Enclosure 1

Estimated CVP Operations Mar 90% Exceedance

Storages

Federal End of the Month Storage/Elevation (TAF/Feet)

			Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar
Trinity		**1844**	**1964**	**1893**	**1782**	**1679**	**1555**	**1439**	**1409**	**1390**	**1400**	**1432**	**1518**	**1615**
	Elev.		2338	2333	2325	2318	2308	2298	2295	2294	2295	2297	2305	2313
Whiskeytown		**207**	**238**	**238**	**238**	**238**	**238**	**230**	**206**	**206**	**206**	**206**	**206**	**206**
	Elev.		1209	1209	1209	1209	1209	1207	1199	1199	1199	1199	1199	1199
Shasta		**3880**	**4132**	**4011**	**3656**	**3077**	**2630**	**2351**	**2226**	**2221**	**2351**	**2548**	**2895**	**3351**
	Elev.		1052	1048	1035	1011	991	977	970	970	977	987	1003	1023
Folsom		**817**	**793**	**904**	**825**	**591**	**449**	**402**	**345**	**296**	**256**	**306**	**412**	**576**
	Elev.		449	459	452	427	410	403	395	386	379	388	405	426
New Melones		**2019**	**1977**	**1946**	**1922**	**1848**	**1784**	**1740**	**1709**	**1721**	**1735**	**1747**	**1770**	**1789**
	Elev.		1050	1047	1045	1038	1032	1028	1025	1026	1027	1028	1031	1033
San Luis		**876**	**773**	**574**	**266**	**88**	**8**	**72**	**198**	**382**	**526**	**666**	**699**	**762**
	Elev.		510	485	445	421	399	414	431	451	476	491	493	505
Total			9877	9567	8689	7521	6665	6234	6093	6215	6474	6905	7500	8298

State End of the Month Reservoir Storage (TAF)

Oroville													
San Luis	**898**	**849**	**761**	**652**	**609**	**510**	**566**	**593**	**605**	**719**	**746**	**723**	**803**
Total San Luis (TAF)	**1774**	**1622**	**1335**	**919**	**697**	**518**	**638**	**791**	**986**	**1245**	**1411**	**1422**	**1565**

Monthly River Releases (TAF/cfs)

Trinity	TAF	36	92	47	28	53	52	23	18	18	18	17	18
	cfs	**600**	**1,498**	**783**	**450**	**857**	**870**	**373**	**300**	**300**	**300**	**300**	**300**
Clear Creek	TAF	13	13	17	9	9	9	12	12	12	12	11	12
	cfs	**218**	**216**	**288**	**150**	**150**	**150**	**200**	**200**	**200**	**200**	**200**	**200**
Sacramento	TAF	297	492	625	799	645	476	369	268	200	200	180	200
	cfs	**5000**	**8000**	**10500**	**13000**	**10500**	**8000**	**6000**	**4500**	**3250**	**3250**	**3250**	**3250**
American	TAF	506	77	167	293	204	107	92	89	92	61	56	77
	cfs	**8500**	**1250**	**2811**	**4768**	**3311**	**1798**	**1500**	**1500**	**1500**	**1000**	**1005**	**1250**
Stanislaus	TAF	83	96	56	18	18	18	49	12	12	14	13	12
	cfs	**1400**	**1555**	**940**	**300**	**300**	**300**	**797**	**200**	**200**	**232**	**236**	**200**
Feather	TAF	208	92	119	215	123	108	77	74	77	77	69	108
	cfs	**3500**	**1500**	**2000**	**3500**	**2000**	**1815**	**1250**	**1250**	**1250**	**1250**	**1250**	**1759**

Trinity Diversions (TAF)

	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar
Carr PP	39	67	85	80	71	62	16	21	12	3	2	15
Spring Crk. PP	**10**	**60**	**70**	**70**	**60**	**60**	**30**	**15**	**12**	**10**	**20**	**30**

Delta Summary (TAF)

		Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar
Tracy		93	61	53	225	260	262	265	250	190	190	120	200
USBR Banks		0	0	0	18	18	18	0	0	0	0	0	0
Contra Costa		12.7	12.7	9.8	11.1	12.7	14.0	16.8	18.4	18.3	14.0	14.0	12.7
Total USBR		106	74	63	254	291	294	282	268	208	204	134	213
State Export		77	31	47	121	64	150	151	106	186	190	127	200
Total Export		182	105	110	375	355	444	433	374	394	394	261	413
COA Balance		25	25	0	0	0	87	87	87	87	87	46	46
Old/Middle River Std.													
Old/Middle R. calc.		-164	146	-1,354	-4,912	-4,693	-5,945	-5,221	-4,877	-4,978	-4,960	-3,536	-5,040
Computed DOI		30476	9516	7900	6507	4002	3009	4067	4572	6767	9728	11400	12379
Excess Outflow		19079	1610	0	0	0	0	65	67	2261	3725	0	976
% Export/Inflow		8%	11%	13%	35%	40%	54%	54%	52%	47%	41%	29%	34%
% Export/Inflow std.		35%	35%	35%	65%	65%	65%	65%	65%	65%	65%	45%	35%

Hydrology

	Trinity	Shasta	Folsom	New Melones
Water Year Inflow (TAF)	627	3,621	2,352	972
Year to Date + Forecasted % of mean	52%	65%	86%	92%

4/18/2018

Estimated CVP Operations Mar 50% Exceedance

Storages

Federal End of the Month Storage/Elevation (TAF/Feet)

			Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar
Trinity		**1844**	**1878**	**1860**	**1773**	**1659**	**1514**	**1381**	**1343**	**1330**	**1360**	**1425**	**1535**	**1629**
	Elev.		2332	2331	2325	2316	2304	2293	2290	2288	2291	2297	2306	2314
Whiskeytown		**207**	**238**	**238**	**238**	**238**	**238**	**230**	**206**	**206**	**206**	**206**	**206**	**206**
	Elev.		1209	1209	1209	1209	1209	1207	1199	1199	1199	1199	1199	1199
Shasta		**3880**	**4167**	**4117**	**3801**	**3266**	**2874**	**2647**	**2552**	**2601**	**2792**	**3198**	**3682**	**4240**
	Elev.		1054	1052	1040	1019	1002	991	987	989	998	1016	1036	1056
Folsom		**817**	**823**	**946**	**831**	**660**	**598**	**538**	**489**	**460**	**449**	**477**	**530**	**595**
	Elev.		452	463	452	435	428	421	415	411	410	414	420	428
New Melones		**2019**	**1999**	**2017**	**2021**	**1961**	**1898**	**1857**	**1815**	**1832**	**1855**	**1887**	**1941**	**1918**
	Elev.		1052	1054	1054	1049	1043	1039	1035	1037	1039	1042	1047	1045
San Luis		**876**	**804**	**582**	**389**	**200**	**97**	**150**	**268**	**449**	**656**	**801**	**918**	**966**
	Elev.		512	481	454	428	414	436	462	493	524	524	536	543
Total			9909	9760	9052	7984	7219	6802	6673	6878	7318	7994	8812	9554

State End of the Month Reservoir Storage (TAF)

Oroville													
San Luis	**898**	**844**	**716**	**627**	**563**	**544**	**685**	**829**	**974**	**1131**	**985**	**1021**	**1062**
Total San Luis (TAF)	**1774**	**1648**	**1297**	**1015**	**763**	**642**	**835**	**1097**	**1423**	**1787**	**1786**	**1939**	**2028**

Monthly River Releases (TAF/cfs)

		Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar
Trinity	TAF	36	92	47	28	53	52	23	18	18	18	17	18
	cfs	**600**	**1,498**	**783**	**450**	**857**	**870**	**373**	**300**	**300**	**300**	**300**	**300**
Clear Creek	TAF	13	13	17	9	9	9	12	12	12	15	11	12
	cfs	**218**	**216**	**288**	**150**	**150**	**150**	**200**	**200**	**200**	**240**	**200**	**200**
Sacramento	TAF	268	461	625	799	645	476	369	268	200	200	278	307
	cfs	**4500**	**7500**	**10500**	**13000**	**10500**	**8000**	**6000**	**4500**	**3250**	**3250**	**5000**	**5000**
American	TAF	476	154	252	250	136	132	123	119	123	123	208	246
	cfs	**8000**	**2500**	**4229**	**4067**	**2217**	**2226**	**2007**	**2000**	**2000**	**2000**	**3750**	**4000**
Stanislaus	TAF	83	96	56	18	18	18	49	12	12	14	13	93
	cfs	**1400**	**1555**	**940**	**300**	**300**	**300**	**797**	**200**	**200**	**232**	**236**	**1521**
Feather	TAF	208	92	149	246	246	119	108	104	108	108	97	108
	cfs	**3500**	**1500**	**2500**	**4000**	**4000**	**2000**	**1750**	**1750**	**1750**	**1750**	**1750**	**1750**

Trinity Diversions (TAF)

	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar
Carr PP	35	24	71	84	85	76	26	25	9	0	2	35
Spring Crk. PP	**15**	**25**	**60**	**75**	**75**	**75**	**40**	**20**	**12**	**20**	**35**	**60**

Delta Summary (TAF)

		Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar
Tracy		129	74	219	273	273	261	265	254	260	205	215	221
USBR Banks		0	0	0	24	24	24	0	0	0	0	0	0
Contra Costa		12.7	12.7	9.8	11.1	12.7	14.0	16.8	18.4	18.3	14.0	14.0	12.7
Total USBR		142	86	229	308	310	299	282	272	278	219	229	234
State Export		105	18	106	141	183	261	298	275	260	50	215	187
Total Export		247	105	335	449	493	560	580	547	538	269	444	421
COA Balance		25	25	0	0	16	153	230	224	224	224	224	224
Old/Middle River Std.													
Old/Middle R. calc.		-483	281	-3,941	-5,605	-6,217	-7,257	-6,923	-6,927	-6,577	-3,086	-4,826	-3,440
Computed DOI		33838	13388	7900	6507	4002	3009	4002	4505	8329	17569	23954	25849
Excess Outflow		22441	4441	0	0	0	0	0	0	3823	11566	12553	14445
% Export/Inflow		10%	9%	33%	40%	50%	62%	62%	62%	50%	20%	25%	20%
% Export/Inflow std.		35%	35%	35%	65%	65%	65%	65%	65%	65%	65%	45%	35%

Hydrology

	Trinity	Shasta	Folsom	New Melones
Water Year Inflow (TAF)	539	3,864	2,536	1080
Year to Date + Forecasted % of mean	45%	70%	93%	102%

4/18/2018

April 18, 2018

Upper Sacramento River – April 2018 Preliminary Temperature Analysis

Summary of Temperature Results by Month (Monthly Average Temperature °F)

Initial Compliance Location (°F DAT)	APR	MAY	JUN	JUL	AUG	SEP	OCT	Late Sep-Oct Uncertainty Estimation
March 90%-Exceedance Outlook – 10% Historical Meteorology								
Keswick Dam KWK	52.8	52.0	52.5	53.4	53.9	54.2	52.7	54 - 57
Sac. R. abv Clear Creek CCR	53.0	52.6	53.1	54.0	54.3	54.5	52.6	54 - 58
Balls Ferry BSF	55.3	56.0	56.0	56.0	56.0	56.0	53.7	55 - 59
March 90%-Exceedance Outlook – 50% Historical Meteorology								
Keswick Dam KWK	52.3	52.4	52.9	53.8	54.0	53.9	52.7	53 - 56
Sac. R. abv Clear Creek CCR	52.3	52.9	53.4	54.2	54.4	54.1	52.4	54 - 57
Balls Ferry BSF	54.1	56.0	56.0	56.0	56.0	55.5	53.0	55 - 58
March 50%-Exceedance Outlook – 10% Historical Meteorology								
Keswick Dam KWK	52.9	51.7	52.4	53.4	53.9	54.1	52.7	54 - 57
Sac. R. abv Clear Creek CCR	53.1	52.4	53.1	54.0	54.3	54.4	52.6	54 - 58
Balls Ferry BSF	55.4	56.0	55.9	56.0	56.0	56.0	53.6	55 - 59
March 50%-Exceedance Outlook – 50% Historical Meteorology								
Keswick Dam KWK	52.3	52.0	52.7	53.8	54.0	54.6	51.7	53 - 55
Sac. R. abv Clear Creek CCR	52.3	52.7	53.3	54.2	54.3	54.7	51.5	53 - 57
Balls Ferry BSF	54.3	56.0	55.9	56.0	56.0	56.0	52.2	54 - 58

* The HEC5Q model output is displayed above for the months April through October. Based on past analysis, the temperature model does not perform well in late September and October. One factor is that the modeled release temperatures are cooler than has historically been achieved when all release is through the side gates (lowest gates), especially when there's a large temperature gradient between the pressure relief gates (PRG) and the side gates. For the months of September and October, an uncertainty

estimate is provided based on the Fall Temperature Index (graphics below). This is based on a historical relationship between end-of-September Lake Shasta Volume less than 56°F and likely downstream temperature performances for the early fall months. The range represents the 90% confidence interval based on that data. Refinement of the concepts for those estimates is underway.

Temperature Model Inputs, Assumptions, Limitations and Uncertainty:

1. The latest available profiles for Shasta, Trinity, and Whiskeytown were taken on April 3, April 4, and April 3 respectively. Model results are sensitive to initial reservoir temperature conditions and the model performs best under highly stratified conditions. The April 2018 temperature profile does not yet exhibit conditions for ideal model computations (still nearly isothermal conditions although warming will initiate stratification). The model performs well after the reservoir stratifies, typically in late spring. The concern this year is assuming over or under estimations with variable hydrologic and meteorological conditions and not capturing the stratification with sufficient detail to project.
2. Guidance on forecasted flows from the creeks (e.g., Cow, Cottonwood, Battle, etc.) between Keswick Dam and Bend Bridge are not available beyond 5 days. Creek flows developed from the historical record that most closely reflects current conditions were used for all model runs. The resulting low creek flows cause significant additional warming in the upper Sacramento River during spring.
3. Operation is based on the April 2018 Operation Outlooks and DWR Bulletin 120 inflow projections (monthly flows, reservoir release, and end-of-month reservoir storage) for the 90%- and 50%-exceedances. Trinity Lake inflows are updated with the CNRFC 90% runoff exceedance for the 90% runoff exceedance studies.
4. Although mean daily flows and releases are temperature model inputs, they are based on the mean monthly values from the operation outlooks. Mean daily flow patterns are user defined and are generalized representations. It is important to note that these outlooks do not suggest a certain actual future outcome, but rather the statistical likelihood of an event occurring, including, but not limited to, projected storage and releases. Thus, the outlooks do not provide exact end of month storages or flow rates but general projections that will likely fall within the range of uncertainty based on the different hydrologic runoff conditions between the 90% and 50% runoff exceedance hydrology.
5. Cottonwood Creek flows, Keswick to Bend Bridge local flows, and ACID diversions are mean daily synthesized flows based on the available historical record for a 1922-2002 study period. Inflows were adjusted to a 95% historical exceedance for both the 90% and 50% runoff exceedance studies.
6. Meteorological inputs represent NOAA NWS Climate Prediction Center L3MTO (based on historical 1961 – 2005 monthly mean equilibrium temperature exceedance at 10% and 50% patterned after like months on a 6-hour time-step). Assumed inflow temperature remain static inputs and do not vary with the assumed meteorology. Efforts to extend to more recent years are under way.
7. Meteorology, as well as the flow volume and pattern, significantly influences reservoir inflow temperatures and downstream tributary temperatures; and consequently, the development of the cold-water pool during winter and early spring.
8. Modified model coefficients more closely represent actual Keswick Dam temperatures. As a result, temperature predictions downstream of Keswick Dam are likely to be warmer than actual. Model re-calibrations efforts are underway.

Model Run Date April 16, 2018

Temperature Analysis Results:

Modeling runs explore Sacramento River compliance performance above Clear Creek confluence and Balls Ferry locations by varying hydrology and meteorology. The temperature results for the Sacramento River between Keswick Dam and Balls Ferry are shown in Figures 1 through 4. The fall uncertainty estimation relationship between end-of-September lake volume below 56°F and a Balls Ferry compliance through fall is based on the Figure 5.

Model Run	End of September Cold Water Pool <56°F (TAF)	First Side Gate	Full Side Gates
90% Hydro, 10%L3MTOMet	558	9/7	10/5
90% Hydro, 50% L3MTOMet	699	9/25	NA
50% Hydro, 10% L3MTOMet	587	9/5	10/4
50% Hydro, 50% L3MTOMet	778	10/4	10/26

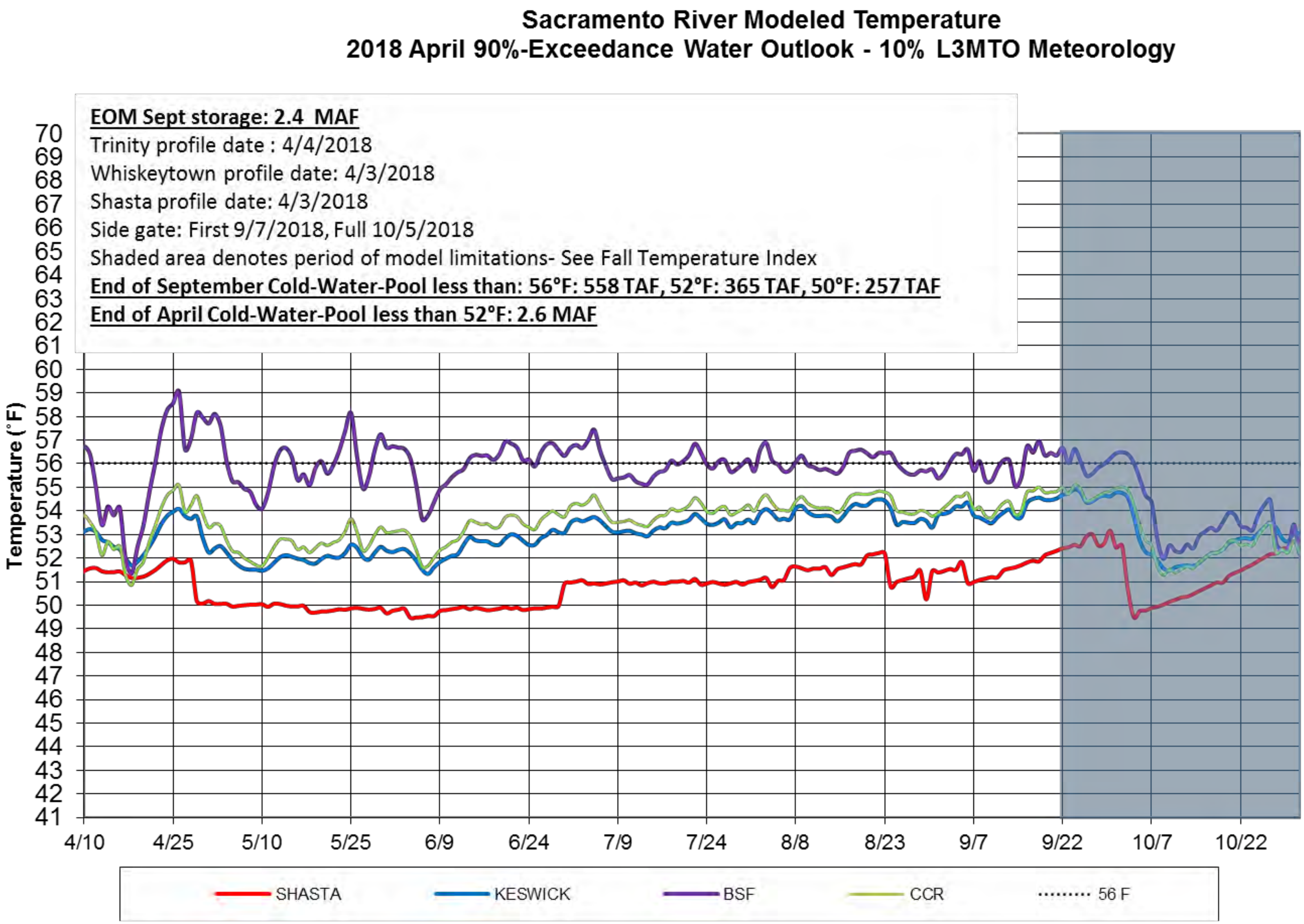
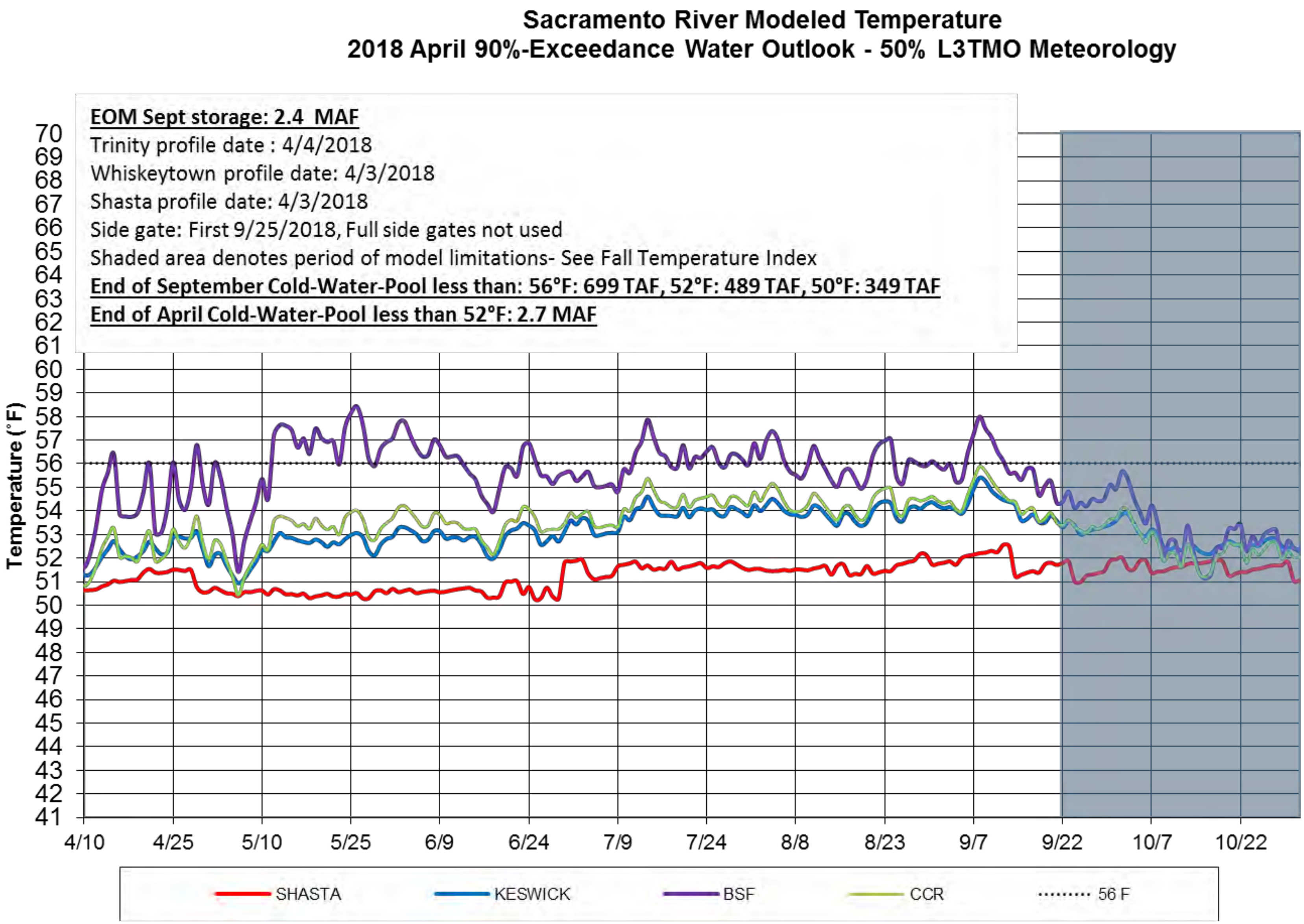

Sacramento River Modeled Temperature
2018 April 90%-Exceedance Water Outlook - 10% L3MTO Meteorology
EOM Sept storage: 2.4 MAF
Trinity profile date : 4/4/2018
Whiskeytown profile date: 4/3/2018
Shasta profile date: 4/3/2018
Side gate: First 9/7/2018, Full 10/5/2018
Shaded area denotes period of model limitations- See Fall Temperature Index
End of September Cold-Water-Pool less than: 56°F: 558 TAF, 52°F: 365 TAF, 50°F: 257 TAF
End of April Cold-Water-Pool less than 52°F: 2.6 MAF
Temperature (˚F)
70
69
68
67
66
65
64
63
62
61
60
59
58
57
56
55
54
53
52
51
50
49
48
47
46
45
44
43
42
41
4/10
4/25
5/10
5/25
6/9
6/24
7/9
7/24
8/8
8/23
9/7
9/22
10/7
10/22
SHASTA
KESWICK
BSF
CCR
56 F

Figure 1


Sacramento River Modeled Temperature
2018 April 90%-Exceedance Water Outlook - 50% L3TMO Meteorology
EOM Sept storage: 2.4 MAF
Trinity profile date : 4/4/2018
Whiskeytown profile date: 4/3/2018
Shasta profile date: 4/3/2018
Side gate: First 9/25/2018, Full side gates not used
Shaded area denotes period of model limitations- See Fall Temperature Index
End of September Cold-Water-Pool less than: 56°F: 699 TAF, 52°F: 489 TAF, 50°F: 349 TAF
End of April Cold-Water-Pool less than 52°F: 2.7 MAF
Temperature (°F)
70
69
68
67
66
65
64
63
62
61
60
59
58
57
56
55
54
53
52
51
50
49
48
47
46
45
44
43
42
41
4/10
4/25
5/10
5/25
6/9
6/24
7/9
7/24
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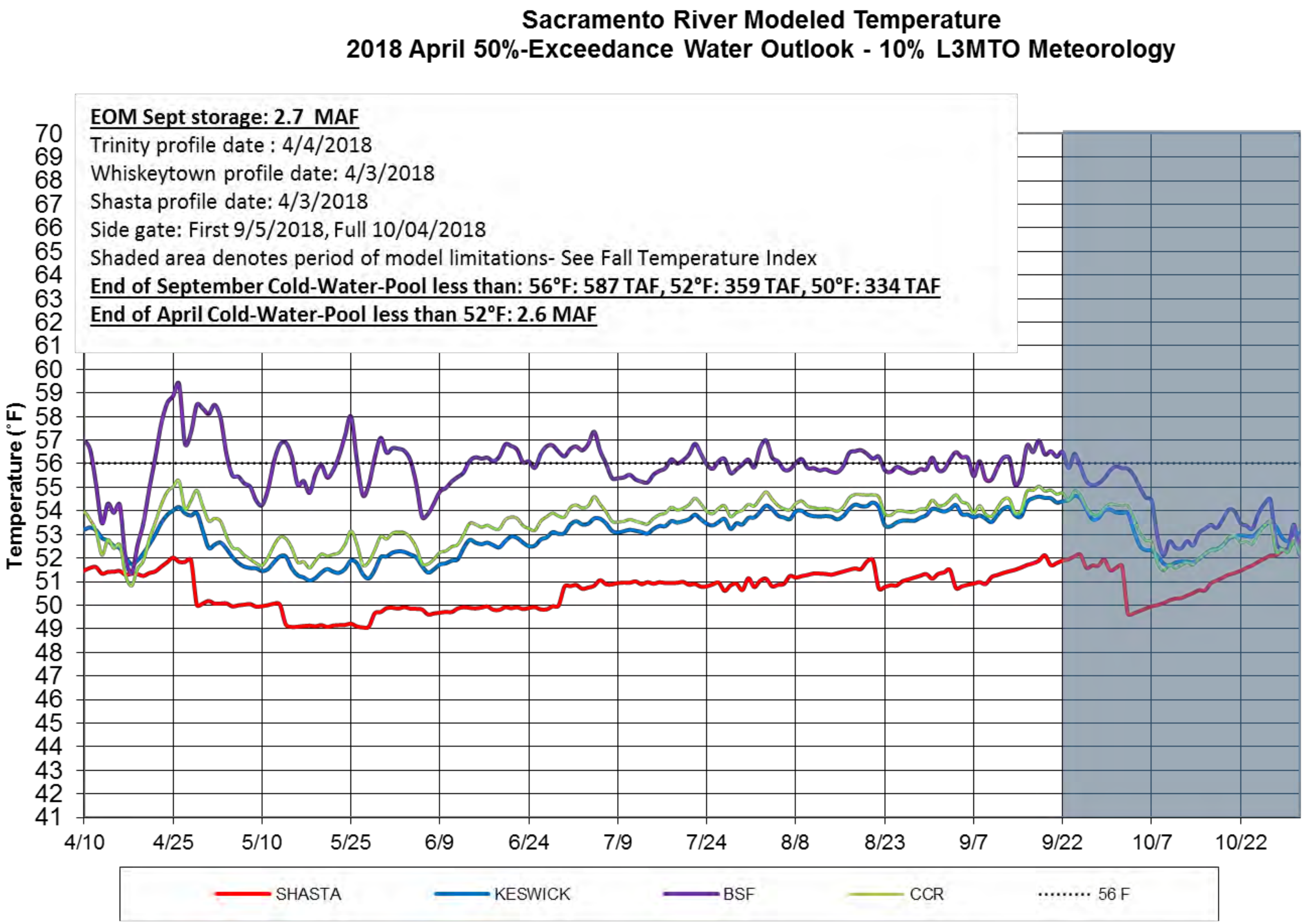
10/22
SHASTA
KESWICK
BSF
CCR
56 F

Figure 2


Sacramento River Modeled Temperature
2018 April 50%-Exceedance Water Outlook - 10% L3MTO Meteorology
EOM Sept storage: 2.7 MAF
Trinity profile date : 4/4/2018
Whiskeytown profile date: 4/3/2018
Shasta profile date: 4/3/2018
Side gate: First 9/5/2018, Full 10/04/2018
Shaded area denotes period of model limitations- See Fall Temperature Index
End of September Cold-Water-Pool less than: 56°F: 587 TAF, 52°F: 359 TAF, 50°F: 334 TAF
End of April Cold-Water-Pool less than 52°F: 2.6 MAF
Temperature (°F)
70
69
68
67
66
65
64
63
62
61
60
59
58
57
56
55
54
53
52
51
50
49
48
47
46
45
44
43
42
41
4/10
4/25
5/10
5/25
6/9
6/24
7/9
7/24
8/8
8/23
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10/7
10/22
SHASTA
KESWICK
BSF
CCR
56 F
Figure 3

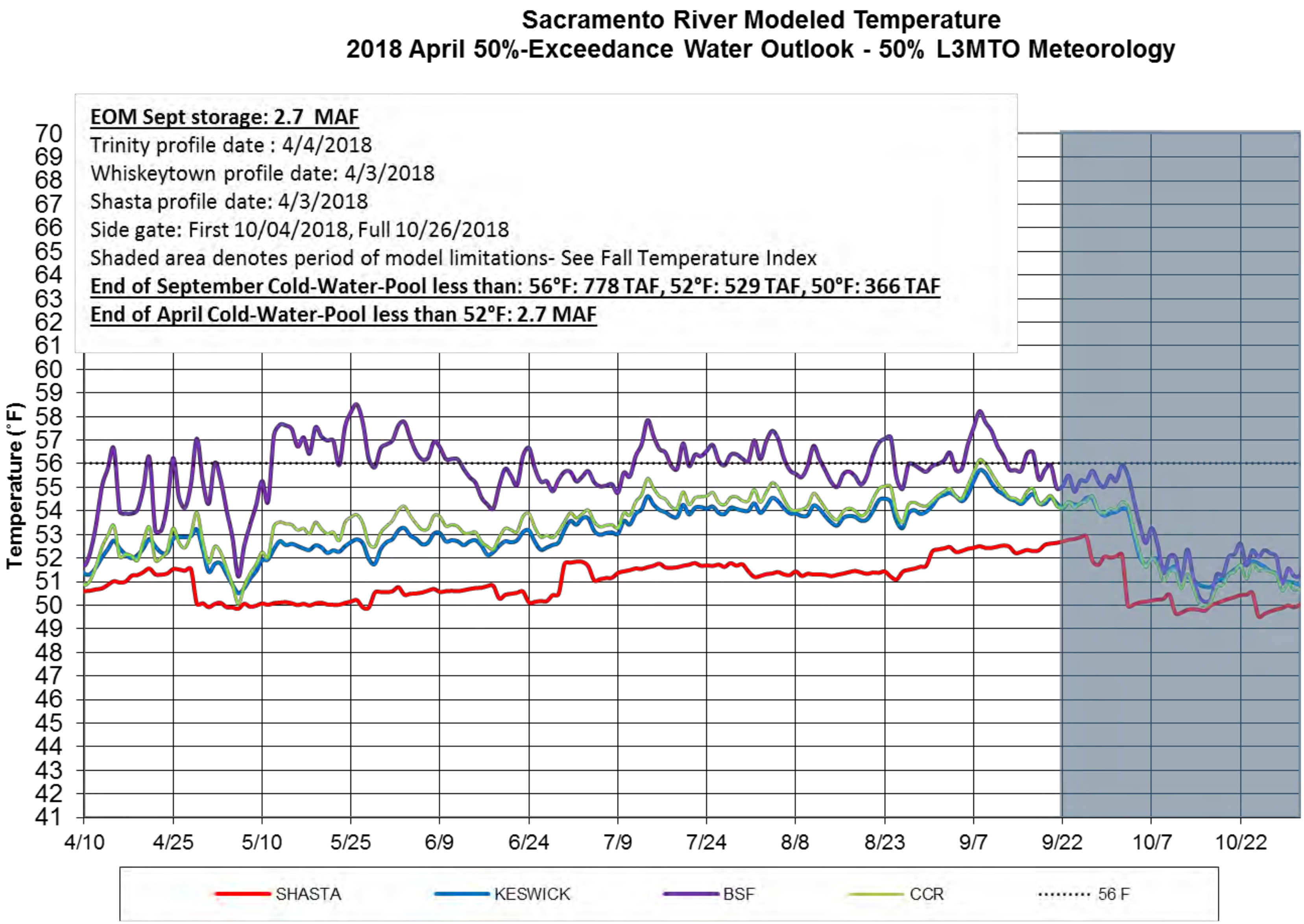
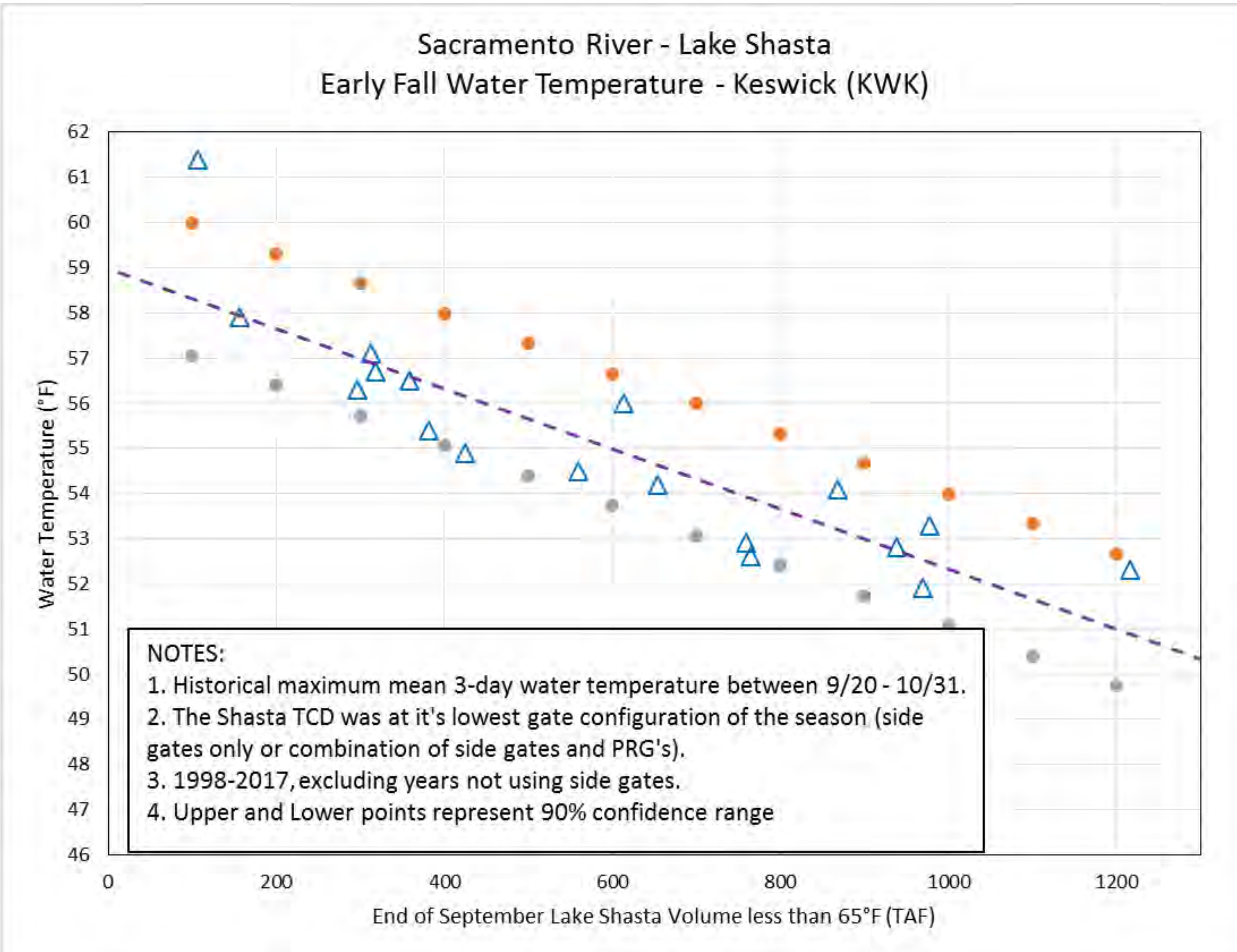
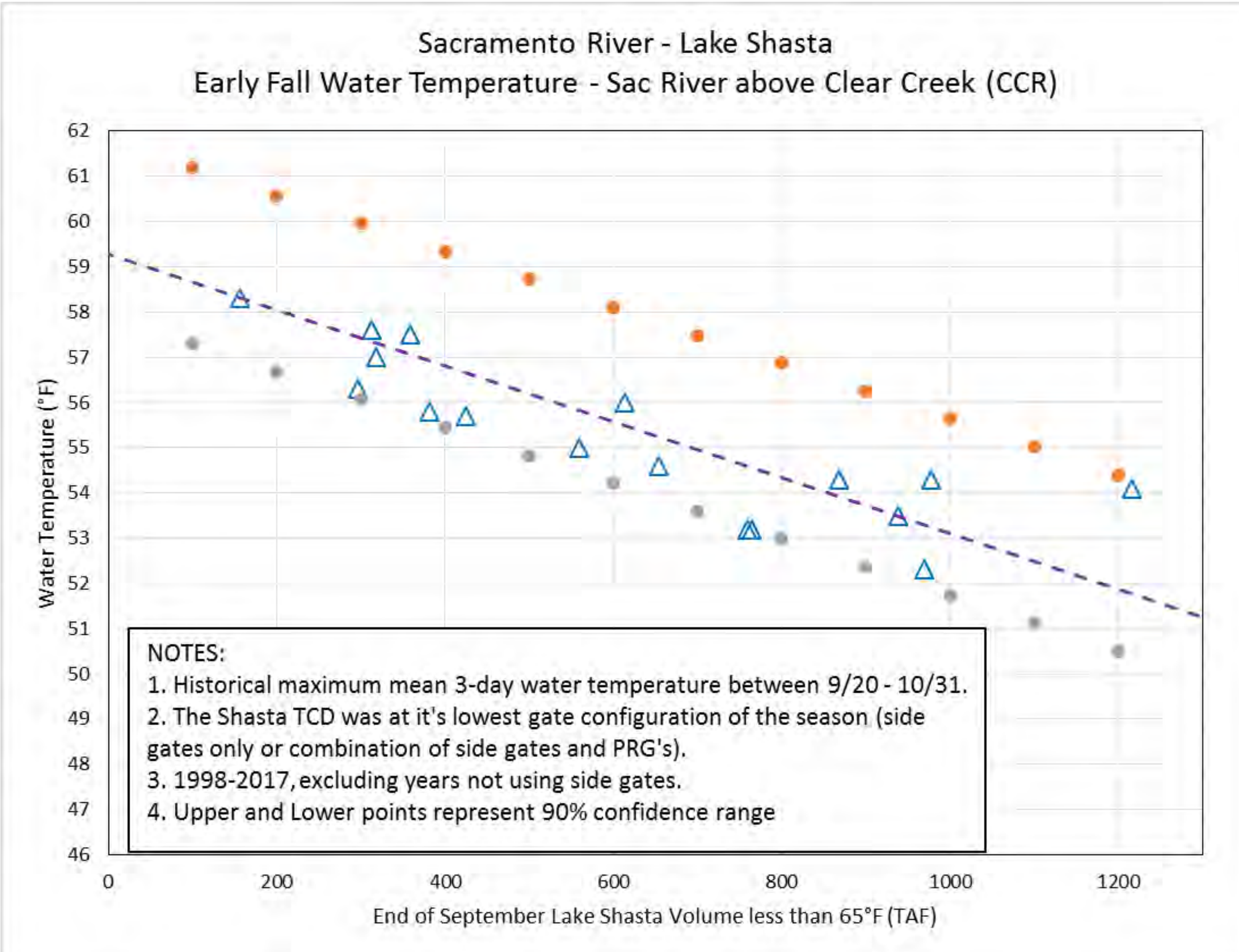

Sacramento River Modeled Temperature
2018 April 50%-Exceedance Water Outlook - 50% L3MTO Meteorology
EOM Sept storage: 2.7 MAF
Trinity profile date : 4/4/2018
Whiskeytown profile date: 4/3/2018
Shasta profile date: 4/3/2018
Side gate: First 10/04/2018, Full 10/26/2018
Shaded area denotes period of model limitations- See Fall Temperature Index
End of September Cold-Water-Pool less than: 56°F: 778 TAF, 52°F: 529 TAF, 50°F: 366 TAF
End of April Cold-Water-Pool less than 52°F: 2.7 MAF
Temperature (°F)
70
69
68
67
66
65
64
63
62
61
60
59
58
57
56
55
54
53
52
51
50
49
48
47
46
45
44
43
42
41
4/10
4/25
5/10
5/25
6/9
6/24
7/9
7/24
8/8
8/23
9/7
9/22
10/7
10/22
SHASTA
KESWICK
BSF
CCR
56 F

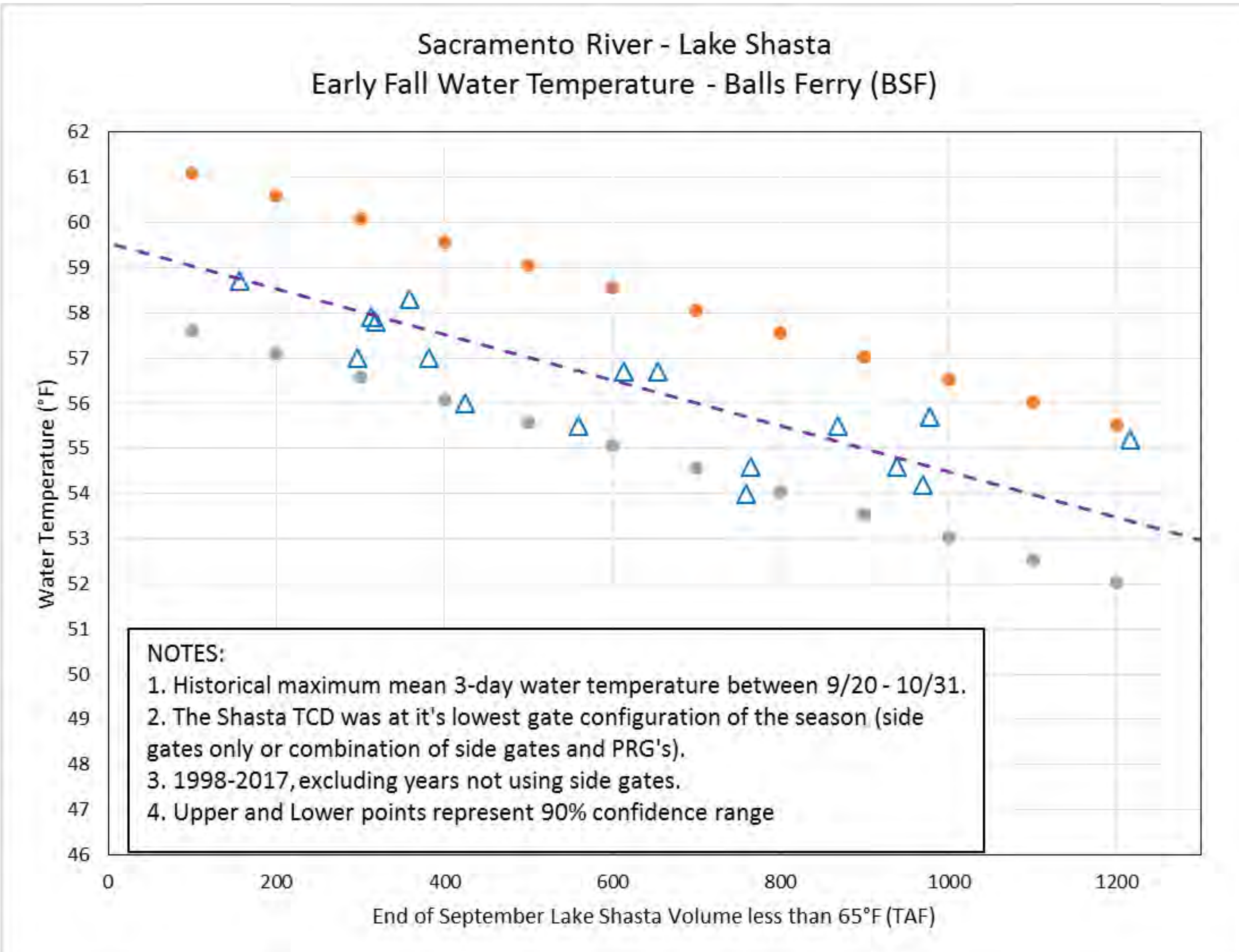
Figure 4

Figure 5 Model Performance and Fall Temperature Index:

1. Based on past analyses, the temperature model does not perform well in late September and October. One factor is that the modeled release temperatures are cooler than has historically been achieved when all release is through the side gates (lowest gates), especially when there's a large temperature gradient between the pressure relief gates (PRG) and the side gates.
2. Based on historical records, the end-of-September Lake Shasta volume below 56˚F can be used as an indicator of fall water temperature in the river reach to Balls Ferry.
3. Based on these records and estimates, the index below illustrates a range of uncertainty in the ability to meet for river temperatures not to exceed 56 ˚F downstream based on the end-of-September lake volume less than 56˚F; see charts below.
4. Refinement of these estimates and concepts is currently underway.


Sacramento River - Lake Shasta
Early Fall Water Temperature - Keswick (KWK)
Water Temperature (°F)
62
61
60
59
58
57
56
55
54
53
52
51
50
49
48
47
46
0
200
400
600
800
1000
1200
End of September Lake Shasta Volume less than 65°F (TAF)
NOTES:
1. Historical maximum mean 3-day water temperature between 9/20 - 10/31.
2. The Shasta TCD was at it's lowest gate configuration of the season (side gates only or combination of side gates and PRG's).
3. 1998-2017, excluding years not using side gates.
4. Upper and Lower points represent 90% confidence range


Sacramento River - Lake Shasta
Early Fall Water Temperature - Sac River above Clear Creek (CCR)
Water Temperature (°F)
62
61
60
59
58
57
56
55
54
53
52
51
50
49
48
47
46
0
200
400
600
800
1000
1200
End of September Lake Shasta Volume less than 65°F (TAF)
NOTES:
1. Historical maximum mean 3-day water temperature between 9/20 - 10/31.
2. The Shasta TCD was at it's lowest gate configuration of the season (side gates only or combination of side gates and PRG's).
3. 1998-2017, excluding years not using side gates.
4. Upper and Lower points represent 90% confidence range


Sacramento River - Lake Shasta
Early Fall Water Temperature - Balls Ferry (BSF)
62
61
60
59
58
57
56
55
54
53
52
51
50
49
48
47
46
Water Temperature (°F)
0
200
400
600
800
1000
1200
End of September Lake Shasta Volume less than 65°F (TAF)
NOTES:
1. Historical maximum mean 3-day water temperature between 9/20 - 10/31.
2. The Shasta TCD was at it's lowest gate configuration of the season (side gates only or combination of side gates and PRG's).
3. 1998-2017, excluding years not using side gates.
4. Upper and Lower points represent 90% confidence range

Enclosure 2

Summary Document for Shasta/Keswick Operational Scenarios
Prepared by the Southwest Fisheries Science Center on April 19th, 2018

Below are results comparing four USBR scenarios ran April 18th 2018. Scenarios differ by hydrology (Input 50 or 90 percent exceedance) and air temperature (10 or 50 exceedance of L3MTO). Inputs from scenarios are used to generate daily average Sacramento River water temperatures using the RAFT model and associated temperature-dependent egg mortality and survival estimates using the NMFS temperature mortality model (Martin et al. 2017) for the 2018 temperature management season (Table 1 and Figures 2-3). Additionally, a set of mortality model runs were generated using USBR's HEC-5Q model output (Table 2 and Figures 4-5) for comparison purposes, where the RAFT model was not used, but temperatures from the HEC-5Q nodes were linearly interpolated in space.

Further details of modeling methods are at: http://oceanview.pfeg.noaa.gov/CVTEMP/

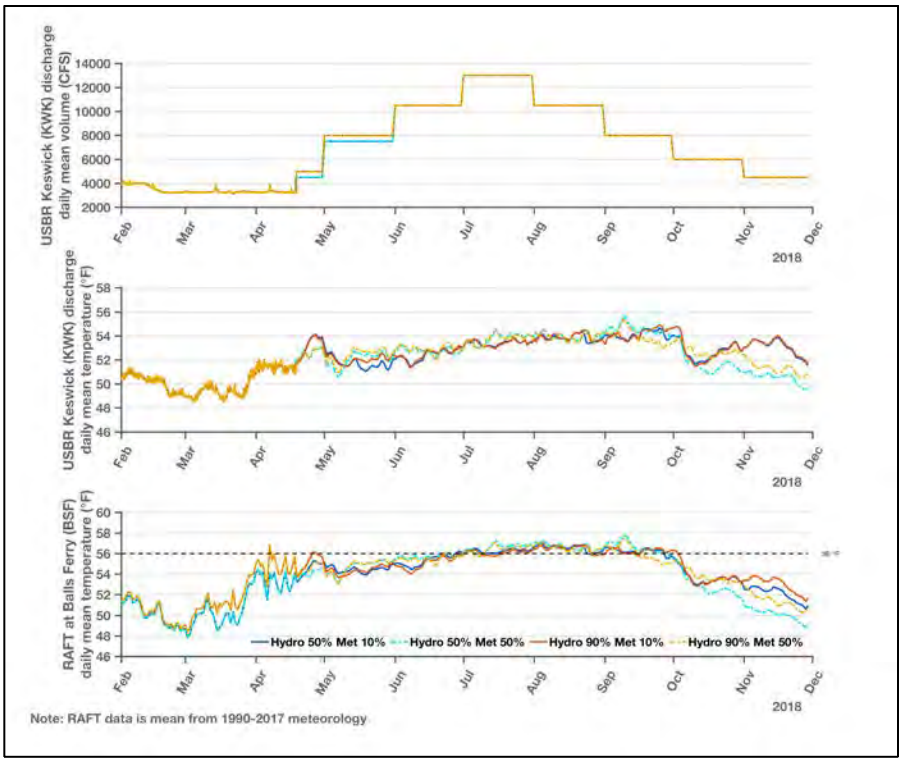


Figure 1: Summary plots showing differences in Keswick discharge volume and temperature, and Balls Ferry RAFT predicted temperature for four scenarios assessed.

Table 1: Estimated temperature-dependent egg mortality under different scenarios assuming a 2012-2017 spatial and temporal redd distribution.

Scenario	Mean (%)	Median (%)	Lower (%)	Upper (%)
APR_18_2018_INPUT_50_OUTPUT_50_10L3MTO	32.40	32.60	0.08	70.60
APR_18_2018_INPUT_50_OUTPUT_50_50L3MTO	44.09	48.02	0.08	74.61
APR_18_2018_INPUT_90_OUTPUT_90_10L3MTO	34.58	35.02	0.08	71.40
APR_18_2018_INPUT_90_OUTPUT_90_50L3MTO	38.52	40.64	0.08	73.45

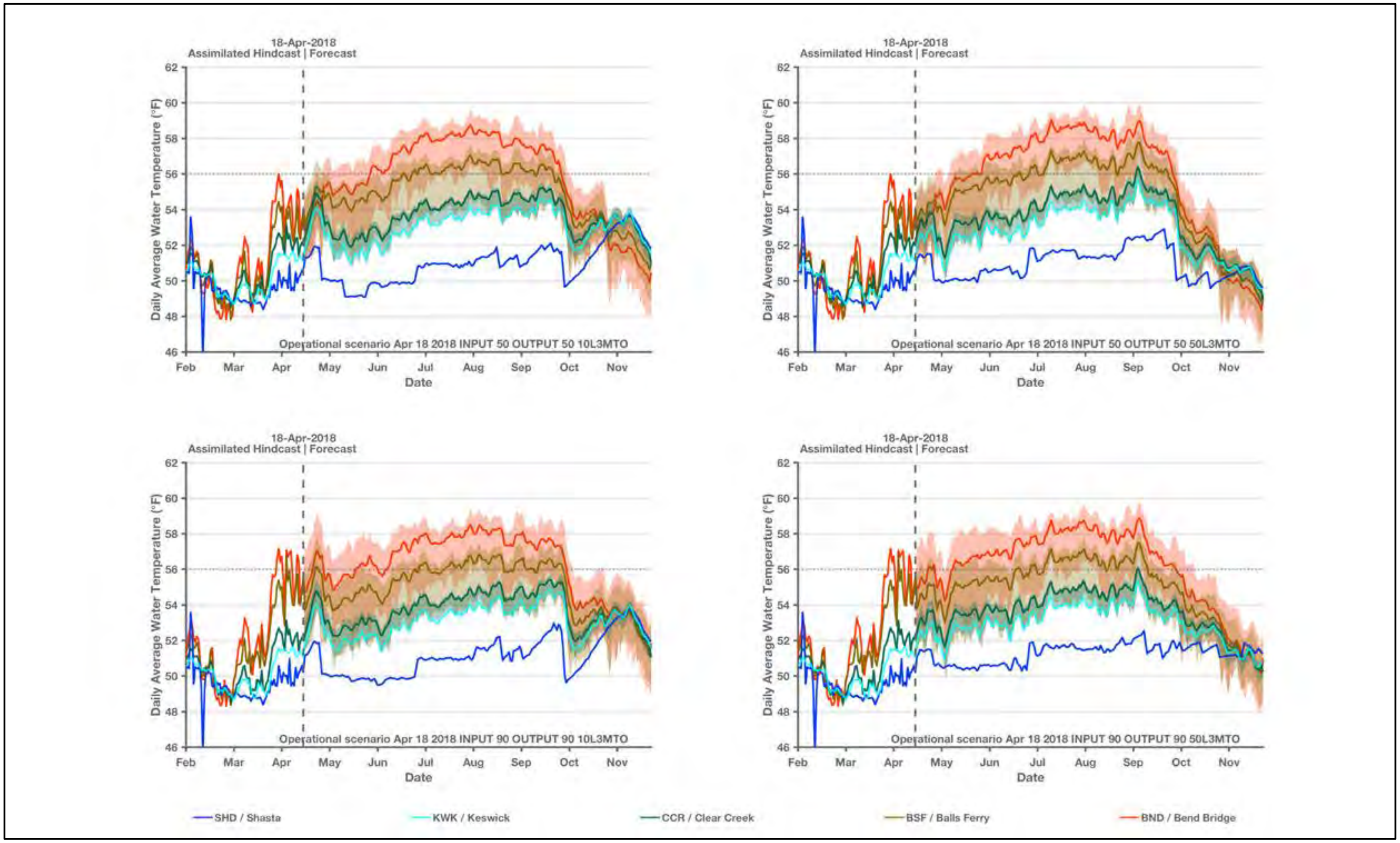


Figure 2: Estimated daily average water temperature produced by scenario input (Shasta and Keswick) and the RAFT model (Clear Creek, Balls Ferry, and Bend Bridge) under the four April 18th 2018 scenarios.

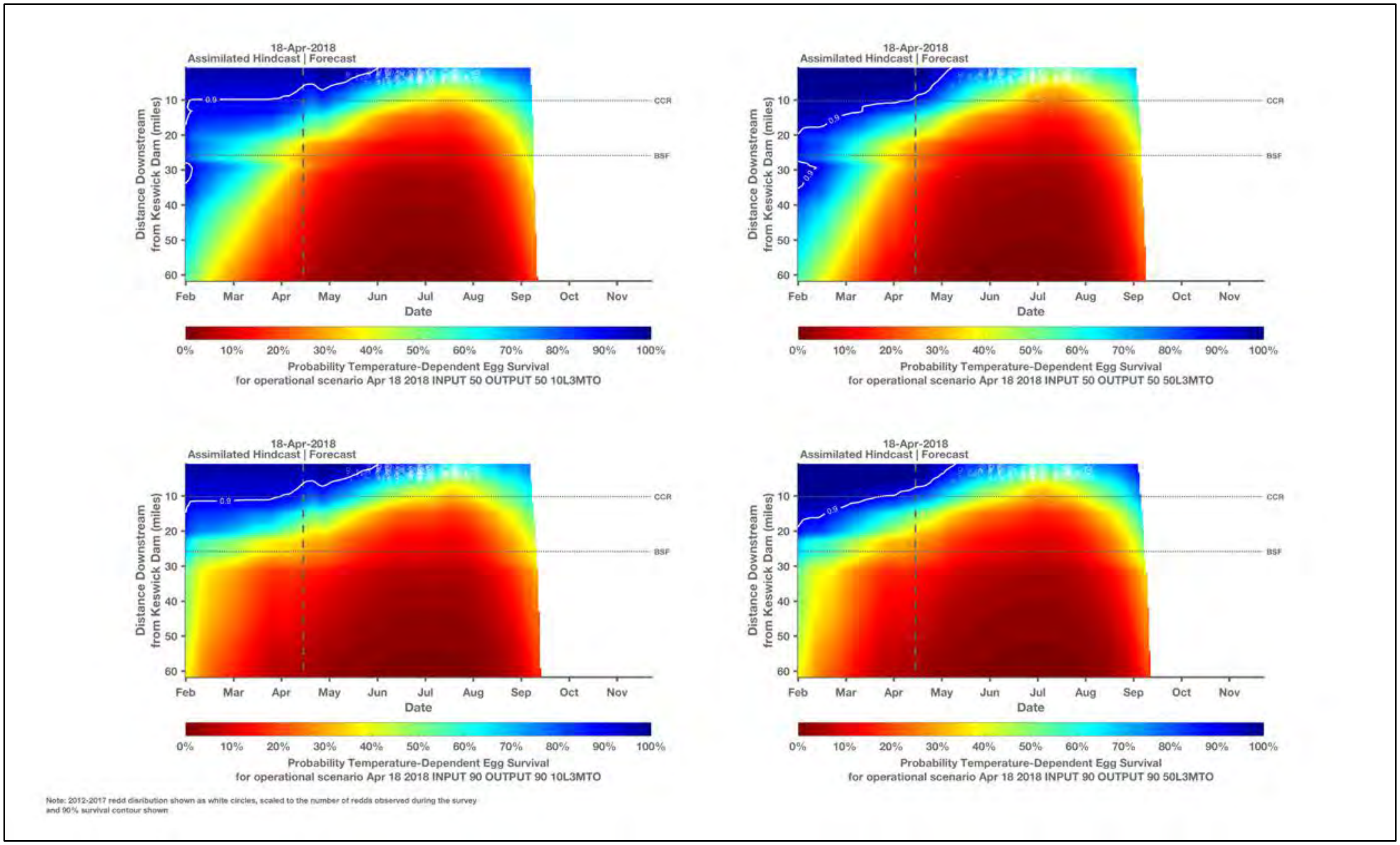


Figure 3: Estimated temperature-dependent egg survival produced by the NMFS temperature mortality model under the four April 18th 2018 scenarios.

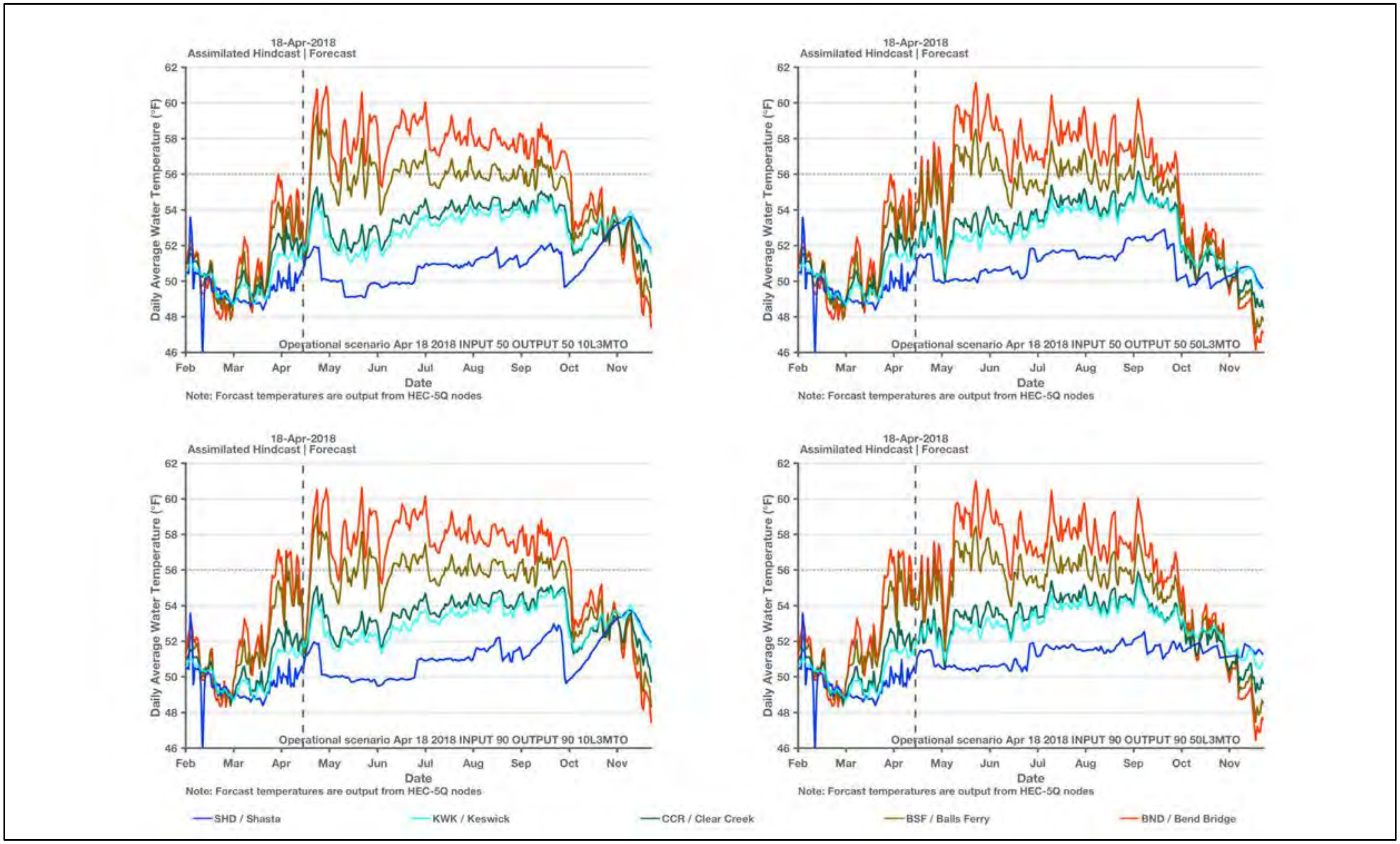


Figure 4: Estimated daily average water temperature produced by scenario input (Shasta, Keswick, Clear Creek, Balls Ferry, and Bend Bridge) under the four April 18th 2018 scenarios using HEC-5Q output.

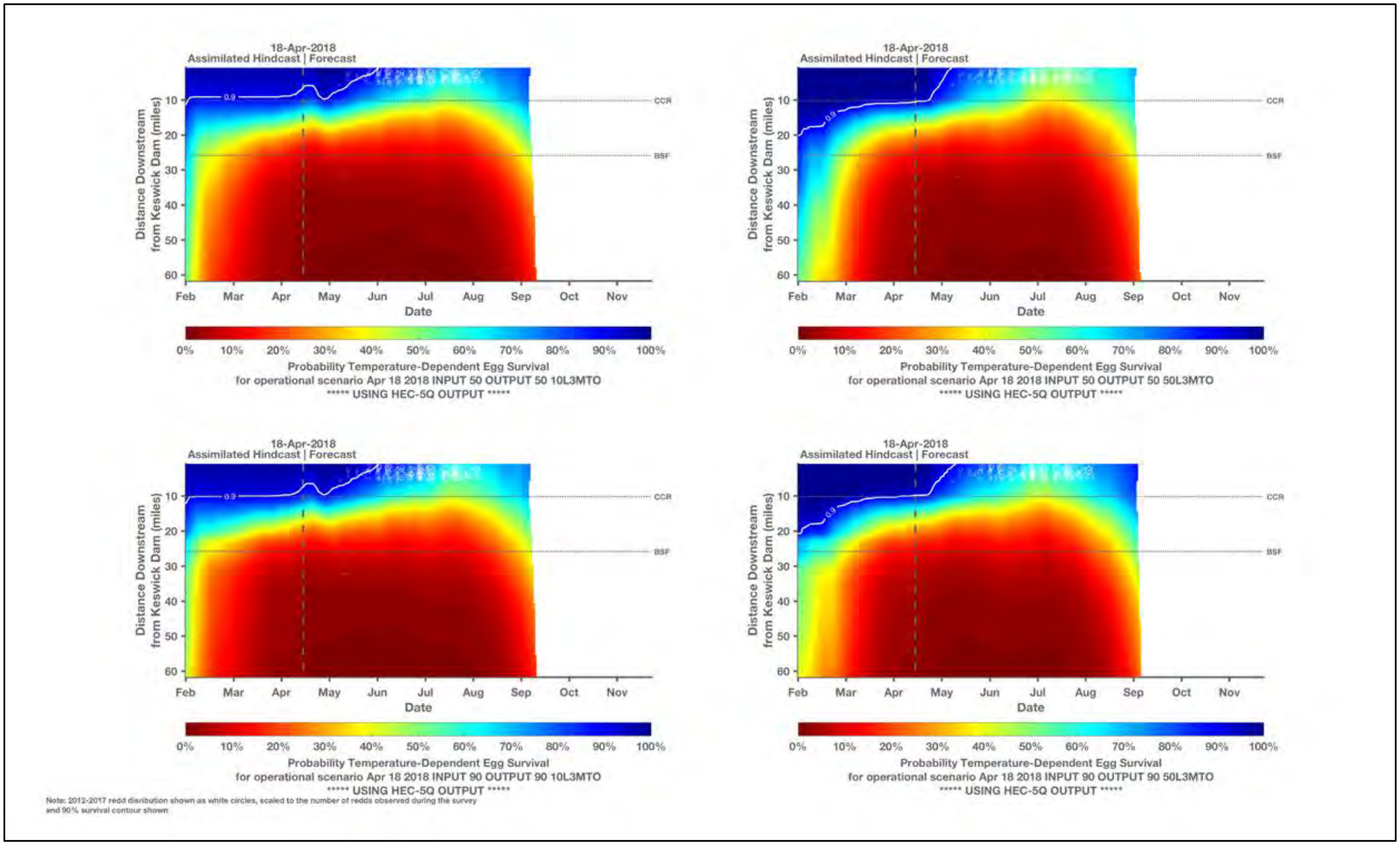


Figure 4: Estimated temperature-dependent egg survival produced by the NMFS temperature mortality model under the four April 18th 2018 scenarios using HEC-5Q output. To generate temperatures between HEC-5Q model nodes (KESWICK, CLEAR_CR, BALL_FERRY, JELLYS_FERRY, BEND_BR, and RED_BLIFF) linear interpolation in space was used.

Table 2: Estimated temperature-dependent egg mortality under different scenarios assuming a 2012-2017 spatial and temporal redd distribution using HEC-5Q output.

Scenario	Mean (%)	Median (%)	Lower (%)	Upper (%)
APR_18_2018_INPUT_50_OUTPUT_50_10L3MTO	29.03	27.54	0.08	69.12
APR_18_2018_INPUT_50_OUTPUT_50_50L3MTO	40.56	43.04	0.08	73.08
APR_18_2018_INPUT_90_OUTPUT_90_10L3MTO	31.32	30.35	0.08	69.78
APR_18_2018_INPUT_90_OUTPUT_90_50L3MTO	35.19	36.01	0.08	71.55

Reference:

Martin, B. T., Pike, A., John, S. N., Hamda, N., Roberts, J., Lindley, S. T. and Danner, E. M. (2017), Phenomenological vs. biophysical models of thermal stress in aquatic eggs. Ecology Letters 20: 50–59. doi:10.1111/ele.12705

Enclosure 3

April 19, 2018

Upper Sacramento River – April 2018 Preliminary Temperature Analysis

Summary of Temperature Results by Month (Monthly Average Temperature °F)

Initial Compliance Location (°F DAT)	APR	MAY	JUN	JUL	AUG	SEP	OCT	Late Sep-Oct Uncertainty Estimation
April 90%-Exceedance Outlook – 10% Historical Meteorology								
Keswick Dam KWK	52.6	51.2	52.4	53.0	53.2	53.4	52.4	53 - 56
Sac. R. abv Clear Creek CCR	53.1	52.1	53.0	53.5	53.6	53.8	52.5	54 - 57
Balls Ferry BSF	55.9	56.6	56.0	55.6	55.6	55.6	53.7	54 - 58

* The HEC5Q model output is displayed above for the months April through October. Based on past analysis, the temperature model does not perform well in late September and October. One factor is that the modeled release temperatures are cooler than has historically been achieved when all release is through the side gates (lowest gates), especially when there's a large temperature gradient between the pressure relief gates (PRG) and the side gates. For the months of September and October, an uncertainty estimate is provided based on the Fall Temperature Index (graphics below). This is based on a historical relationship between end-of-September Lake Shasta Volume less than 56°F and likely downstream temperature performances for the early fall months. The range represents the 90% confidence interval based on that data. Refinement of the concepts for those estimates is underway.

Temperature Model Inputs, Assumptions, Limitations and Uncertainty:

1. The latest available profiles for Shasta, Trinity, and Whiskeytown were taken on April 17, April 4, and April 3 respectively. Model results are sensitive to initial reservoir temperature conditions and the model performs best under highly stratified conditions. The April 2018 temperature profile does not yet exhibit conditions for ideal model computations (still nearly isothermal conditions although warming will initiate stratification). The model performs well after the reservoir stratifies, typically in late spring. The concern this year is assuming over or under estimations with variable hydrologic and meteorological conditions and not capturing the stratification with sufficient detail to project.
2. Guidance on forecasted flows from the creeks (e.g., Cow, Cottonwood, Battle, etc.) between Keswick Dam and Bend Bridge are not available beyond 5 days. Creek flows developed from the historical record that most closely reflects current conditions were used for all model runs. The resulting low creek flows cause significant additional warming in the upper Sacramento River during spring.

3. Operation is based on the April 2018 Operation Outlooks and DWR Bulletin 120 inflow projections (monthly flows, reservoir release, and end-of-month reservoir storage) for the 90%- and 50%-exceedances. Trinity Lake inflows are updated with the CNRFC 90% runoff exceedance for the 90% runoff exceedance studies.
4. Although mean daily flows and releases are temperature model inputs, they are based on the mean monthly values from the operation outlooks. Mean daily flow patterns are user defined and are generalized representations. It is important to note that these outlooks do not suggest a certain actual future outcome, but rather the statistical likelihood of an event occurring, including, but not limited to, projected storage and releases. Thus, the outlooks do not provide exact end of month storages or flow rates but general projections that will likely fall within the range of uncertainty based on the different hydrologic runoff conditions between the 90% and 50% runoff exceedance hydrology.
5. Cottonwood Creek flows, Keswick to Bend Bridge local flows, and ACID diversions are mean daily synthesized flows based on the available historical record for a 1922-2002 study period. Inflows were adjusted to a 95% historical exceedance for both the 90% and 50% runoff exceedance studies.
6. Meteorological inputs represent NOAA NWS Climate Prediction Center L3MTO (based on historical 1961 – 2005 monthly mean equilibrium temperature exceedance at 10% and 50% patterned after like months on a 6-hour time-step). Assumed inflow temperature remain static inputs and do not vary with the assumed meteorology. Efforts to extend to more recent years are under way.
7. Meteorology, as well as the flow volume and pattern, significantly influences reservoir inflow temperatures and downstream tributary temperatures; and consequently, the development of the cold-water pool during winter and early spring.
8. Modified model coefficients more closely represent actual Keswick Dam temperatures. As a result, temperature predictions downstream of Keswick Dam are likely to be warmer than actual. Model re-calibrations efforts are underway.

Model Run Date April 18, 2018

<u>Temperature Analysis Results</u>:

Modeling runs explore Sacramento River compliance performance above Clear Creek confluence and Balls Ferry locations by varying hydrology and meteorology. The temperature results for the Sacramento River between Keswick Dam and Balls Ferry are shown in Figures 1. The fall uncertainty estimation relationship between end-of-September lake volume below 56°F and a Balls Ferry compliance through fall is based on the Figure 5.

Model Run	**End of September Cold Water Pool <56°F (TAF)**	**First Side Gate**	**Full Side Gates**
90% Hydro, 10% Historical Met	682	9/1	10/9

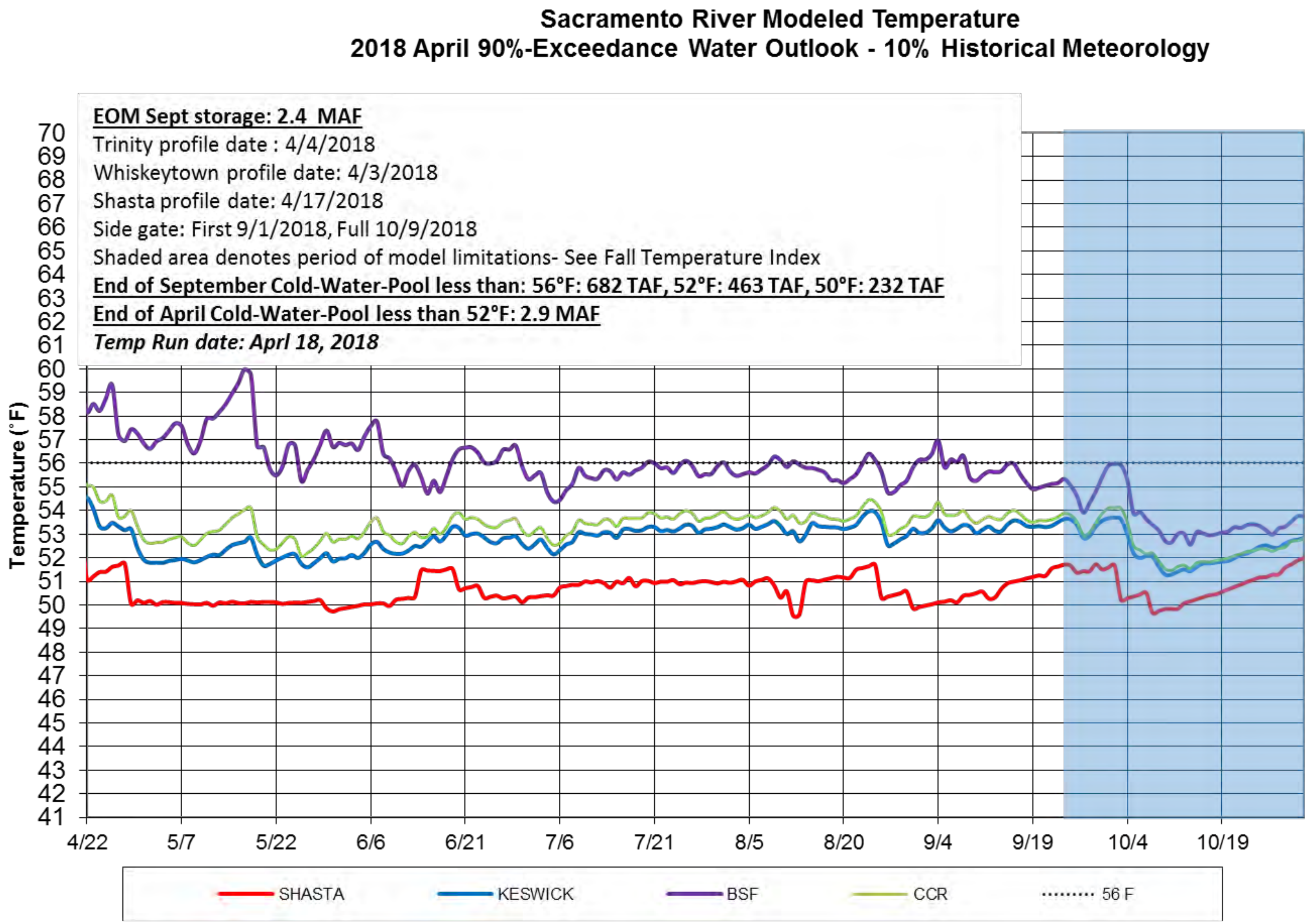
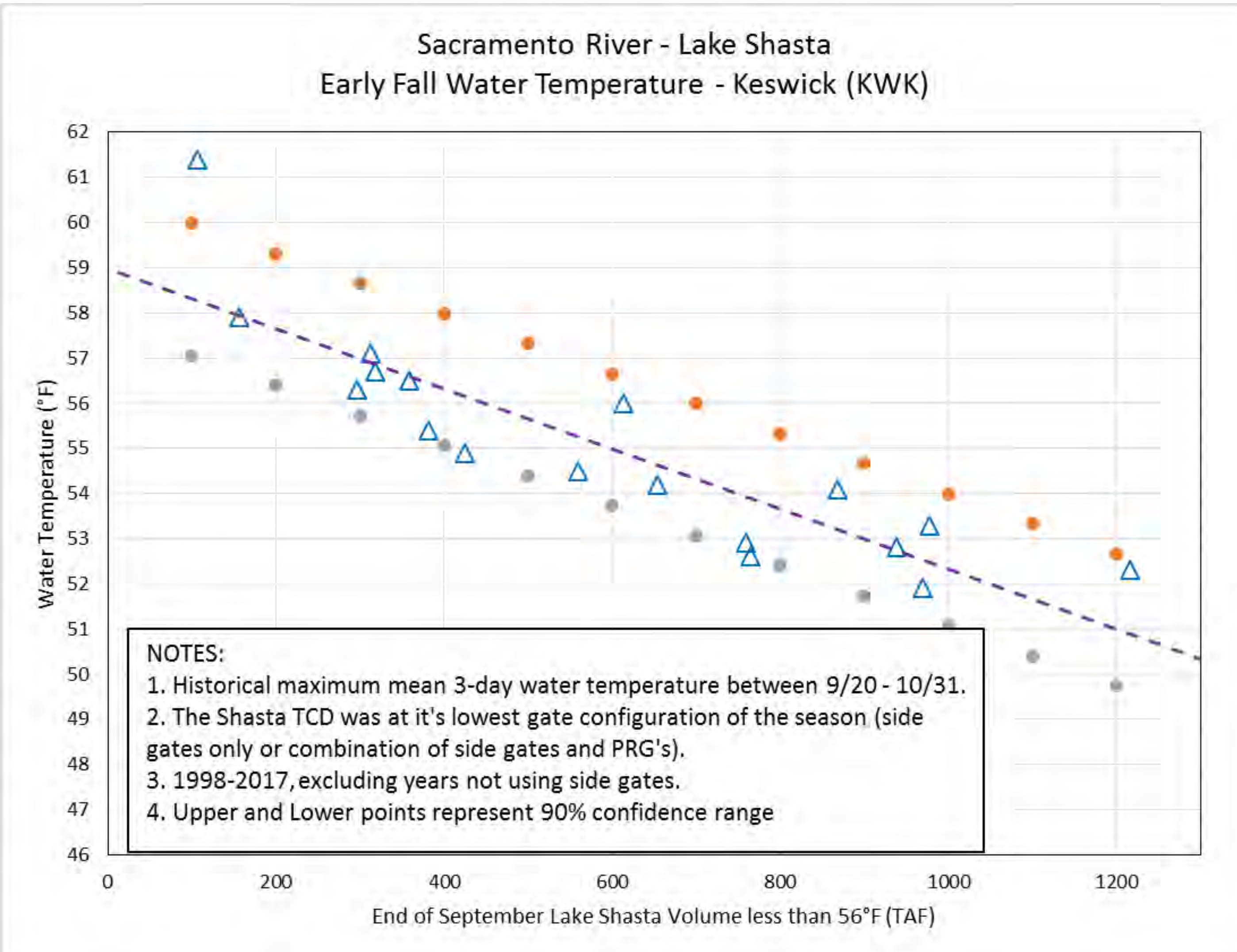

Sacramento River Modeled Temperature
2018 April 90%-Exceedance Water Outlook - 10% Historical Meteorology
EOM Sept storage: 2.4 MAF
Trinity profile date : 4/4/2018
Whiskeytown profile date: 4/3/2018
Shasta profile date: 4/17/2018
Side gate: First 9/1/2018, Full 10/9/2018
Shaded area denotes period of model limitations- See Fall Temperature Index
End of September Cold-Water-Pool less than: 56°F: 682 TAF, 52°F: 463 TAF, 50°F: 232 TAF
End of April Cold-Water-Pool less than 52°F: 2.9 MAF
Temp Run date: Aprl 18, 2018
Temperature (°F)
70
69
68
67
66
65
64
63
62
61
60
59
58
57
56
55
54
53
52
51
50
49
48
47
46
45
44
43
42
41
4/22
5/7
5/22
6/6
6/21
7/6
7/21
8/5
8/20
9/4
9/19
10/4
10/19
SHASTA
KESWICK
BSF
CCR
56 F

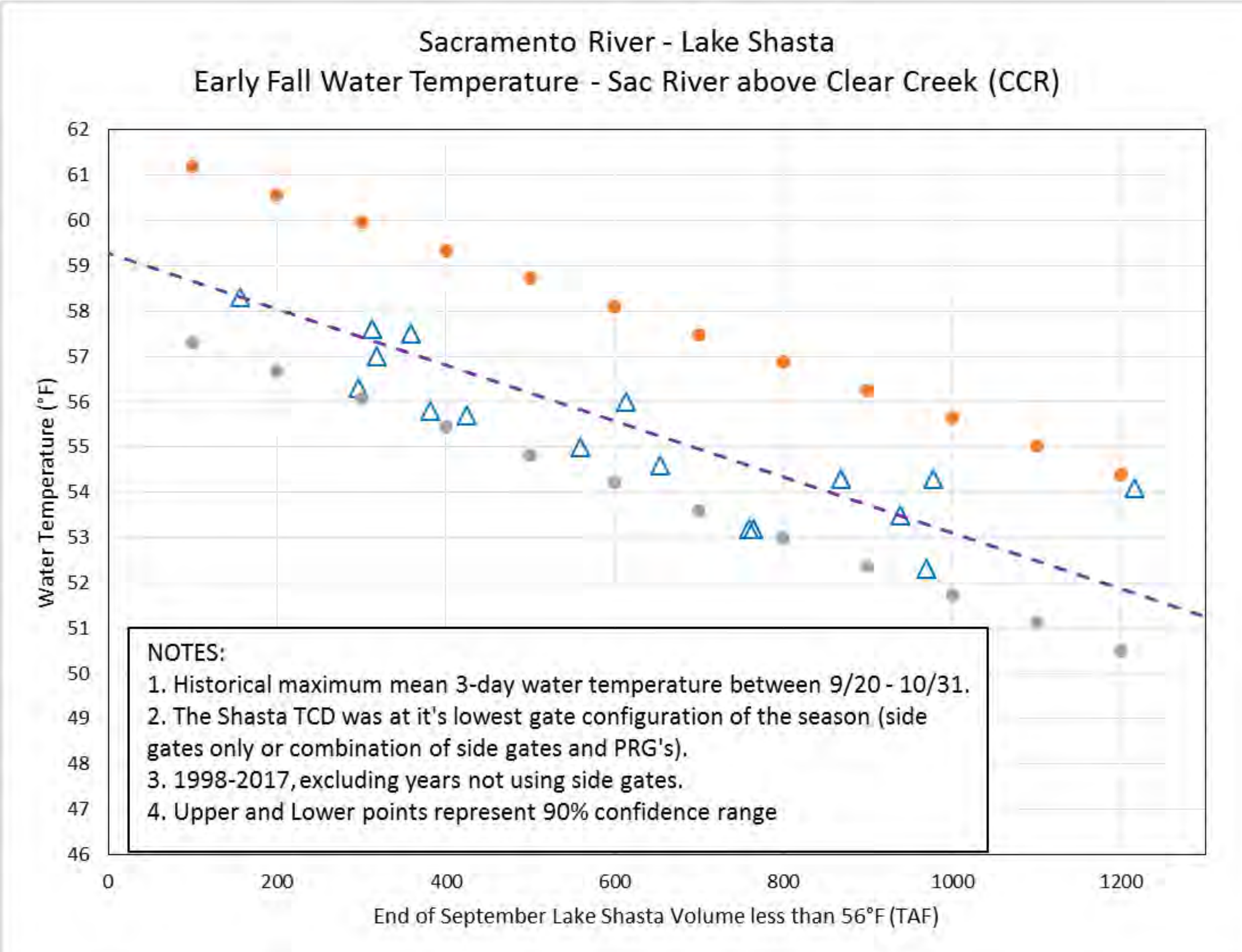
Figure 1

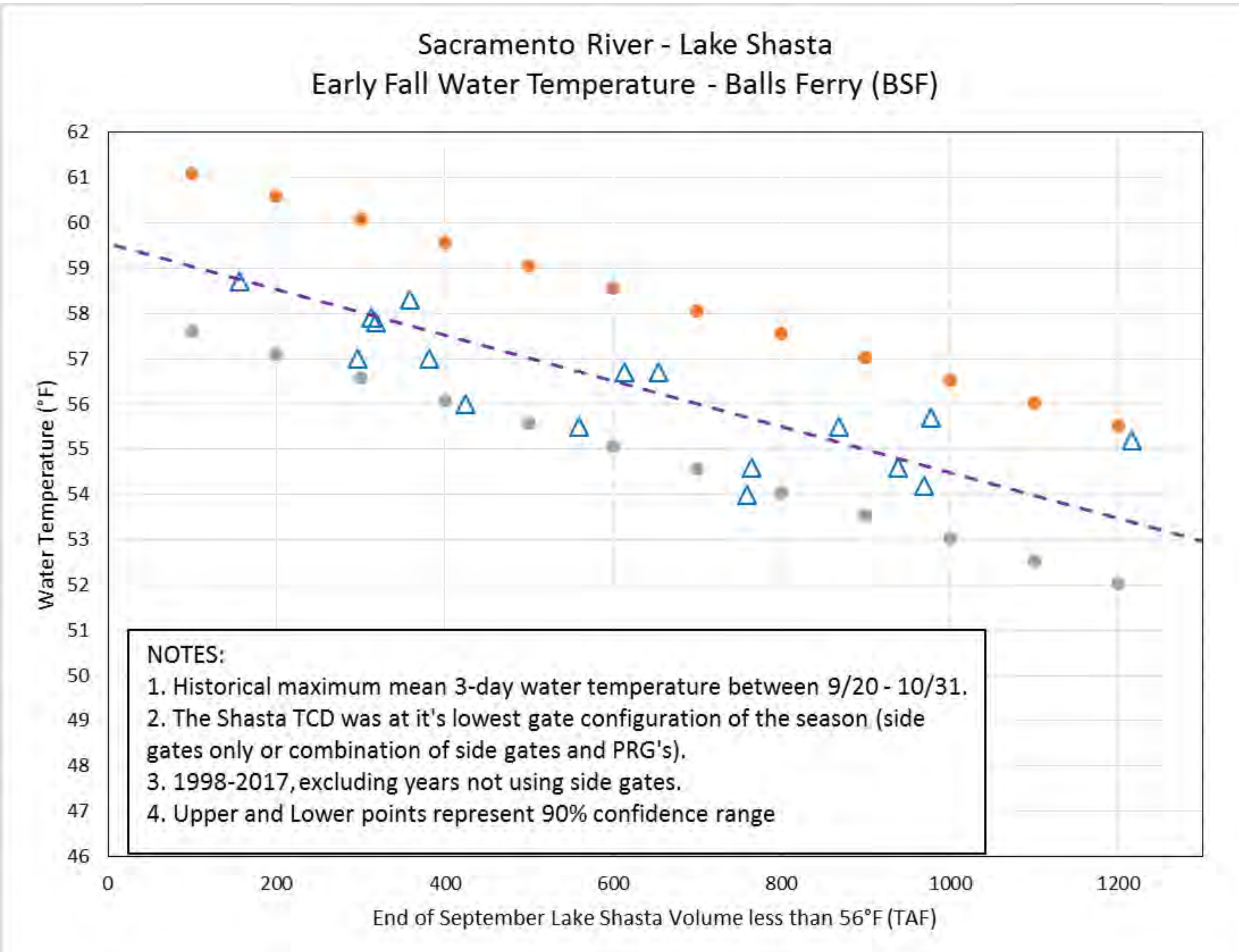
Figures Model Performance and Fall Temperature Index:

1. Based on past analyses, the temperature model does not perform well in late September and October. One factor is that the modeled release temperatures are cooler than has historically been achieved when all release is through the side gates (lowest gates), especially when there's a large temperature gradient between the pressure relief gates (PRG) and the side gates.
2. Based on historical records, the end-of-September Lake Shasta volume below 56˚F can be used as an indicator of fall water temperature in the river reach to Balls Ferry.
3. Based on these records and estimates, the index below illustrates a range of uncertainty in the ability to meet for river temperatures not to exceed 56 ˚F downstream based on the end-of-September lake volume less than 56˚F; see charts below.
4. Refinement of these estimates and concepts is currently underway.



Sacramento River - Lake Shasta
Early Fall Water Temperature - Keswick (KWK)
Water Temperature (°F)
62
61
60
59
58
57
56
55
54
53
52
51
50
49
48
47
46
0
200
400
600
800
1000
1200
End of September Lake Shasta Volume less than 56°F (TAF)
NOTES:
1. Historical maximum mean 3-day water temperature between 9/20 - 10/31.
2. The Shasta TCD was at it's lowest gate configuration of the season (side gates only or combination of side gates and PRG's).
3. 1998-2017, excluding years not using side gates.
4. Upper and Lower points represent 90% confidence range


Sacramento River - Lake Shasta
Early Fall Water Temperature - Sac River above Clear Creek (CCR)
Water Temperature (°F)
62
61
60
59
58
57
56
55
54
53
52
51
50
49
48
47
46
0
200
400
600
800
1000
1200
End of September Lake Shasta Volume less than 56°F (TAF)
NOTES:
1. Historical maximum mean 3-day water temperature between 9/20 - 10/31.
2. The Shasta TCD was at it's lowest gate configuration of the season (side gates only or combination of side gates and PRG's).
3. 1998-2017, excluding years not using side gates.
4. Upper and Lower points represent 90% confidence range



Sacramento River - Lake Shasta
Early Fall Water Temperature - Balls Ferry (BSF)
Water Temperature (°F)
62
61
60
59
58
57
56
55
54
53
52
51
50
49
48
47
46
0
200
400
600
800
1000
1200
End of September Lake Shasta Volume less than 56°F (TAF)
NOTES:
1. Historical maximum mean 3-day water temperature between 9/20 - 10/31.
2. The Shasta TCD was at it's lowest gate configuration of the season (side gates only or combination of side gates and PRG's).
3. 1998-2017, excluding years not using side gates.
4. Upper and Lower points represent 90% confidence range

Enclosure 4

April 24, 2018

Upper Sacramento River – April 2018 Preliminary Temperature Analysis

Summary of Temperature Results by Month (Monthly Average Temperature °F)

Initial Compliance Location (°F DAT)	ARR	MAY	JUN	JUL	AUG	SEP	OCT	Late Sep-Oct Uncertainty Estimation
April 90%-Exceedance Outlook – 10% Historical Meteorology								
Keswick Dam KWK	52.6	52.0	52.4	53.0	53.1	53.3	52.2	53 - 56
Sac. R. abv Clear Creek CCR	53.1	52.9	53.1	53.5	53.6	53.7	52.3	54 - 58
Balls Ferry BSF	55.9	57.2	56.1	55.5	55.5	55.5	53.6	55 - 58
April 90%-Exceedance Outlook – 50% Historical Meteorology								
Keswick Dam KWK	52.5	51.9	52.0	53.0	53.0	53.1	52.0	53 - 56
Sac. R. abv Clear Creek CCR	52.9	52.7	52.6	53.4	53.5	53.5	52.1	54 - 58
Balls Ferry BSF	55.5	56.6	55.5	55.3	55.3	55.2	53.2	55 - 58
April 50%-Exceedance Outlook – 10% Historical Meteorology								
Keswick Dam KWK	52.3	51.3	52.0	52.8	53.1	53.3	52.0	53 - 56
Sac. R. abv Clear Creek CCR	52.9	52.1	52.5	53.2	53.4	53.5	52.1	54 - 58
Balls Ferry BSF	55.8	56.7	55.4	55.1	55.2	55.2	53.3	55 - 58
April 50%-Exceedance Outlook – 50% Historical Meteorology								
Keswick Dam KWK	52.2	50.9	52.2	52.8	53.2	53.1	51.8	53 - 56
Sac. R. abv Clear Creek CCR	52.7	51.5	52.6	53.1	53.4	53.3	51.9	53 - 57
Balls Ferry BSF	55.3	55.8	55.3	54.9	55.1	54.9	53.0	54 - 58

* The HEC5Q model output is displayed above for the months April through October. Based on past analysis, the temperature model does not perform well in late September and October. One factor is that the modeled release temperatures are cooler than has historically been achieved when all release is through the side gates (lowest gates), especially when there's a large temperature gradient between the pressure relief gates (PRG) and the side gates. For the months of September and October, an uncertainty estimate is provided based on the Fall Temperature Index (graphics below). This is based on a historical relationship between end-of-

September Lake Shasta Volume less than 56°F and likely downstream temperature performances for the early fall months. The range represents the 90% confidence interval based on that data. Refinement of the concepts for those estimates is underway.

Temperature Model Inputs, Assumptions, Limitations and Uncertainty:

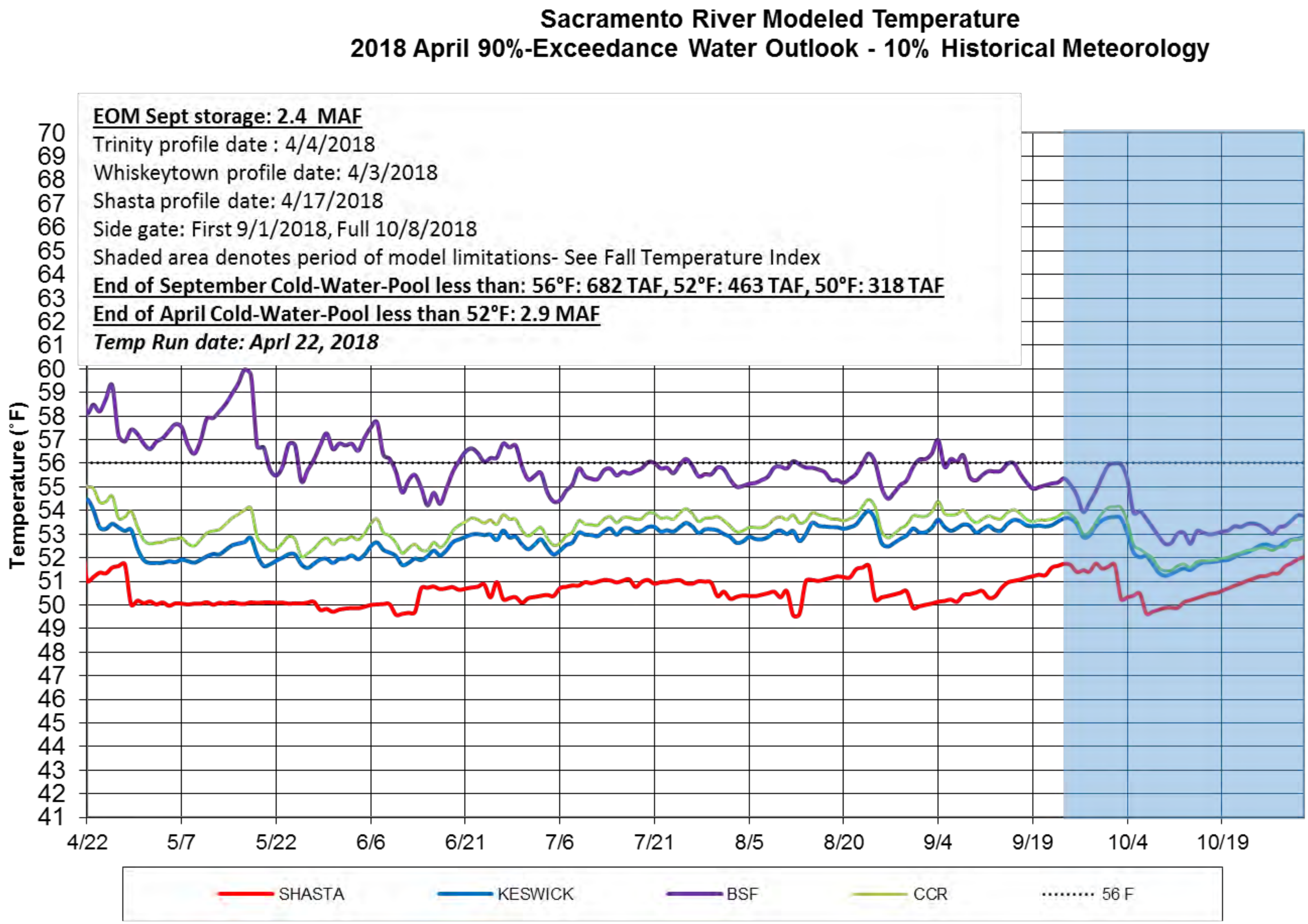
1. The latest available profiles for Shasta, Trinity, and Whiskeytown were taken on April 17, April 4, and April 3 respectively. Model results are sensitive to initial reservoir temperature conditions and the model performs best under highly stratified conditions. The April 2018 temperature profile does not yet exhibit conditions for ideal model computations (still nearly isothermal conditions although warming will initiate stratification). The model performs well after the reservoir stratifies, typically in late spring. The concern this year is assuming over or under estimations with variable hydrologic and meteorological conditions and not capturing the stratification with sufficient detail to project.
2. Guidance on forecasted flows from the creeks (e.g., Cow, Cottonwood, Battle, etc.) between Keswick Dam and Bend Bridge are not available beyond 5 days. Creek flows developed from the historical record that most closely reflects current conditions were used for all model runs. The resulting low creek flows cause significant additional warming in the upper Sacramento River during spring.
3. Operation is based on the April 2018 Operation Outlooks and DWR Bulletin 120 inflow projections (monthly flows, reservoir release, and end-of-month reservoir storage) for the 90%- and 50%-exceedances. Trinity Lake inflows are updated with the CNRFC 90% runoff exceedance for the 90% runoff exceedance studies.
4. Although mean daily flows and releases are temperature model inputs, they are based on the mean monthly values from the operation outlooks. Mean daily flow patterns are user defined and are generalized representations. It is important to note that these outlooks do not suggest a certain actual future outcome, but rather the statistical likelihood of an event occurring, including, but not limited to, projected storage and releases. Thus, the outlooks do not provide exact end of month storages or flow rates but general projections that will likely fall within the range of uncertainty based on the different hydrologic runoff conditions between the 90% and 50% runoff exceedance hydrology.
5. Cottonwood Creek flows, Keswick to Bend Bridge local flows, and ACID diversions are mean daily synthesized flows based on the available historical record for a 1922-2002 study period. Inflows were adjusted to a 95% historical exceedance for both the 90% and 50% runoff exceedance studies.
6. Meteorological inputs represent historical (1985 – 2017) monthly mean equilibrium temperature exceedance at 10% and 50% patterned after like months on a 6-hour time-step. Assumed inflow temperature remain static inputs and do not vary with the assumed meteorology.
7. Meteorology, as well as the flow volume and pattern, significantly influences reservoir inflow temperatures and downstream tributary temperatures; and consequently, the development of the cold-water pool during winter and early spring.
8. Modified model coefficients more closely represent actual Keswick Dam temperatures. As a result, temperature predictions downstream of Keswick Dam are likely to be warmer than actual. Model re-calibrations efforts are underway.

Model Run Date April 22, 2018

Temperature Analysis Results:

Modeling runs explore Sacramento River compliance performance above Clear Creek confluence and Balls Ferry locations by varying hydrology and meteorology. The temperature results for the Sacramento River between Keswick Dam and Balls Ferry are shown in Figures 1. The fall uncertainty estimation relationship between end-of-September lake volume below 56°F and a Balls Ferry compliance through fall is based on the Figures 5-7.

Model Run	End of September Cold Water Pool <56°F (TAF)	First Side Gate	Full Side Gates
90% Hydro, 10% Historical Met	682	9/1	10/8
90% Hydro, 50% Historical Met	682	9/1	10/10
50% Hydro, 10% Historical Met	690	9/1	10/9
50% Hydro, 50% Historical Met	725	9/3	10/12


Sacramento River Modeled Temperature
2018 April 90%-Exceedance Water Outlook - 10% Historical Meteorology
EOM Sept storage: 2.4 MAF
Trinity profile date : 4/4/2018
Whiskeytown profile date: 4/3/2018
Shasta profile date: 4/17/2018
Side gate: First 9/1/2018, Full 10/8/2018
Shaded area denotes period of model limitations- See Fall Temperature Index
End of September Cold-Water-Pool less than: 56°F: 682 TAF, 52°F: 463 TAF, 50°F: 318 TAF
End of April Cold-Water-Pool less than 52°F: 2.9 MAF
Temp Run date: Aprl 22, 2018
Temperature (°F)
70
69
68
67
66
65
64
63
62
61
60
59
58
57
56
55
54
53
52
51
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49
48
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43
42
41
4/22
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5/22
6/6
6/21
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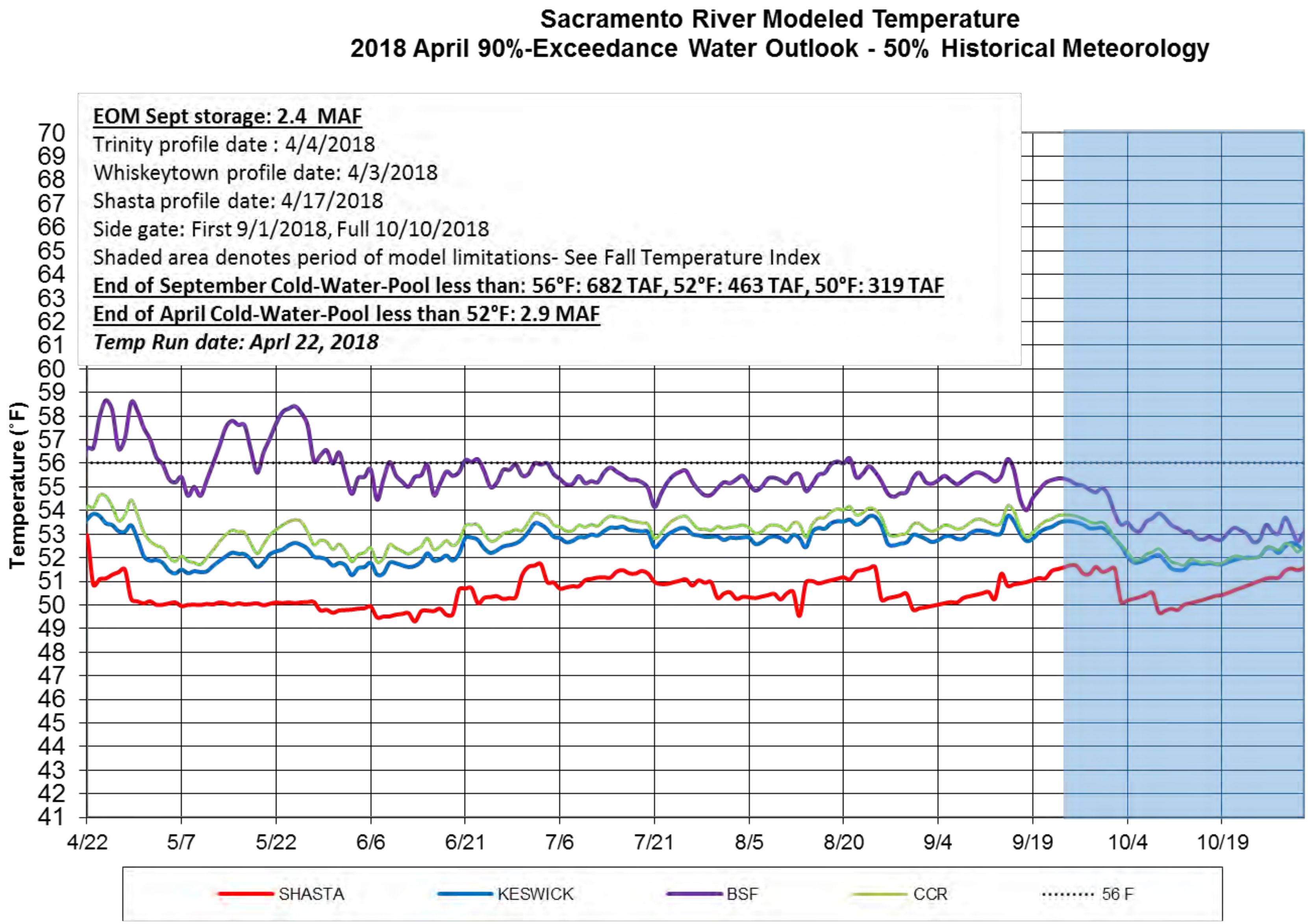
10/4
10/19
SHASTA
KESWICK
BSF
CCR
56 F

Figure 1


Sacramento River Modeled Temperature
2018 April 90%-Exceedance Water Outlook - 50% Historical Meteorology
EOM Sept storage: 2.4 MAF
Trinity profile date : 4/4/2018
Whiskeytown profile date: 4/3/2018
Shasta profile date: 4/17/2018
Side gate: First 9/1/2018, Full 10/10/2018
Shaded area denotes period of model limitations- See Fall Temperature Index
End of September Cold-Water-Pool less than: 56°F: 682 TAF, 52°F: 463 TAF, 50°F: 319 TAF
End of April Cold-Water-Pool less than 52°F: 2.9 MAF
Temp Run date: Aprl 22, 2018
Temperature (°F)
70
69
68
67
66
65
64
63
62
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41
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5/22
6/6
6/21
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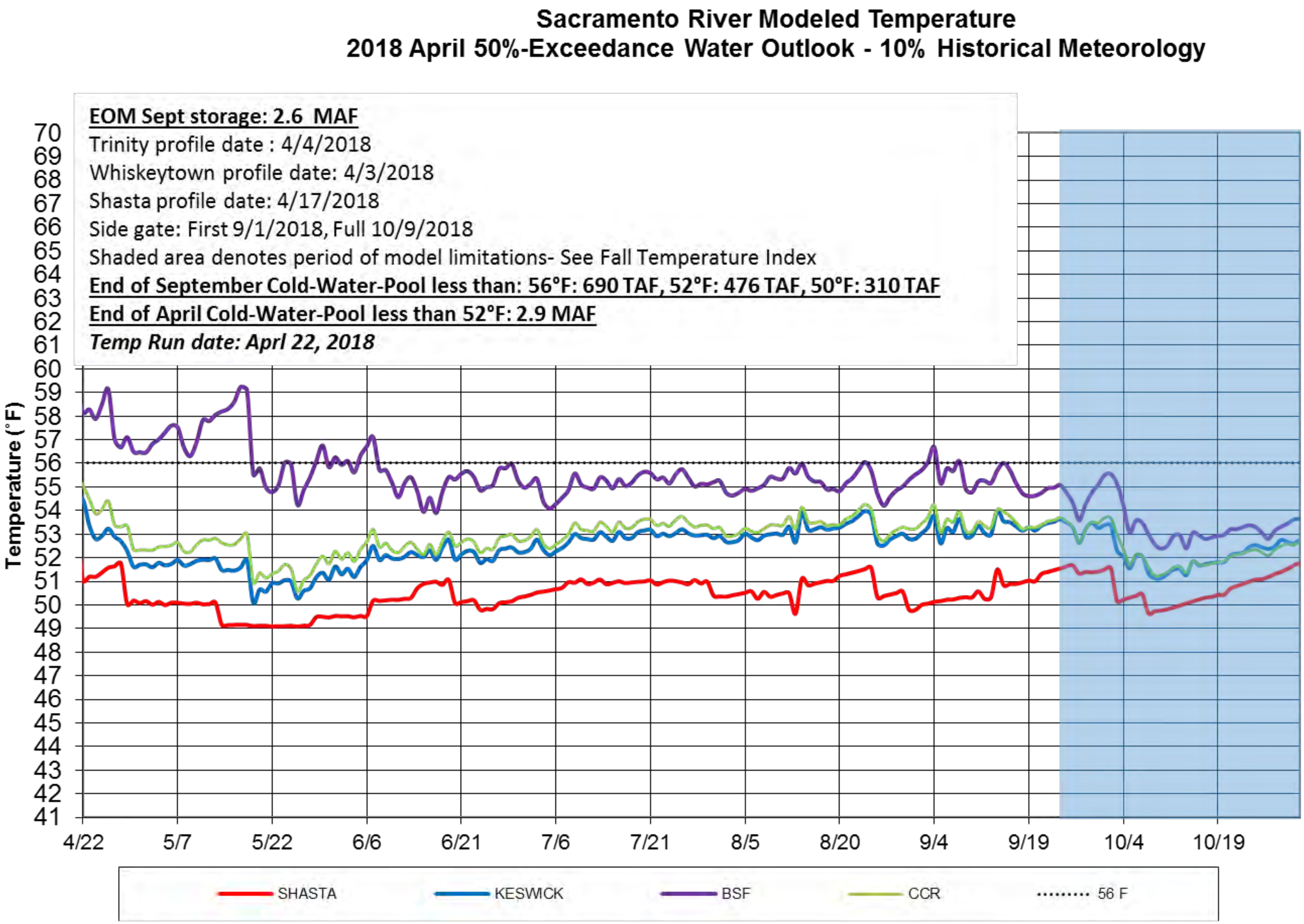
9/19
10/4
10/19
SHASTA
KESWICK
BSF
CCR
56 F

Figure 2


Sacramento River Modeled Temperature
2018 April 50%-Exceedance Water Outlook - 10% Historical Meteorology
EOM Sept storage: 2.6 MAF
Trinity profile date : 4/4/2018
Whiskeytown profile date: 4/3/2018
Shasta profile date: 4/17/2018
Side gate: First 9/1/2018, Full 10/9/2018
Shaded area denotes period of model limitations- See Fall Temperature Index
End of September Cold-Water-Pool less than: 56°F: 690 TAF, 52°F: 476 TAF, 50°F: 310 TAF
End of April Cold-Water-Pool less than 52°F: 2.9 MAF
Temp Run date: Aprl 22, 2018
Temperature (°F)
70
69
68
67
66
65
64
63
62
61
60
59
58
57
56
55
54
53
52
51
50
49
48
47
46
45
44
43
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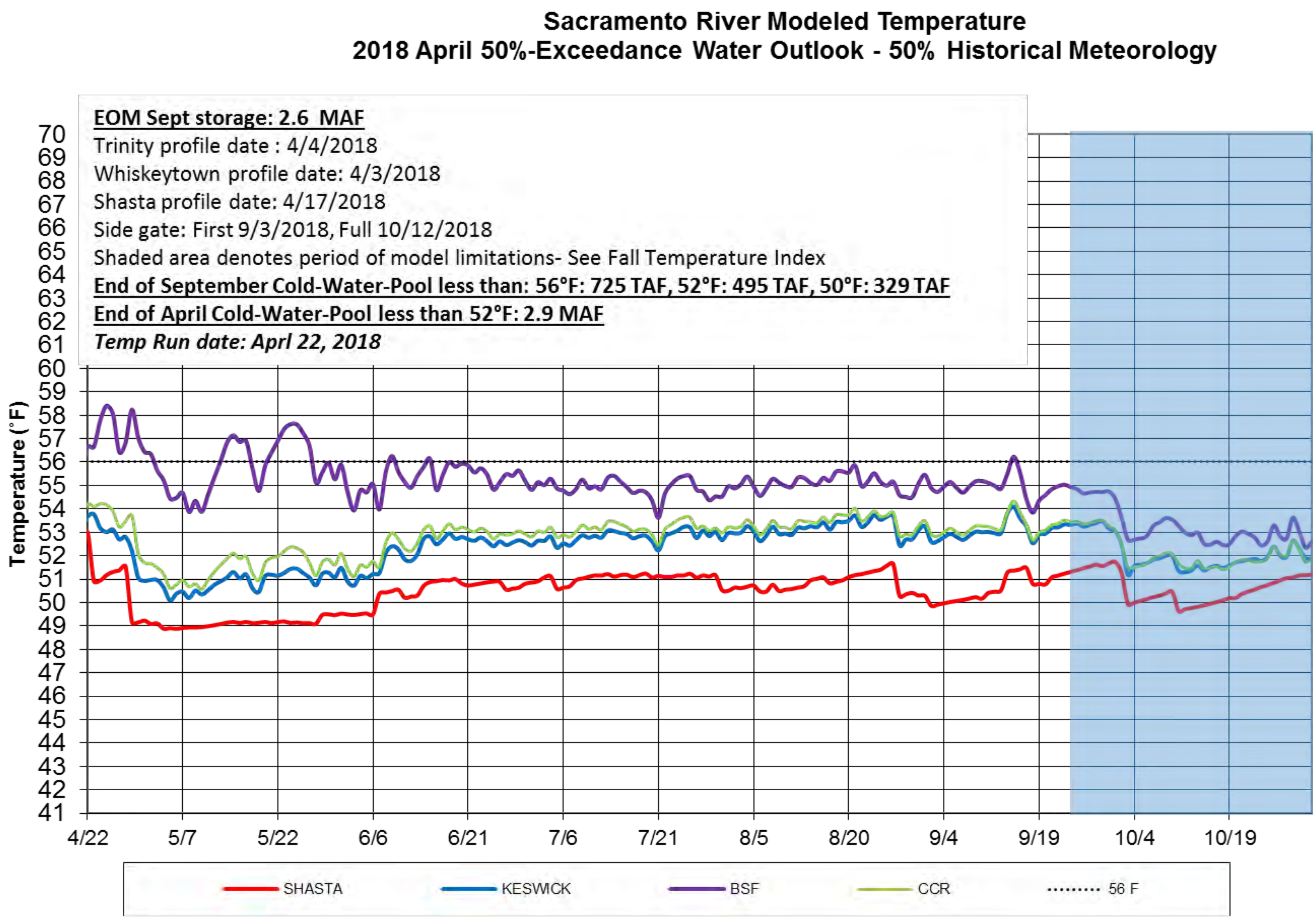
41
4/22
5/7
5/22
6/6
6/21
7/6
7/21
8/5
8/20
9/4
9/19
10/4
10/19
SHASTA
KESWICK
BSF
CCR
56 F

Figure 3



Sacramento River Modeled Temperature
2018 April 50%-Exceedance Water Outlook - 50% Historical Meteorology
EOM Sept storage: 2.6 MAF
Trinity profile date : 4/4/2018
Whiskeytown profile date: 4/3/2018
Shasta profile date: 4/17/2018
Side gate: First 9/3/2018, Full 10/12/2018
Shaded area denotes period of model limitations- See Fall Temperature Index
End of September Cold-Water-Pool less than: 56°F: 725 TAF, 52°F: 495 TAF, 50°F: 329 TAF
End of April Cold-Water-Pool less than 52°F: 2.9 MAF
Temp Run date: Aprl 22, 2018
Temperature (°F)
70
69
68
67
66
65
64
63
62
61
60
59
58
57
56
55
54
53
52
51
50
49
48
47
46
45
44
43
42
41
4/22
5/7
5/22
6/6
6/21
7/6
7/21
8/5
8/20
9/4
9/19
10/4
10/19
SHASTA
KESWICK
BSF
CCR
56 F

Figure 4

Figures 5-7 Model Performance and Fall Temperature Index:

1. Based on past analyses, the temperature model does not perform well in late September and October. One factor is that the modeled release temperatures are cooler than has historically been achieved when all release is through the side gates (lowest gates), especially when there's a large temperature gradient between the pressure relief gates (PRG) and the side gates.
2. Based on historical records, the end-of-September Lake Shasta volume below 56˚F can be used as an indicator of fall water temperature in the river reach to Balls Ferry.
3. Based on these records and estimates, the index below illustrates a range of uncertainty in the ability to meet for river temperatures not to exceed 56 ˚F downstream based on the end-of-September lake volume less than 56˚F; see charts below.
4. Refinement of these estimates and concepts is currently underway.

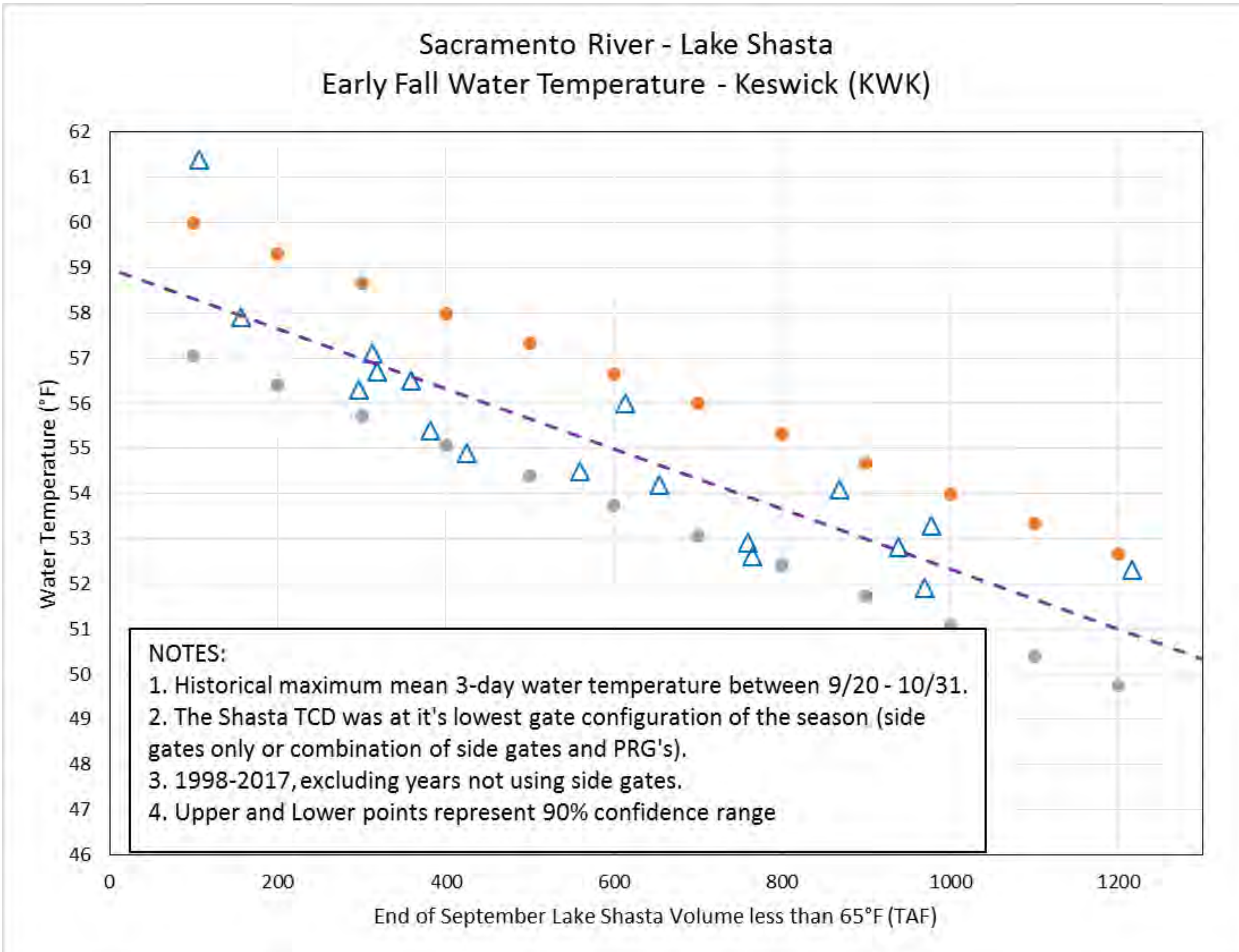
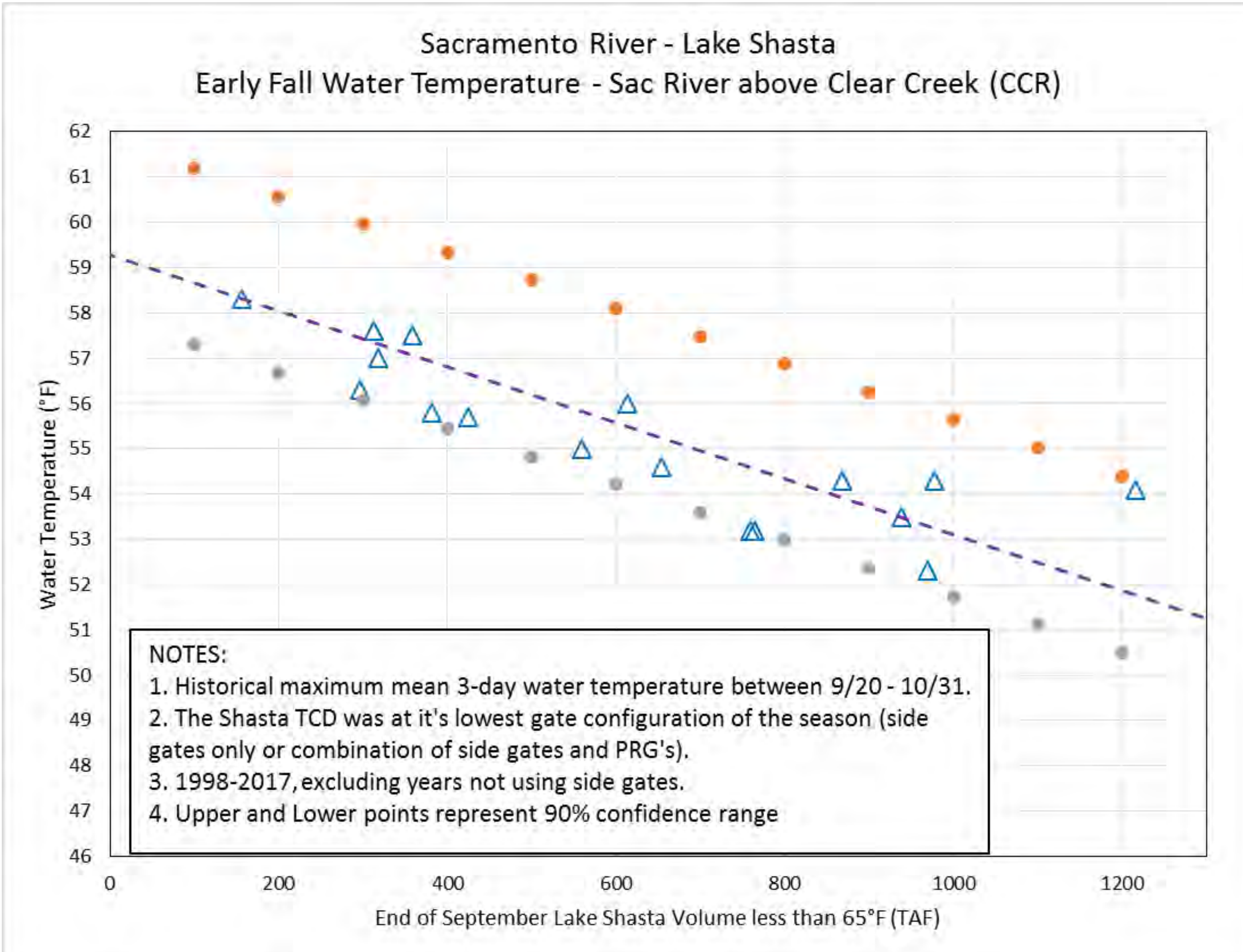

Sacramento River - Lake Shasta
Early Fall Water Temperature - Keswick (KWK)
62
61
60
59
58
57
56
55
54
53
52
51
50
49
48
47
46
Water Temperature (°F)
0
200
400
600
800
1000
1200
End of September Lake Shasta Volume less than 65°F (TAF)
NOTES:
1. Historical maximum mean 3-day water temperature between 9/20 - 10/31.
2. The Shasta TCD was at it's lowest gate configuration of the season (side gates only or combination of side gates and PRG's).
3. 1998-2017, excluding years not using side gates.
4. Upper and Lower points represent 90% confidence range

Figure 5


Sacramento River - Lake Shasta
Early Fall Water Temperature - Sac River above Clear Creek (CCR)
Water Temperature (°F)
62
61
60
59
58
57
56
55
54
53
52
51
50
49
48
47
46
0
200
400
600
800
1000
1200
End of September Lake Shasta Volume less than 65°F (TAF)
NOTES:
1. Historical maximum mean 3-day water temperature between 9/20 - 10/31.
2. The Shasta TCD was at it's lowest gate configuration of the season (side gates only or combination of side gates and PRG's).
3. 1998-2017, excluding years not using side gates.
4. Upper and Lower points represent 90% confidence range
Figure 6

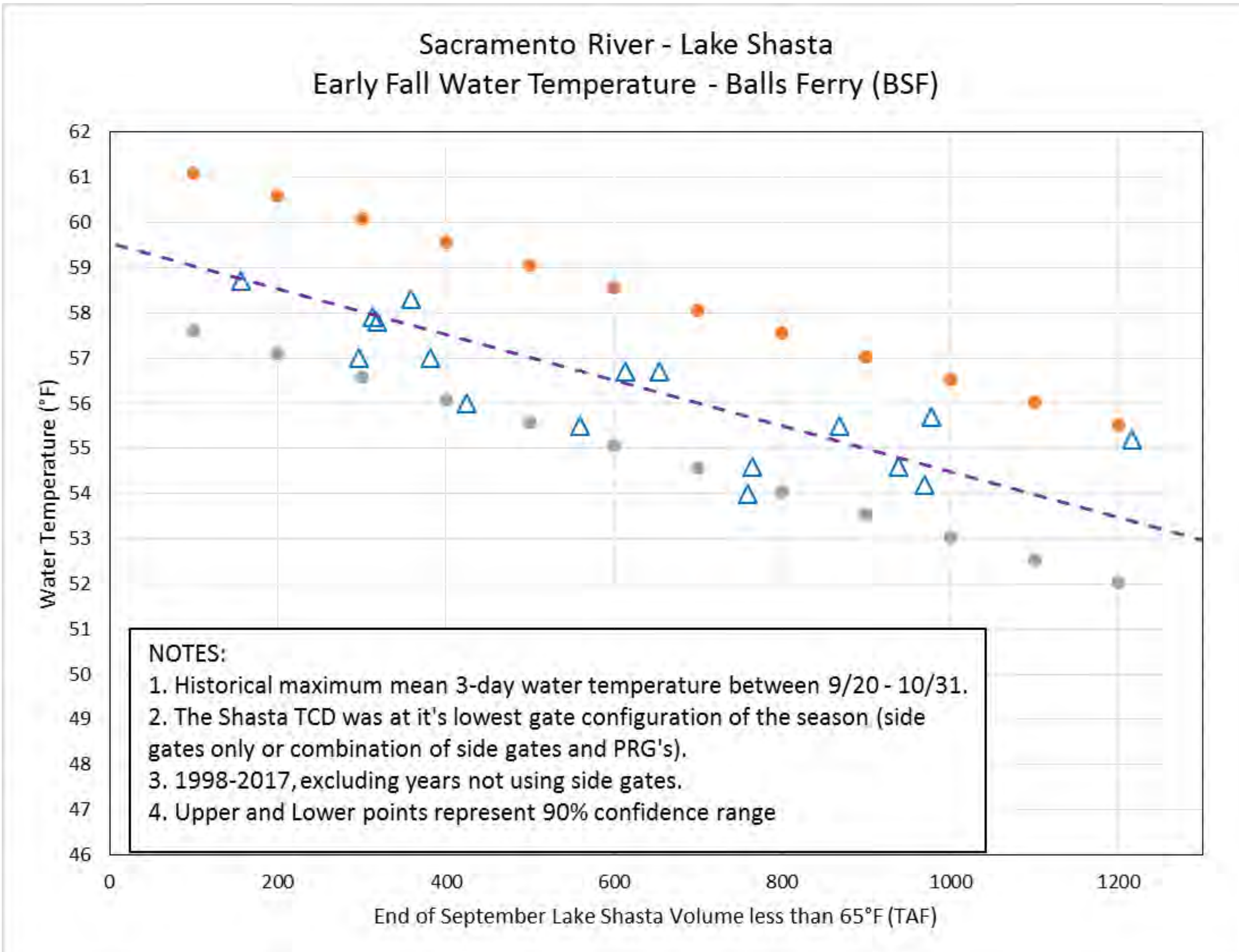

Sacramento River - Lake Shasta
Early Fall Water Temperature - Balls Ferry (BSF)
62
61
60
59
58
57
56
55
54
53
52
51
50
49
48
47
46
Water Temperature (°F)
0
200
400
600
800
1000
1200
End of September Lake Shasta Volume less than 65°F (TAF)
NOTES:
1. Historical maximum mean 3-day water temperature between 9/20 - 10/31.
2. The Shasta TCD was at it's lowest gate configuration of the season (side gates only or combination of side gates and PRG's).
3. 1998-2017, excluding years not using side gates.
4. Upper and Lower points represent 90% confidence range

Figure 7

April 24, 2018

Upper Sacramento River – April 2018 Preliminary Temperature Analysis

Summary of Temperature Results by Month (Monthly Average Temperature °F)

Initial Compliance Location (°F DAT)	ARR	MAY	JUN	JUL	AUG	SEP	OCT	Late Sep-Oct Uncertainty Estimation
April 90%-Exceedance Outlook – 10% Historical Meteorology								
Keswick Dam KWK	52.6	52.0	52.4	52.5	52.4	52.6	53.1	54 - 56
Sac. R. abv Clear Creek CCR	53.1	52.9	53.0	53.0	52.9	53.0	53.2	54 - 58
Balls Ferry BSF	55.9	57.2	56.0	55.1	54.9	54.9	54.3	55 - 58

* The HEC5Q model output is displayed above for the months April through October. Based on past analysis, the temperature model does not perform well in late September and October. One factor is that the modeled release temperatures are cooler than has historically been achieved when all release is through the side gates (lowest gates), especially when there's a large temperature gradient between the pressure relief gates (PRG) and the side gates. For the months of September and October, an uncertainty estimate is provided based on the Fall Temperature Index (graphics below). This is based on a historical relationship between end-of-September Lake Shasta Volume less than 56°F and likely downstream temperature performances for the early fall months. The range represents the 90% confidence interval based on that data. Refinement of the concepts for those estimates is underway.

<u>Temperature Model Inputs, Assumptions, Limitations and Uncertainty</u>:

1. The latest available profiles for Shasta, Trinity, and Whiskeytown were taken on April 17, April 4, and April 3 respectively. Model results are sensitive to initial reservoir temperature conditions and the model performs best under highly stratified conditions. The April 2018 temperature profile does not yet exhibit conditions for ideal model computations (still nearly isothermal conditions although warming will initiate stratification). The model performs well after the reservoir stratifies, typically in late spring. The concern this year is assuming over or under estimations with variable hydrologic and meteorological conditions and not capturing the stratification with sufficient detail to project.
2. Guidance on forecasted flows from the creeks (e.g., Cow, Cottonwood, Battle, etc.) between Keswick Dam and Bend Bridge are not available beyond 5 days. Creek flows developed from the historical record that most closely reflects current conditions were used for all model runs. The resulting low creek flows cause significant additional warming in the upper Sacramento River during spring.
3. Operation is based on the April 2018 Operation Outlooks and DWR Bulletin 120 inflow projections (monthly flows, reservoir

release, and end-of-month reservoir storage) for the 90%- and 50%-exceedances. Trinity Lake inflows are updated with the CNRFC 90% runoff exceedance for the 90% runoff exceedance studies.

4. Although mean daily flows and releases are temperature model inputs, they are based on the mean monthly values from the operation outlooks. Mean daily flow patterns are user defined and are generalized representations. It is important to note that these outlooks do not suggest a certain actual future outcome, but rather the statistical likelihood of an event occurring, including, but not limited to, projected storage and releases. Thus, the outlooks do not provide exact end of month storages or flow rates but general projections that will likely fall within the range of uncertainty based on the different hydrologic runoff conditions between the 90% and 50% runoff exceedance hydrology.

5. Cottonwood Creek flows, Keswick to Bend Bridge local flows, and ACID diversions are mean daily synthesized flows based on the available historical record for a 1922-2002 study period. Inflows were adjusted to a 95% historical exceedance for both the 90% and 50% runoff exceedance studies.

6. Meteorological inputs represent historical (1985 – 2017) monthly mean equilibrium temperature exceedance at 10% and 50% patterned after like months on a 6-hour time-step. Assumed inflow temperature remain static inputs and do not vary with the assumed meteorology.

7. Meteorology, as well as the flow volume and pattern, significantly influences reservoir inflow temperatures and downstream tributary temperatures; and consequently, the development of the cold-water pool during winter and early spring.

8. Modified model coefficients more closely represent actual Keswick Dam temperatures. As a result, temperature predictions downstream of Keswick Dam are likely to be warmer than actual. Model re-calibrations efforts are underway.

Model Run Date April 22, 2018

Temperature Analysis Results:

Modeling runs explore Sacramento River compliance performance above Clear Creek confluence and Balls Ferry locations by varying hydrology and meteorology. The temperature results for the Sacramento River between Keswick Dam and Balls Ferry are shown in Figures 1. The fall uncertainty estimation relationship between end-of-September lake volume below 56°F and a Balls Ferry compliance through fall is based on the Figures 2-4.

Model Run	**End of September Cold Water Pool <56°F (TAF)**	**First Side Gate**	**Full Side Gates**
90% Hydro, 10% Historical Met	625	8/21	9/22

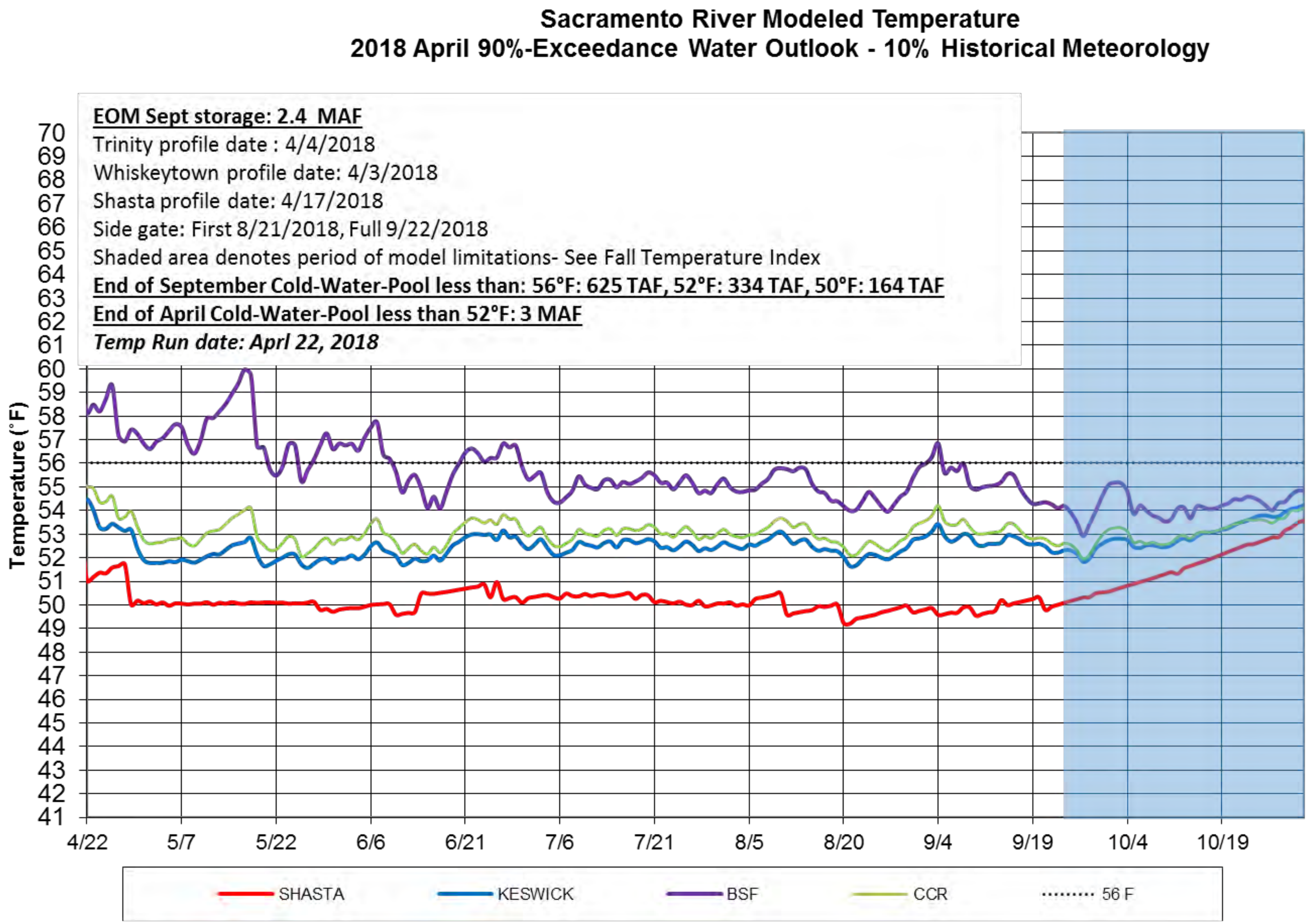

Sacramento River Modeled Temperature
2018 April 90%-Exceedance Water Outlook - 10% Historical Meteorology
EOM Sept storage: 2.4 MAF
Trinity profile date : 4/4/2018
Whiskeytown profile date: 4/3/2018
Shasta profile date: 4/17/2018
Side gate: First 8/21/2018, Full 9/22/2018
Shaded area denotes period of model limitations- See Fall Temperature Index
End of September Cold-Water-Pool less than: 56°F: 625 TAF, 52°F: 334 TAF, 50°F: 164 TAF
End of April Cold-Water-Pool less than 52°F: 3 MAF
Temp Run date: Apri2 22, 2018
Temperature (°F)
70
69
68
67
66
65
64
63
62
61
60
59
58
57
56
55
54
53
52
51
50
49
48
47
46
45
44
43
42
41
4/22
5/7
5/22
6/6
6/21
7/6
7/21
8/5
8/20
9/4
9/19
10/4
10/19
SHASTA
KESWICK
BSF
CCR
56 F

Figure 1

Figures 2-4 Model Performance and Fall Temperature Index:

1. Based on past analyses, the temperature model does not perform well in late September and October. One factor is that the modeled release temperatures are cooler than has historically been achieved when all release is through the side gates (lowest gates), especially when there's a large temperature gradient between the pressure relief gates (PRG) and the side gates.
2. Based on historical records, the end-of-September Lake Shasta volume below 56˚F can be used as an indicator of fall water temperature in the river reach to Balls Ferry.
3. Based on these records and estimates, the index below illustrates a range of uncertainty in the ability to meet for river temperatures not to exceed 56 ˚F downstream based on the end-of-September lake volume less than 56˚F; see charts below.
4. Refinement of these estimates and concepts is currently underway.

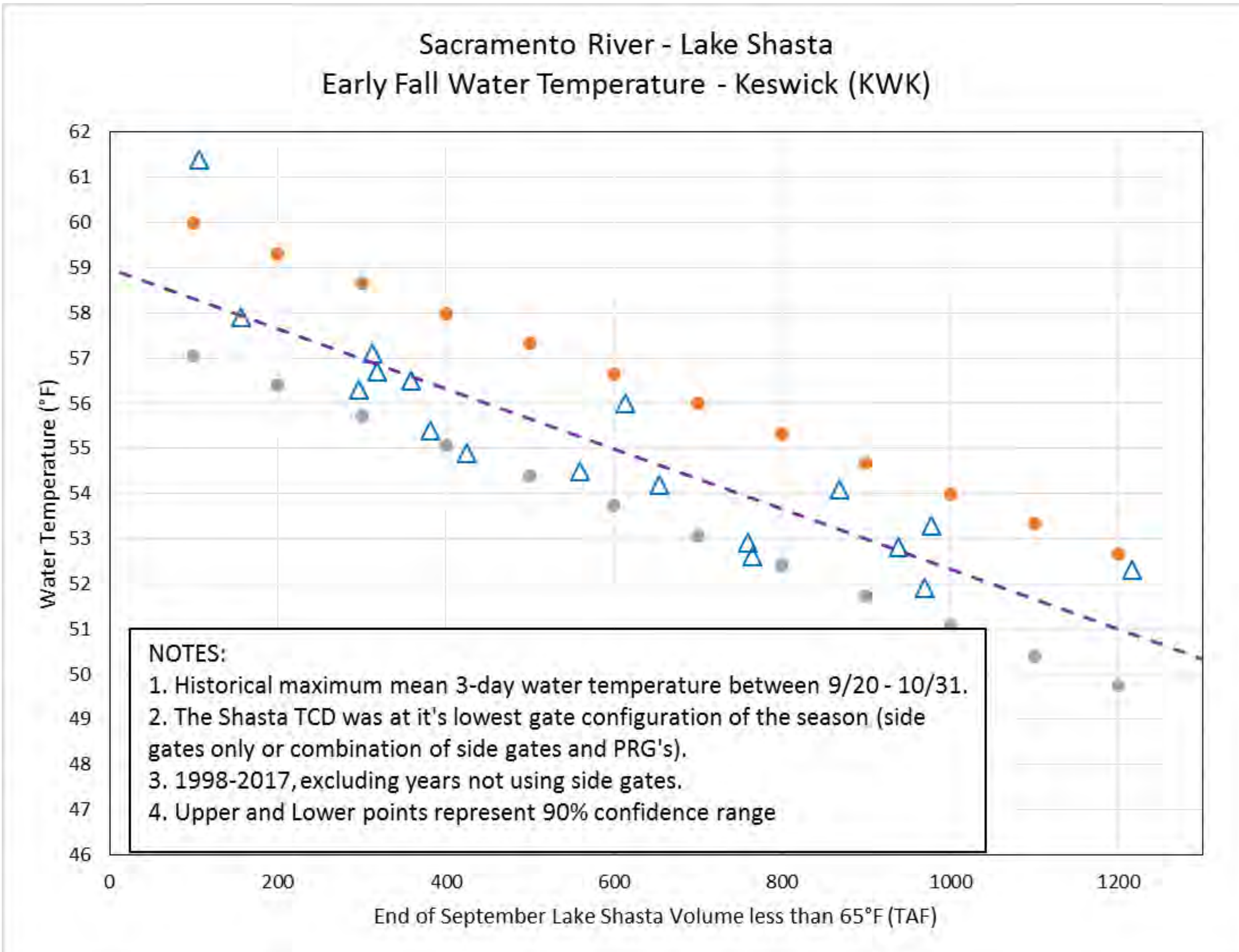
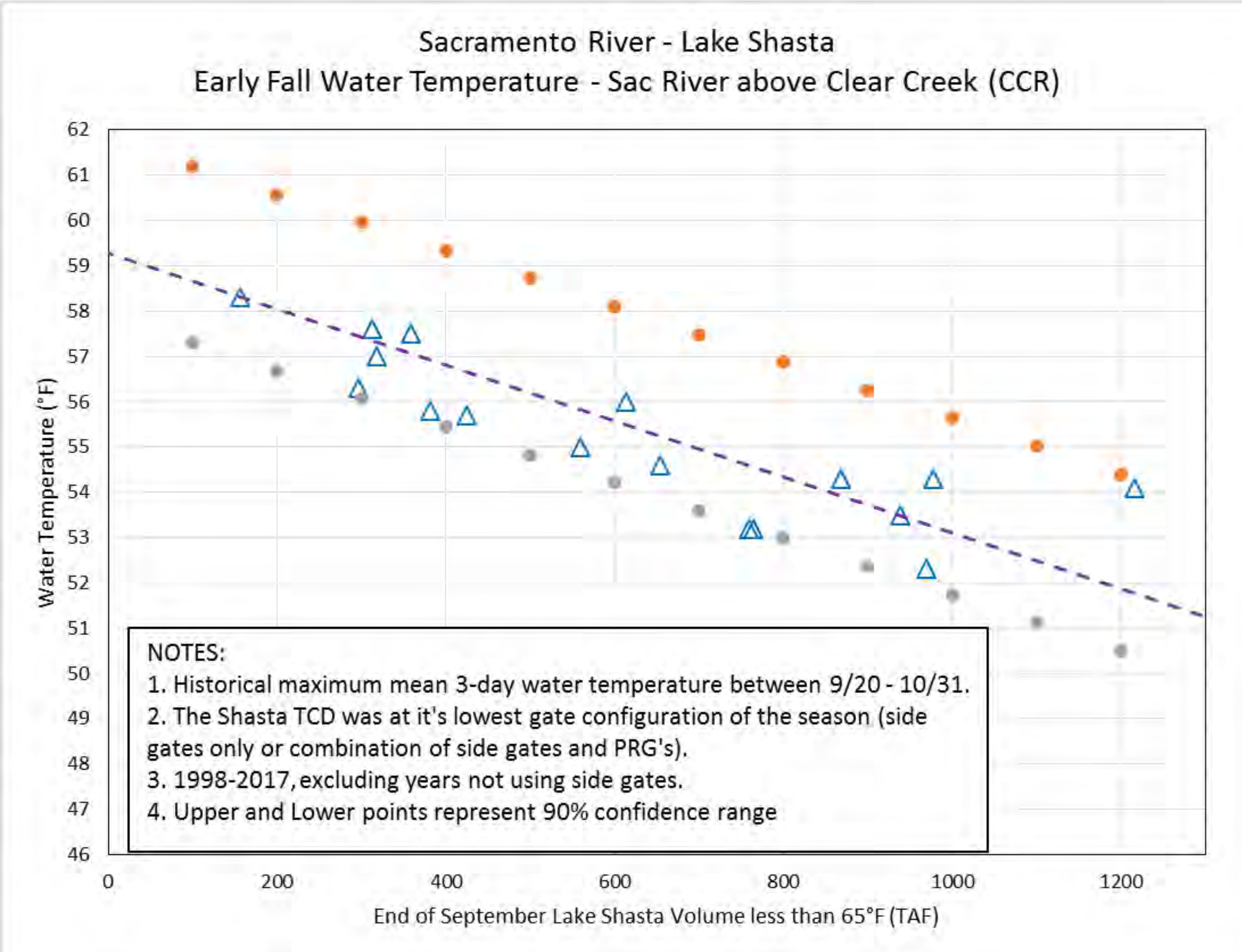

Sacramento River - Lake Shasta
Early Fall Water Temperature - Keswick (KWK)
62
61
60
59
58
57
56
55
54
53
52
51
50
49
48
47
46
Water Temperature (°F)
0
200
400
600
800
1000
1200
End of September Lake Shasta Volume less than 65°F (TAF)
NOTES:
1. Historical maximum mean 3-day water temperature between 9/20 - 10/31.
2. The Shasta TCD was at it's lowest gate configuration of the season (side gates only or combination of side gates and PRG's).
3. 1998-2017, excluding years not using side gates.
4. Upper and Lower points represent 90% confidence range

Figure 2



Sacramento River - Lake Shasta
Early Fall Water Temperature - Sac River above Clear Creek (CCR)
Water Temperature (°F)
62
61
60
59
58
57
56
55
54
53
52
51
50
49
48
47
46
NOTES:
1. Historical maximum mean 3-day water temperature between 9/20 - 10/31.
2. The Shasta TCD was at it's lowest gate configuration of the season (side gates only or combination of side gates and PRG's).
3. 1998-2017, excluding years not using side gates.
4. Upper and Lower points represent 90% confidence range
0
200
400
600
800
1000
1200
End of September Lake Shasta Volume less than 65°F (TAF)

Figure 3

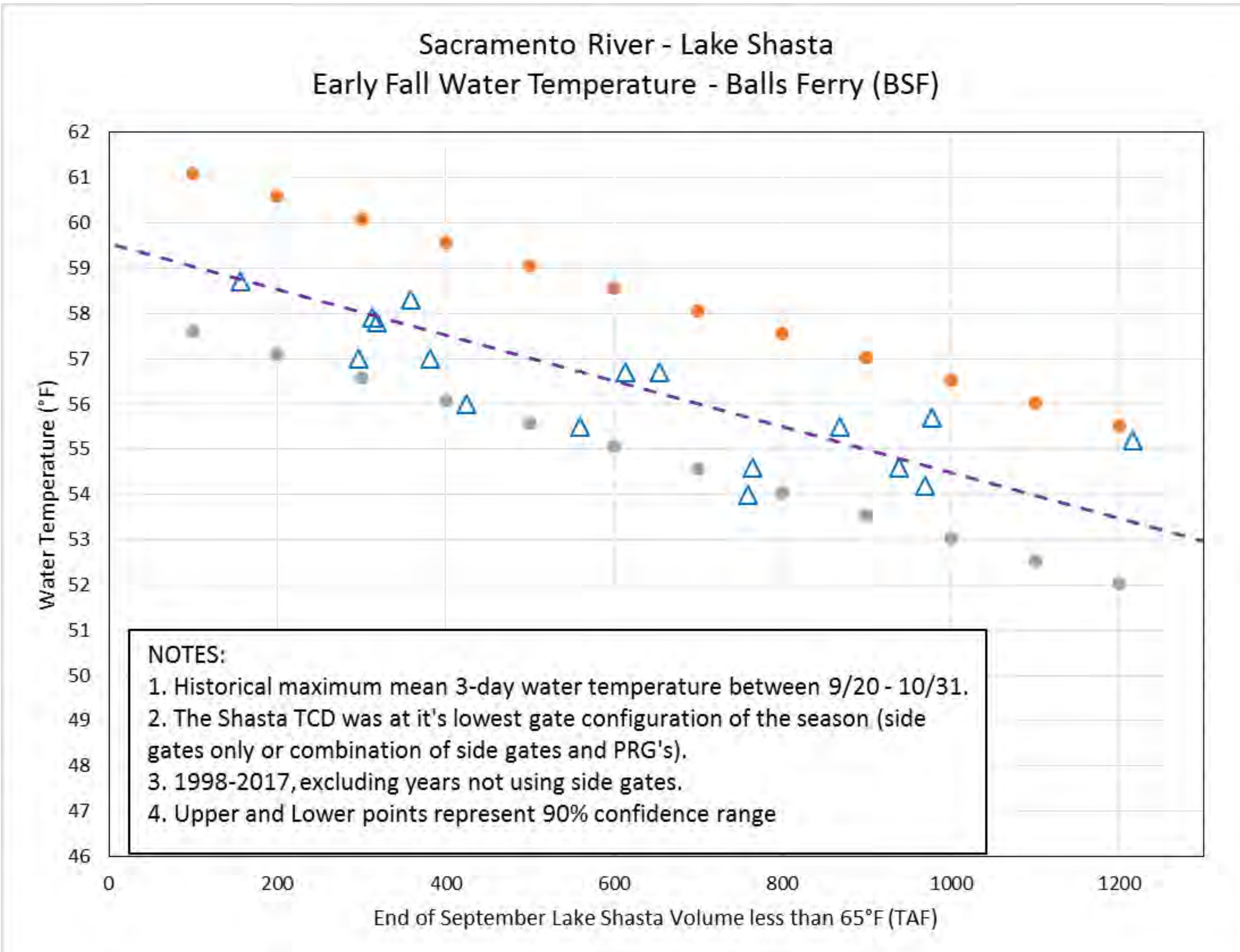

Sacramento River - Lake Shasta
Early Fall Water Temperature - Balls Ferry (BSF)
Water Temperature (°F)
62
61
60
59
58
57
56
55
54
53
52
51
50
49
48
47
46
0
200
400
600
800
1000
1200
End of September Lake Shasta Volume less than 65°F (TAF)
NOTES:
1. Historical maximum mean 3-day water temperature between 9/20 - 10/31.
2. The Shasta TCD was at it's lowest gate configuration of the season (side gates only or combination of side gates and PRG's).
3. 1998-2017, excluding years not using side gates.
4. Upper and Lower points represent 90% confidence range

Figure 4

Enclosure 5

Summary Document for Shasta/Keswick Operational Scenarios
Prepared by the Southwest Fisheries Science Center on May 14th, 2018

Below are results comparing five USBR scenarios ran Apr 26th 2018. Scenarios differ by hydrology (Input 50 or 90 percent exceedance) and air temperature (10 or 50 exceedance of L3MTO), with one scenario (ending of CCR) targeting temperature compliance at CCR rather than BSF (all others). A set of mortality model runs were generated using USBR's HEC-5Q model output (Table 1 and Figures 4-5) where temperatures from the HEC-5Q nodes were linearly interpolated in space.

Further details of modeling methods are at: http://oceanview.pfeg.noaa.gov/CVTEMP/

Table 1: Estimated temperature-dependent egg mortality under different scenarios assuming a 2012-2017 spatial and temporal redd distribution using HEC-5Q output.

Scenario	Mean (%)	Median (%)	Lower (%)	Upper (%)
APR_26_2018_INPUT_50_OUTPUT_50_10L3MTO	10.38	3.15	0.08	55.02
APR_26_2018_INPUT_50_OUTPUT_50_50L3MTO	9.44	2.02	0.08	54.16
APR_26_2018_INPUT_90_OUTPUT_90_10L3MTO	11.88	3.08	0.08	58.41
APR_26_2018_INPUT_90_OUTPUT_90_50L3MTO	9.77	2.07	0.08	55.01
APR_26_2018_INPUT_90_OUTPUT_90_10L3MTO_CCR	5.16	0.27	0.08	44.30

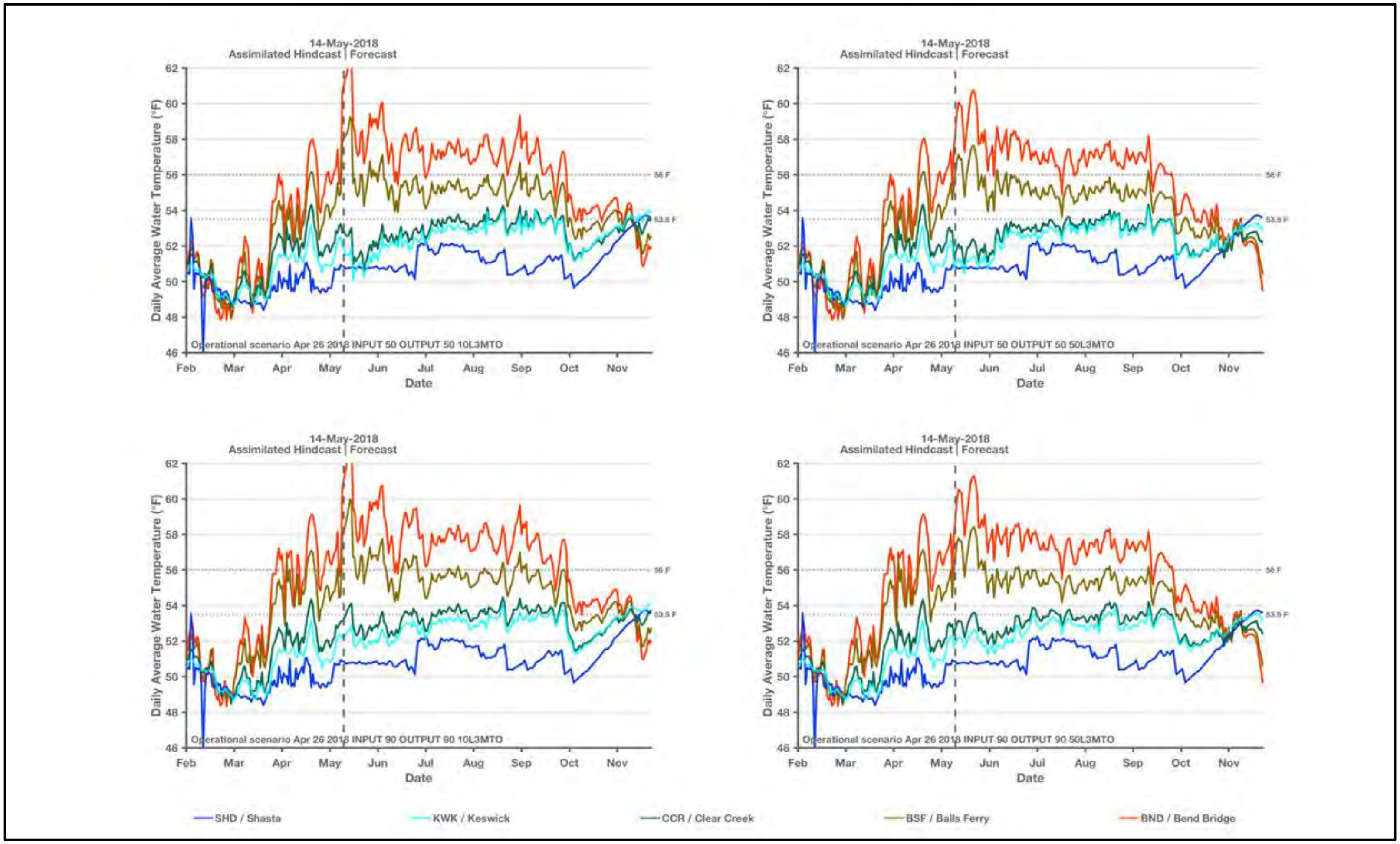


Figure 2: Estimated daily average water temperature produced by scenario input (Shasta and Keswick) and the RAFT model (Clear Creek, Balls Ferry, and Bend Bridge) under the four Apr 26th 2018 scenarios using HEC-5Q output.

Figure 3: Estimated daily average water temperature produced by scenario input (Shasta and Keswick) and the RAFT model (Clear Creek, Balls Ferry, and Bend Bridge) under the one April 26th 2018 scenario targeting CCR using HEC-5Q output.

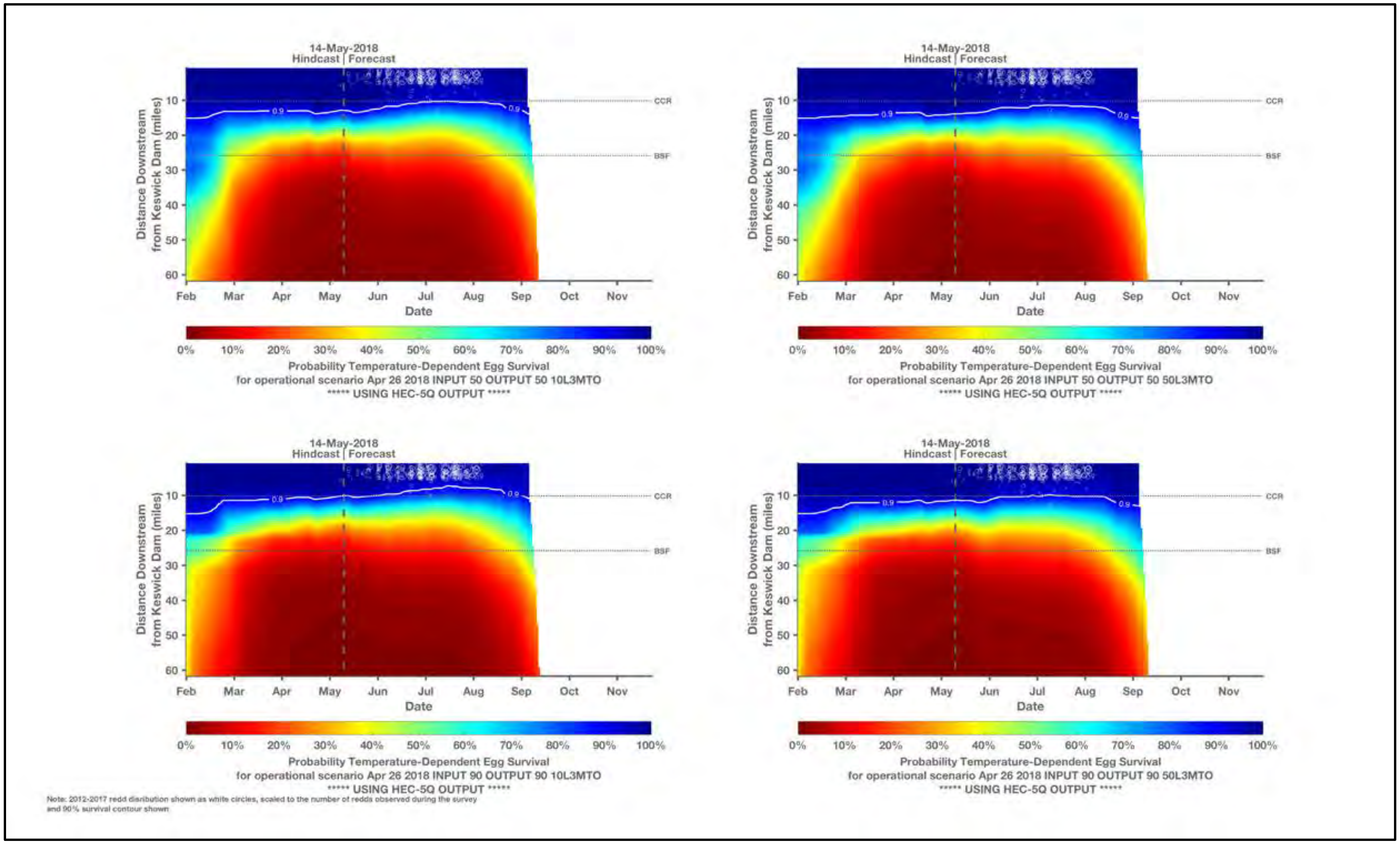


Figure 3: Estimated temperature-dependent egg survival produced by the NMFS temperature mortality model under the four April 26th 2018 scenarios using HEC-5Q output.

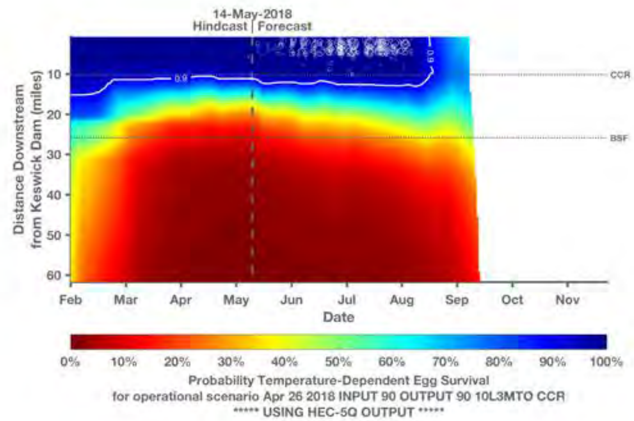


Figure 3: Estimated temperature-dependent egg survival produced by the NMFS temperature mortality model under the one April 26th 2018 scenario targeting CCR using HEC-5Q output.

Reference:

Martin, B. T., Pike, A., John, S. N., Hamda, N., Roberts, J., Lindley, S. T. and Danner, E. M. (2017), Phenomenological vs. biophysical models of thermal stress in aquatic eggs. Ecology Letters 20: 50–59. doi:10.1111/ele.12705

Enclosure 6

May 08, 2018

Upper Sacramento River – April 2018 Preliminary Temperature Analysis

Summary of Temperature Results by Month (Monthly Average Temperature °F)

Location	MAY	JUN	JUL	AUG	SEP	OCT	Late Sep-Oct Uncertainty Estimation
April 90%-Exceedance Outlook – 10% Historical Meteorology 53.5°F CCR							
Keswick Dam KWK	52.8	52.9	53.0	52.9	53.1	52.9	54 - 57
Sac. R. abv Clear Creek CCR	53.5	53.5	53.5	53.4	53.5	53.0	54 - 58
Balls Ferry BSF	57.2	56.5	55.5	55.3	55.3	54.1	55 - 59
April 50%-Exceedance Outlook – 10% Historical Meteorology 53.5°F CCR							
Keswick Dam KWK	52.8	52.9	53.0	52.9	53.1	52.9	54 - 57
Sac. R. abv Clear Creek CCR	53.5	53.5	53.5	53.4	53.5	52.9	54 - 58
Balls Ferry BSF	57.4	56.4	55.6	55.3	55.3	54.1	55 - 59
April 90%-Exceedance Outlook – 10% Historical Meteorology 53°F CCR (May) 56°F BSF (Jun-Oct)							
Keswick Dam KWK	52.8	52.4	53.5	53.6	53.5	52.3	54 - 56
Sac. R. abv Clear Creek CCR	53.5	53.0	54.0	54.1	53.9	52.4	54 - 58
Balls Ferry BSF	57.2	56.0	56.0	56.0	55.6	53.6	55 - 58
April 50%-Exceedance Outlook – 10% Historical Meteorology 53°F CCR (May) 56°F BSF (Jun-Oct)							
Keswick Dam KWK	52.8	52.3	53.5	53.6	53.6	52.3	53 - 56
Sac. R. abv Clear Creek CCR	53.5	52.9	54.0	54.1	54.0	52.4	54 - 57
Balls Ferry BSF	57.3	56.0	56.0	56.0	55.8	53.6	55 - 58

* The HEC5Q model output is displayed above for the months April through October. Based on past analysis, the temperature model does not perform well in late September and October. One factor is that the modeled release temperatures are cooler than has

historically been achieved when all release is through the side gates (lowest gates), especially when there's a large temperature gradient between the pressure relief gates (PRG) and the side gates. For the months of September and October, an uncertainty estimate is provided based on the Fall Temperature Index (graphics below). This is based on a historical relationship between end-of-September Lake Shasta Volume less than 56°F and likely downstream temperature performances for the early fall months. The range represents the 90% confidence interval based on that data. Refinement of the concepts for those estimates is underway.

<u>Temperature Model Inputs, Assumptions, Limitations and Uncertainty</u>:

1. The latest available profiles for Shasta, Trinity, and Whiskeytown were taken on May 1, May 3, and May 2 respectively. Model results are sensitive to initial reservoir temperature conditions and the model performs best under highly stratified conditions. The model performs well after the reservoir stratifies, typically in late spring. The concern this year is assuming over or under estimations with variable hydrologic and meteorological conditions and not capturing the stratification with sufficient detail to project.
2. Guidance on forecasted flows from the creeks (e.g., Cow, Cottonwood, Battle, etc.) between Keswick Dam and Bend Bridge are not available beyond 5 days. Creek flows developed from the historical record that most closely reflects current conditions were used for all model runs. The resulting low creek flows can cause significant additional warming in the upper Sacramento River during spring.
3. Operation is based on the April 2018 Operation Outlooks and DWR Bulletin 120 inflow projections (monthly flows, reservoir release, and end-of-month reservoir storage) for the 90%- and 50%-exceedances. Trinity Lake inflows are updated with the CNRFC 90% runoff exceedance for the 90% runoff exceedance studies. The April 2018 Operation Outlook is modified to adjust for real-time operations in early May suggesting the monthly Keswick release may average closer to 8,500 cfs.
4. Although mean daily flows and releases are temperature model inputs, they are based on the mean monthly values from the operation outlooks. Mean daily flow patterns are user defined and are generalized representations. It is important to note that these outlooks do not suggest a certain actual future outcome, but rather the statistical likelihood of an event occurring, including, but not limited to, projected storage and releases. Thus, the outlooks do not provide exact end of month storages or flow rates but general projections that will likely fall within the range of uncertainty based on the different hydrologic runoff conditions between the 90% and 50% runoff exceedance hydrology.
5. Cottonwood Creek flows, Keswick to Bend Bridge local flows, and ACID diversions are mean daily synthesized flows based on the available historical record for a 1922-2002 study period. Inflows were adjusted to a 95% historical exceedance for both the 90% and 50% runoff exceedance studies.
6. Meteorological inputs represent historical (1985 – 2017) monthly mean equilibrium temperature exceedance at 10% and 50% patterned after like months on a 6-hour time-step, or as noted. Assumed inflow temperature remain static inputs and do not vary with the assumed meteorology.

7. Meteorology, as well as the flow volume and pattern, significantly influences reservoir inflow temperatures and downstream tributary temperatures; and consequently, the development of the cold-water pool during winter and early spring.
8. Modified model coefficients more closely represent actual Keswick Dam temperatures. As a result, temperature predictions downstream of Keswick Dam are likely to be warmer than actual. Model re-calibrations efforts are underway.

Model Run Date May 7-8, 2018

Temperature Analysis Results:

Modeling runs explore Sacramento River compliance performance above Clear Creek confluence and Balls Ferry locations by varying hydrology and temperature compliance target location and temperature. The temperature results for the Sacramento River between Keswick Dam and Balls Ferry are shown in Figures 1-4. The fall uncertainty estimation relationship between end-of-September lake volume below 56°F and a Balls Ferry compliance through fall is based on the Figures 5-7.

Model Run	End of September Cold Water Pool <56°F (TAF)	First Side Gate	Full Side Gates
(1) 90% Hydro, 10% Historical Met 53.5 CCR	587	8/27	10/3
(2) 50% Hydro, 10% Historical Met 53.5 CCR	610	8/26	10/1
(3) 90% Hydro, 10% Historical Met 53 CCR (May) & 56 BSF (Jun-Oct)	633	9/8	10/6
(4) 50% Hydro, 10% Historical Met 53 CCR (May) & 56 BSF (Jun-Oct)	649	9/9	10/8

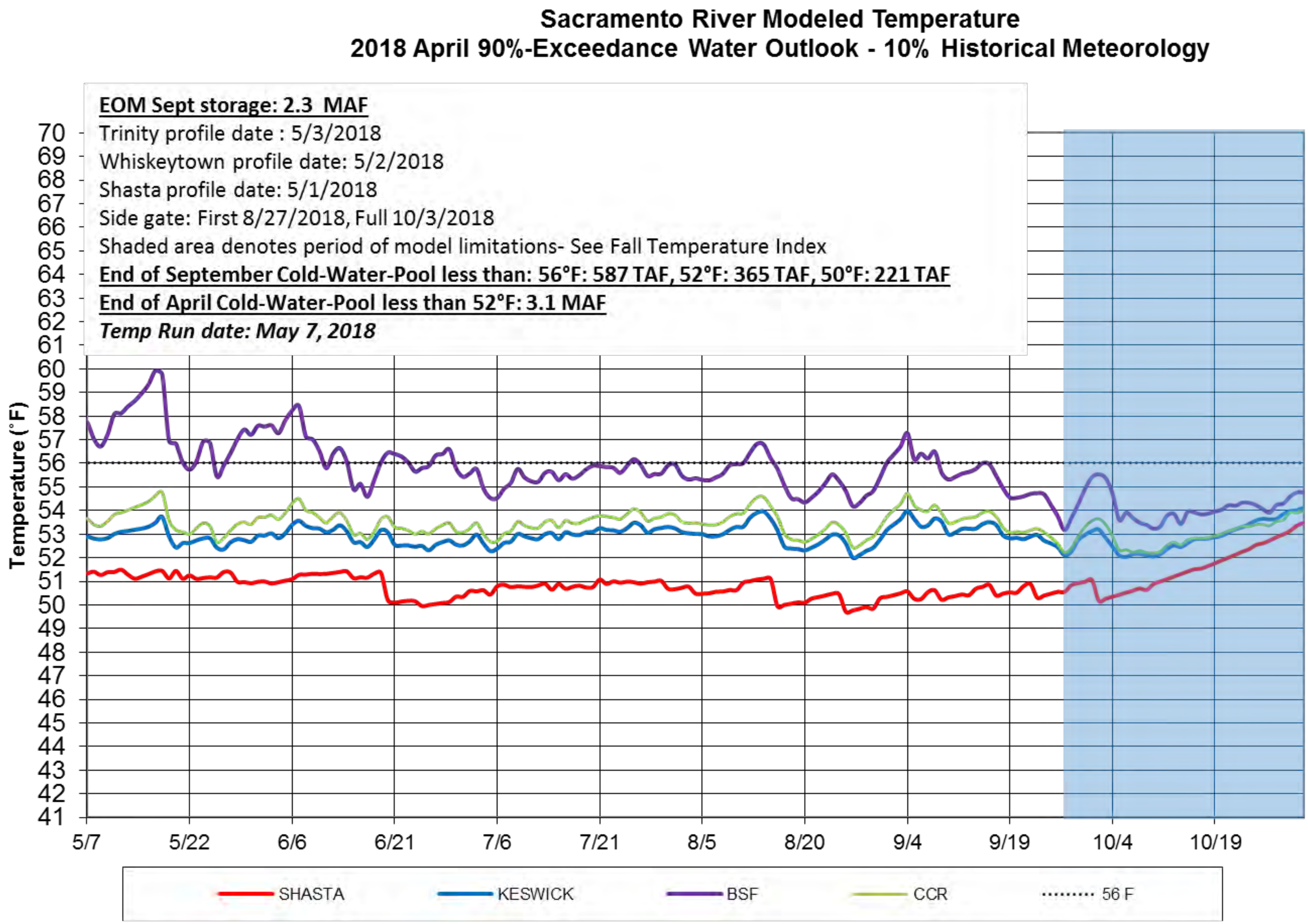
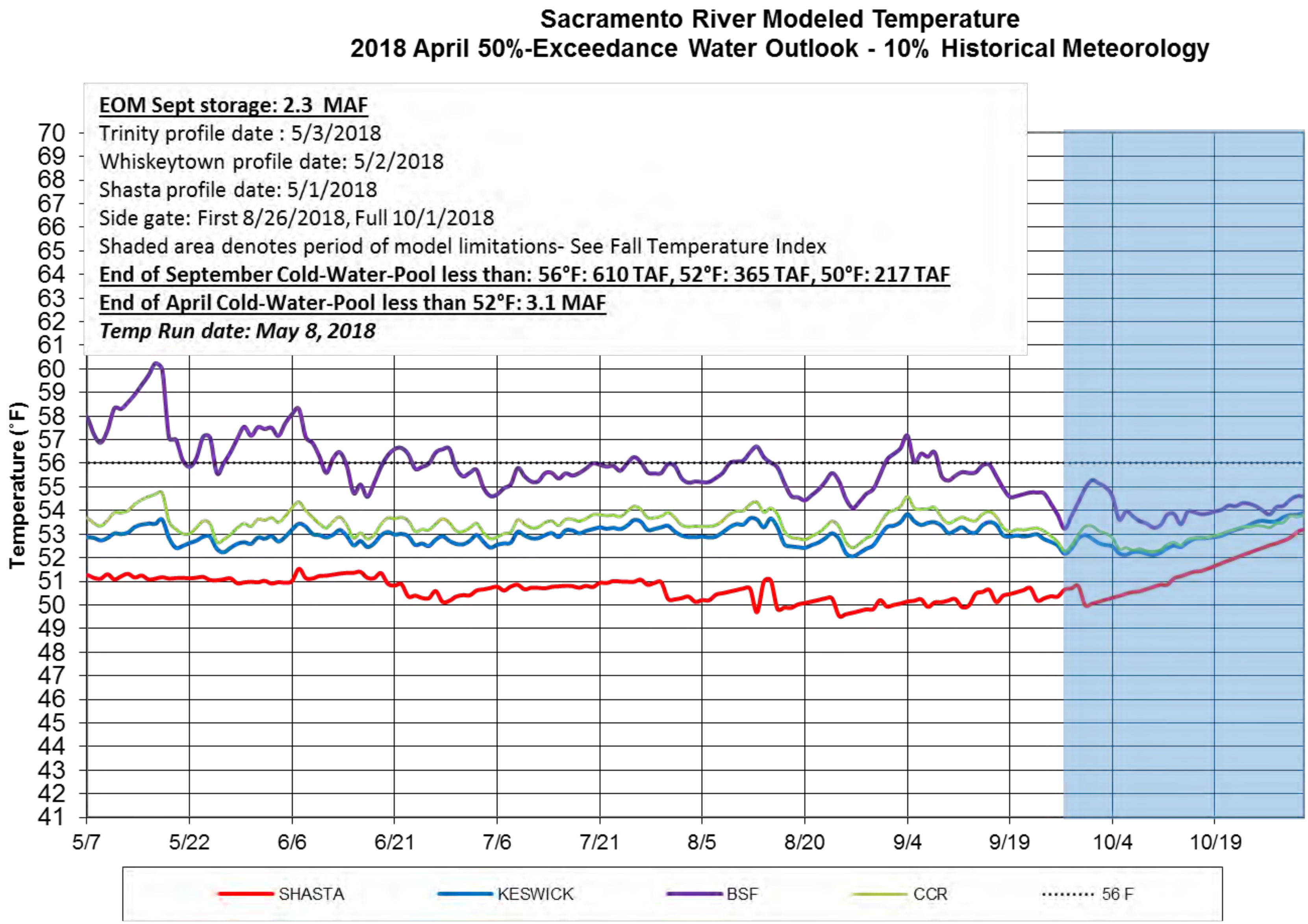

Sacramento River Modeled Temperature
2018 April 90%-Exceedance Water Outlook - 10% Historical Meteorology
EOM Sept storage: 2.3 MAF
Trinity profile date : 5/3/2018
Whiskeytown profile date: 5/2/2018
Shasta profile date: 5/1/2018
Side gate: First 8/27/2018, Full 10/3/2018
Shaded area denotes period of model limitations- See Fall Temperature Index
End of September Cold-Water-Pool less than: 56°F: 587 TAF, 52°F: 365 TAF, 50°F: 221 TAF
End of April Cold-Water-Pool less than 52°F: 3.1 MAF
Temp Run date: May 7, 2018
Temperature (°F)
70
69
68
67
66
65
64
63
62
61
60
59
58
57
56
55
54
53
52
51
50
49
48
47
46
45
44
43
42
41
5/7
5/22
6/6
6/21
7/6
7/21
8/5
8/20
9/4
9/19
10/4
10/19
SHASTA
KESWICK
BSF
CCR
56 F

Figure 1


Sacramento River Modeled Temperature
2018 April 50%-Exceedance Water Outlook - 10% Historical Meteorology
EOM Sept storage: 2.3 MAF
Trinity profile date : 5/3/2018
Whiskeytown profile date: 5/2/2018
Shasta profile date: 5/1/2018
Side gate: First 8/26/2018, Full 10/1/2018
Shaded area denotes period of model limitations- See Fall Temperature Index
End of September Cold-Water-Pool less than: 56°F: 610 TAF, 52°F: 365 TAF, 50°F: 217 TAF
End of April Cold-Water-Pool less than 52°F: 3.1 MAF
Temp Run date: May 8, 2018
Temperature (˚F)
70
69
68
67
66
65
64
63
62
61
60
59
58
57
56
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46
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44
43
42
41
5/7
5/22
6/6
6/21
7/6
7/21
8/5
8/20
9/4
9/19
10/4
10/19
SHASTA
KESWICK
BSF
CCR
56 F

Figure 2

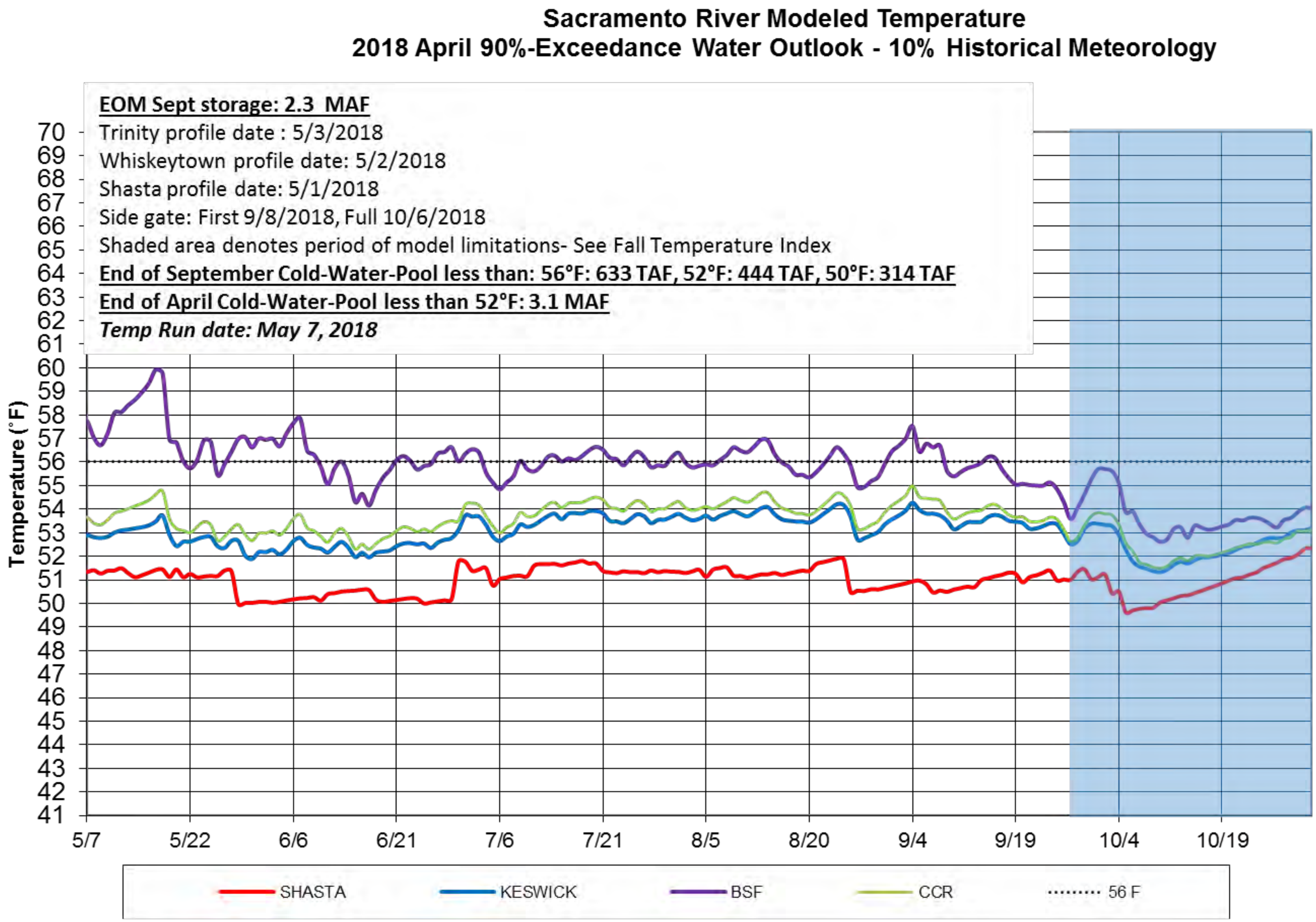

Sacramento River Modeled Temperature
2018 April 90%-Exceedance Water Outlook - 10% Historical Meteorology
EOM Sept storage: 2.3 MAF
Trinity profile date : 5/3/2018
Whiskeytown profile date: 5/2/2018
Shasta profile date: 5/1/2018
Side gate: First 9/8/2018, Full 10/6/2018
Shaded area denotes period of model limitations- See Fall Temperature Index
End of September Cold-Water-Pool less than: 56°F: 633 TAF, 52°F: 444 TAF, 50°F: 314 TAF
End of April Cold-Water-Pool less than 52°F: 3.1 MAF
Temp Run date: May 7, 2018
Temperature (°F)
70
69
68
67
66
65
64
63
62
61
60
59
58
57
56
55
54
53
52
51
50
49
48
47
46
45
44
43
42
41
5/7
5/22
6/6
6/21
7/6
7/21
8/5
8/20
9/4
9/19
10/4
10/19
SHASTA
KESWICK
BSF
CCR
56 F

Figure 3

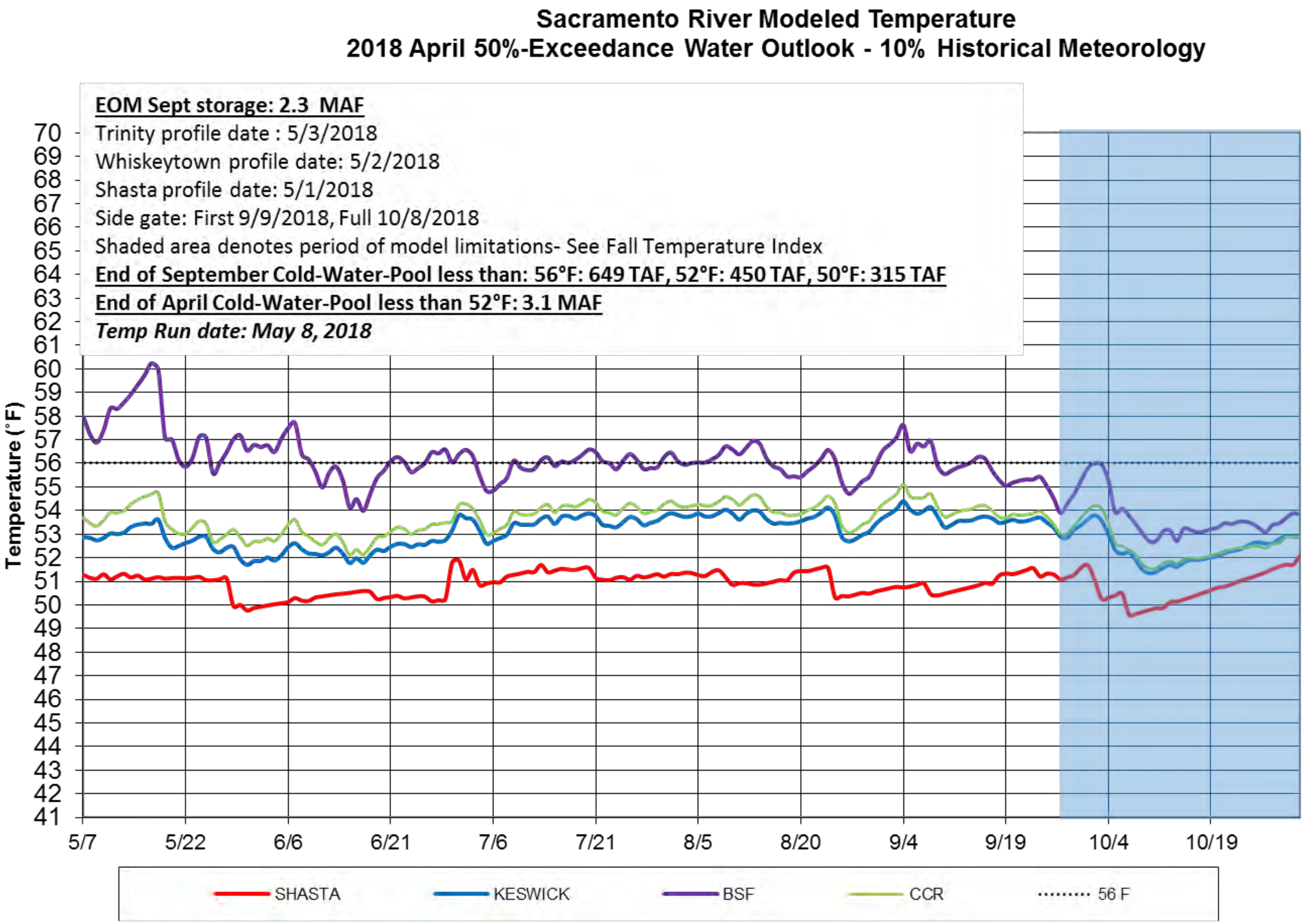

Sacramento River Modeled Temperature
2018 April 50%-Exceedance Water Outlook - 10% Historical Meteorology
EOM Sept storage: 2.3 MAF
Trinity profile date : 5/3/2018
Whiskeytown profile date: 5/2/2018
Shasta profile date: 5/1/2018
Side gate: First 9/9/2018, Full 10/8/2018
Shaded area denotes period of model limitations- See Fall Temperature Index
End of September Cold-Water-Pool less than: 56°F: 649 TAF, 52°F: 450 TAF, 50°F: 315 TAF
End of April Cold-Water-Pool less than 52°F: 3.1 MAF
Temp Run date: May 8, 2018
Temperature (°F)
70
69
68
67
66
65
64
63
62
61
60
59
58
57
56
55
54
53
52
51
50
49
48
47
46
45
44
43
42
41
5/7
5/22
6/6
6/21
7/6
7/21
8/5
8/20
9/4
9/19
10/4
10/19
SHASTA
KESWICK
BSF
CCR
56 F

Figure 4

Figures 5-7 Model Performance and Fall Temperature Index:

1. Based on past analyses, the temperature model does not perform well in late September and October. One factor is that the modeled release temperatures are cooler than has historically been achieved when all release is through the side gates (lowest gates), especially when there's a large temperature gradient between the pressure relief gates (PRG) and the side gates.
2. Based on historical records, the end-of-September Lake Shasta volume below 56˚F can be used as an indicator of fall water temperature in the river reach to Balls Ferry.
3. Based on these records and estimates, the index below illustrates a range of uncertainty in the ability to meet for river temperatures not to exceed 56 ˚F downstream based on the end-of-September lake volume less than 56˚F; see charts below.
4. Refinement of these estimates and concepts is currently underway.

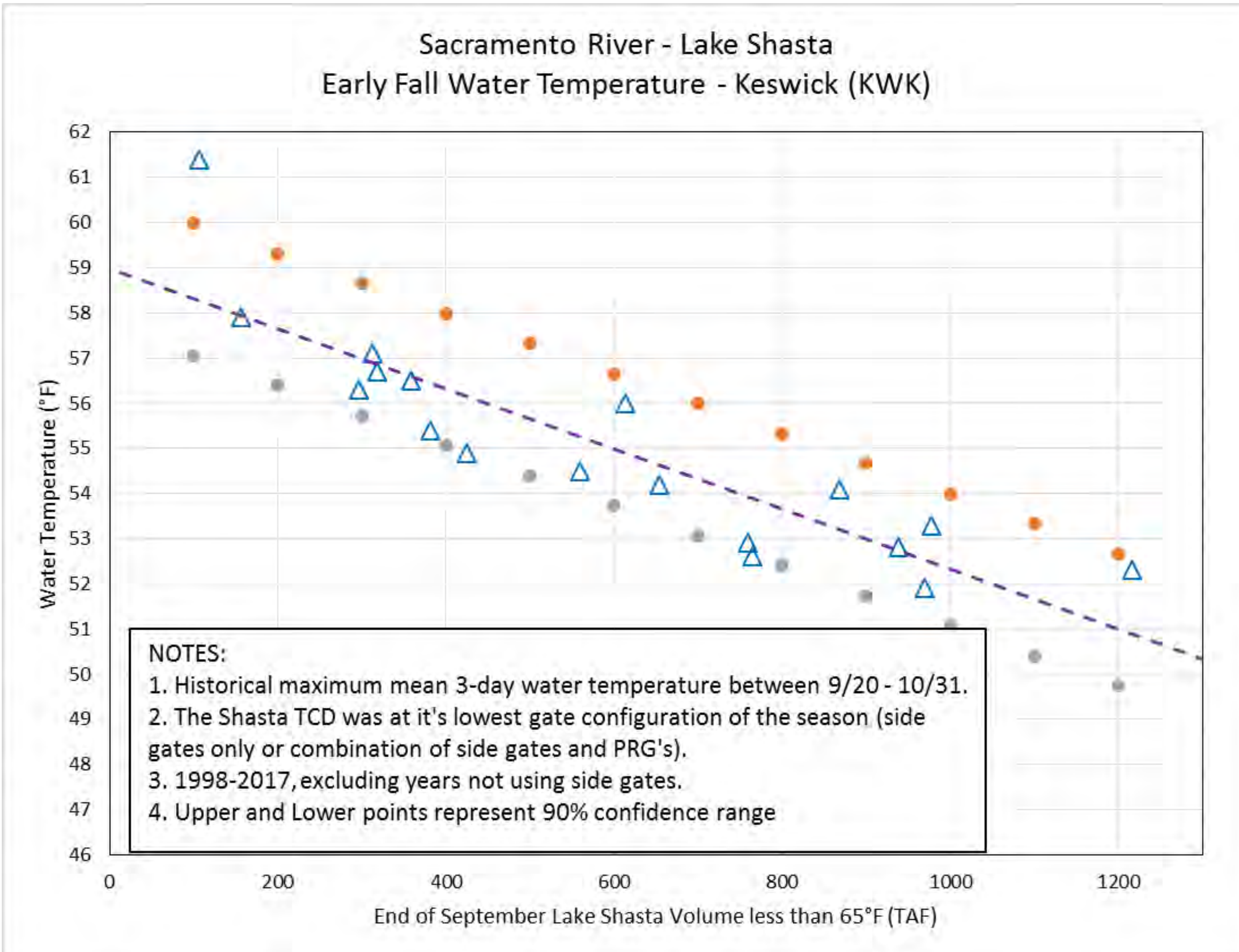

Sacramento River - Lake Shasta
Early Fall Water Temperature - Keswick (KWK)
Water Temperature (°F)
62
61
60
59
58
57
56
55
54
53
52
51
50
49
48
47
46
0
200
400
600
800
1000
1200
End of September Lake Shasta Volume less than 65°F (TAF)
NOTES:
1. Historical maximum mean 3-day water temperature between 9/20 - 10/31.
2. The Shasta TCD was at it's lowest gate configuration of the season (side gates only or combination of side gates and PRG's).
3. 1998-2017, excluding years not using side gates.
4. Upper and Lower points represent 90% confidence range

Figure 5

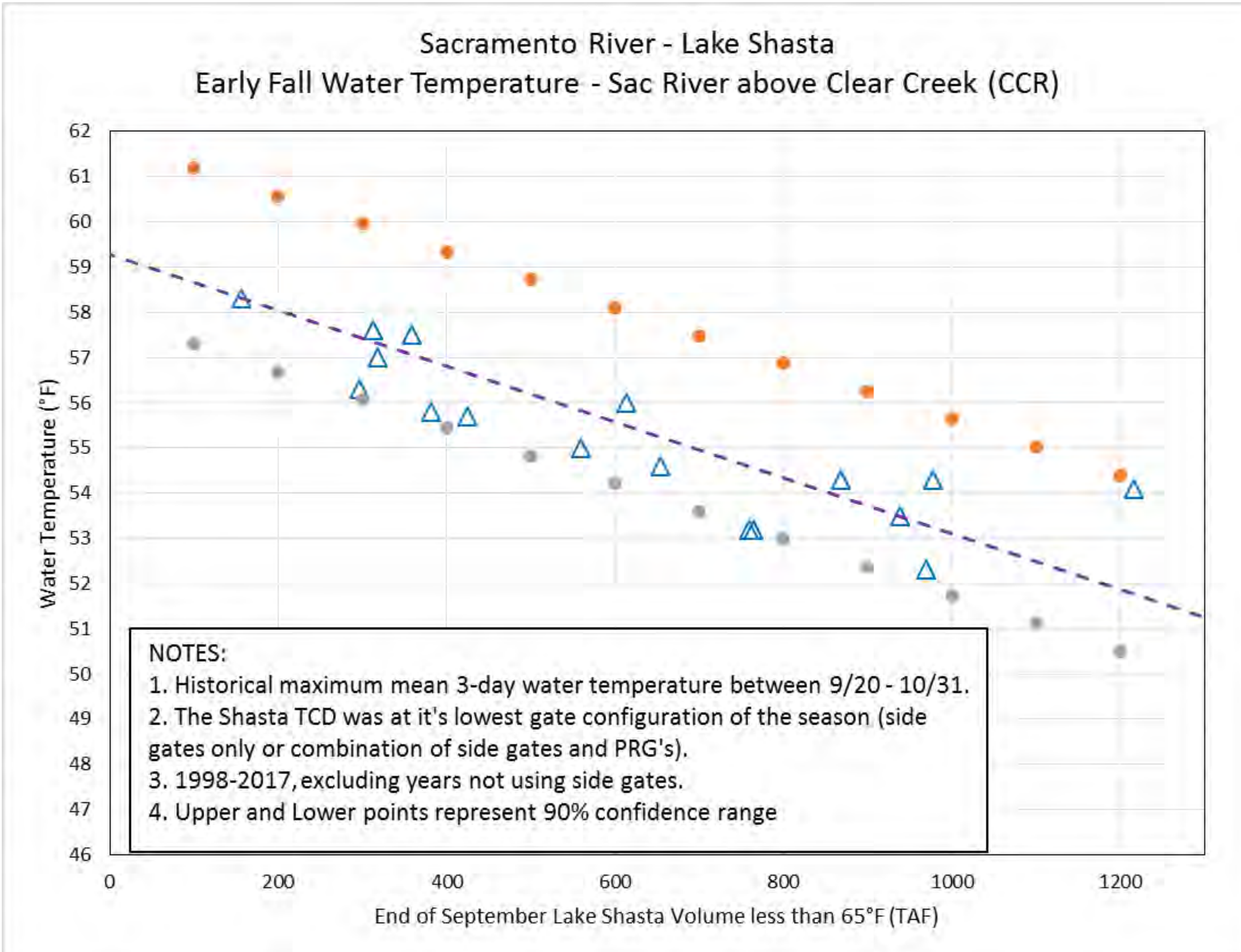

Sacramento River - Lake Shasta
Early Fall Water Temperature - Sac River above Clear Creek (CCR)
Water Temperature (°F)
62
61
60
59
58
57
56
55
54
53
52
51
50
49
48
47
46
0
200
400
600
800
1000
1200
End of September Lake Shasta Volume less than 65°F (TAF)
NOTES:
1. Historical maximum mean 3-day water temperature between 9/20 - 10/31.
2. The Shasta TCD was at it's lowest gate configuration of the season (side gates only or combination of side gates and PRG's).
3. 1998-2017, excluding years not using side gates.
4. Upper and Lower points represent 90% confidence range

Figure 6

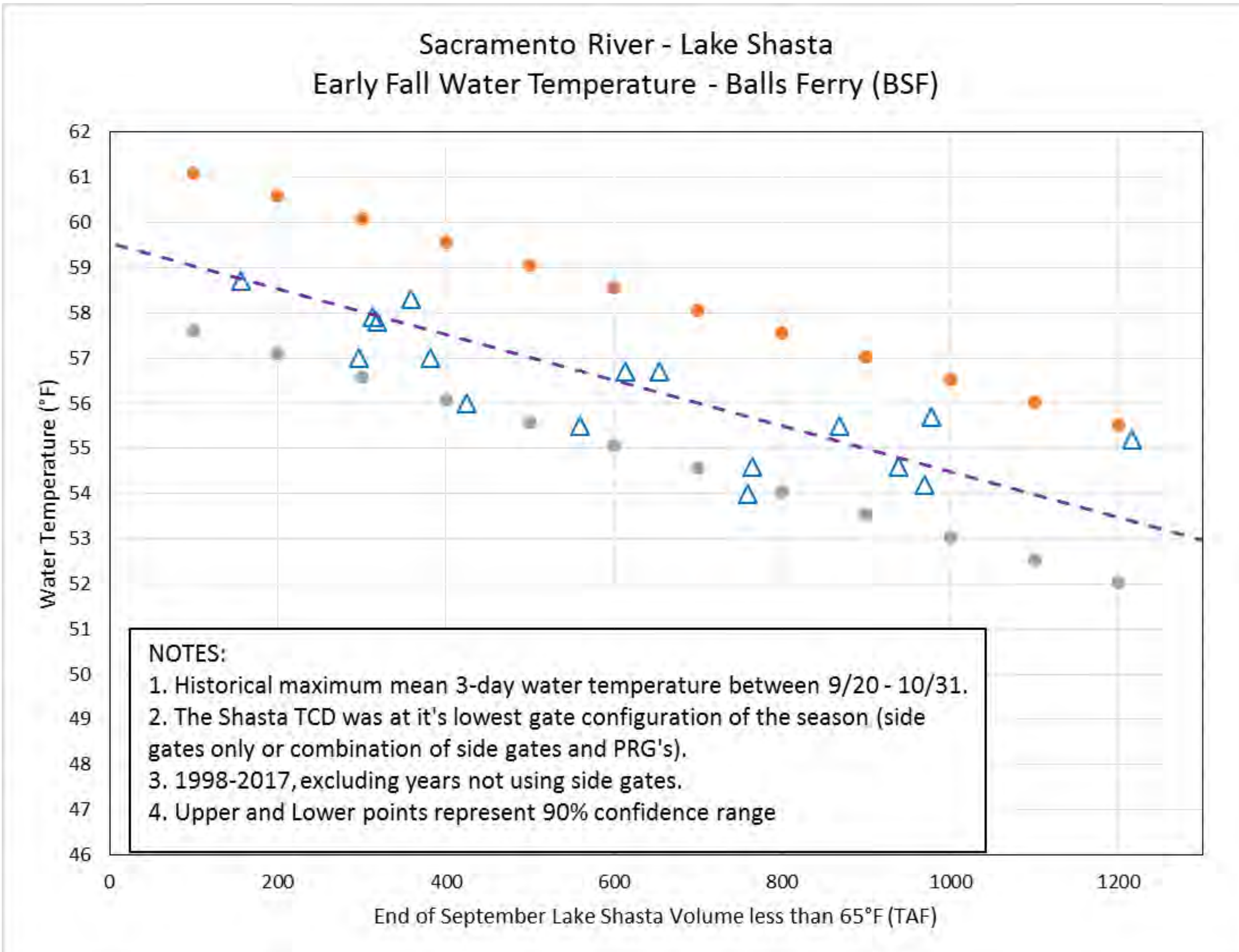

Sacramento River - Lake Shasta
Early Fall Water Temperature - Balls Ferry (BSF)
Water Temperature (°F)
62
61
60
59
58
57
56
55
54
53
52
51
50
49
48
47
46
0
200
400
600
800
1000
1200
End of September Lake Shasta Volume less than 65°F (TAF)
NOTES:
1. Historical maximum mean 3-day water temperature between 9/20 - 10/31.
2. The Shasta TCD was at it's lowest gate configuration of the season (side gates only or combination of side gates and PRG's).
3. 1998-2017, excluding years not using side gates.
4. Upper and Lower points represent 90% confidence range

Figure 7

Enclosure 7

Summary Document for Shasta/Keswick Operational Scenarios
Prepared by the Southwest Fisheries Science Center on May 9th, 2018

Below are results comparing four USBR scenarios ran May 8th 2018. Scenarios differ by hydrology (Input 50 or 90 percent exceedance) and temperature target strategies (53.5 F at CCR for the entire season, or 53 at CCR in May followed by 56 at BSF from June to October), with air temperature at 10 exceedances of L3MTO. Inputs from scenarios are used to generate daily average Sacramento River water temperatures using the RAFT model and associated temperature-dependent egg mortality and survival estimates using the NMFS temperature mortality model (Martin et al. 2017) for the 2018 temperature management season (Table 1 and Figures 2-3). Additionally, a set of mortality model runs were generated using USBR's HEC-5Q model output (Table 2 and Figures 4-5) for comparison purposes, where the RAFT model was not used, but temperatures from the HEC-5Q nodes were linearly interpolated in space.

Further details of modeling methods are at: http://oceanview.pfeg.noaa.gov/CVTEMP/

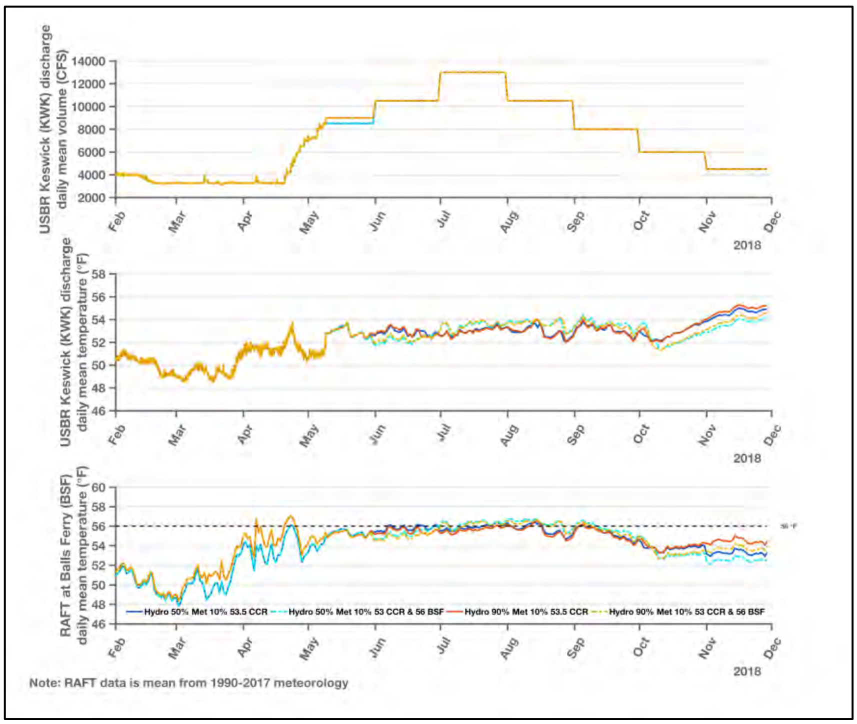


Figure 1: Summary plots showing differences in Keswick discharge volume and temperature, and Balls Ferry RAFT predicted temperature for four scenarios assessed.

Table 1: Estimated temperature-dependent egg mortality under different scenarios assuming a 2012-2017 spatial and temporal redd distribution.

Scenario	Mean (%)	Median (%)	Lower (%)	Upper (%)
MAY_08_2018_INPUT_50_OUTPUT_50_10L3MTO_53_CCR	11.95	3.63	0.08	58.78
MAY_08_2018_INPUT_50_OUTPUT_50_10L3MTO_53_CCR_56_BSF	25.24	22.49	0.08	67.56
MAY_08_2018_INPUT_90_OUTPUT_90_10L3MTO_53_CCR	12.49	4.84	0.08	58.64
MAY_08_2018_INPUT_90_OUTPUT_90_10L3MTO_53_CCR_56_BSF	24.37	21.12	0.08	67.02

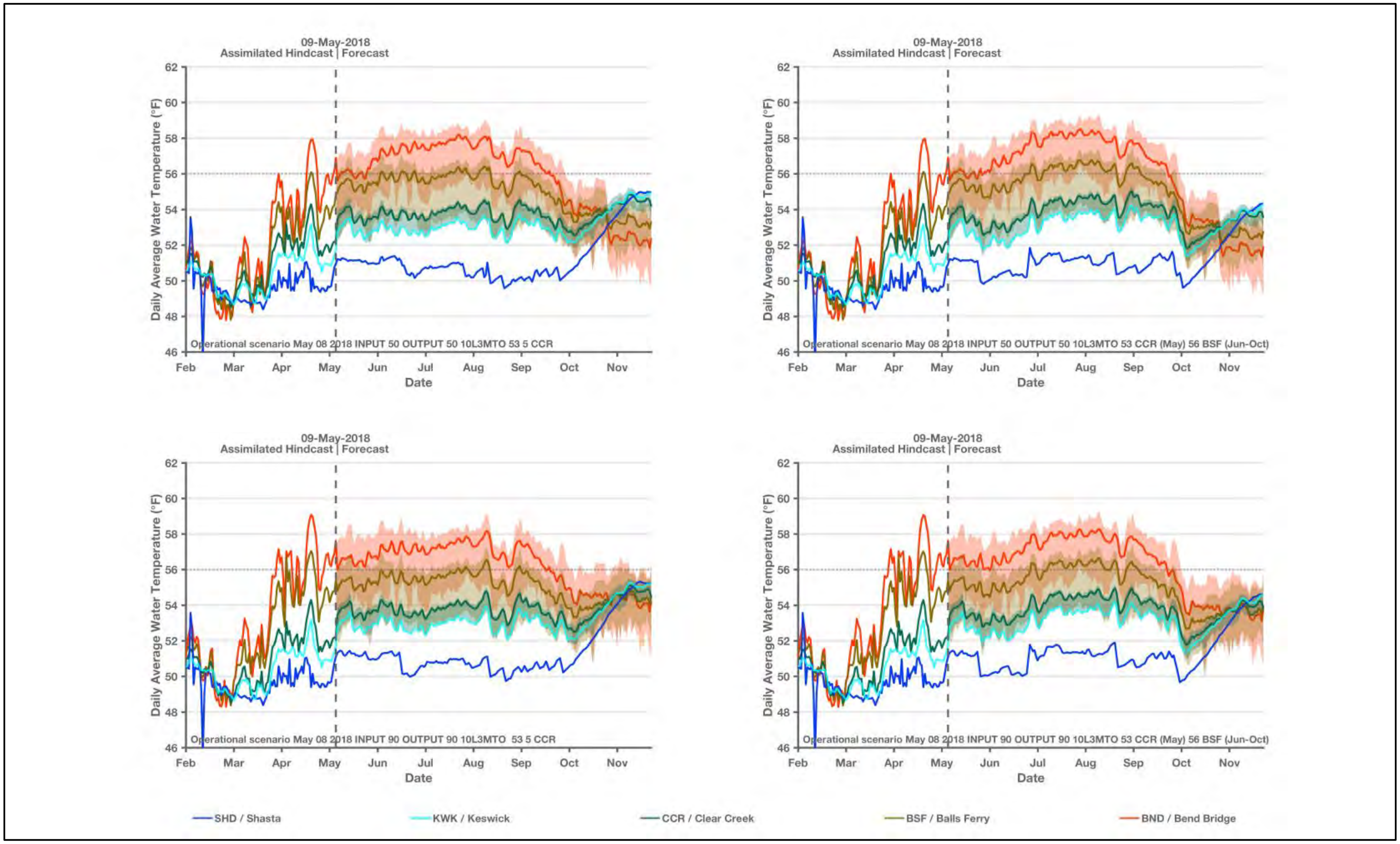


Figure 2: Estimated daily average water temperature produced by scenario input (Shasta and Keswick) and the RAFT model (Clear Creek, Balls Ferry, and Bend Bridge) under the four May 8th 2018 scenarios.

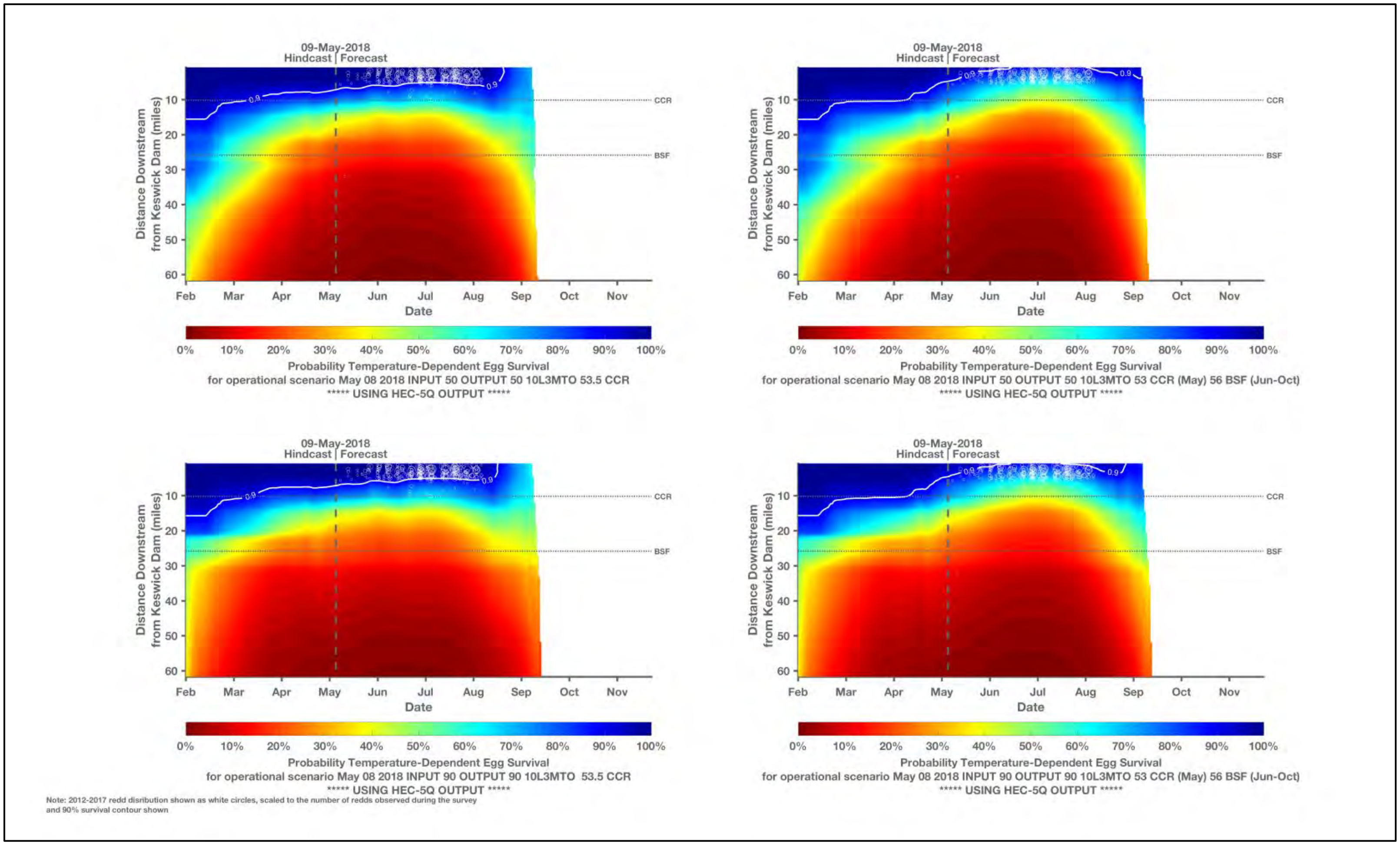


Figure 3: Estimated temperature-dependent egg survival produced by the NMFS temperature mortality model under the four May 8th 2018 scenarios.

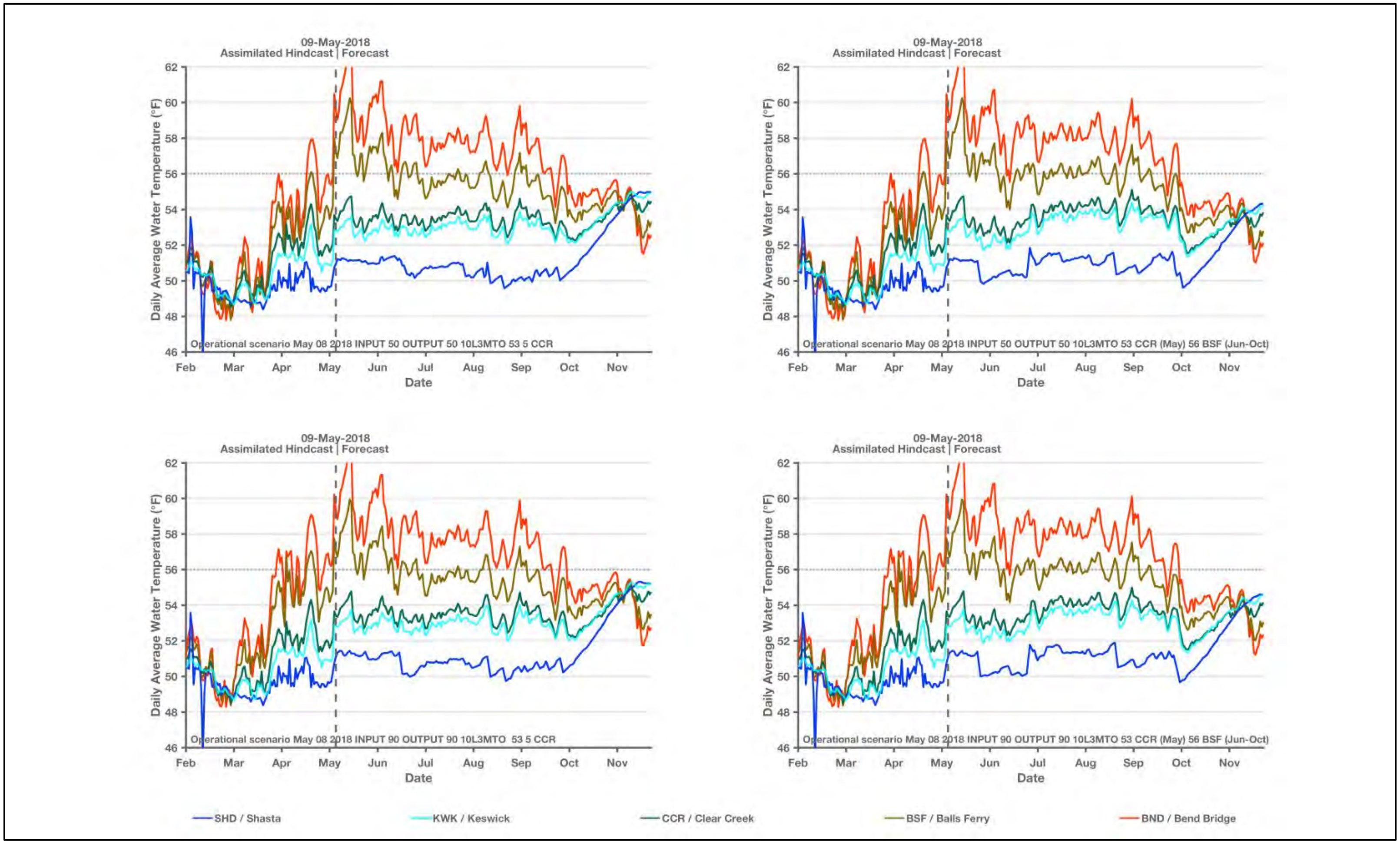


Figure 4: Estimated daily average water temperature produced by scenario input (Shasta, Keswick, Clear Creek, Balls Ferry, and Bend Bridge) under the four May 8th 2018 scenarios using HEC-5Q output.

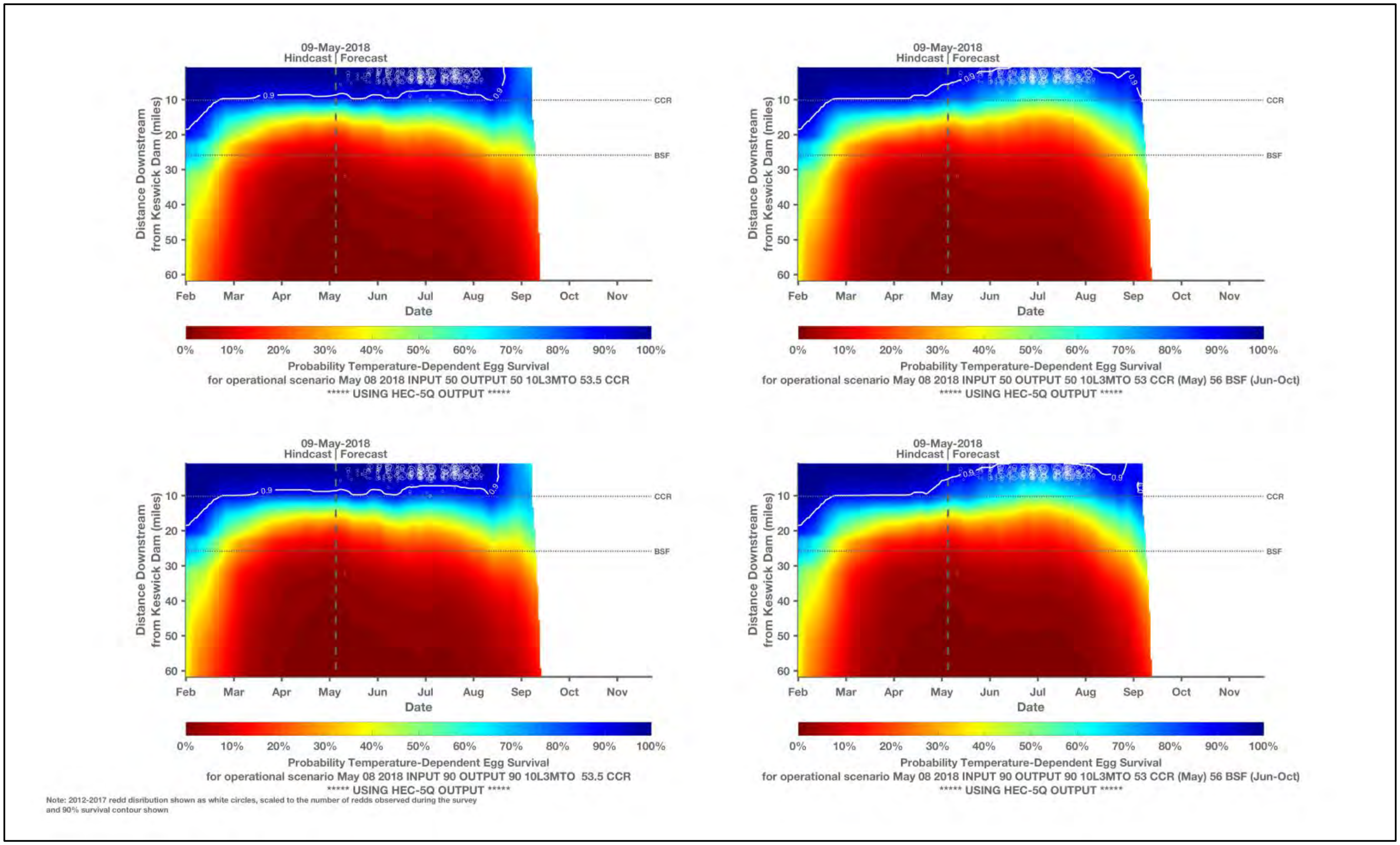


Figure 4: Estimated temperature-dependent egg survival produced by the NMFS temperature mortality model under the four May 8th 2018 scenarios using HEC-5Q output. To generate temperatures between HEC-5Q model nodes (KESWICK, CLEAR_CR, BALL_FERRY, JELLYS_FERRY, BEND_BR, and RED_BLIFF) linear interpolation in space was used.

Table 2: Estimated temperature-dependent egg mortality under different scenarios assuming a 2012-2017 spatial and temporal redd distribution using HEC-5Q output.

Scenario	Mean (%)	Median (%)	Lower (%)	Upper (%)
MAY_08_2018_INPUT_50_OUTPUT_50_10L3MTO_53_CCR	10.90	2.94	0.08	56.61
MAY_08_2018_INPUT_50_OUTPUT_50_10L3MTO_53_CCR_56_BSF	23.11	19.24	0.08	65.92
MAY_08_2018_INPUT_90_OUTPUT_90_10L3MTO_53_CCR	11.46	4.16	0.08	56.47
MAY_08_2018_INPUT_90_OUTPUT_90_10L3MTO_53_CCR_56_BSF	22.3	17.9	0.08	65.35

Reference:

Martin, B. T., Pike, A., John, S. N., Hamda, N., Roberts, J., Lindley, S. T. and Danner, E. M. (2017), Phenomenological vs. biophysical models of thermal stress in aquatic eggs. Ecology Letters 20: 50–59. doi:10.1111/ele.12705

Enclosure 8

Estimated CVP Operations Apr 90% Exceedance

Storages

Federal End of the Month Storage/Elevation (TAF/Feet)

			Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar
Trinity		1844	1964	1893	1782	1679	1555	1439	1409	1390	1400	1432	1518	1615
	Elev.		2338	2333	2325	2318	2308	2298	2295	2294	2295	2297	2305	2313
Whiskeytown		207	238	238	238	238	238	230	206	206	206	206	206	206
	Elev.		1209	1209	1209	1209	1209	1207	1199	1199	1199	1199	1199	1199
Shasta		3880	4132	3981	3625	3046	2600	2320	2196	2190	2321	2518	2865	3321
	Elev.		1052	1047	1034	1010	989	975	968	968	975	985	1002	1021
Folsom		817	793	904	825	591	449	402	345	296	256	306	412	576
	Elev.		449	459	452	427	410	403	395	386	379	388	405	426
New Melones		2019	1977	1946	1922	1848	1784	1740	1709	1721	1735	1747	1770	1789
	Elev.		1050	1047	1045	1038	1032	1028	1025	1026	1027	1028	1031	1033
San Luis		876	773	574	266	88	8	72	198	382	526	666	699	762
	Elev.		510	485	445	421	399	414	431	451	476	491	493	505
Total			9877	9536	8658	7491	6634	6204	6063	6185	6443	6874	7470	8268

State End of the Month Reservoir Storage (TAF)

Oroville													
San Luis Total San Luis (TAF)	1774	1622	1335	919	697	518	638	791	986	1245	1411	1422	1565

Monthly River Releases (TAF/cfs)

		Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar
Trinity	TAF	36	92	47	28	53	52	23	18	18	18	17	18
	cfs	600	1,498	783	450	857	870	373	300	300	300	300	300
Clear Creek	TAF	13	13	17	9	9	9	12	12	12	12	11	12
	cfs	218	216	288	150	150	150	200	200	200	200	200	200
Sacramento	TAF	297	523	625	799	645	476	369	268	200	200	180	200
	cfs	5000	8500	10500	13000	10500	8000	6000	4500	3250	3250	3250	3250
American	TAF	506	77	167	293	204	107	92	89	92	61	56	77
	cfs	8500	1250	2811	4768	3311	1798	1500	1500	1500	1000	1005	1250
Stanislaus	TAF	83	96	56	18	18	18	49	12	12	14	13	12
	cfs	1400	1555	940	300	300	300	797	200	200	232	236	200
Feather													
	cfs												

Trinity Diversions (TAF)

	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar
Carr PP	39	67	85	80	71	62	16	21	12	3	2	15
Spring Crk. PP	10	60	70	70	60	60	30	15	12	10	20	30

Delta Summary (TAF)

		Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar
Tracy		93	61	53	225	260	262	265	250	190	190	120	200
USBR Banks		0	0	0	18	18	18	0	0	0	0	0	0
Contra Costa		12.7	12.7	9.8	11.1	12.7	14.0	16.8	18.4	18.3	14.0	14.0	12.7
Total USBR		106	74	63	254	291	294	282	268	208	204	134	213
State Export													
Total Export		182	105	110	375	355	444	433	374	394	394	261	413
COA Balance		25	25	0	0	0	87	87	87	87	87	46	46
Old/Middle River Std.													
Old/Middle R. calc.		-164	146	-1,354	-4,912	-4,693	-5,945	-5,221	-4,877	-4,978	-4,960	-3,536	-5,040
Computed DOI		30476	10004	7900	6507	4002	3009	4067	4572	6767	9728	11400	12379
Excess Outflow		19079	2098	0	0	0	0	65	67	2261	3725	0	976
% Export/Inflow		8%	11%	13%	35%	40%	54%	54%	52%	47%	41%	29%	34%
% Export/Inflow std.		35%	35%	35%	65%	65%	65%	65%	65%	65%	65%	45%	35%

Hydrology

	Trinity	Shasta	Folsom	New Melones
Water Year Inflow (TAF) Year to Date + Forecasted	627	3,621	2,352	972
% of mean	52%	65%	86%	92%

CVP actual operations do not follow any forecasted operation or outlook; actual operations are based on real-time conditions.
CVP operational forecasts or outlooks represent general system-wide dynamics and do not necessarily address specific watershed/tributary details.
CVP releases or export values represent monthly averages.
CVP Operations are updated monthly as new hydrology information is made available December through May.

5/10/2018

Estimated CVP Operations Apr 50% Exceedance

Storages

Federal End of the Month Storage/Elevation (TAF/Feet)

			Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar
Trinity		1844	1878	1860	1773	1659	1514	1381	1343	1330	1360	1425	1535	1629
	Elev.		2332	2331	2325	2316	2304	2293	2290	2288	2291	2297	2306	2314
Whiskeytown		207	238	238	238	238	238	230	206	206	206	206	206	206
	Elev.		1209	1209	1209	1209	1209	1207	1199	1199	1199	1199	1199	1199
Shasta		3880	4167	4055	3739	3205	2813	2586	2491	2541	2731	3138	3622	4179
	Elev.		1054	1050	1038	1017	999	989	984	986	995	1014	1033	1054
Folsom		817	813	937	885	715	604	528	480	451	439	468	521	586
	Elev.		451	462	458	441	429	420	414	410	409	412	419	427
New Melones		2019	1996	2014	2018	1958	1894	1853	1812	1829	1852	1884	1938	1915
	Elev.		1052	1054	1054	1048	1043	1039	1035	1036	1039	1042	1047	1044
San Luis		876	816	594	341	152	54	106	224	396	604	748	865	937
	Elev.		508	471	418	387	372	409	443	469	498	491	498	503
Total			9908	9698	8994	7927	7117	6684	6556	6752	7192	7868	8687	9452

State End of the Month Reservoir Storage (TAF)

Oroville													
San Luis Total San Luis (TAF)	1774	1596	1186	676	421	317	598	904	1164	1488	1406	1487	1540

Monthly River Releases (TAF/cfs)

Trinity	TAF	36	92	47	28	53	52	23	18	18	18	17	18
	cfs	600	1,498	783	450	857	870	373	300	300	300	300	300
Clear Creek	TAF	13	13	17	9	9	9	12	12	12	15	11	12
	cfs	218	216	288	150	150	150	200	200	200	240	200	200
Sacramento	TAF	268	523	625	799	645	476	369	268	200	200	278	307
	cfs	4500	8500	10500	13000	10500	8000	6000	4500	3250	3250	5000	5000
American	TAF	535	154	188	249	184	149	123	119	123	123	208	246
	cfs	9000	2500	3158	4053	3000	2500	2000	2000	2000	2000	3750	4000
Stanislaus	TAF	86	96	56	18	18	18	49	12	12	14	13	93
	cfs	1454	1555	940	300	300	300	797	200	200	232	236	1521
Feather													

Trinity Diversions (TAF)

	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar
Carr PP	35	24	71	84	85	76	26	25	9	0	2	35
Spring Crk. PP	15	25	60	75	75	75	40	20	12	20	35	60

Delta Summary (TAF)

		Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar
Tracy		113	74	155	273	274	260	265	245	260	205	215	221
USBR Banks		0	0	0	24	24	24	0	0	0	0	0	0
Contra Costa		12.7	12.7	9.8	11.1	12.7	14.0	16.8	18.4	18.3	14.0	14.0	12.7
Total USBR		126	86	165	308	311	298	282	263	278	219	229	234
State Export													
Total Export		231	105	182	528	589	694	686	531	538	269	444	421
COA Balance		25	25	0	0	0	0	0	0	0	0	0	0
Old/Middle River Std.													
Old/Middle R. calc.		-494	281	-1,960	-6,594	-7,419	-8,991	-8,251	-6,720	-6,577	-3,086	-4,826	-3,440
Computed DOI		36611	13892	7900	6507	4018	3026	4018	4522	8085	17325	23701	25588
Excess Outflow		25214	4945	0	0	16	17	16	17	3579	11322	12301	14185
% Export/Inflow		9%	9%	21%	44%	54%	66%	65%	61%	51%	20%	25%	21%
% Export/Inflow std.		35%	35%	35%	65%	65%	65%	65%	65%	65%	65%	45%	35%

Hydrology

	Trinity	Shasta		Folsom	New Melones
Water Year Inflow (TAF)	539	3,864		2,586	1080
Year to Date + Forecasted % of mean	45%	70%		95%	102%

CVP actual operations do not follow any forecasted operation or outlook; actual operations are based on real-time conditions.
CVP operational forecasts or outlooks represent general system-wide dynamics and do not necessarily address specific watershed/tributary details.
CVP releases or export values represent monthly averages.
CVP Operations are updated monthly as new hydrology information is made available December through May.

5/10/2018

May 10, 2018

Upper Sacramento River – April 2018 Preliminary Temperature Analysis

Summary of Temperature Results by Month (Monthly Average Temperature °F)

Location	MAY	JUN	JUL	AUG	SEP	OCT	Late Sep-Oct Uncertainty Estimation
April 90%-Exceedance Outlook – 10% Historical Meteorology 53.5°F CCR							
Keswick Dam KWK	52.8	52.9	53.0	52.9	53.1	52.9	54 - 57
Sac. R. abv Clear Creek CCR	53.5	53.5	53.5	53.4	53.5	53.0	54 - 58
Balls Ferry BSF	57.2	56.5	55.5	55.3	55.3	54.1	55 - 59
April 90%-Exceedance Outlook – 50% Historical Meteorology 53.5°F CCR							
Keswick Dam KWK	52.9	53.0	53.1	53.0	53.0	52.3	54 - 56
Sac. R. abv Clear Creek CCR	53.5	53.5	53.5	53.5	53.4	52.4	54 - 58
Balls Ferry BSF	56.8	56.3	55.3	55.3	55.1	53.5	55 - 58
April 50%-Exceedance Outlook – 10% Historical Meteorology 53.5°F CCR							
Keswick Dam KWK	52.8	52.9	53.0	52.9	53.1	52.9	54 - 57
Sac. R. abv Clear Creek CCR	53.5	53.5	53.5	53.4	53.5	52.9	54 - 58
Balls Ferry BSF	57.4	56.4	55.6	55.3	55.3	54.1	55 - 59
April 50%-Exceedance Outlook – 50% Historical Meteorology 53.5°F CCR							
Keswick Dam KWK	52.9	52.9	53.1	53.0	53.1	52.3	53 - 56
Sac. R. abv Clear Creek CCR	53.5	53.5	53.5	53.4	53.5	52.3	54 - 58
Balls Ferry BSF	56.9	56.2	55.3	55.3	55.2	53.4	55 - 58

* The HEC5Q model output is displayed above for the months April through October. Based on past analysis, the temperature model does not perform well in late September and October. One factor is that the modeled release temperatures are cooler than has

historically been achieved when all release is through the side gates (lowest gates), especially when there's a large temperature gradient between the pressure relief gates (PRG) and the side gates. For the months of September and October, an uncertainty estimate is provided based on the Fall Temperature Index (graphics below). This is based on a historical relationship between end-of-September Lake Shasta Volume less than 56°F and likely downstream temperature performances for the early fall months. The range represents the 90% confidence interval based on that data. Refinement of the concepts for those estimates is underway.

Temperature Model Inputs, Assumptions, Limitations and Uncertainty:

1. The latest available profiles for Shasta, Trinity, and Whiskeytown were taken on May 1, May 3, and May 2 respectively. Model results are sensitive to initial reservoir temperature conditions and the model performs best under highly stratified conditions. The model performs well after the reservoir stratifies, typically in late spring. The concern this year is assuming over or under estimations with variable hydrologic and meteorological conditions and not capturing the stratification with sufficient detail to project.
2. Guidance on forecasted flows from the creeks (e.g., Cow, Cottonwood, Battle, etc.) between Keswick Dam and Bend Bridge are not available beyond 5 days. Creek flows developed from the historical record that most closely reflects current conditions were used for all model runs. The resulting low creek flows can cause significant additional warming in the upper Sacramento River during spring.
3. Operation is based on the April 2018 Operation Outlooks and DWR Bulletin 120 inflow projections (monthly flows, reservoir release, and end-of-month reservoir storage) for the 90%- and 50%-exceedances. Trinity Lake inflows are updated with the CNRFC 90% runoff exceedance for the 90% runoff exceedance studies. The April 2018 Operation Outlook is modified to adjust for real-time operations in early May suggesting the monthly Keswick release may average closer to 8,500 cfs.
4. Although mean daily flows and releases are temperature model inputs, they are based on the mean monthly values from the operation outlooks. Mean daily flow patterns are user defined and are generalized representations. It is important to note that these outlooks do not suggest a certain actual future outcome, but rather the statistical likelihood of an event occurring, including, but not limited to, projected storage and releases. Thus, the outlooks do not provide exact end of month storages or flow rates but general projections that will likely fall within the range of uncertainty based on the different hydrologic runoff conditions between the 90% and 50% runoff exceedance hydrology.
5. Cottonwood Creek flows, Keswick to Bend Bridge local flows, and ACID diversions are mean daily synthesized flows based on the available historical record for a 1922-2002 study period. Inflows were adjusted to a 95% historical exceedance for both the 90% and 50% runoff exceedance studies.
6. Meteorological inputs represent historical (1985 – 2017) monthly mean equilibrium temperature exceedance at 10% and 50% patterned after like months on a 6-hour time-step, or as noted. Assumed inflow temperature remain static inputs and do not vary with the assumed meteorology.

7. Meteorology, as well as the flow volume and pattern, significantly influences reservoir inflow temperatures and downstream tributary temperatures; and consequently, the development of the cold-water pool during winter and early spring.
8. Modified model coefficients more closely represent actual Keswick Dam temperatures. As a result, temperature predictions downstream of Keswick Dam are likely to be warmer than actual. Model re-calibrations efforts are underway.

Model Run Date May 7-10, 2018

Temperature Analysis Results:

Modeling runs explore Sacramento River compliance performance above Clear Creek confluence and Balls Ferry locations by varying hydrology and temperature compliance target location and temperature. The temperature results for the Sacramento River between Keswick Dam and Balls Ferry are shown in Figures 1-4. The fall uncertainty estimation relationship between end-of-September lake volume below 56°F and a Balls Ferry compliance through fall is based on the Figures 5-7.

Model Run	End of September Cold Water Pool <56°F (TAF)	First Side Gate	Full Side Gates
(1) 90% Hydro, 10% Historical Met 53.5 CCR	578	8/27	10/3
(2) 90% Hydro, 50% Historical Met 53.5 CCR	625	9/1	10/4
(3) 50% Hydro, 10% Historical Met 53.5 CCR	610	8/26	10/1
(4) 50% Hydro, 50% Historical Met 53.5 CCR	649	9/1	10/4

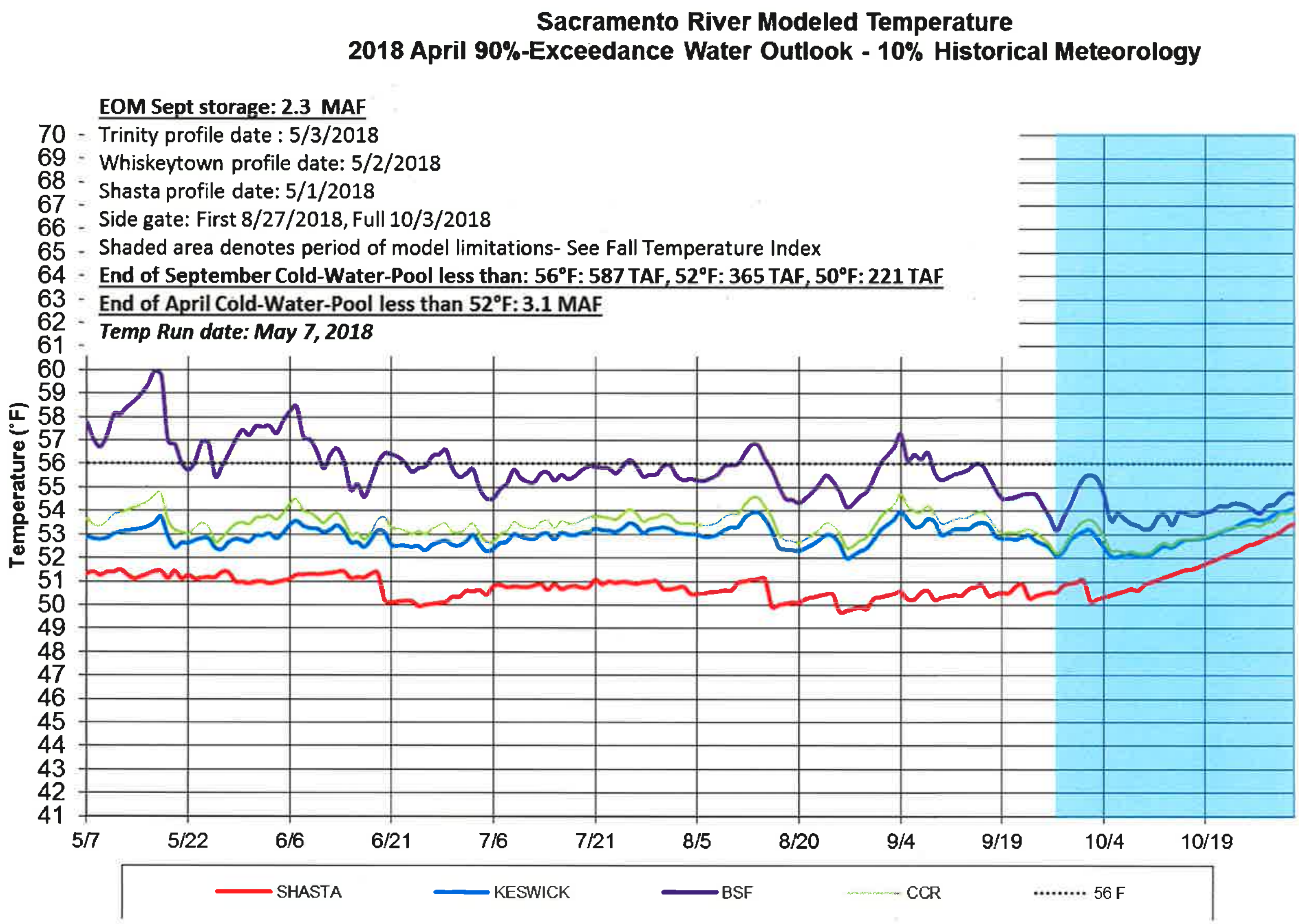
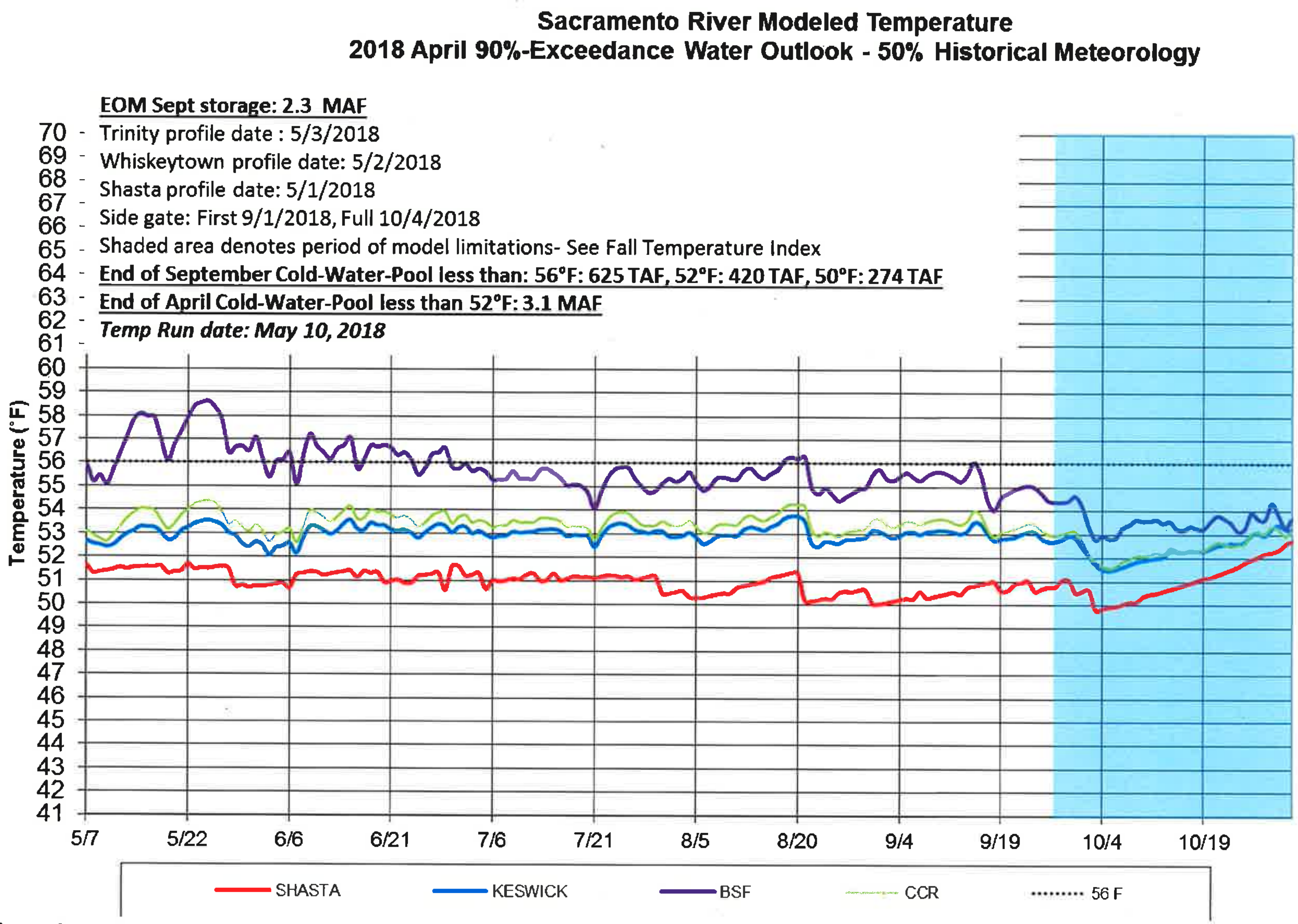
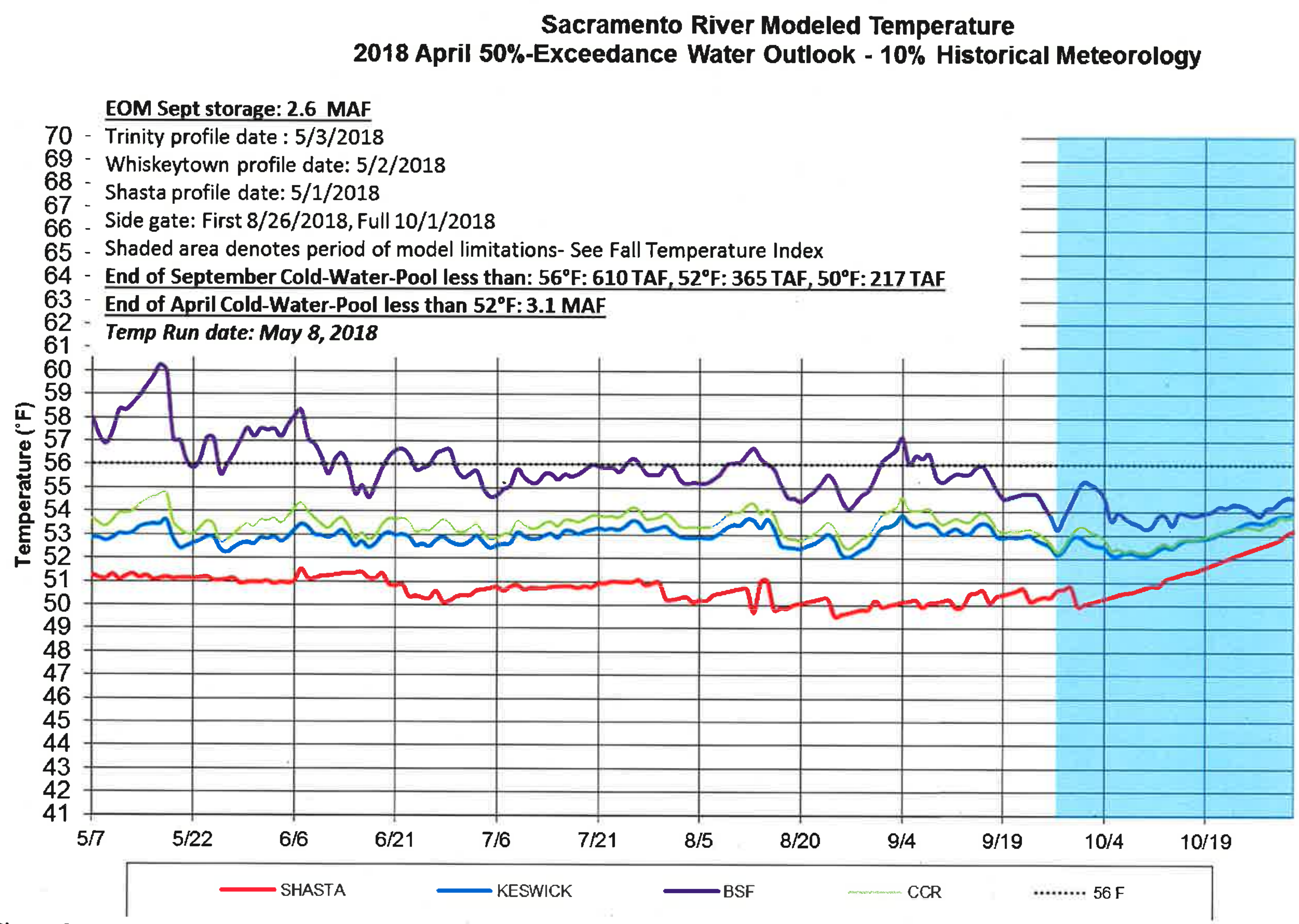

Sacramento River Modeled Temperature
2018 April 90%-Exceedance Water Outlook - 10% Historical Meteorology
EOM Sept storage: 2.3 MAF
Trinity profile date : 5/3/2018
Whiskeytown profile date: 5/2/2018
Shasta profile date: 5/1/2018
Side gate: First 8/27/2018, Full 10/3/2018
Shaded area denotes period of model limitations- See Fall Temperature Index
End of September Cold-Water-Pool less than: 56°F: 587 TAF, 52°F: 365 TAF, 50°F: 221 TAF
End of April Cold-Water-Pool less than 52°F: 3.1 MAF
Temp Run date: May 7, 2018
Temperature (°F)
70
69
68
67
66
65
64
63
62
61
60
59
58
57
56
55
54
53
52
51
50
49
48
47
46
45
44
43
42
41
5/7
5/22
6/6
6/21
7/6
7/21
8/5
8/20
9/4
9/19
10/4
10/19
SHASTA
KESWICK
BSF
CCR
56 F

Figure 1



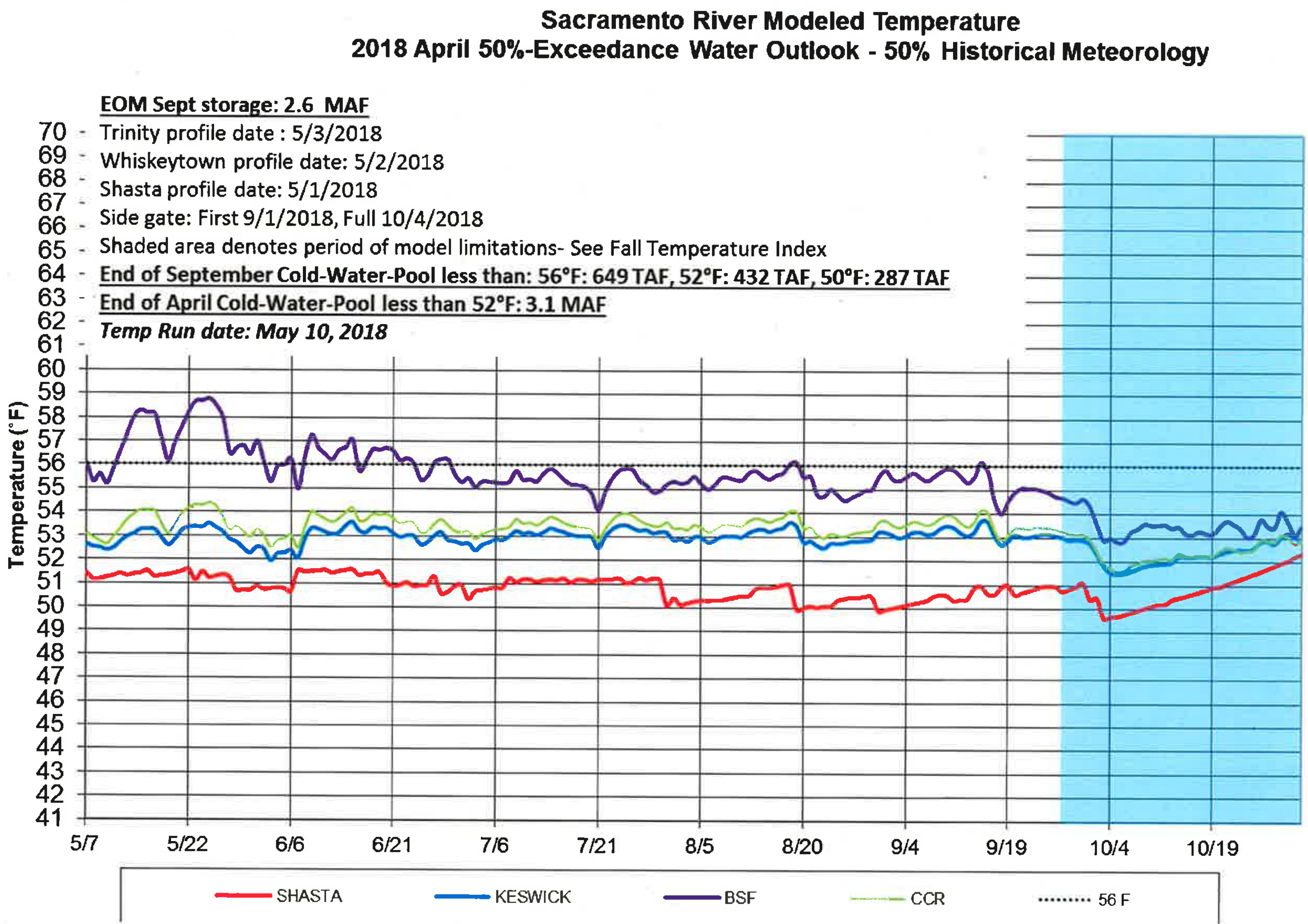
Sacramento River Modeled Temperature
2018 April 90%-Exceedance Water Outlook - 50% Historical Meteorology
EOM Sept storage: 2.3 MAF
Trinity profile date : 5/3/2018
Whiskeytown profile date: 5/2/2018
Shasta profile date: 5/1/2018
Side gate: First 9/1/2018, Full 10/4/2018
Shaded area denotes period of model limitations- See Fall Temperature Index
End of September Cold-Water-Pool less than: 56°F: 625 TAF, 52°F: 420 TAF, 50°F: 274 TAF
End of April Cold-Water-Pool less than 52°F: 3.1 MAF
Temp Run date: May 10, 2018
Temperature (°F)
70
69
68
67
66
65
64
63
62
61
60
59
58
57
56
55
54
53
52
51
50
49
48
47
46
45
44
43
42
41
5/7
5/22
6/6
6/21
7/6
7/21
8/5
8/20
9/4
9/19
10/4
10/19
SHASTA
KESWICK
BSF
CCR
56 F

Figure 2



Sacramento River Modeled Temperature
2018 April 50%-Exceedance Water Outlook - 10% Historical Meteorology
EOM Sept storage: 2.6 MAF
Trinity profile date : 5/3/2018
Whiskeytown profile date: 5/2/2018
Shasta profile date: 5/1/2018
Side gate: First 8/26/2018, Full 10/1/2018
Shaded area denotes period of model limitations- See Fall Temperature Index
End of September Cold-Water-Pool less than: 56°F: 610 TAF, 52°F: 365 TAF, 50°F: 217 TAF
End of April Cold-Water-Pool less than 52°F: 3.1 MAF
Temp Run date: May 8, 2018
Temperature (°F)
70
69
68
67
66
65
64
63
62
61
60
59
58
57
56
55
54
53
52
51
50
49
48
47
46
45
44
43
42
41
5/7
5/22
6/6
6/21
7/6
7/21
8/5
8/20
9/4
9/19
10/4
10/19
SHASTA
KESWICK
BSF
CCR
56 F

Figure 3



Sacramento River Modeled Temperature
2018 April 50%-Exceedance Water Outlook - 50% Historical Meteorology
EOM Sept storage: 2.6 MAF
Trinity profile date : 5/3/2018
Whiskeytown profile date: 5/2/2018
Shasta profile date: 5/1/2018
Side gate: First 9/1/2018, Full 10/4/2018
Shaded area denotes period of model limitations- See Fall Temperature Index
End of September Cold-Water-Pool less than: 56°F: 649 TAF, 52°F: 432 TAF, 50°F: 287 TAF
End of April Cold-Water-Pool less than 52°F: 3.1 MAF
Temp Run date: May 10, 2018
Temperature (°F)
70
69
68
67
66
65
64
63
62
61
60
59
58
57
56
55
54
53
52
51
50
49
48
47
46
45
44
43
42
41
5/7
5/22
6/6
6/21
7/6
7/21
8/5
8/20
9/4
9/19
10/4
10/19
SHASTA
KESWICK
BSF
CCR
56 F

Figure 4

Figures 5-7 Model Performance and Fall Temperature Index:

1. Based on past analyses, the temperature model does not perform well in late September and October. One factor is that the modeled release temperatures are cooler than has historically been achieved when all release is through the side gates (lowest gates), especially when there's a large temperature gradient between the pressure relief gates (PRG) and the side gates.
2. Based on historical records, the end-of-September Lake Shasta volume below 56˚F can be used as an indicator of fall water temperature in the river reach to Balls Ferry.
3. Based on these records and estimates, the index below illustrates a range of uncertainty in the ability to meet for river temperatures not to exceed 56 ˚F downstream based on the end-of-September lake volume less than 56˚F; see charts below.
4. Refinement of these estimates and concepts is currently underway.

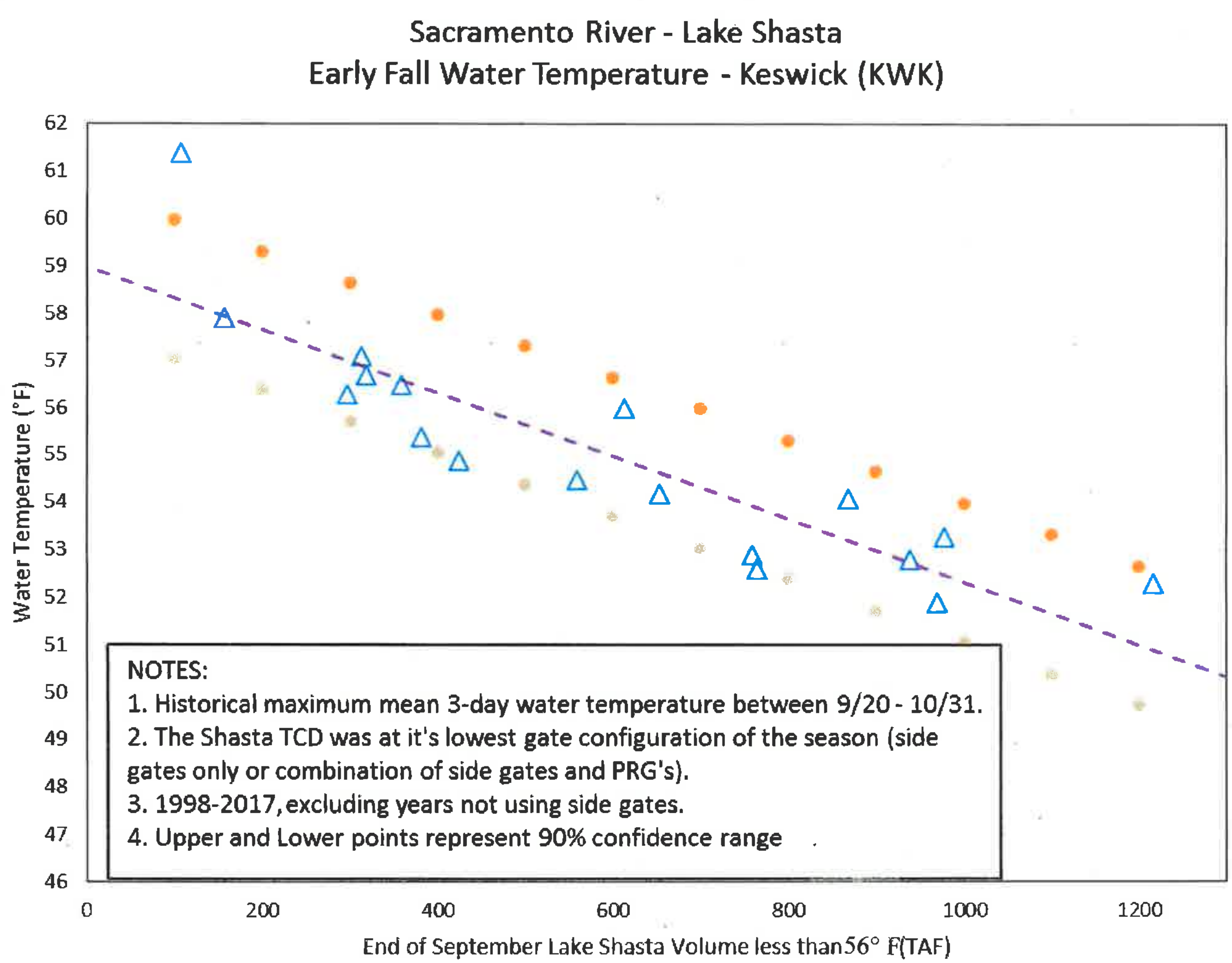

Sacramento River - Lake Shasta
Early Fall Water Temperature - Keswick (KWK)
Water Temperature (°F)
62
61
60
59
58
57
56
55
54
53
52
51
50
49
48
47
46
0
200
400
600
800
1000
1200
End of September Lake Shasta Volume less than 56° F(TAF)
NOTES:
1. Historical maximum mean 3-day water temperature between 9/20 - 10/31.
2. The Shasta TCD was at it's lowest gate configuration of the season (side gates only or combination of side gates and PRG's).
3. 1998-2017, excluding years not using side gates.
4. Upper and Lower points represent 90% confidence range

Figure 5

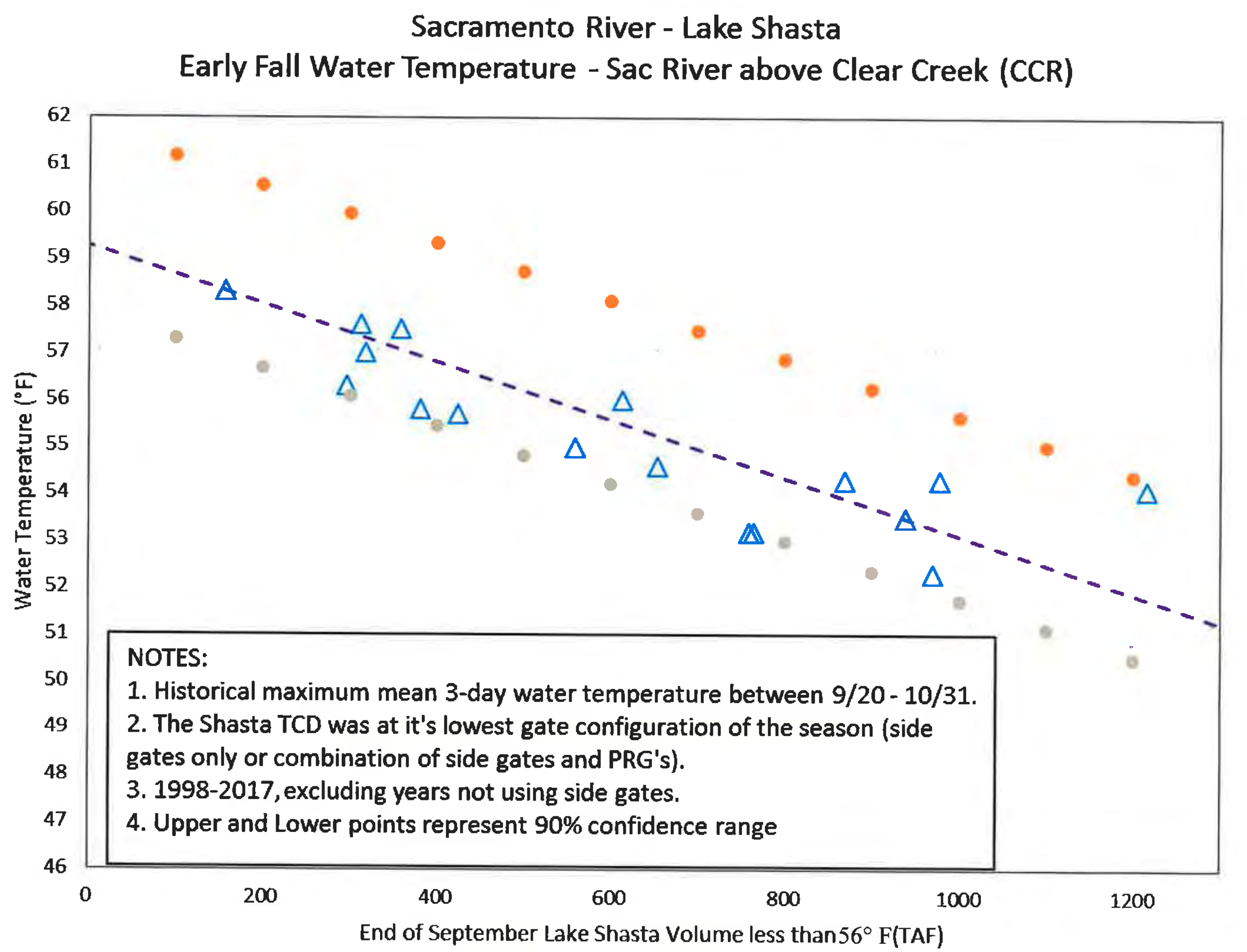

Sacramento River - Lake Shasta
Early Fall Water Temperature - Sac River above Clear Creek (CCR)
62
61
60
59
58
57
56
55
54
53
52
51
50
49
48
47
46
Water Temperature (°F)
0
200
400
600
800
1000
1200
End of September Lake Shasta Volume less than 56° F(TAF)
NOTES:
1. Historical maximum mean 3-day water temperature between 9/20 - 10/31.
2. The Shasta TCD was at it's lowest gate configuration of the season (side gates only or combination of side gates and PRG's).
3. 1998-2017, excluding years not using side gates.
4. Upper and Lower points represent 90% confidence range

Figure 6

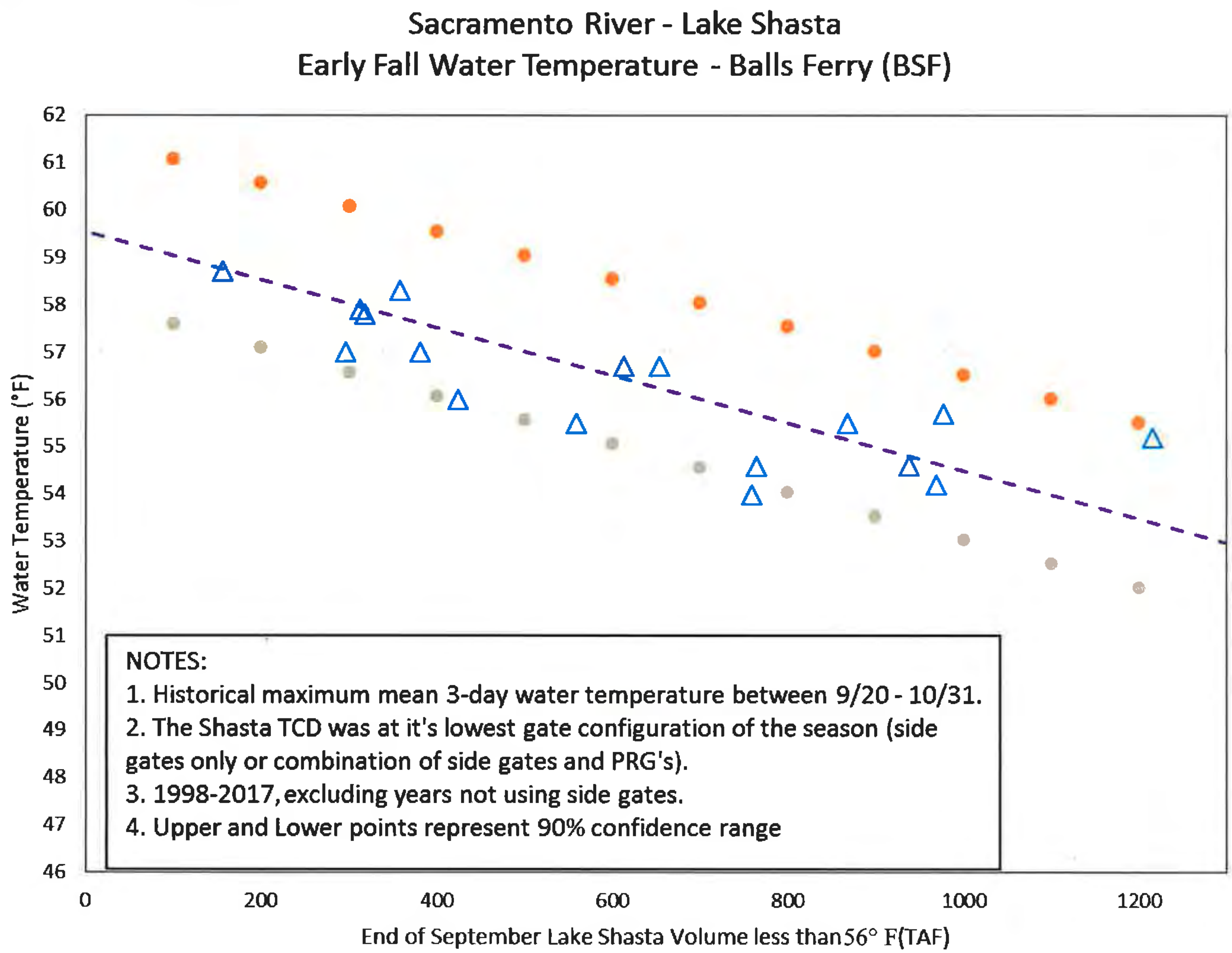

Sacramento River - Lake Shasta
Early Fall Water Temperature - Balls Ferry (BSF)
Water Temperature (°F)
62
61
60
59
58
57
56
55
54
53
52
51
50
49
48
47
46
0
200
400
600
800
1000
1200
End of September Lake Shasta Volume less than 56° F(TAF)
NOTES:
1. Historical maximum mean 3-day water temperature between 9/20 - 10/31.
2. The Shasta TCD was at it's lowest gate configuration of the season (side gates only or combination of side gates and PRG's).
3. 1998-2017, excluding years not using side gates.
4. Upper and Lower points represent 90% confidence range

Figure 7

May 10, 2018

Upper Sacramento River – April 2018 Preliminary Temperature Analysis

Summary of Temperature Results by Month (Monthly Average Temperature °F)

Location	MAY	JUN	JUL	AUG	SEP	OCT	Late Sep-Oct Uncertainty Estimation
April 90%-Exceedance Outlook – 10% Historical Meteorology 53°F CCR (May) 56°F BSF (Jun-Oct)							
Keswick Dam KWK	52.3	52.3	53.5	53.6	53.5	52.4	54 - 57
Sac. R. abv Clear Creek CCR	53.0	53.0	54.0	54.1	53.9	52.5	54 - 58
Balls Ferry BSF	56.8	56.0	56.0	56.0	55.6	53.7	55 - 58
April 90%-Exceedance Outlook – 50% Historical Meteorology 53°F CCR (May) 56°F BSF (Jun-Oct)							
Keswick Dam KWK	52.4	52.7	53.8	53.6	53.2	52.0	53 - 56
Sac. R. abv Clear Creek CCR	53.0	53.2	54.2	54.0	53.6	52.1	54 - 57
Balls Ferry BSF	56.4	56.0	56.0	55.9	55.3	53.2	55 - 58
April 50%-Exceedance Outlook – 10% Historical Meteorology 53°F CCR (May) 56°F BSF (Jun-Oct)							
Keswick Dam KWK	52.3	52.3	53.4	53.6	53.6	52.4	53 - 56
Sac. R. abv Clear Creek CCR	53.0	53.0	53.9	54.1	54.0	52.5	54 - 58
Balls Ferry BSF	57.0	56.0	55.9	56.0	55.8	53.7	55 - 58
April 50%-Exceedance Outlook – 50% Historical Meteorology 53°F CCR (May) 56°F BSF (Jun-Oct)							
Keswick Dam KWK	52.3	52.7	53.8	53.8	53.4	52.0	53 - 56
Sac. R. abv Clear Creek CCR	53.0	53.2	54.2	54.2	53.7	52.1	54 - 57
Balls Ferry BSF	56.5	56.0	56.0	56.0	55.4	53.2	55 - 58

* The HEC5Q model output is displayed above for the months April through October. Based on past analysis, the temperature model does not perform well in late September and October. One factor is that the modeled release temperatures are cooler than has

historically been achieved when all release is through the side gates (lowest gates), especially when there's a large temperature gradient between the pressure relief gates (PRG) and the side gates. For the months of September and October, an uncertainty estimate is provided based on the Fall Temperature Index (graphics below). This is based on a historical relationship between end-of-September Lake Shasta Volume less than 56°F and likely downstream temperature performances for the early fall months. The range represents the 90% confidence interval based on that data. Refinement of the concepts for those estimates is underway.

Temperature Model Inputs, Assumptions, Limitations and Uncertainty:

1. The latest available profiles for Shasta, Trinity, and Whiskeytown were taken on May 1, May 3, and May 2 respectively. Model results are sensitive to initial reservoir temperature conditions and the model performs best under highly stratified conditions. The model performs well after the reservoir stratifies, typically in late spring. The concern this year is assuming over or under estimations with variable hydrologic and meteorological conditions and not capturing the stratification with sufficient detail to project.
2. Guidance on forecasted flows from the creeks (e.g., Cow, Cottonwood, Battle, etc.) between Keswick Dam and Bend Bridge are not available beyond 5 days. Creek flows developed from the historical record that most closely reflects current conditions were used for all model runs. The resulting low creek flows can cause significant additional warming in the upper Sacramento River during spring.
3. Operation is based on the April 2018 Operation Outlooks and DWR Bulletin 120 inflow projections (monthly flows, reservoir release, and end-of-month reservoir storage) for the 90%- and 50%-exceedances. Trinity Lake inflows are updated with the CNRFC 90% runoff exceedance for the 90% runoff exceedance studies. The April 2018 Operation Outlook is modified to adjust for real-time operations in early May suggesting the monthly Keswick release may average closer to 8,500 cfs.
4. Although mean daily flows and releases are temperature model inputs, they are based on the mean monthly values from the operation outlooks. Mean daily flow patterns are user defined and are generalized representations. It is important to note that these outlooks do not suggest a certain actual future outcome, but rather the statistical likelihood of an event occurring, including, but not limited to, projected storage and releases. Thus, the outlooks do not provide exact end of month storages or flow rates but general projections that will likely fall within the range of uncertainty based on the different hydrologic runoff conditions between the 90% and 50% runoff exceedance hydrology.
5. Cottonwood Creek flows, Keswick to Bend Bridge local flows, and ACID diversions are mean daily synthesized flows based on the available historical record for a 1922-2002 study period. Inflows were adjusted to a 95% historical exceedance for both the 90% and 50% runoff exceedance studies.
6. Meteorological inputs represent historical (1985 – 2017) monthly mean equilibrium temperature exceedance at 10% and 50% patterned after like months on a 6-hour time-step, or as noted. Assumed inflow temperature remain static inputs and do not vary with the assumed meteorology.

7. Meteorology, as well as the flow volume and pattern, significantly influences reservoir inflow temperatures and downstream tributary temperatures; and consequently, the development of the cold-water pool during winter and early spring.
8. Modified model coefficients more closely represent actual Keswick Dam temperatures. As a result, temperature predictions downstream of Keswick Dam are likely to be warmer than actual. Model re-calibrations efforts are underway.

Model Run Date May 10, 2018

Temperature Analysis Results:

Modeling runs explore Sacramento River compliance performance above Clear Creek confluence and Balls Ferry locations by varying hydrology and temperature compliance target location and temperature. The temperature results for the Sacramento River between Keswick Dam and Balls Ferry are shown in Figures 1-4. The fall uncertainty estimation relationship between end-of-September lake volume below 56°F and a Balls Ferry compliance through fall is based on the Figures 5-7.

Model Run	**End of September Cold Water Pool <56°F (TAF)**	**First Side Gate**	**Full Side Gates**
(1) 90% Hydro, 10% Historical Met 53 CCR (May) & 56 BSF (Jun-Oct)	618	9/8	10/5
(2) 90% Hydro, 50% Historical Met 53 CCR (May) & 56 BSF (Jun-Oct)	707	9/13	10/14
(3) 50% Hydro, 10% Historical Met 53 CCR (May) & 56 BSF (Jun-Oct)	641	9/8	10/7
(4) 50% Hydro, 50% Historical Met 53 CCR (May) & 56 BSF (Jun-Oct)	707	9/18	10/14

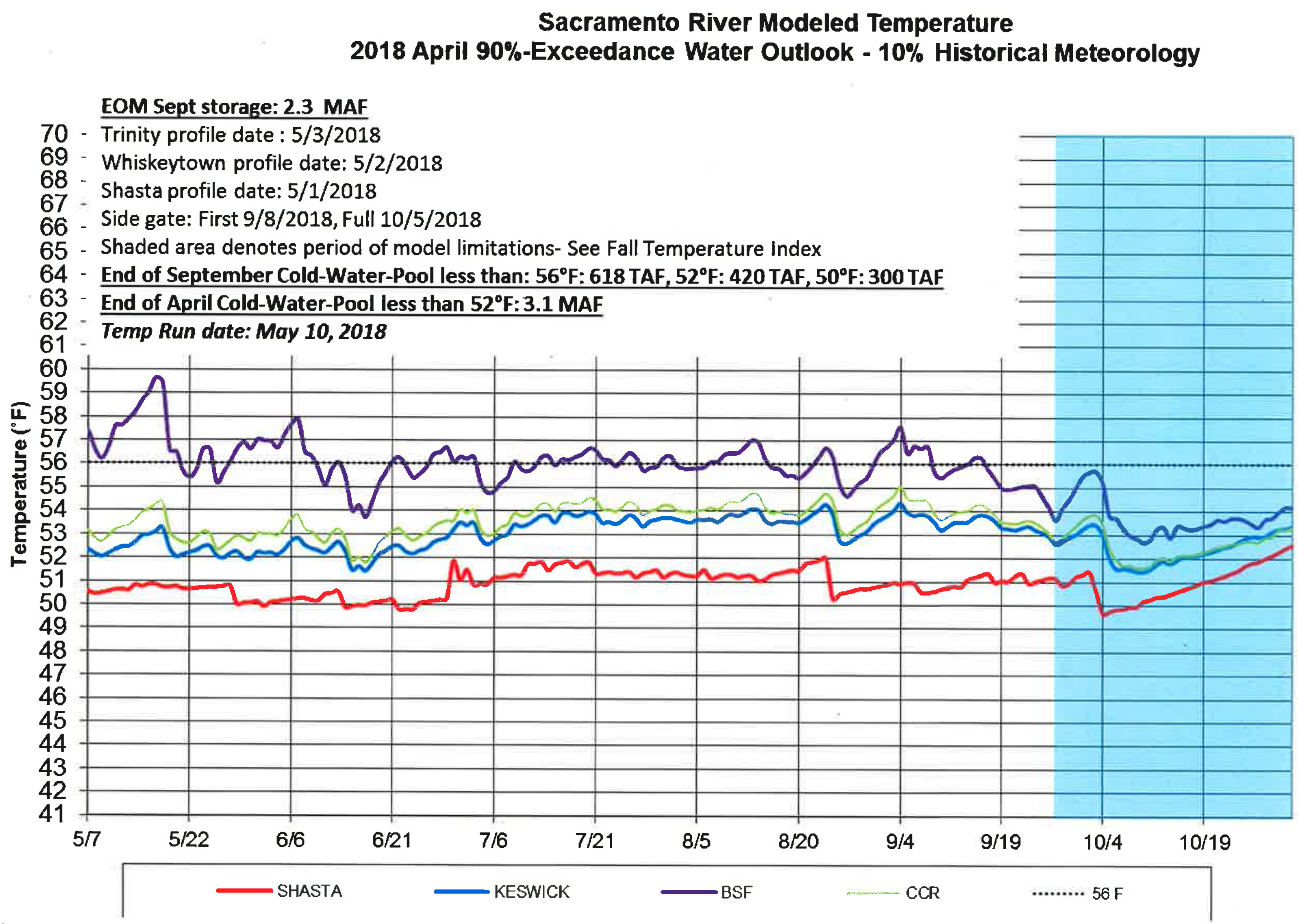
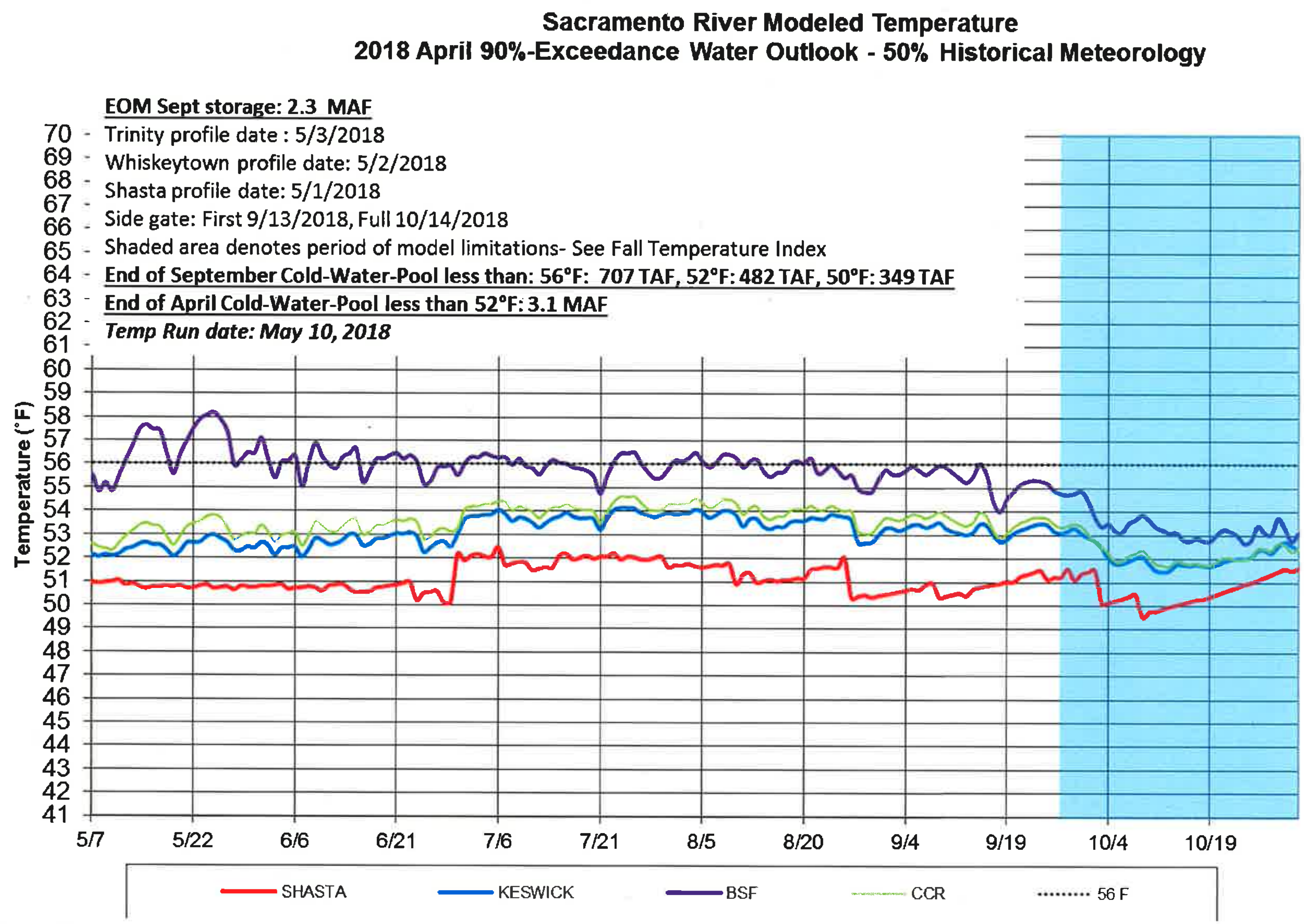

Sacramento River Modeled Temperature
2018 April 90%-Exceedance Water Outlook - 10% Historical Meteorology
EOM Sept storage: 2.3 MAF
Trinity profile date : 5/3/2018
Whiskeytown profile date: 5/2/2018
Shasta profile date: 5/1/2018
Side gate: First 9/8/2018, Full 10/5/2018
Shaded area denotes period of model limitations- See Fall Temperature Index
End of September Cold-Water-Pool less than: 56°F: 618 TAF, 52°F: 420 TAF, 50°F: 300 TAF
End of April Cold-Water-Pool less than 52°F: 3.1 MAF
Temp Run date: May 10, 2018
Temperature (°F)
70
69
68
67
66
65
64
63
62
61
60
59
58
57
56
55
54
53
52
51
50
49
48
47
46
45
44
43
42
41
5/7
5/22
6/6
6/21
7/6
7/21
8/5
8/20
9/4
9/19
10/4
10/19
SHASTA
KESWICK
BSF
CCR
56 F

Figure 1


Sacramento River Modeled Temperature
2018 April 90%-Exceedance Water Outlook - 50% Historical Meteorology
EOM Sept storage: 2.3 MAF
Trinity profile date : 5/3/2018
Whiskeytown profile date: 5/2/2018
Shasta profile date: 5/1/2018
Side gate: First 9/13/2018, Full 10/14/2018
Shaded area denotes period of model limitations- See Fall Temperature Index
End of September Cold-Water-Pool less than: 56°F: 707 TAF, 52°F: 482 TAF, 50°F: 349 TAF
End of April Cold-Water-Pool less than 52°F: 3.1 MAF
Temp Run date: May 10, 2018
Temperature (°F)
70
69
68
67
66
65
64
63
62
61
60
59
58
57
56
55
54
53
52
51
50
49
48
47
46
45
44
43
42
41
5/7
5/22
6/6
6/21
7/6
7/21
8/5
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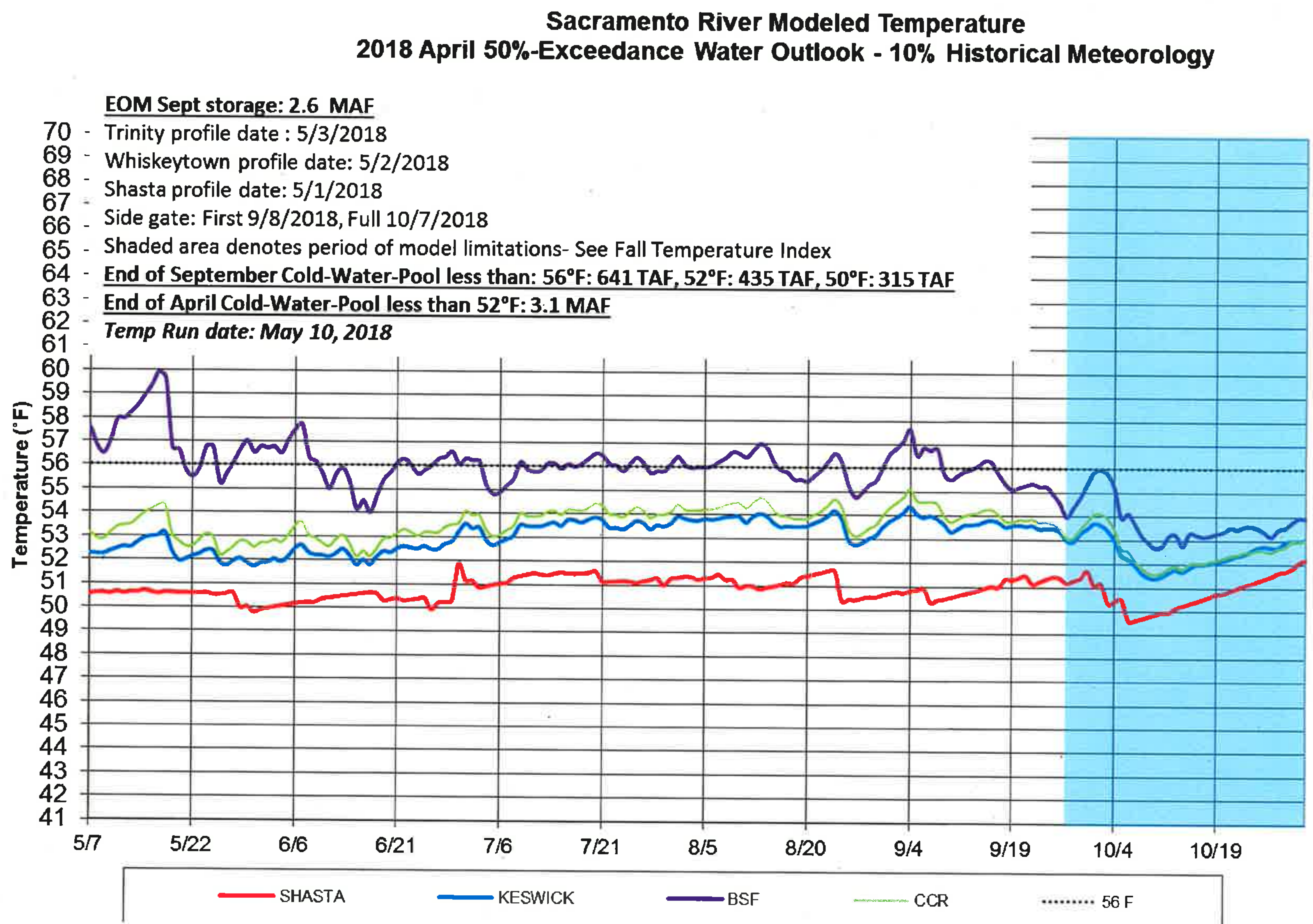
9/4
9/19
10/4
10/19
SHASTA
KESWICK
BSF
CCR
56 F

Figure 2


Sacramento River Modeled Temperature
2018 April 50%-Exceedance Water Outlook - 10% Historical Meteorology
EOM Sept storage: 2.6 MAF
Trinity profile date : 5/3/2018
Whiskeytown profile date: 5/2/2018
Shasta profile date: 5/1/2018
Side gate: First 9/8/2018, Full 10/7/2018
Shaded area denotes period of model limitations- See Fall Temperature Index
End of September Cold-Water-Pool less than: 56°F: 641 TAF, 52°F: 435 TAF, 50°F: 315 TAF
End of April Cold-Water-Pool less than 52°F: 3.1 MAF
Temp Run date: May 10, 2018
Temperature (°F)
70
69
68
67
66
65
64
63
62
61
60
59
58
57
56
55
54
53
52
51
50
49
48
47
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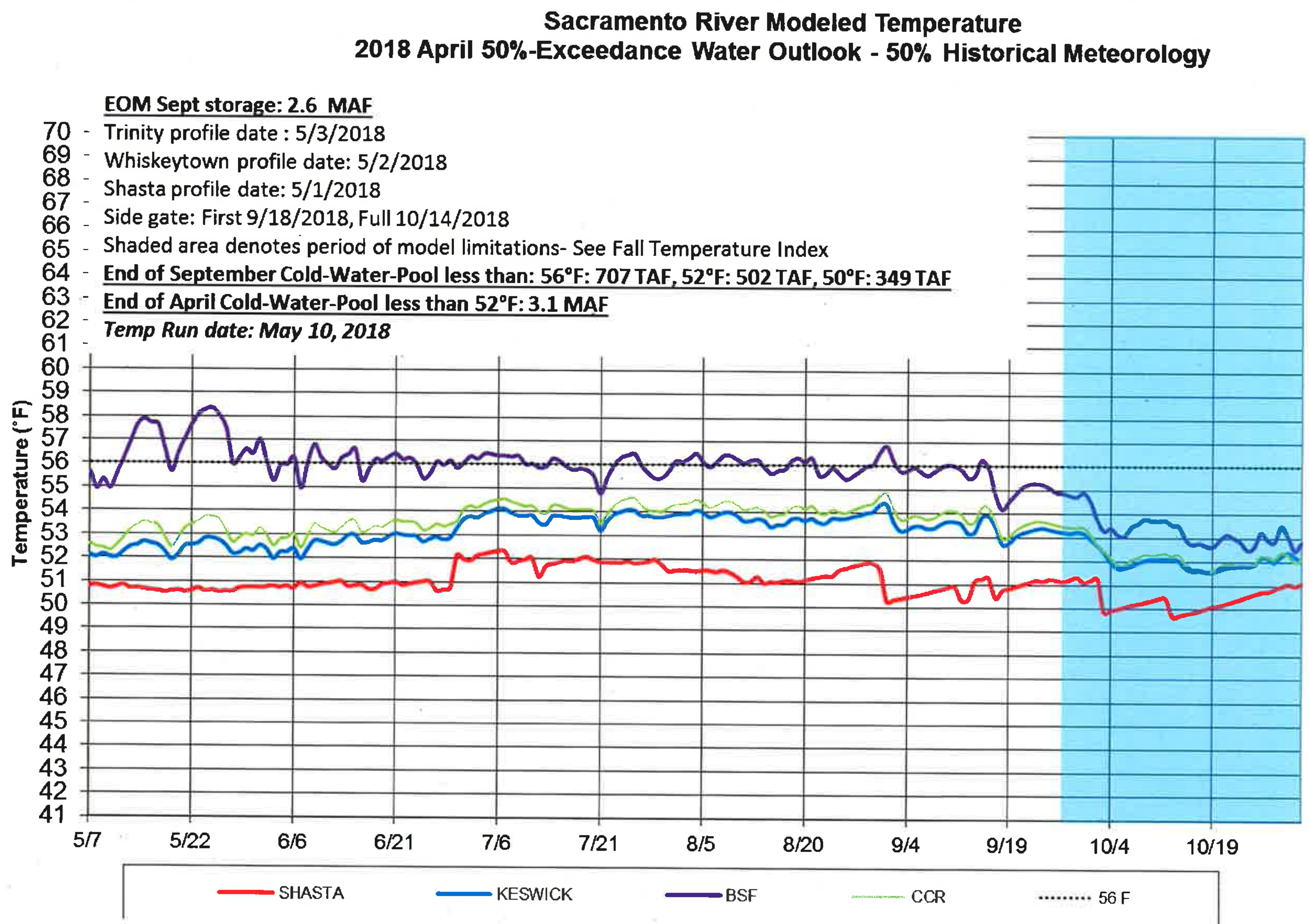
45
44
43
42
41
5/7
5/22
6/6
6/21
7/6
7/21
8/5
8/20
9/4
9/19
10/4
10/19
SHASTA
KESWICK
BSF
CCR
56 F

Figure 3


Sacramento River Modeled Temperature
2018 April 50%-Exceedance Water Outlook - 50% Historical Meteorology
EOM Sept storage: 2.6 MAF
Trinity profile date : 5/3/2018
Whiskeytown profile date: 5/2/2018
Shasta profile date: 5/1/2018
Side gate: First 9/18/2018, Full 10/14/2018
Shaded area denotes period of model limitations- See Fall Temperature Index
End of September Cold-Water-Pool less than: 56°F: 707 TAF, 52°F: 502 TAF, 50°F: 349 TAF
End of April Cold-Water-Pool less than 52°F: 3.1 MAF
Temp Run date: May 10, 2018
Temperature (°F)
70
69
68
67
66
65
64
63
62
61
60
59
58
57
56
55
54
53
52
51
50
49
48
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43
42
41
5/7
5/22
6/6
6/21
7/6
7/21
8/5
8/20
9/4
9/19
10/4
10/19
SHASTA
KESWICK
BSF
CCR
56 F

Figure 4

Figures 5-7 Model Performance and Fall Temperature Index:

1. Based on past analyses, the temperature model does not perform well in late September and October. One factor is that the modeled release temperatures are cooler than has historically been achieved when all release is through the side gates (lowest gates), especially when there's a large temperature gradient between the pressure relief gates (PRG) and the side gates.
2. Based on historical records, the end-of-September Lake Shasta volume below 56˚F can be used as an indicator of fall water temperature in the river reach to Balls Ferry.
3. Based on these records and estimates, the index below illustrates a range of uncertainty in the ability to meet for river temperatures not to exceed 56 ˚F downstream based on the end-of-September lake volume less than 56˚F; see charts below.
4. Refinement of these estimates and concepts is currently underway.

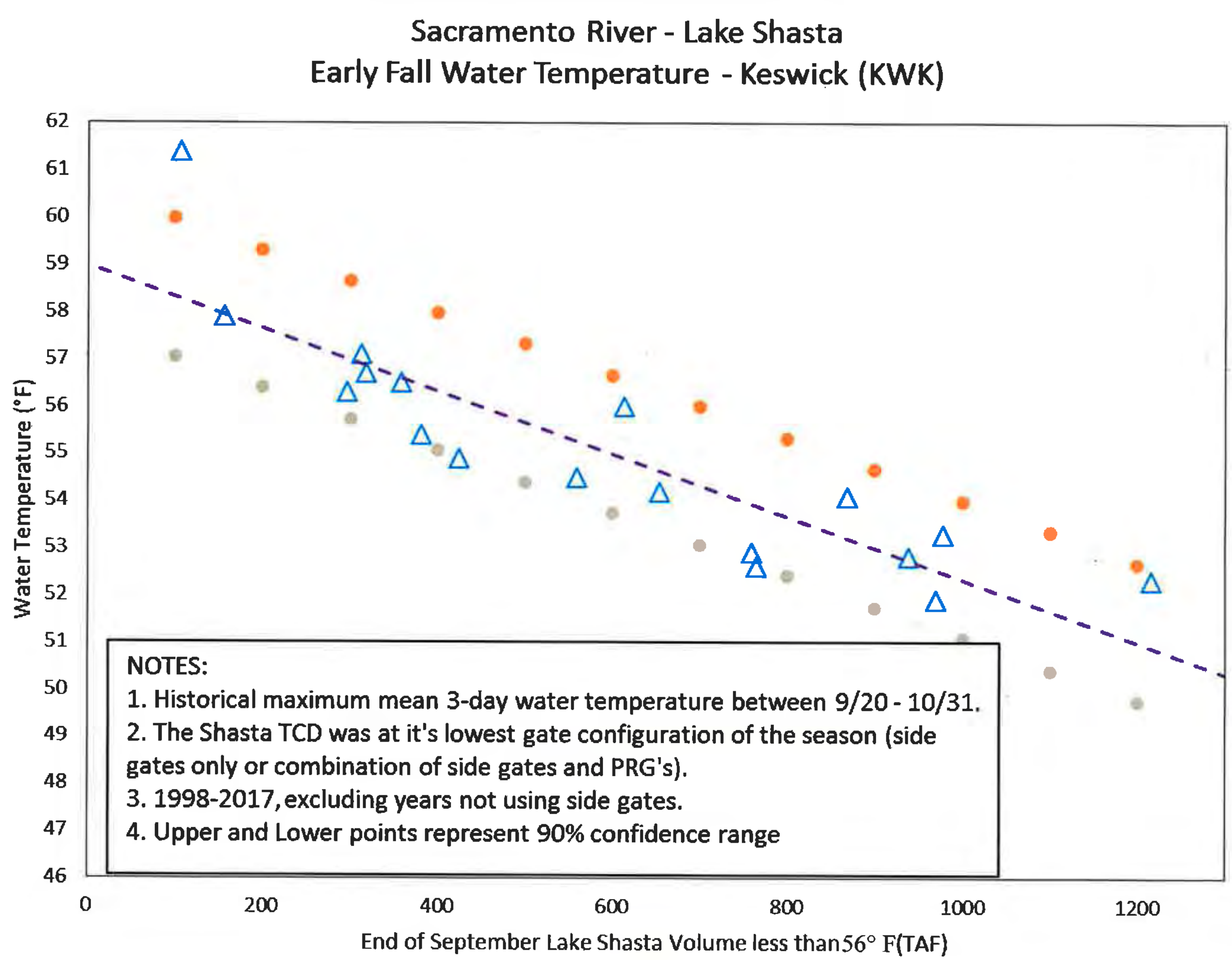

Sacramento River - Lake Shasta
Early Fall Water Temperature - Keswick (KWK)
Water Temperature (°F)
62
61
60
59
58
57
56
55
54
53
52
51
50
49
48
47
46
0
200
400
600
800
1000
1200
End of September Lake Shasta Volume less than 56° F(TAF)
NOTES:
1. Historical maximum mean 3-day water temperature between 9/20 - 10/31.
2. The Shasta TCD was at it's lowest gate configuration of the season (side gates only or combination of side gates and PRG's).
3. 1998-2017, excluding years not using side gates.
4. Upper and Lower points represent 90% confidence range

Figure 5

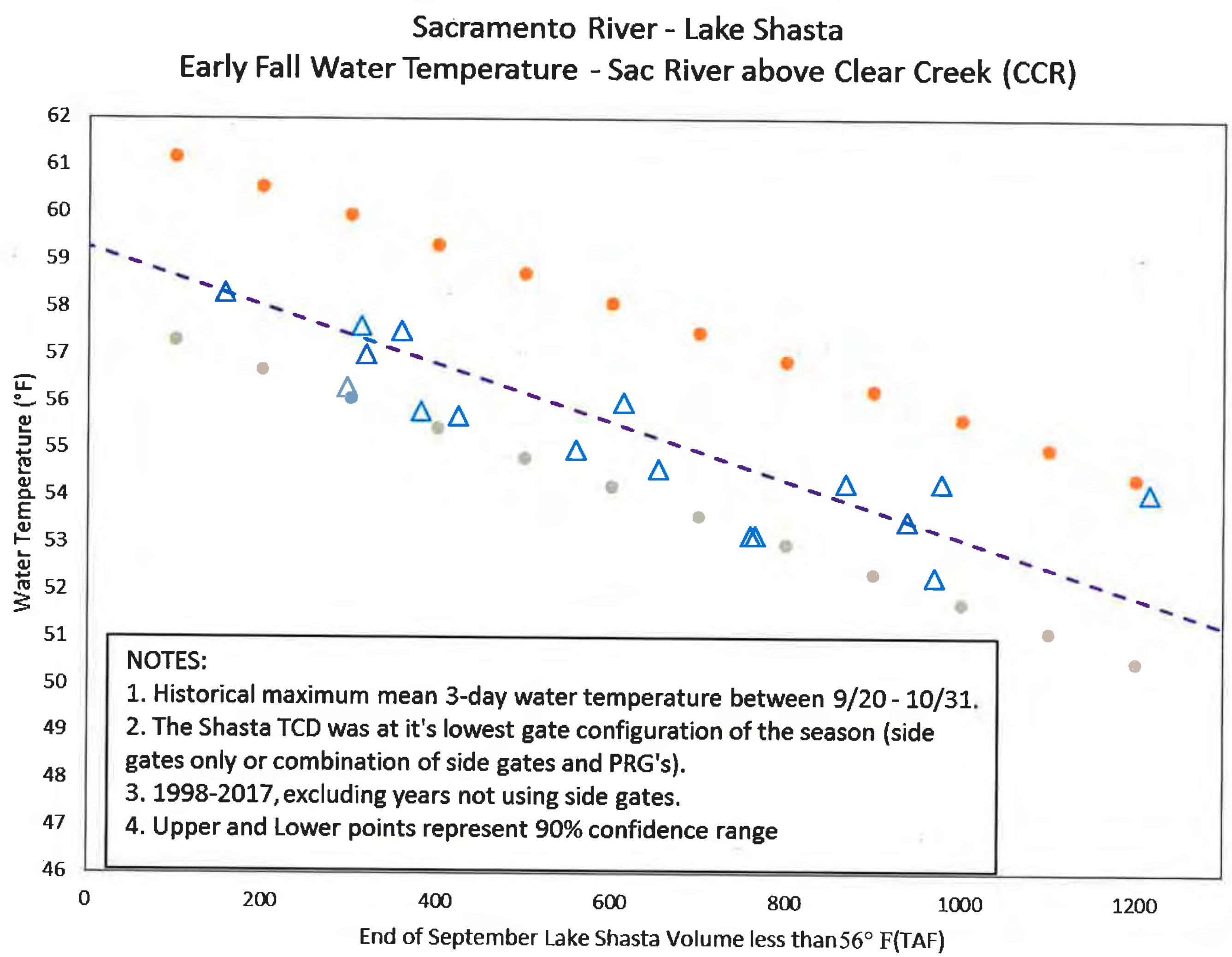
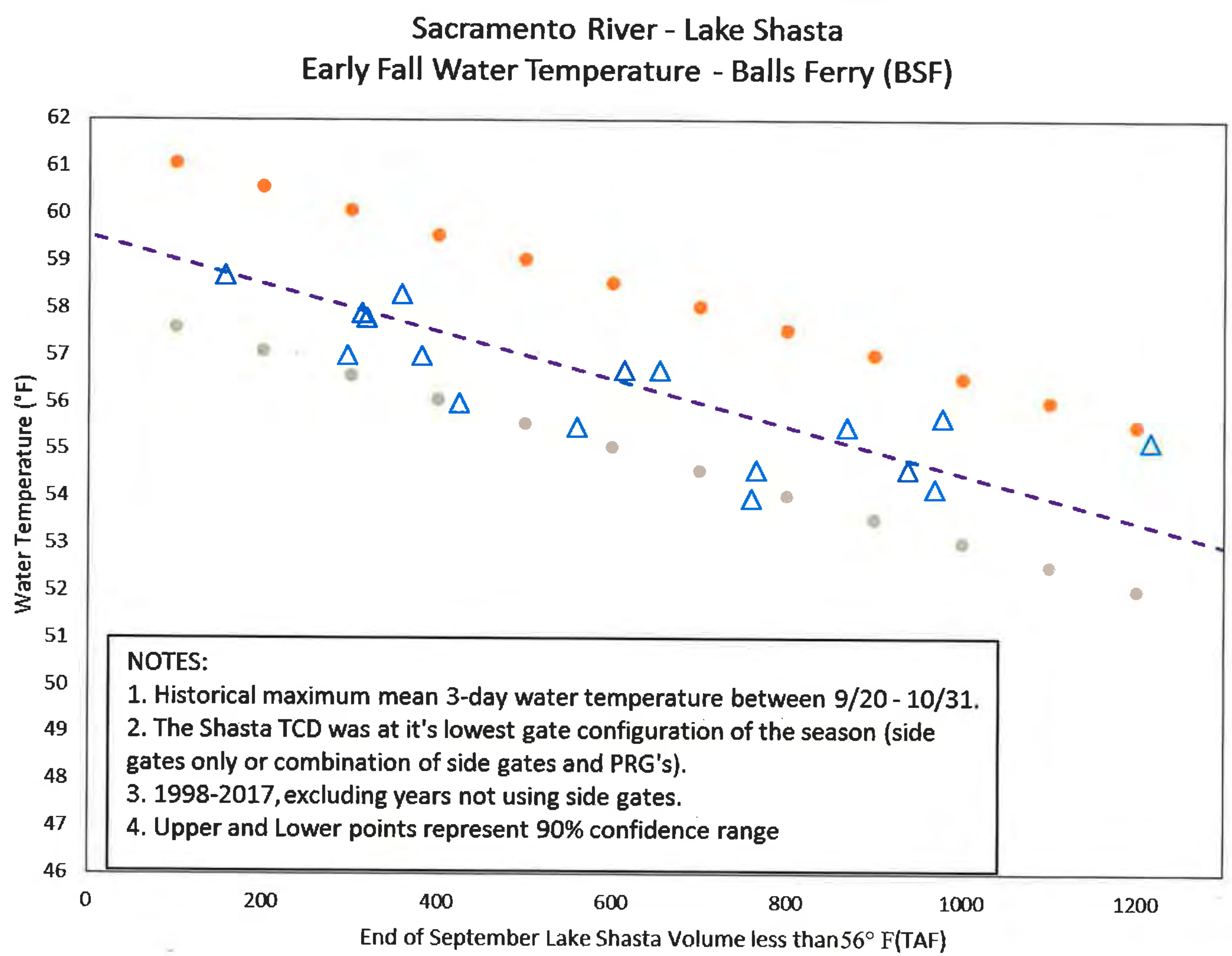

Sacramento River - Lake Shasta
Early Fall Water Temperature - Sac River above Clear Creek (CCR)
Water Temperature (°F)
62
61
60
59
58
57
56
55
54
53
52
51
50
49
48
47
46
0
200
400
600
800
1000
1200
End of September Lake Shasta Volume less than 56° F(TAF)
NOTES:
1. Historical maximum mean 3-day water temperature between 9/20 - 10/31.
2. The Shasta TCD was at it's lowest gate configuration of the season (side gates only or combination of side gates and PRG's).
3. 1998-2017, excluding years not using side gates.
4. Upper and Lower points represent 90% confidence range

Figure 6


Sacramento River - Lake Shasta
Early Fall Water Temperature - Balls Ferry (BSF)
Water Temperature (°F)
62
61
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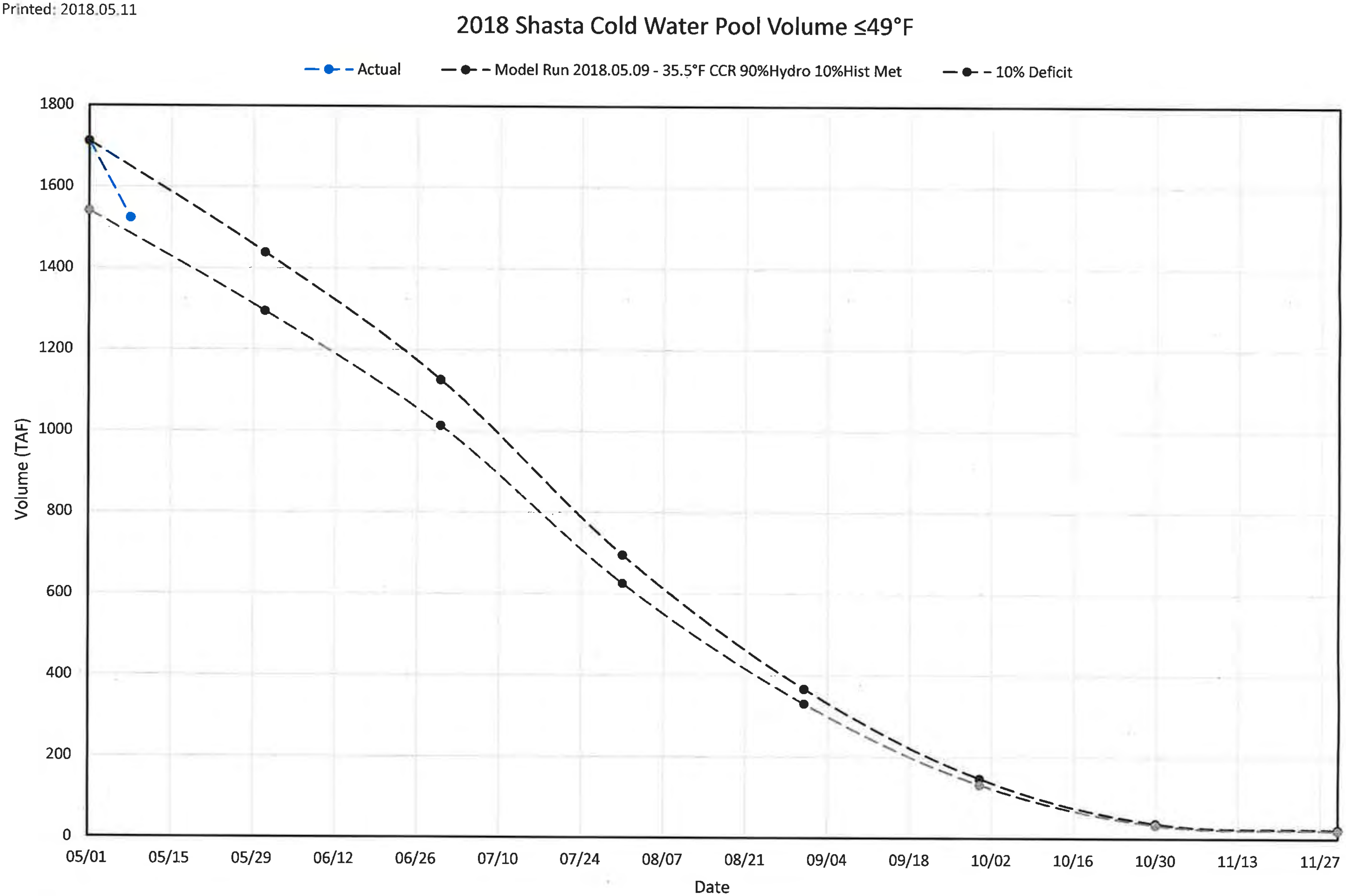
47
46
0
200
400
600
800
1000
1200
End of September Lake Shasta Volume less than 56° F(TAF)
NOTES:
1. Historical maximum mean 3-day water temperature between 9/20 - 10/31.
2. The Shasta TCD was at it's lowest gate configuration of the season (side gates only or combination of side gates and PRG's).
3. 1998-2017, excluding years not using side gates.
4. Upper and Lower points represent 90% confidence range

Figure 7

Printed: 2018.05.11



Enclosure 9

Summary Document for Shasta/Keswick Operational Scenarios
Prepared by the Southwest Fisheries Science Center on May 14th, 2018

Below are results comparing four USBR scenarios ran May 10th 2018. Scenarios differ by hydrology (Input 50 or 90 percent exceedance) and temperature target strategies (53.5 F at CCR for the entire season, or 53 at CCR in May followed by 56 at BSF from June to October), with air temperature at 10 exceedances of L3MTO. Inputs from scenarios are used to generate daily average Sacramento River water temperatures using the RAFT model and associated temperature-dependent egg mortality and survival estimates using the NMFS temperature mortality model (Martin et al. 2017) for the 2018 temperature management season (Table 1 and Figures 2,3,6 and 7). Additionally, a set of mortality model runs were generated using USBR's HEC-5Q model output (Table 2 and Figures 4,5,8, and 9) for comparison purposes, where the RAFT model was not used, but temperatures from the HEC-5Q nodes were linearly interpolated in space.

Further details of modeling methods are at: http://oceanview.pfeg.noaa.gov/CVTEMP/

Table 1: Estimated temperature-dependent egg mortality under different scenarios assuming a 2012-2017 spatial and temporal redd distribution.

Scenario	Mean (%)	Median (%)	Lower (%)	Upper (%)
MAY_10_2018_INPUT_50_OUTPUT_50_10L3MTO_53_CCR	11.95	3.63	0.03	58.78
MAY_10_2018_INPUT_50_OUTPUT_50_50L3MTO_53_CCR	11.33	2.02	0.04	58.88
MAY_10_2018_INPUT_90_OUTPUT_90_10L3MTO_53_CCR	12.49	4.84	0.08	58.64
MAY_10_2018_INPUT_90_OUTPUT_90_50L3MTO_53_CCR	11.04	2.47	0.04	58.06
MAY_10_2018_INPUT_50_OUTPUT_50_10L3MTO_53_CCR_56_BSF	25.61	22.99	0.08	67.74
MAY_10_2018_INPUT_50_OUTPUT_50_50L3MTO_53_CCR_56_BSF	27.96	26.54	0.08	68.78
MAY_10_2018_INPUT_90_OUTPUT_90_10L3MTO_53_CCR_56_BSF	24.46	21.41	0.08	66.83
MAY_10_2018_INPUT_90_OUTPUT_90_50L3MTO_53_CCR_56_BSF	24.03	20.56	0.08	66.57

Table 2: Estimated temperature-dependent egg mortality under different scenarios assuming a 2012-2017 spatial and temporal redd distribution using HEC-5Q output.

Scenario	Mean (%)	Median (%)	Lower (%)	Upper (%)
MAY_10_2018_INPUT_50_OUTPUT_50_10L3MTO_53_CCR	10.9	2.94	0.08	56.61
MAY_10_2018_INPUT_50_OUTPUT_50_50L3MTO_53_CCR	11.46	4.16	0.08	56.47
MAY_10_2018_INPUT_90_OUTPUT_90_10L3MTO_53_CCR	9.86	1.23	0.08	56.42
MAY_10_2018_INPUT_90_OUTPUT_90_50L3MTO_53_CCR	9.69	1.79	0.08	55.66
MAY_10_2018_INPUT_50_OUTPUT_50_10L3MTO_53_CCR_56_BSF	23.39	19.54	0.08	66.13
MAY_10_2018_INPUT_50_OUTPUT_50_50L3MTO_53_CCR_56_BSF	22.49	18.32	0.08	65.17
MAY_10_2018_INPUT_90_OUTPUT_90_10L3MTO_53_CCR_56_BSF	24.82	22.35	0.08	67.05
MAY_10_2018_INPUT_90_OUTPUT_90_50L3MTO_53_CCR_56_BSF	21.28	16.97	0.08	64.59

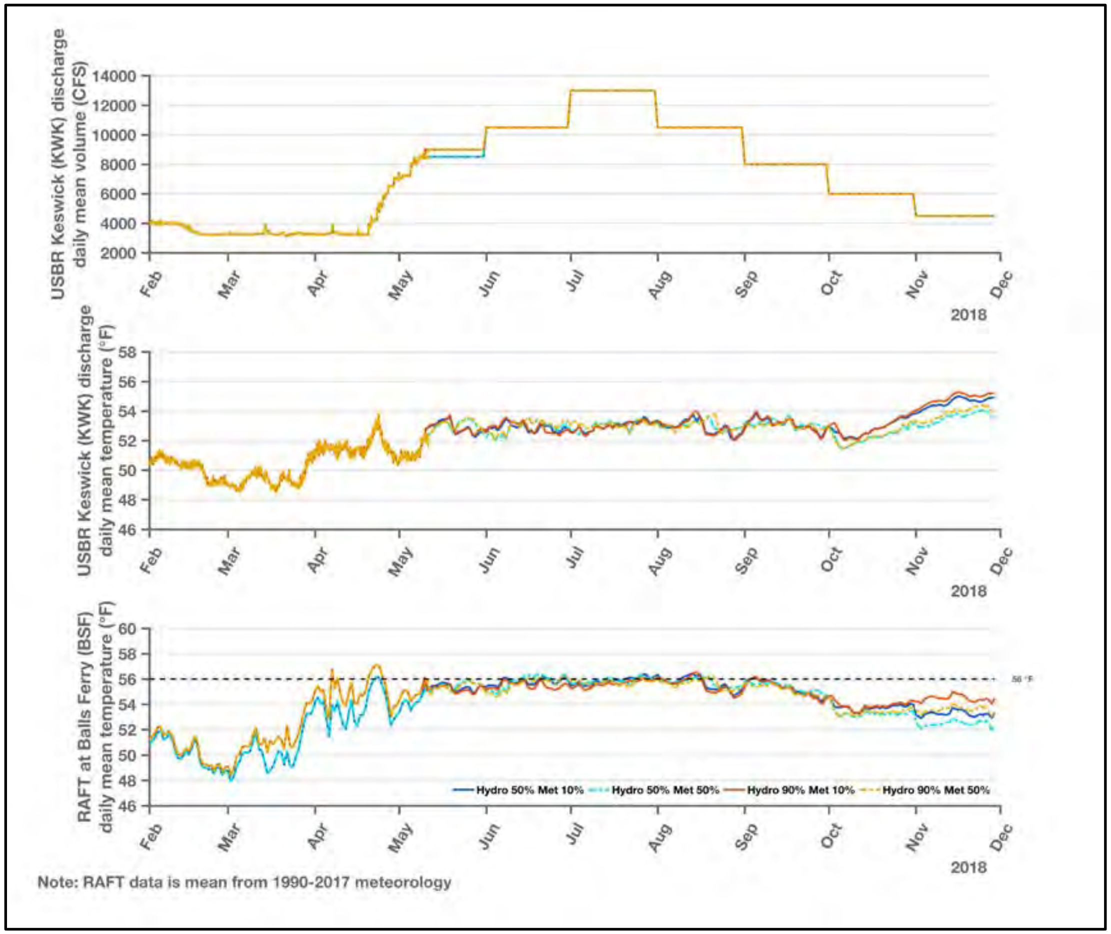


Figure 1: Summary plots showing differences in Keswick discharge volume and temperature, and Balls Ferry RAFT predicted temperature for four scenarios assessed under the scenarios targeting a CCR temperature of 53.5 F.

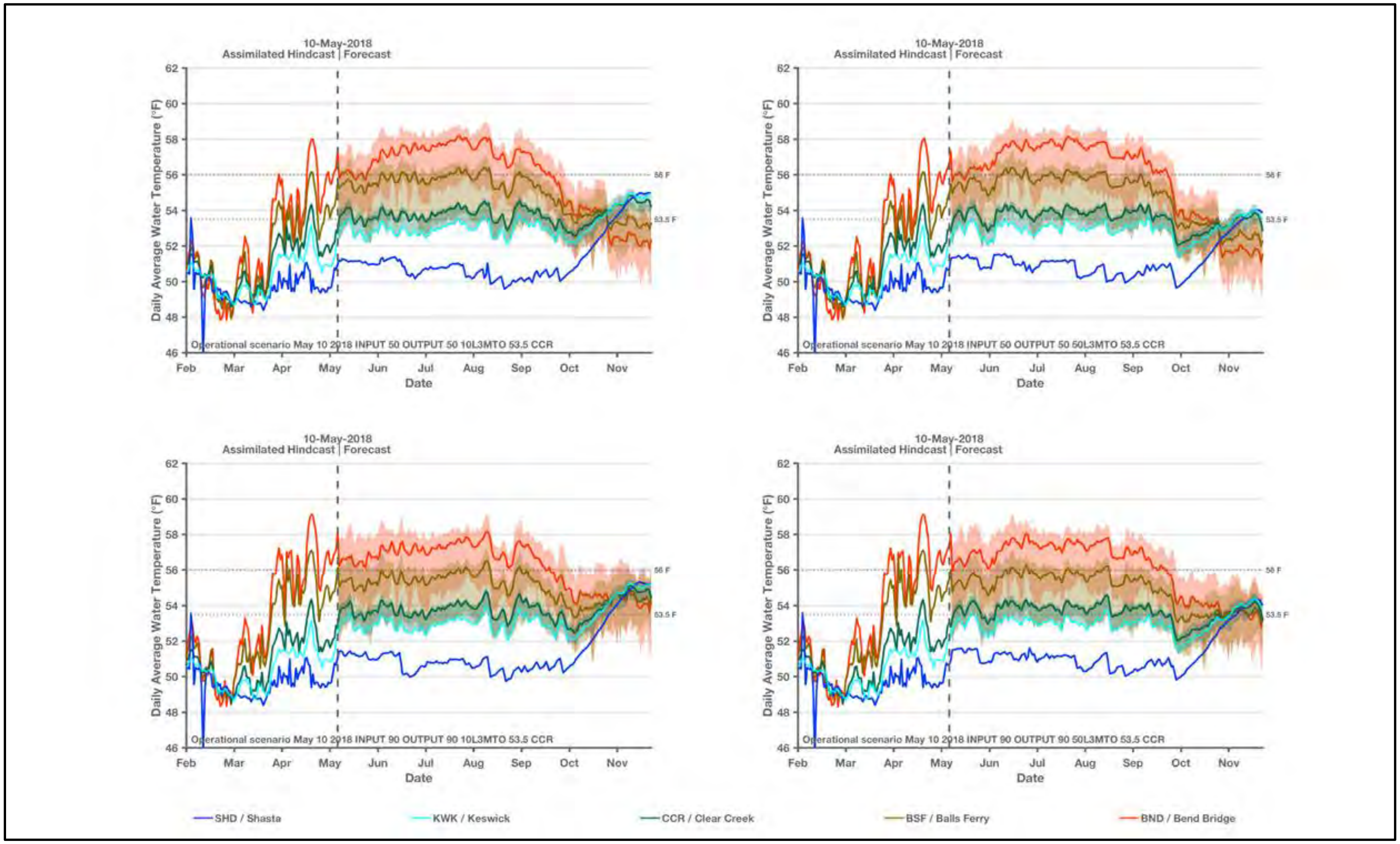


Figure 2: Estimated daily average water temperature produced by scenario input (Shasta and Keswick) and the RAFT model (Clear Creek, Balls Ferry, and Bend Bridge) under the four May 10th 2018 scenarios targeting a CCR temperature of 53.5 F.

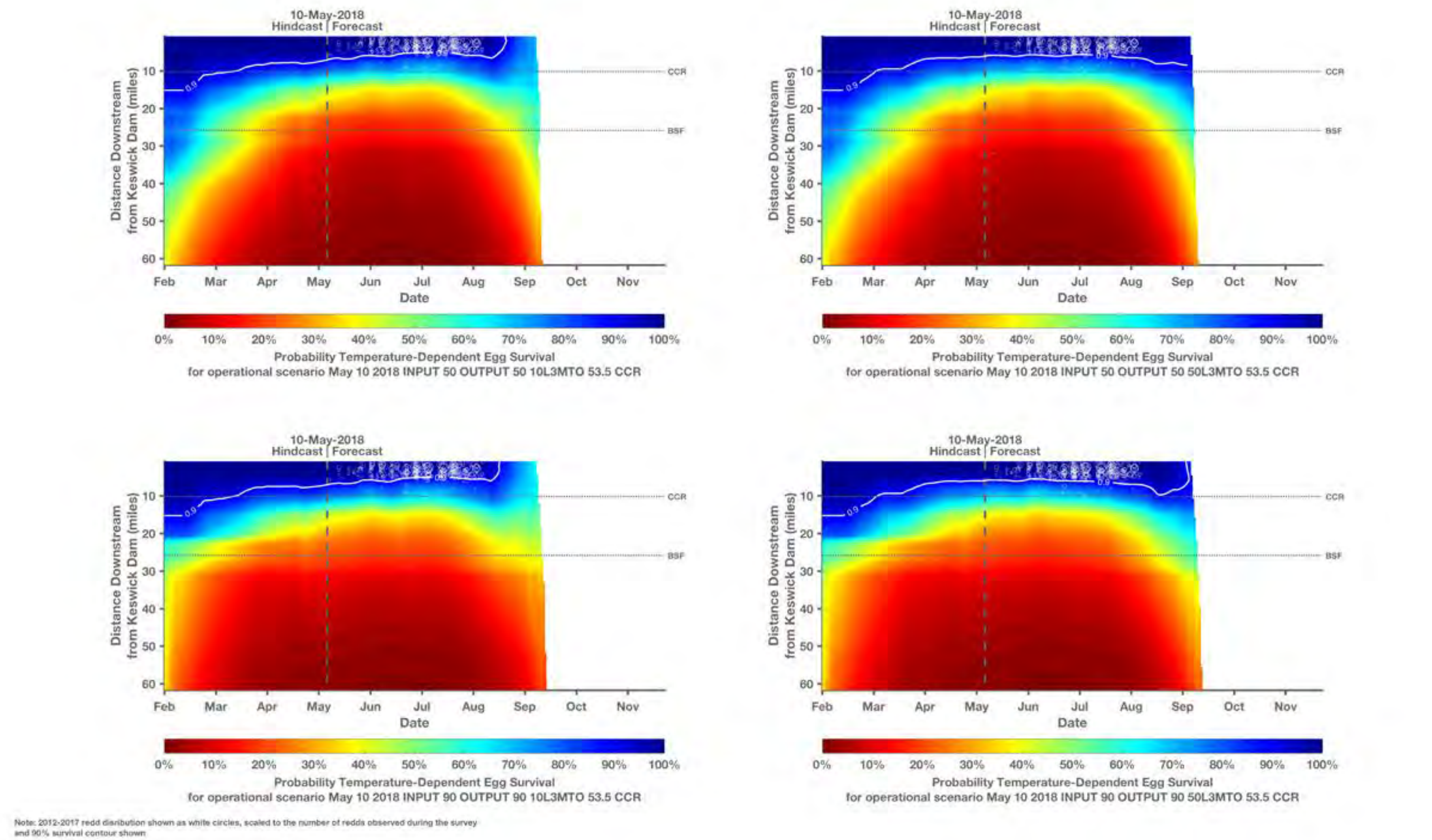


Figure 3: Estimated temperature-dependent egg survival produced by the NMFS temperature mortality model under the four May 10th 2018 scenarios targeting a CCR temperature of 53.5 F.

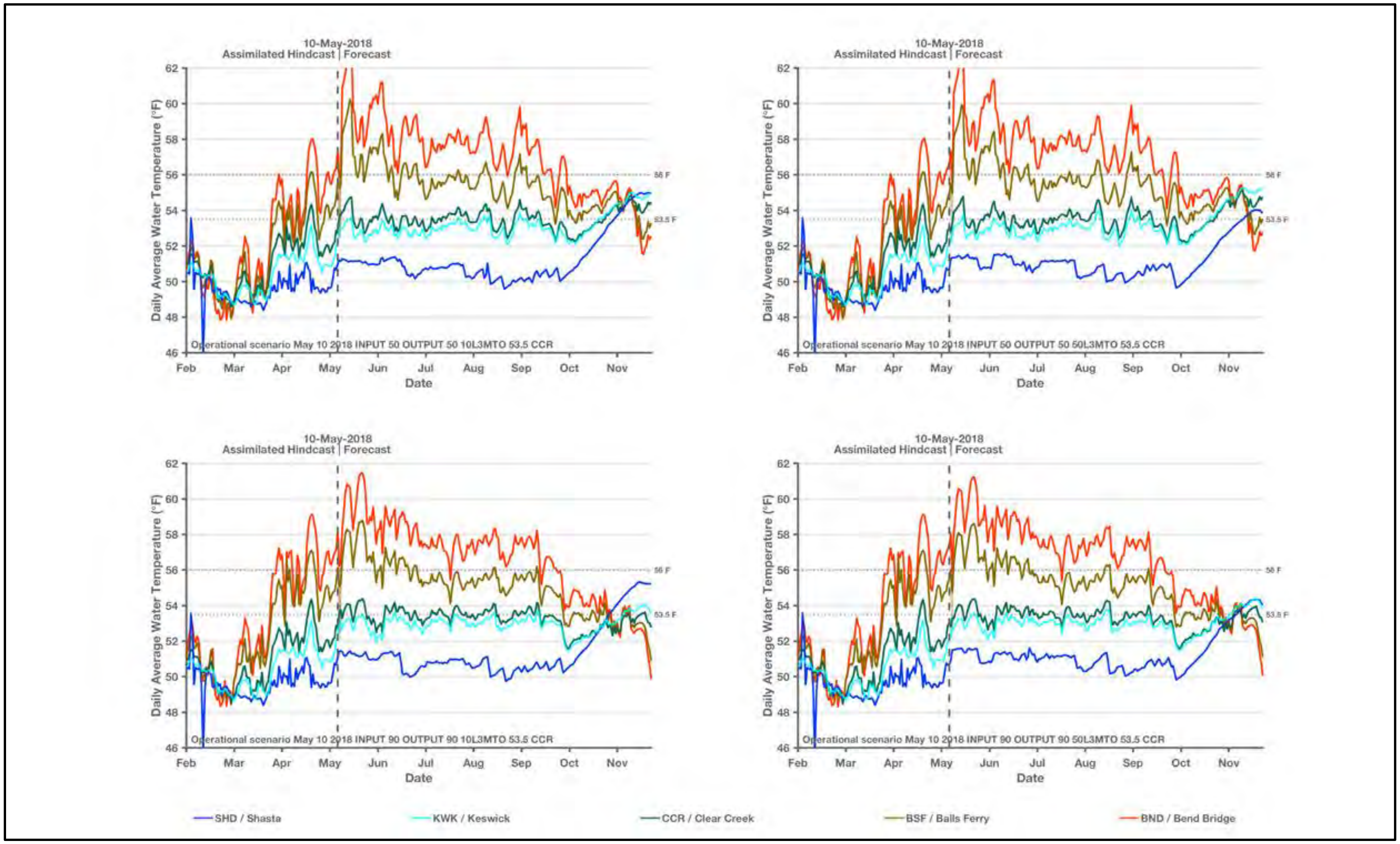


Figure 4: Estimated daily average water temperature produced by scenario input (Shasta, Keswick, Clear Creek, Balls Ferry, and Bend Bridge) under the four May 10th 2018 scenarios targeting a CCR temperature of 53.5 F using HEC-5Q output.

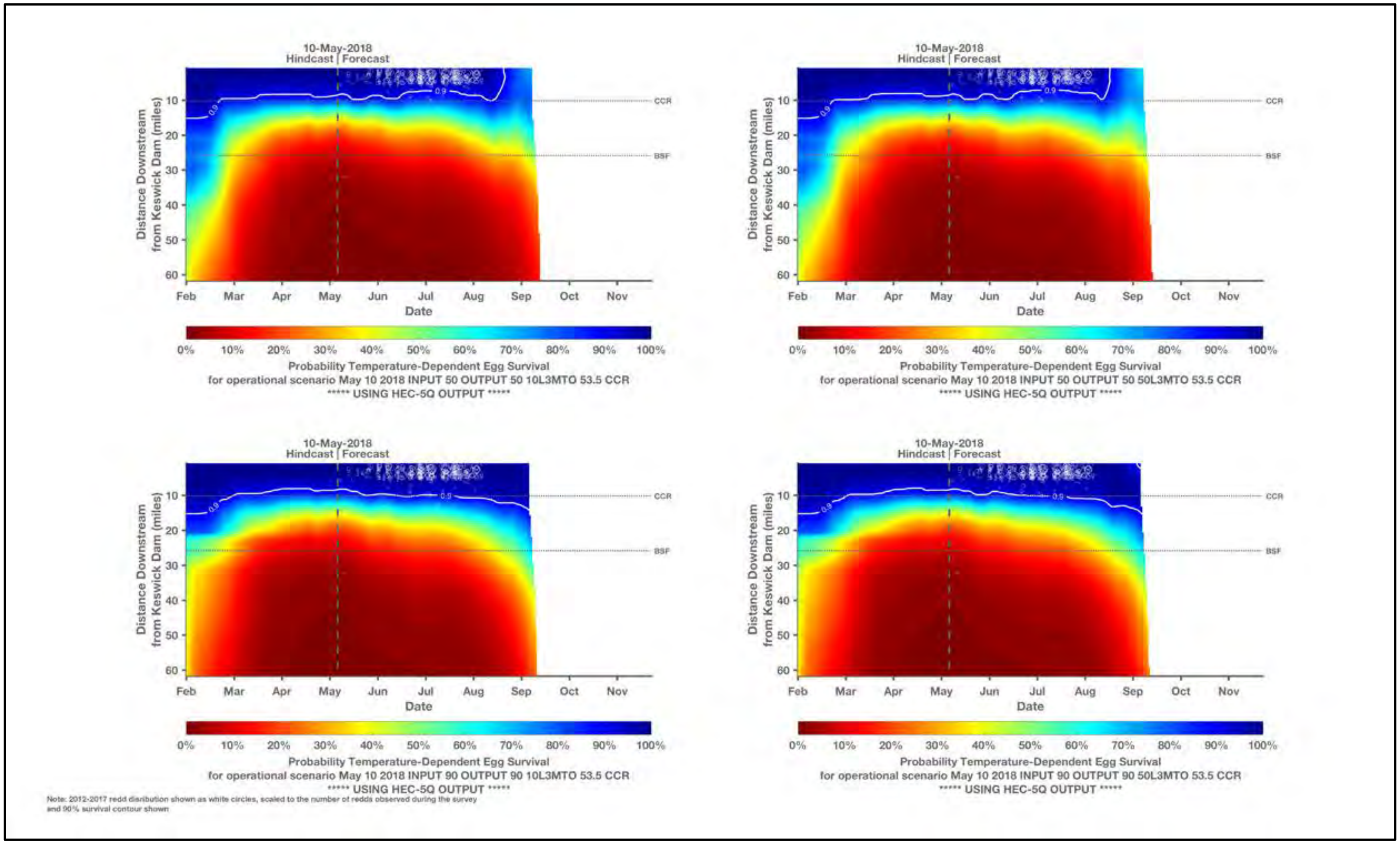


Figure 4: Estimated temperature-dependent egg survival produced by the NMFS temperature mortality model under the four May 10th 2018 scenarios targeting a CCR temperature of 53.5 F using HEC-5Q output. To generate temperatures between HEC-5Q model nodes (KESWICK, CLEAR_CR, BALL_FERRY, JELLYS_FERRY, BEND_BR, and RED_BLIFF) linear interpolation in space was used.

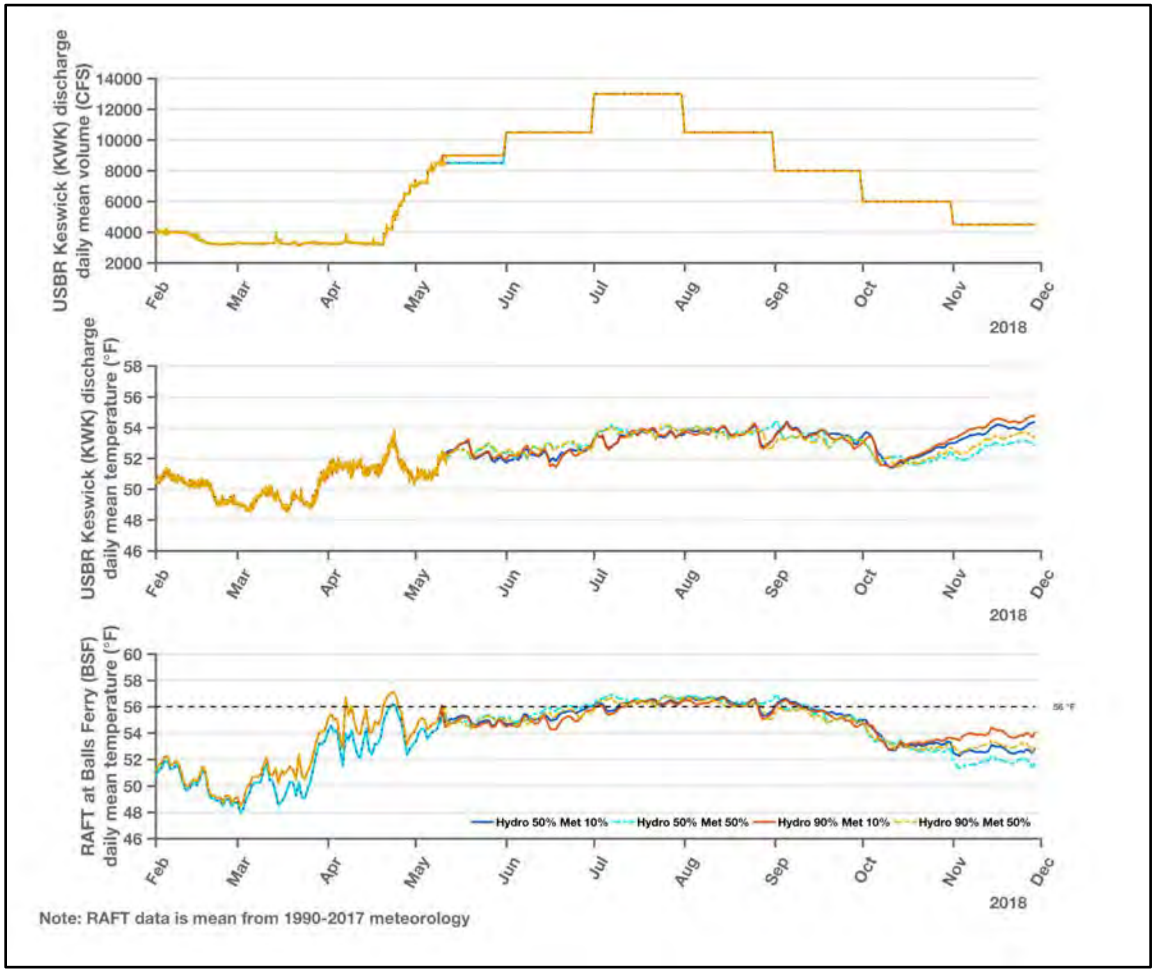


Figure 5: Summary plots showing differences in Keswick discharge volume and temperature, and Balls Ferry RAFT predicted temperature for four scenarios assessed targeting a CCR temperature of 53 F in May and a BSF temperature of 56 F from June-Oct.

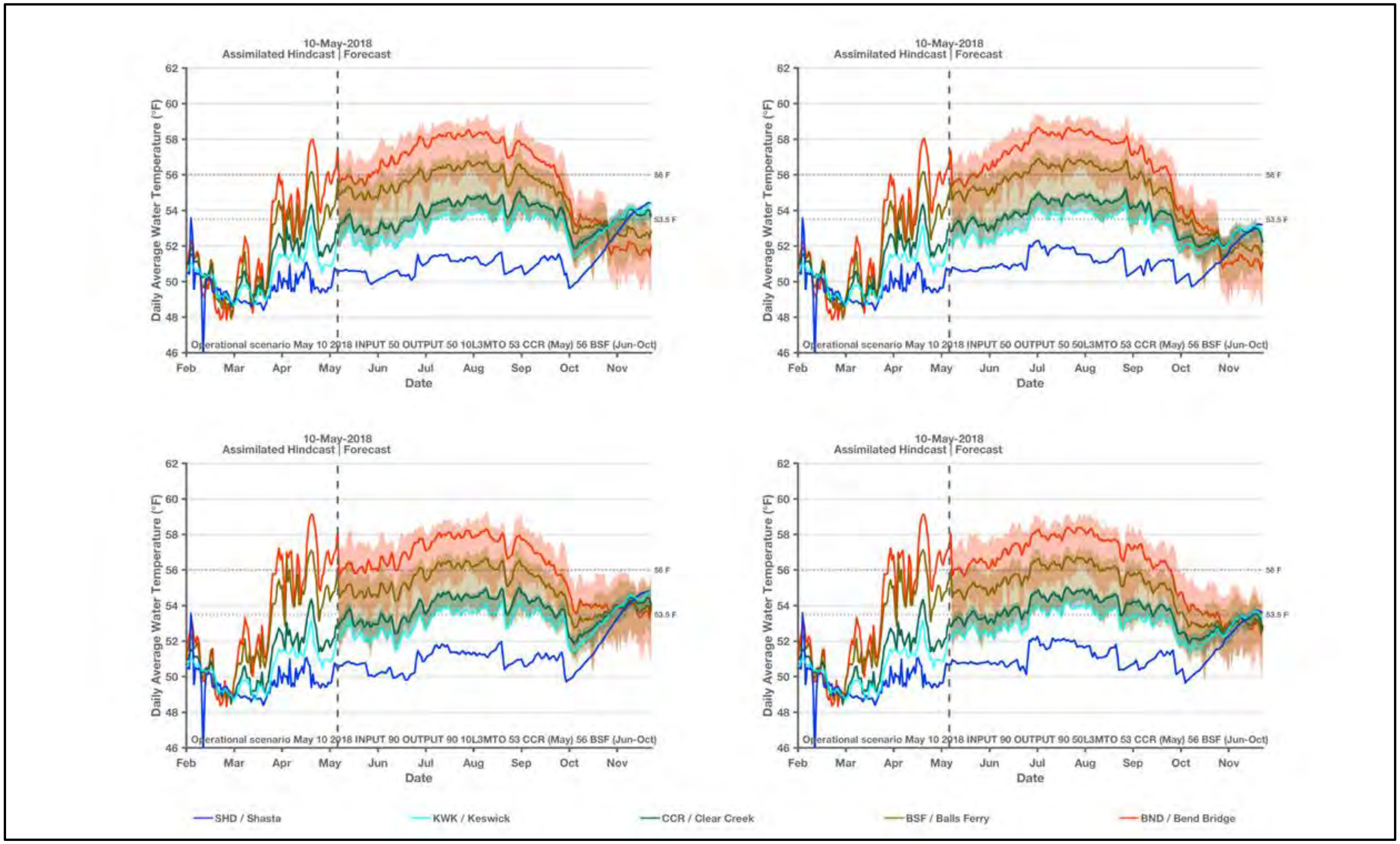


Figure 6: Estimated daily average water temperature produced by scenario input (Shasta and Keswick) and the RAFT model (Clear Creek, Balls Ferry, and Bend Bridge) under the four May 10th 2018 scenarios targeting a CCR temperature of 53 F in May and a BSF temperature of 56 F from June-Oct.

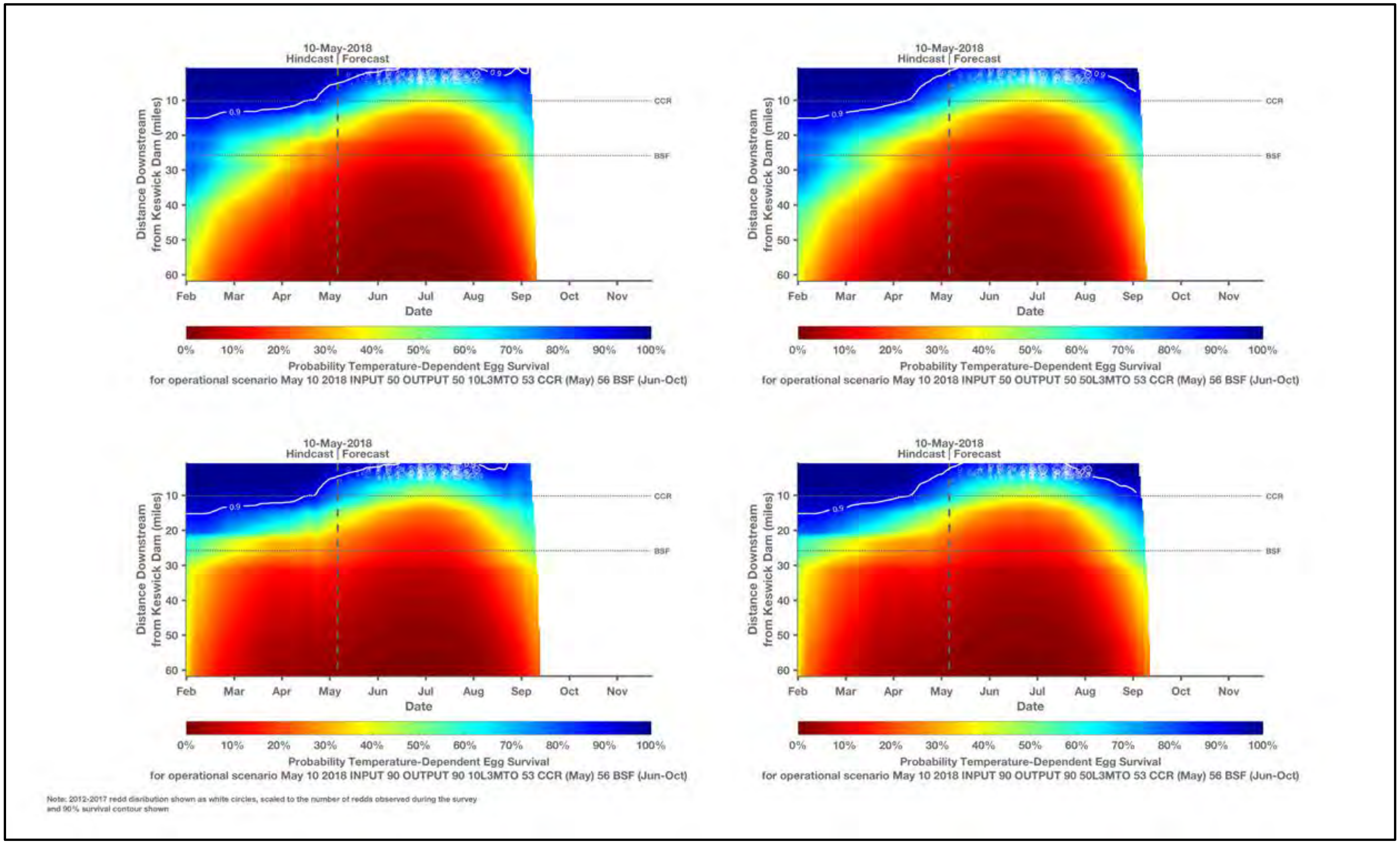


Figure 7: Estimated temperature-dependent egg survival produced by the NMFS temperature mortality model under the four May 10th 2018 scenarios targeting a CCR temperature of 53 F in May and a BSF temperature of 56 F from June-Oct.

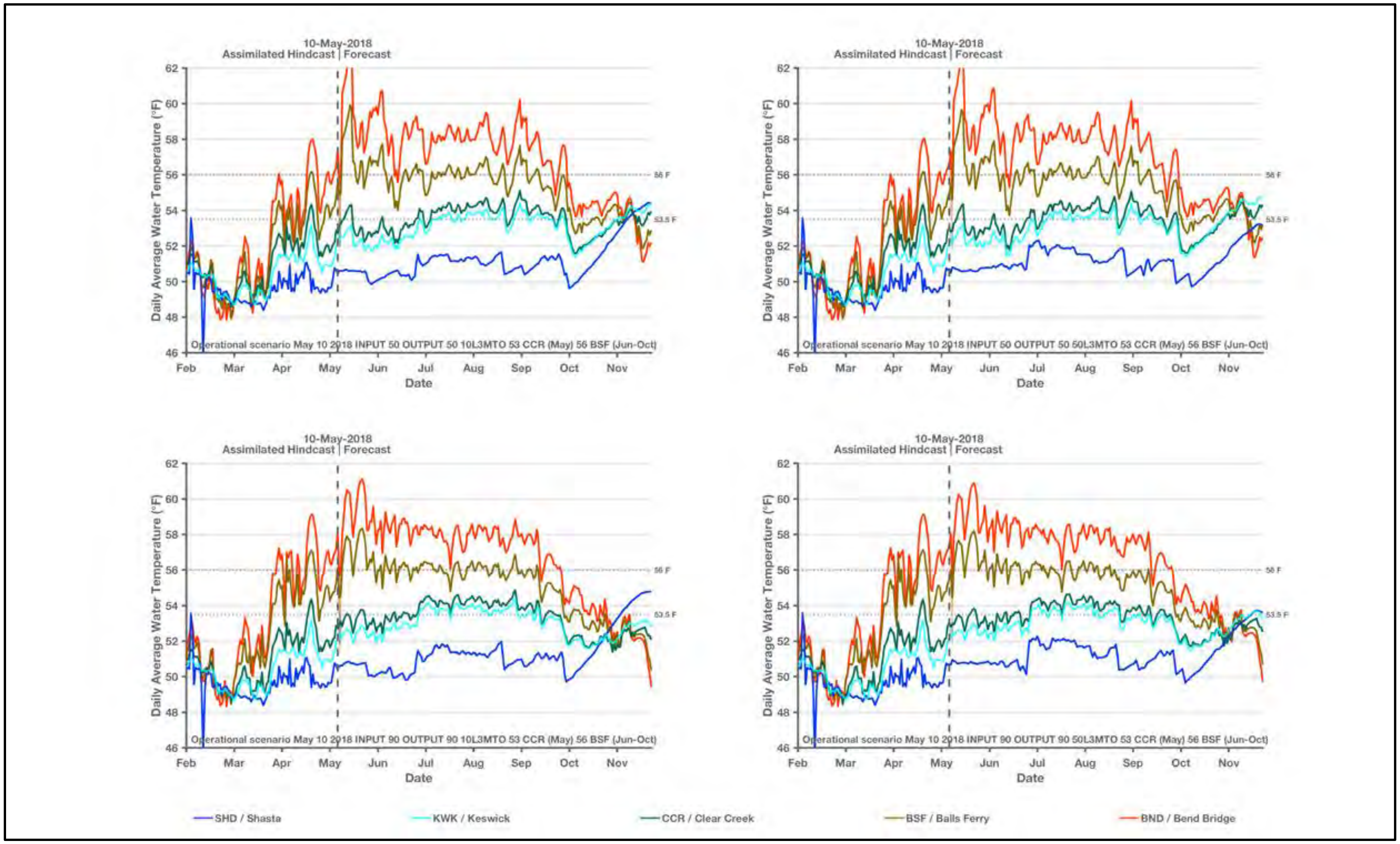


Figure 8: Estimated daily average water temperature produced by scenario input (Shasta, Keswick, Clear Creek, Balls Ferry, and Bend Bridge) under the four May 10th 2018 scenarios targeting a CCR temperature of 53 F in May and a BSF temperature of 56 F from June-Oct using HEC-5Q output.

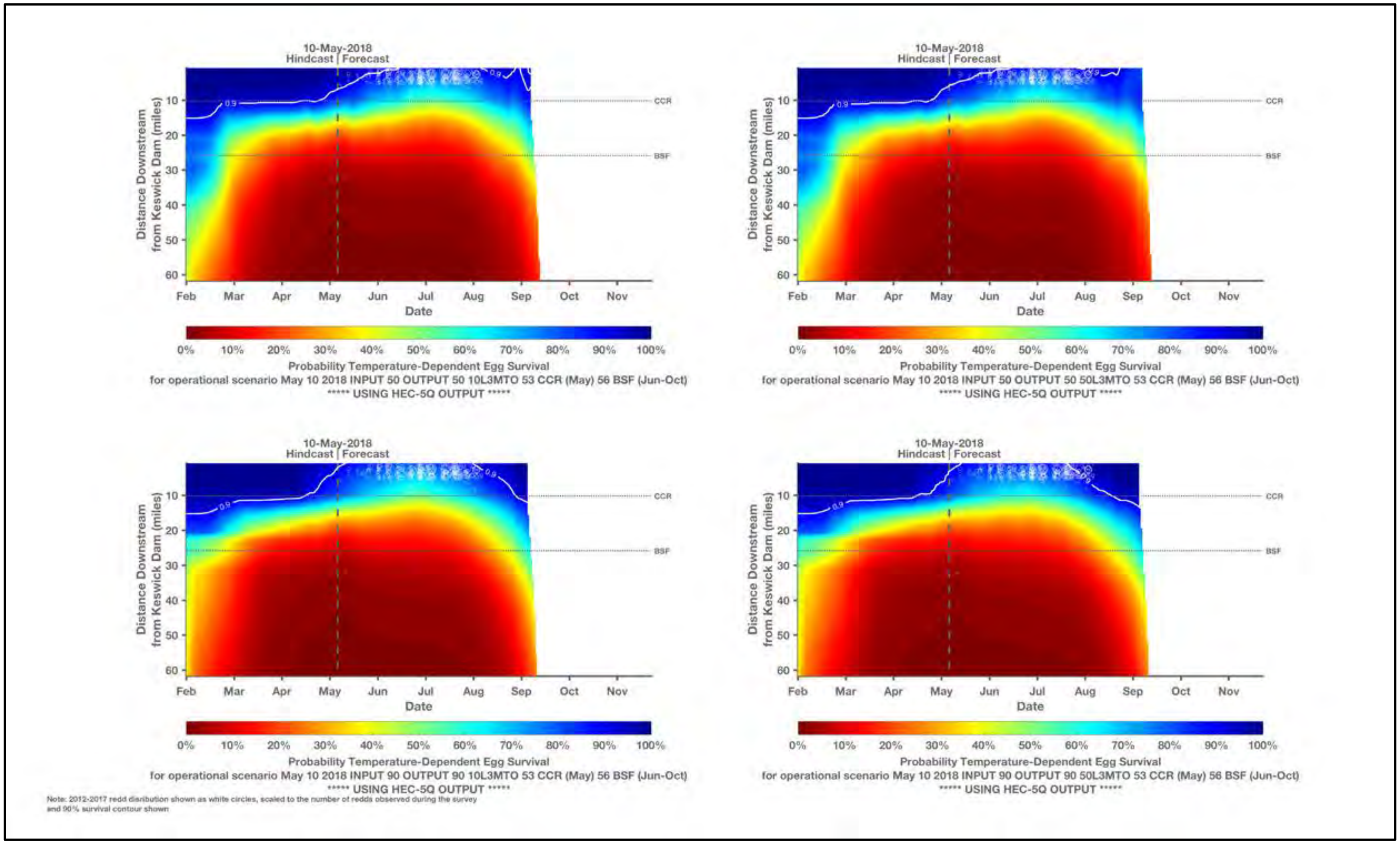


Figure 9: Estimated temperature-dependent egg survival produced by the NMFS temperature mortality model under the four May 10th 2018 scenarios targeting a CCR temperature of 53 F in May and a BSF temperature of 56 F from June-Oct using HEC-5Q output. To generate temperatures between HEC-5Q model nodes (KESWICK, CLEAR_CR, BALL_FERRY, JELLYS_FERRY, BEND_BR, and RED_BLIFF) linear interpolation in space was used.

Reference:

Martin, B. T., Pike, A., John, S. N., Hamda, N., Roberts, J., Lindley, S. T. and Danner, E. M. (2017), Phenomenological vs. biophysical models of thermal stress in aquatic eggs. Ecology Letters 20: 50–59. doi:10.1111/ele.12705

Table 1. Summary of temperature-dependent egg mortality from various hydrologic scenarios.

Date	Date of Shasta profile	Scenario	Hydrology	Meteorological inputs	Temperature model	Mean egg mortality (%)	Median egg mortality (%)	Lower confidence level egg mortality (%)	Upper confidence level egg mortality (%)
4/18/2018	4/3/2018	56°F Balls Ferry (BSF)	50%	10%L3MTO	RAFT	32.40	32.6	0.08	70.60
4/18/2018	4/3/2018	56°F BSF	50%	10%L3MTO	HEC-5Q	29.03	27.54	0.08	69.12
4/18/2018	4/3/2018	56°F BSF	50%	50%L3MTO	RAFT	44.09	48.02	0.08	74.61
4/18/2018	4/3/2018	56°F BSF	50%	50%L3MTO	HEC-5Q	40.56	43.04	0.08	73.08
4/18/2018	4/3/2018	56°F BSF	90%	10%L3MTO	RAFT	34.58	35.02	0.08	71.40
4/18/2018	4/3/2018	56°F BSF	90%	10%L3MTO	HEC-5Q	31.32	30.35	0.08	69.78
4/18/2018	4/3/2018	56°F BSF	90%	50%L3MTO	RAFT	38.52	40.64	0.08	73.45
4/18/2018	4/3/2018	56°F BSF	90%	50%L3MTO	HEC-5Q	35.19	36.01	0.08	71.55
4/20/2018	4/17/2018	56°F BSF	90%	10%L3MTO	RAFT	14.46	4.95	0.08	61.79
4/20/2018	4/17/2018	56°F BSF	90%	10%L3MTO	HEC-5Q	12.86	3.46	0.08	59.98
4/24/2018	4/17/2018	55.5°F BSF	50%	50% (1985-2017)	HEC-5Q	9.44	2.02	0.08	54.16
4/24/2018	4/17/2018	55.5°F BSF	50%	10% (1985-2017)	HEC-5Q	10.38	3.15	0.08	55.02
4/24/2018	4/17/2018	55.5°F BSF	90%	50% (1985-2017)	HEC-5Q	9.77	2.07	0.08	55.01
4/24/2018	4/17/2018	55.5°F BSF	90%	10% (1985-2017)	HEC-5Q	11.88	3.08	0.08	58.41
4/24/2018	4/17/2018	53°F CCR	90%	10% (1985-2017)	HEC-5Q	5.16	0.27	0.08	44.30
5/10/2018	5/1/2018	53.5°F CCR	50%	10% (1985-2017)	RAFT	11.95	3.63	0.03	58.78
5/10/2018	5/1/2018	53.5°F CCR	50%	10% (1985-2017)	HEC-5Q	10.90	2.94	0.08	56.61
5/10/2018	5/1/2018	53.5°F CCR	50%	50% (1985-2017)	RAFT	11.33	2.02	0.04	58.88
5/10/2018	5/1/2018	53.5°F CCR	50%	50% (1985-2017)	HEC-5Q	11.46	4.16	0.08	56.47
5/10/2018	5/1/2018	53.5°F CCR	90%	10% (1985-2017)	RAFT	12.49	4.84	0.08	58.64
5/10/2018	5/1/2018	53.5°F CCR	90%	10% (1985-2017)	HEC-5Q	9.86	1.23	0.08	56.42
5/10/2018	5/1/2018	53.5°F CCR	90%	50% (1985-2017)	RAFT	11.04	2.47	0.04	58.06
5/10/2018	5/1/2018	53.5°F CCR	90%	50% (1985-2017)	HEC-5Q	9.69	1.79	0.08	55.66
5/10/2018	5/1/2018	53°F CCR May, 56°F BSF June-October	50%	10% (1985-2017)	RAFT	25.61	22.99	0.08	67.74
5/10/2018	5/1/2018	53°F CCR May, 56°F BSF June-October	50%	10% (1985-2017)	HEC-5Q	23.39	19.54	0.08	66.13
5/10/2018	5/1/2018	53°F CCR May, 56°F BSF June-October	50%	50% (1985-2017)	RAFT	27.96	26.54	0.08	68.78
5/10/2018	5/1/2018	53°F CCR May, 56°F BSF June-October	50%	50% (1985-2017)	HEC-5Q	22.49	18.32	0.08	65.17
5/10/2018	5/1/2018	53°F CCR May, 56°F BSF June-October	90%	10% (1985-2017)	RAFT	24.46	21.41	0.08	66.83

5/10/2018	5/1/2018	53°F CCR May, 56°F BSF June-October	90%	10% (1985-2017)	HEQ-5Q	24.82	22.35	0.08	67.05
5/10/2018	5/1/2018	53°F CCR May, 56°F BSF June-October	90%	50% (1985-2017)	RAFT	24.03	20.56	0.08	66.57
5/10/2018	5/1/2018	53°F CCR May, 56°F BSF June-October	90%	50% (1985-2017)	HEQ-5Q	21.28	16.97	0.08	64.59

*Temperature-dependent egg mortality results assume a 2012-2017 spatial and temporal winter-run Chinook salmon redd distribution