33	0.42	0.91	2.65	-1.13	-0.33	0.42	0.91	2.65	-1.02	-0.27	0.48	0.95	2.70
	5 - 27	-1.07	0.15	0.92	1.54	4.32	-1.07	0.15	0.92	1.54	4.32	-0.98	0.21	0.99	1.60	4.39
	28 - 31	0.05	1.29	1.83	2.41	3.52	0.05	1.29	1.83	2.41	3.52	0.15	1.36	1.89	2.46	3.57

Table A-1. Distribution of stages (feet) by study period in 2004.

		ROLD046					ROLD047					ROLD059				
		Min	0.25	Avg	0.75	Max	Min	0.25	Avg	0.75	Max	Min	0.25	Avg	0.75	Max
Jan	1 - 31	-1.27	-0.07	0.65	1.17	4.32	-1.27	-0.07	0.65	1.17	4.32	-0.92	0.06	0.80	1.30	4.47
Feb	1 - 18	-1.06	-0.12	0.63	1.18	3.99	-1.06	-0.12	0.63	1.18	3.99	-0.96	0.03	0.78	1.32	4.18
	19 - 29	-0.51	0.78	1.40	1.95	4.33	-0.51	0.78	1.40	1.95	4.33	-0.20	0.93	1.57	2.11	4.57
Mar	1 - 15	-0.96	0.16	0.80	1.25	3.30	-0.96	0.16	0.80	1.25	3.30	-0.55	0.35	0.99	1.41	3.54
	16 -31	-1.28	0.14	0.70	1.21	3.08	-1.28	0.14	0.70	1.21	3.08	-0.87	0.36	0.89	1.40	3.27
Apr	1 - 12	-1.27	-0.04	0.62	1.18	3.37	-1.27	-0.04	0.62	1.18	3.37	-0.92	0.08	0.75	1.29	3.52
	12 - 15	-1.09	0.10	0.77	1.47	2.71	-1.09	0.10	0.77	1.47	2.71	-0.74	0.25	0.94	1.58	2.88
	15 - 30	-1.53	0.16	0.92	1.67	3.25	0.14	0.90	1.31	1.70	2.63	0.04	0.86	1.28	1.66	2.64
May	1 - 21	-1.25	0.34	1.17	1.96	4.12	0.29	0.99	1.48	1.81	3.53	0.21	0.96	1.45	1.78	3.65
	21 - 31	-1.14	0.13	1.01	1.82	3.61	-0.10	0.45	1.14	1.66	3.24	-0.23	0.48	1.16	1.69	3.44
Jun	1 - 3	-1.26	0.29	1.13	1.82	3.86	0.02	0.60	1.17	1.63	3.21	-0.06	0.59	1.16	1.60	3.31
	3 - 4	-1.84	-0.76	-0.04	0.77	1.90	-0.21	-0.04	0.79	1.44	3.14	-0.24	-0.04	0.77	1.40	3.06
	4 - 6	-2.22	-0.77	0.31	1.38	3.00	0.69	0.90	1.26	1.52	2.38	0.70	0.90	1.26	1.48	2.37
	6 - 30	-1.29	0.05	0.81	1.51	3.52	0.97	1.46	1.74	1.95	3.00	1.00	1.46	1.74	1.94	3.10
Jul	1 - 11	-1.30	-0.17	0.72	1.59	4.07	1.12	1.62	1.93	2.16	3.23	1.15	1.62	1.93	2.14	3.39
	12 - 31	-1.50	-0.43	0.37	0.92	3.39	1.01	1.44	1.69	1.88	2.77	1.04	1.45	1.69	1.85	2.84
Aug	1 - 31	-1.45	-0.37	0.37	1.02	3.05	1.00	1.44	1.66	1.83	2.59	1.03	1.45	1.66	1.82	2.62
Sep	1 - 27	-1.70	-0.07	0.66	1.40	3.06	1.41	1.66	1.89	2.07	2.91	1.44	1.67	1.89	2.07	3.00
	27 - 30	-1.22	-0.36	0.38	1.04	2.97	1.34	1.43	1.54	1.58	2.30	1.35	1.43	1.54	1.58	2.30
Oct	1 - 20	-1.78	-0.25	0.72	1.59	4.42	1.37	1.59	1.90	2.09	3.94	1.37	1.59	1.90	2.08	4.10
	21 - 31	-1.44	-0.03	0.63	1.17	3.32	1.73	1.85	2.05	2.18	3.18	1.73	1.85	2.04	2.17	3.35
Nov	2 - 8	-1.74	-0.19	0.41	0.99	2.72	-0.23	1.78	1.88	2.04	2.52	0.81	1.79	1.91	2.03	2.51
	11 - 30	-1.64	-0.11	0.56	1.05	3.50	-1.64	-0.11	0.56	1.05	3.50	-1.26	0.05	0.72	1.20	3.67
Dec	1 - 4	-1.52	-0.62	0.21	0.75	2.51	-1.52	-0.62	0.21	0.75	2.51	-1.16	-0.42	0.37	0.87	2.66
	5 - 27	-1.42	-0.07	0.73	1.34	4.23	-1.42	-0.07	0.73	1.34	4.23	-1.12	0.08	0.88	1.49	4.40
	28 - 31	-0.23	1.09	1.67	2.27	3.38	-0.23	1.09	1.67	2.27	3.38	0.02	1.24	1.81	2.41	3.54

Table A-1 – cont. Distribution of stages (feet) by study period in 2004.

		MIDDB					RMID027					MHR				
		Min	0.25	Avg	0.75	Max	Min	0.25	Avg	0.75	Max	Min	0.25	Avg	0.75	Max
Jan	1 - 31	-1.24	0.32	1.07	1.71	4.64	-1.23	0.32	1.08	1.72	4.66	-0.64	0.51	1.20	1.70	4.65
Feb	1 - 18	-1.07	0.19	0.98	1.59	4.22	-1.05	0.20	0.99	1.61	4.24	-0.62	0.43	1.12	1.65	4.21
	19 - 29	-0.53	1.06	1.75	2.38	4.47	-0.50	1.07	1.76	2.39	4.49	0.13	1.34	1.93	2.48	4.56
Mar	1 - 15	-0.97	0.48	1.21	1.83	3.55	-0.96	0.50	1.22	1.85	3.57	-0.24	0.77	1.40	1.89	3.62
	16 -31	-1.27	0.39	1.04	1.66	3.34	-1.26	0.42	1.05	1.68	3.35	-0.65	0.70	1.24	1.77	3.38
Apr	1 - 12	-1.25	0.12	0.89	1.57	3.52	-1.24	0.14	0.89	1.56	3.54	-0.64	0.33	1.00	1.55	3.52
	12 - 15	-1.08	0.20	0.91	1.68	2.85	0.15	1.08	1.37	1.64	2.88	0.30	0.98	1.38	1.70	2.95
	15 - 30	-1.45	0.16	0.97	1.77	3.27	0.61	1.11	1.47	1.74	3.09	0.44	0.98	1.36	1.67	2.91
May	1 - 21	-1.18	0.35	1.21	2.01	4.14	0.66	1.15	1.61	1.91	4.03	0.46	0.99	1.49	1.82	3.86
	21 - 31	-1.01	0.16	1.07	1.92	3.59	-0.13	0.52	1.23	1.80	3.54	-0.22	0.48	1.20	1.78	3.60
Jun	1 - 3	-0.98	0.50	1.36	2.03	3.97	0.00	0.77	1.47	2.00	3.81	-0.13	0.60	1.28	1.70	3.69
	3 - 4	-2.93	-1.55	-0.67	0.35	1.57	-0.38	-0.02	0.60	0.98	2.17	-0.46	-0.11	0.54	1.02	2.71
	4 - 6	-2.57	-0.87	0.22	1.24	2.91	0.10	0.60	1.01	1.25	2.76	0.08	0.54	0.94	1.14	2.70
	6 - 30	-0.94	0.32	1.04	1.71	3.53	0.54	1.10	1.46	1.70	3.42	0.51	1.07	1.42	1.66	3.32
Jul	1 - 11	-1.02	0.27	1.14	2.00	4.20	0.83	1.20	1.68	1.99	4.08	0.82	1.19	1.65	1.96	3.84
	12 - 31	-1.19	0.16	0.95	1.61	3.57	0.68	1.13	1.50	1.65	3.47	0.68	1.11	1.46	1.65	3.19
Aug	1 - 31	-1.13	0.14	0.94	1.65	3.27	0.80	1.16	1.49	1.65	3.17	0.80	1.15	1.47	1.65	2.96
Sep	1 - 27	-1.39	0.28	1.10	1.89	3.36	1.14	1.29	1.65	1.91	3.31	1.17	1.33	1.67	1.94	3.20
	27 - 30	-0.91	-0.01	0.84	1.60	3.09	1.12	1.19	1.44	1.60	2.95	1.13	1.20	1.41	1.55	2.70
Oct	1 - 20	-1.48	0.04	0.99	1.86	4.55	1.13	1.26	1.66	1.84	4.49	1.14	1.29	1.67	1.85	4.34
	21 - 31	-1.16	0.27	1.01	1.70	3.42	1.22	1.31	1.64	1.83	3.27	1.28	1.39	1.70	1.89	3.24
Nov	2 - 8	-1.44	0.12	0.79	1.56	2.69	1.17	1.28	1.50	1.63	2.62	1.22	1.34	1.58	1.73	2.67
	11 - 30	-1.64	0.10	0.84	1.51	3.65	-1.63	0.11	0.85	1.52	3.67	-1.04	0.26	0.93	1.45	3.66
Dec	1 - 4	-1.53	-0.27	0.54	1.22	2.68	-1.52	-0.22	0.54	1.23	2.69	-0.93	-0.07	0.61	1.11	2.68
	5 - 27	-1.39	0.18	1.00	1.65	4.39	-1.37	0.19	1.01	1.66	4.41	-0.92	0.35	1.10	1.69	4.36
	28 - 31	-0.23	1.37	1.94	2.65	3.84	-0.22	1.37	1.94	2.64	3.85	0.25	1.43	2.00	2.61	3.77

Table A-1 – cont. Distribution of stages (feet) by study period in 2004.

		RMID040					ROLD074					SANUB				
		Min	0.25	Avg	0.75	Max	Min	0.25	Avg	0.75	Max	Min	0.25	Avg	0.75	Max
Jan	1 - 31	-0.37	0.54	1.24	1.72	4.64	0.34	1.34	1.90	2.35	4.60	0.34	1.34	1.90	2.35	4.60
Feb	1 - 18	-0.51	0.49	1.18	1.71	4.27	0.33	1.25	1.82	2.27	4.12	0.33	1.25	1.82	2.27	4.12
	19 - 29	0.32	1.51	2.07	2.60	4.66	1.28	2.50	2.92	3.38	4.69	1.28	2.50	2.92	3.38	4.69
Mar	1 - 15	0.30	1.07	1.64	2.05	3.78	1.76	2.32	2.78	3.16	4.15	1.76	2.32	2.78	3.16	4.15
	16 -31	-0.16	1.01	1.50	2.00	3.53	0.96	2.09	2.59	3.06	4.02	0.96	2.09	2.59	3.06	4.02
Apr	1 - 12	-0.33	0.60	1.21	1.69	3.63	0.85	1.64	2.08	2.47	3.58	0.85	1.64	2.08	2.47	3.58
	12 - 15	0.12	0.88	1.40	1.87	3.07	0.91	1.54	1.97	2.38	3.20	0.91	1.54	1.97	2.38	3.20
	15 - 30	0.00	0.75	1.26	1.70	2.95	-0.54	0.70	1.24	1.78	3.03	1.58	3.59	3.77	4.00	4.50
May	1 - 21	0.09	0.86	1.45	1.93	3.89	-0.08	0.93	1.52	2.05	4.00	2.08	3.49	3.77	4.01	5.03
	21 - 31	-0.14	0.70	1.38	1.98	3.69	0.56	1.36	1.90	2.37	3.74	0.56	1.36	1.90	2.37	3.74
Jun	1 - 3	0.02	0.76	1.44	1.92	3.71	0.81	1.48	2.03	2.54	3.58	0.81	1.48	2.03	2.54	3.58
	3 - 4	-0.11	0.11	0.80	1.47	3.05	0.63	1.05	1.63	2.18	3.25	0.63	1.05	1.63	2.18	3.25
	4 - 6	0.69	0.87	1.26	1.45	2.76	0.88	1.25	1.70	2.03	3.01	0.88	1.25	1.70	2.03	3.01
	6 - 30	0.90	1.39	1.71	1.93	3.29	1.08	1.67	2.02	2.32	3.47	1.08	1.67	2.02	2.32	3.47
Jul	1 - 11	1.09	1.55	1.90	2.15	3.72	1.22	1.81	2.17	2.46	3.66	1.22	1.81	2.17	2.46	3.66
	12 - 31	0.98	1.40	1.69	1.86	3.00	1.11	1.62	1.97	2.23	3.27	1.11	1.62	1.97	2.23	3.27
Aug	1 - 31	0.99	1.42	1.67	1.85	2.81	1.09	1.63	1.96	2.23	3.23	1.09	1.63	1.96	2.23	3.23
Sep	1 - 27	1.40	1.61	1.88	2.09	3.10	1.50	1.81	2.12	2.38	3.30	1.50	1.81	2.12	2.38	3.30
	27 - 30	1.30	1.38	1.51	1.56	2.50	1.39	1.49	1.59	1.61	2.47	1.39	1.74	2.15	2.55	3.22
Oct	1 - 20	1.31	1.51	1.83	1.99	4.20	1.42	1.61	1.92	2.08	4.22	1.29	1.86	2.33	2.68	4.73
	21 - 31	1.63	1.76	1.98	2.08	3.41	1.84	1.97	2.17	2.26	3.50	2.41	2.99	3.26	3.52	4.26
Nov	2 - 8	1.47	1.71	1.87	2.00	2.74	1.65	1.92	2.17	2.38	3.01	1.65	1.92	2.17	2.38	3.01
	11 - 30	-0.84	0.43	1.05	1.52	3.73	0.11	1.14	1.64	2.06	3.65	0.11	1.14	1.64	2.06	3.65
Dec	1 - 4	-0.75	0.04	0.70	1.18	2.77	0.16	0.91	1.30	1.70	2.74	0.16	0.91	1.30	1.70	2.74
	5 - 27	-0.71	0.47	1.21	1.78	4.41	0.22	1.20	1.79	2.23	4.29	0.22	1.20	1.79	2.23	4.29
	28 - 31	0.40	1.60	2.10	2.67	3.72	1.19	2.17	2.62	3.11	3.94	1.19	2.17	2.62	3.11	3.94

Table A-1 – cont. Distribution of stages (feet) by study period in 2004.

		ROLD040					ROLD047					ROLD059				
		Min	0.25	Avg	0.75	Max	Min	0.25	Avg	0.75	Max	Min	0.25	Avg	0.75	Max
Jan	1 - 31	-15710	-5882	-2837	1492	8102	-2776	-598	230	1272	3070	-741	-96	215	505	1233
Feb	1 - 18	-15114	-5756	-2441	2170	9644	-2752	-642	221	1319	3020	-758	-120	190	497	1158
	19 - 29	-14944	-5089	-2044	1984	6991	-2717	-537	348	1386	2920	-712	-20	309	595	1255
Mar	1 - 15	-14483	-5238	-2314	2040	6795	-2542	-573	286	1357	2680	-612	-43	300	601	1144
	16 -31	-13595	-5261	-1975	2290	6927	-2544	-632	251	1373	2391	-628	-79	267	594	1104
Apr	1 - 12	-13053	-6158	-2231	2242	7058	-2618	-874	95	1308	2381	-768	-150	190	543	1036
	12 - 15	-11175	-6814	-2144	2815	5922	-2319	-1008	219	1481	1898	-596	-250	218	565	895
	15 - 30	-10276	-4343	-334	3953	5683	-2078	-423	-204	0	243	-532	-424	-138	183	654
May	1 - 21	-10343	-4964	-446	4219	6976	-1620	-477	-215	0	677	-548	-392	-110	210	738
	21 - 31	-10800	-5355	-949	3203	6539	-1124	-479	43	552	946	-208	-32	139	309	712
Jun	1 - 3	-13698	-8281	-3915	651	7531	-1665	-501	-138	429	667	-392	-18	132	289	854
	3 - 4	-6446	-2736	5	3784	7384	-603	-190	-94	0	589	-554	-445	-110	170	508
	4 - 6	-7734	-3855	-1650	1077	4676	-978	0	-106	0	113	-405	-53	89	188	571
	6 - 30	-12192	-6235	-3712	-1414	6864	-1197	0	-72	0	463	-258	-62	72	200	685
Jul	1 - 11	-14487	-6804	-4118	-1460	7530	-1613	0	-76	11	565	-248	-133	32	188	781
	12 - 31	-14997	-6183	-4240	-2083	9267	-1295	0	-55	0	329	-232	-109	59	223	675
Aug	1 - 31	-13960	-6290	-4222	-2309	7645	-1028	0	-34	0	223	-304	-111	71	242	544
Sep	1 - 27	-13113	-6025	-3983	-1692	6064	-862	0	-17	0	422	-312	-187	19	224	451
	27 - 30	-11953	-6525	-4368	-2172	5989	-966	0	-46	0	80	-241	-59	2	70	308
Oct	1 - 20	-11511	-7216	-4291	-1565	8129	-1439	0	-80	0	915	-352	-155	-67	-3	467
	21 - 31	-12786	-5796	-3773	-1547	8304	-1088	0	-30	22	622	-200	-98	-32	-3	555
Nov	2 - 8	-10787	-5400	-3678	-1829	4886	-603	0	41	4	3831	-226	-139	33	159	1163
	11 - 30	-14669	-6829	-3095	1756	6436	-2517	-783	173	1333	2369	-799	-132	174	491	1040
Dec	1 - 4	-10668	-6742	-3391	1208	8112	-1602	-728	122	1200	2563	-414	-144	145	447	924
	5 - 27	-13725	-6610	-2479	2230	10887	-2379	-817	185	1320	3034	-675	-159	170	501	1105
	28 - 31	-9773	-6964	-2402	2064	4815	-1573	-883	236	1373	1952	-413	-78	238	560	667

Table A-2 Distribution of flows (cfs) by study period in 2004.

		MIDatVICT					RMID027					RMID040				
		Min	0.25	Avg	0.75	Max	Min	0.25	Avg	0.75	Max	Min	0.25	Avg	0.75	Max
Jan	1 - 31	-11385	-7196	-3348	444	4055	-1618	-588	17	614	2081	-220	-27	5	38	96
Feb	1 - 18	-10989	-6983	-2872	1111	5064	-1645	-571	21	617	1828	-131	-20	10	35	134
	19 - 29	-10908	-6998	-3229	690	4473	-1642	-595	58	681	1871	-130	-8	46	92	182
Mar	1 - 15	-10495	-7396	-3447	464	3670	-1479	-601	22	620	1681	-75	43	67	95	152
	16 -31	-10153	-6996	-2886	1486	4639	-1451	-572	20	619	1633	-53	39	67	101	169
Apr	1 - 12	-9609	-6400	-2341	2031	4777	-1490	-669	-19	599	1606	-77	41	55	72	150
	12 - 15	-8131	-5564	-1189	3017	4284	-941	-240	17	260	1321	-104	-49	23	79	167
	15 - 30	-8244	-4462	-642	3533	4641	-1367	-396	-69	210	828	-108	-80	-18	37	157
May	1 - 21	-8615	-4799	-619	3665	5410	-1523	-510	-84	282	984	-143	-60	7	67	176
	21 - 31	-8003	-4557	-768	3173	5115	-1292	-487	-13	409	901	-89	35	73	111	196
Jun	1 - 3	-10277	-6172	-2281	2309	12090	-1663	-741	-156	384	1287	-140	34	71	118	205
	3 - 4	1851	4336	5905	7312	10755	-681	16	7	16	1040	-88	-13	52	104	230
	4 - 6	-2671	-639	2071	4733	7089	-1093	-153	-93	16	742	-44	74	98	115	192
	6 - 30	-8576	-4627	-2171	72	5747	-1312	-277	-47	177	947	-96	93	108	128	158
Jul	1 - 11	-11410	-6531	-3277	520	3833	-1645	-328	-30	284	1231	-202	90	94	128	166
	12 - 31	-11623	-7655	-4041	-174	3775	-1420	-208	-39	159	1008	-181	85	85	115	141
Aug	1 - 31	-11637	-7732	-3952	381	4131	-1301	-187	-24	171	725	-137	80	83	110	148
Sep	1 - 27	-10452	-7103	-3271	1280	4028	-1022	-212	27	271	690	-124	85	81	112	153
	27 - 30	-9658	-6832	-3205	955	3870	-1115	-151	-15	157	620	-138	33	45	82	111
Oct	1 - 20	-8679	-5829	-2220	1570	4361	-1365	-218	7	241	1021	-208	49	63	104	183
	21 - 31	-9856	-6479	-2934	842	4062	-1319	-154	57	279	1115	-145	88	96	136	166
Nov	2 - 8	-8815	-6079	-2953	982	3607	-769	-89	70	233	776	-16	106	115	129	177
	11 - 30	-10505	-6255	-2300	2174	4949	-1512	-634	-7	584	1607	-103	17	30	51	131
Dec	1 - 4	-8760	-5756	-2704	983	4024	-915	-556	-36	477	1417	-63	13	23	39	75
	5 - 27	-10326	-6327	-2363	1654	5507	-1446	-621	1	604	1811	-145	13	31	55	179
	28 - 31	-9879	-7139	-2714	2111	5045	-1031	-760	-16	712	1088	-129	-38	26	80	138

Table A-2 cont. Distribution of flows (cfs) by study period in 2004.

		GRL009					ORP					ROLD074				
		Min	0.25	Avg	0.75	Max	Min	0.25	Avg	0.75	Max	Min	0.25	Avg	0.75	Max
Jan	1 - 31	-4353	62	1273	2943	5828	132	1297	1444	1653	2200	-301	1066	1440	1845	2560
Feb	1 - 18	-4253	-108	1210	3015	5345	-317	1260	1367	1564	1878	-558	1056	1373	1793	2426
	19 - 29	-3993	467	1688	3297	5808	781	1718	1931	2203	2576	265	1539	1967	2382	3080
Mar	1 - 15	-3417	732	1800	3402	5472	1281	1976	2108	2253	2687	1222	1861	2181	2500	3176
	16 -31	-3388	475	1709	3313	5157	997	1794	1992	2221	2816	899	1676	2066	2369	3364
Apr	1 - 12	-3807	-227	1227	3128	4847	405	1443	1576	1770	2156	15	1290	1656	2011	2706
	12 - 15	-3164	-880	1245	3231	4111	454	1130	1363	1638	1750	433	1123	1355	1778	2091
	15 - 30	-4517	-2147	401	2917	3441	-958	-252	344	855	1559	0	272	331	334	1991
May	1 - 21	-4742	-2475	387	2940	3806	-664	-234	429	968	2120	244	416	460	493	3591
	21 - 31	-3188	-1724	809	2955	3813	435	789	1066	1308	1822	229	915	1152	1480	1959
Jun	1 - 3	-4430	-1844	430	2794	3473	123	808	1085	1367	1616	-364	960	1256	1667	2156
	3 - 4	-1981	498	1749	3652	4502	1045	1266	1389	1519	1656	584	974	1368	1834	2174
	4 - 6	-1597	171	268	623	1257	-17	389	730	1092	1483	-74	423	888	1395	2113
	6 - 30	-1967	80	266	652	1570	-286	151	540	934	1544	-291	188	677	1200	2156
Jul	1 - 11	-2723	195	313	784	1857	-314	33	498	890	1653	-341	75	613	1205	2161
	12 - 31	-2259	200	275	467	1477	-386	-6	500	996	1760	-423	53	608	1202	2062
Aug	1 - 31	-1830	188	307	465	1365	-401	-33	525	1031	1886	-443	37	628	1245	2145
Sep	1 - 27	-1641	322	446	646	1480	-339	-56	510	1036	1688	-364	-1	599	1233	1958
	27 - 30	-1908	189	143	309	1001	-262	79	225	366	649	-118	144	286	437	672
Oct	1 - 20	-2647	132	210	610	2510	-153	76	179	276	753	-138	128	255	379	803
	21 - 31	-2068	547	567	888	2142	211	410	520	596	1158	255	523	617	710	1026
Nov	2 - 8	-1142	503	595	743	1378	-72	268	635	1014	1550	-45	318	759	1221	2290
	11 - 30	-4156	-468	1030	2932	4832	3	1071	1215	1413	1729	-327	952	1250	1646	2218
Dec	1 - 4	-2376	-398	909	2793	4757	412	987	1123	1360	1602	1	935	1168	1460	1898
	5 - 27	-3765	-517	1037	2963	5524	-443	1044	1195	1471	1868	-750	982	1232	1615	2158
	28 - 31	-2168	-633	1180	2942	3715	797	1268	1436	1590	2047	628	1077	1477	1912	2443

Table A-2 cont. Distribution of flows (cfs) by study period in 2004.

		VICT					ROLD034					RSAN072				
		Min	0.25	Avg	0.75	Max	Min	0.25	Avg	0.75	Max	Min	0.25	Avg	0.75	Max
Jan	1 - 31	-1987	1413	3402	5691	9293	-16832	-11291	-6188	-2141	5171	-2805	-1171	266	1626	2392
Feb	1 - 18	-2528	433	2932	5384	8323	-16417	-10804	-5281	-602	6722	-2697	-1160	298	1703	2364
	19 - 29	-2593	997	3315	5700	8756	-16558	-10941	-5955	-1303	5378	-2415	-598	864	2099	2718
Mar	1 - 15	-1721	1477	3456	5891	8344	-16127	-11688	-6376	-2218	4731	-1726	108	1166	2277	2690
	16 -31	-2835	216	2890	5572	7778	-15064	-10929	-5272	-71	5919	-1672	50	1149	2206	2866
Apr	1 - 12	-2660	-639	2261	4625	7167	-14027	-9384	-4064	1835	6762	-2154	-671	696	1987	2305
	12 - 15	-2670	-1483	1261	3924	6875	-12909	-7640	-1992	4030	6211	-1586	-594	756	1958	2143
	15 - 30	-2531	-1918	555	2730	6326	-11929	-5656	-781	4827	6607	-1264	2307	2640	3118	3457
May	1 - 21	-2976	-2039	496	2793	7182	-13450	-6096	-791	4899	7589	109	2051	2531	3084	3564
	21 - 31	-2648	-1558	688	2705	5887	-11697	-5796	-1068	4094	7070	-2065	-751	604	1767	2377
Jun	1 - 3	-7823	-759	2043	4122	7298	-14834	-8588	-3948	2237	7286	-2699	-1369	103	1780	2047
	3 - 4	-7543	-6226	-5805	-5603	-4061	-14049	-10229	-5577	-261	5554	-2618	-1217	303	1775	2372
	4 - 6	-5275	-3581	-2336	-784	865	-13445	-8639	-5019	-966	3357	-2475	-1049	263	1660	2005
	6 - 30	-3241	942	2045	3306	6488	-14992	-7305	-3533	1509	4702	-2525	-597	580	1727	2199
Jul	1 - 11	-1409	1285	3181	4826	8390	-16731	-9560	-5880	-1869	4170	-2734	-906	465	1712	2307
	12 - 31	-1447	1523	3946	6561	9029	-17472	-12324	-7209	-2368	3781	-2896	-961	358	1590	2155
Aug	1 - 31	-1497	1111	3881	6745	9151	-17704	-12504	-7004	-1404	4459	-2700	-959	365	1600	2129
Sep	1 - 27	-1628	234	3278	6072	8526	-16394	-11330	-5761	495	4392	-2306	-837	487	1714	2154
	27 - 30	-1492	255	3136	5949	7851	-15058	-10698	-5714	-350	4051	-1645	-442	734	1961	2127
Oct	1 - 20	-1674	1	2184	3915	7384	-13855	-8115	-3939	785	5007	-1947	-25	1003	2016	2721
	21 - 31	-1311	554	2994	5062	7739	-14830	-9770	-5440	-837	3816	-324	1440	2009	2678	3092
Nov	2 - 8	-1202	535	3001	5291	7136	-13784	-9778	-5414	-519	3327	-1364	47	1002	1870	2279
	11 - 30	-2895	-748	2292	4695	7815	-15551	-9389	-4124	2057	6517	-2522	-1128	319	1678	2259
Dec	1 - 4	-1849	672	2613	4234	7044	-13934	-8530	-4812	-344	5133	-1756	-1130	235	1603	1901
	5 - 27	-3541	-208	2370	4599	7971	-15417	-9442	-4329	795	7315	-2772	-1133	318	1677	2539
	28 - 31	-2694	-904	2673	5778	7620	-14723	-11071	-4653	2375	6410	-2519	-1456	247	1911	2239

Table A-2 cont. Distribution of flows (cfs) by study period in 2004.