EXHIBIT ARWA-907

Technical Memorandum 9

Lower American River Water Temperature Regression Relationships

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1.0 INTRODUCTION

This technical memorandum documents a multiple regression modeling approach for predicting daily average and daily maximum water temperature in the lower American River (LAR) based on air temperature, Nimbus discharge to the LAR, and Folsom Dam release water temperature. Water temperature regression equations were developed for the LAR at Hazel Avenue and Watt Avenue and a set of regression equations was developed to predict water temperature at any river mile location along the LAR between Nimbus Dam and the confluence with the Sacramento River. The regression relationships are suitable to be used in a variety of ways to predict LAR water temperatures, but were specifically developed to be used in combination with the Folsom Reservoir CE-QUAL-W2 Temperature Model (Technical Memorandum 5) to iterate between Automated Temperature Selection Procedure (ATSP) schedules (Water Forum 2004; Water Forum 2006) and to analyze the effects of different alternatives on LAR water temperatures.

2.0 LOWER AMERICAN RIVER DATA SOURCES

The sources for the discharge, water temperature, and air temperature data used in the regression equations are provided in Table 1 and the locations of these data sources are shown in Map 1. All data were quality controlled prior to use in the analyses.

3.0 AVERAGE DAILY WATER TEMPERATURES

3.1 METHODS

Regression Equation Input Data

Water temperature regression variables used for the LAR were 1) daily average discharge in the LAR, 2) daily average water temperature below Folsom Dam, 3) daily average air temperature and 4) river mile / river location (Table 1).

The discharge used in the water temperature regressions was calculated by daily-averaging Folsom Dam outflows (California Data Exchange Center ([CDEC] CDEC-FOL) and subtracting the daily average Folsom South Canal Diversion flows (CDEC-FSC). The resulting discharge approximated the daily average flow in the LAR.

The water temperature data for Folsom Dam releases were obtained from the USGS gaging station / CDEC station below Folsom Dam (USGS 11446220/ CDEC-AFD).

Historical local air temperature data for the LAR were obtained from the California Irrigation Management Information System (CIMIS) meteorological (MET) station at Fair Oaks (CIMIS-131).

Historical water temperature data for the LAR below Lake Natoma were available from three locations: Hazel Avenue (RM 22.3); William B Park (RM 13.3); and Watt Avenue (RM 9.2). In addition, some limited water temperature data (limited years) at various locations on the American River were obtained from CBEC, Inc. (Chris Hammersmark, Pers. Comm.) and used to "spot" validate the regressions.

Multiple Regression Equation Approach

General

To predict daily average water temperature at Hazel Avenue or Watt Avenue, a multiple regression equation was developed at each location that related daily average water temperature at that location to daily average flow releases into the LAR, daily average water temperature of Folsom Dam (CDED-FOL) releases, and local daily average air temperatures (CIMIS-131 at Fair Oaks) for the period 2001 –2009[1]. To predict daily average water temperature at any river mile on the LAR, the river mile water temperature regression included the river mile of each water temperature station (Hazel Avenue, William B. Pond, Watt Avenue) in the dataset as an additional parameter.

The daily average water temperature regressions were developed for each month of the year. The monthly approach helped account for seasonal variables not included in the regressions (e.g., solar radiation). The regression relationships were, however, designed to predict daily water temperatures for any day of the year. To do that, the regression equation monthly coefficients and constants are linearly interpolated between the monthly values (with monthly values centered at the middle of each month) to obtain daily regression coefficients for each day of the year.

Water Release Lag Time

When water is released from Folsom Dam, it takes between 1 and 8 days for the water to travel through Lake Natoma, be released from Nimbus dam, and reach Watt Avenue, depending on the flow rate. When flows or the water temperature of Folsom Dam releases were relatively steady from day-to-day, incorporating a release lag time into the regression equations did not significantly increase the accuracy of the regression equations. Conversely, if releases, particularly the water temperature of the releases, changed significantly from day-to-day (e.g., water from different reservoir levels), incorporating the water release lag time into the regression was beneficial. For the Watt Avenue regression, which was specifically intended to be used in conjunction with the Folsom Reservoir CE-QUAL-W2 model to update Folsom Reservoir temperature control device (TCD) operations and meet ATSP schedules on a daily basis, a version of the regression equations was developed that incorporated the released water lag time.

A mathematical relationship for calculating lag time between Folsom Dam and Watt Avenue was developed by analyzing hydrodynamic results from the CE-QUAL-W2 model of Lake Natoma (Technical Memorandum 6 Lake Natoma CE-QUAL-W2 Model and Calibration Report) and the HecRas model of the Lower American (Chris Hammersmark, Pers. Comm.). The relationship is shown in Figure 1. The equation is as follows[2]:

$$Lag\ time\ (days) = 3966.8 * (35.314 * Flow(cms))^{-0.944} \quad (1)$$

[1] The location of the gaging station at Watt Avenue moved in 2009; only data prior to this were used in the development of the regression relationships.

[2] Final equation provided by Chris Hammersmark (CBEC, Inc.) by email to Vanessa Martinez (Cardno) on 1/29/2015

Based on preliminary analysis, it was determined that the best-fit Watt Avenue temperature regression included lagging only the Folsom release temperature using Equation 1. Time lagging other variables (flow rate, air temperature) was not beneficial to the regression.

3.2 RESULTS

Hazel Avenue

The monthly constants and regression coefficients used to predict daily average water temperature for Hazel Avenue are shown in Table 2. The overall regression performance is shown in Figure 2 by plotting measured versus regression-based average daily temperatures at Hazel Avenue. A time series comparison of the predicted and measured water temperatures from 2001-2009 at Hazel Avenue is shown in Figure 3. Flow rate influenced water temperature in the later spring/summer, but had less effect on water temperature in winter/early spring months. The seasonal influence of flow rate on water temperatures is shown in Attachment A Figure 1.

Watt Avenue

The monthly constants and regression coefficients used to predict daily average water temperatures at Watt Avenue are shown in Table 3 for the Folsom release temperature time lagged regression and in Table 4 for the "without time lag" regression. The overall regression performance (with lagged release temperature) is shown in Figure 4 by plotting measured versus regression-based average daily temperatures at Watt Avenue. A time series comparison of the predicted and measured water temperatures from 2001-2009 at Watt Avenue is shown in Figure 5**Error! Reference source not found.**. Discharge influenced water temperature in the later spring/summer, but had less effect on water temperature in winter/early spring months. The seasonal influence of flow rate on water temperatures is shown inAttachment A Figure 2. Lower American River Flow only versus Water Temperature at Watt Avenue Regression Relationships (2001-2009).

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River Mile Locations

The monthly constants and regression coefficients used to predict daily average water temperatures at any specified RM along the LAR are shown in Table 5. The overall regression performance is shown in Figure 6 by plotting measured versus regression-based average daily temperatures at river mile locations where data are available. Predicted (regression-based) water temperatures at five mile increments along the LAR for a subset of the calibration time period (2009--2010) is shown in Figure 7. Model versus data comparisons are shown at three locations along the Lower American River for 2001-2011 in Figure 8. Similar to the Hazel Avenue and Watt Avenue regressions, flow rate influenced water temperature more in the spring/summer months than in the winter months, particularly in the lower sections of the reach.

4.0 MAXIMUM DAILY WATER TEMPERATURES

4.1 METHODS

Regression Equation Input Data

Maximum water temperature regression variables for the LAR were 1) daily average discharge in the LAR, 2) daily maximum 3) daily average water temperature (at Hazel Ave., William B Pond, Watt Ave., depending on regression), 4) daily average air temperature, and 5) river mile / river location (for river mile regression) (Table 1).

The discharge input used in the water temperature regressions was calculated by daily-averaging Folsom Dam outflows (California Data Exchange Center ([CDEC] CDEC-FOL) and subtracting the daily average Folsom South Canal Diversion flows (CDEC-FSC). The resulting discharge approximated the daily average flow in the LAR.

Historical air temperature data for the LAR were obtained from the California Irrigation Management Information System (CIMIS) meteorological (MET) station at Fair Oaks (CIMIS-131).

Historical water temperature data for the LAR below Lake Natoma were available from: Hazel Avenue (RM 22.3), William B Park (RM 13.3), and Watt Avenue (RM 9.2). In addition, some limited water temperature data (limited years) at various locations on the American River were obtained from CBEC, Inc. (Chris Hammersmark, Pers. Comm.), and used to "spot" validate the regressions.

Multiple Regression Equation Approach

General

To predict daily maximum water temperature at Hazel Avenue or Watt Avenue, a multiple regression equation was developed at each location that related daily maximum water temperature at that location to daily average flow releases into the LAR, daily average water temperature, and daily average air temperatures (CIMIS-131 at Fair Oaks) for the period 2001 – 2011. To predict daily maximum water temperature at any river mile on the LAR, the river mile water temperature regression included the river mile of each water temperature station (Hazel Ave., William B. Pond, Watt Ave.) in the dataset. River mile was included as a scaled power parameter, modified by two coefficients (i.e., a*RiverMile^b). The final regression requires using the regression developed in Section 3.0 Average Daily Water Temperatures to provide the average water temperature input to the equations.

The daily maximum water temperature regressions were developed for each month of the year. The monthly approach helped account for seasonal variables not included in the regressions (e.g., solar radiation). The regression relationships were, however, designed to predict daily maximum water temperatures for any day of the year. To do that, the regression equation monthly coefficients and constants are interpolated between the monthly values (with monthly values centered at the middle of each month) to obtain daily regression coefficients for each day of the year.

4.2 RESULTS

Hazel Avenue

The monthly constants and regression coefficients used to predict daily maximum water temperature for Hazel Avenue are shown in Table 6. All months showed very robust relationships with R^2 values between 0.96 and 1.00. The overall regression performance is shown in Figure 9 by plotting measured versus regression-based maximum daily temperatures at Hazel Avenue. A time series comparison of the predicted and measured water temperatures from 2001-2011 at Hazel Avenue is shown in Figure 10.

Watt Avenue

The monthly constants and regression coefficients used to predict daily maximum water temperature for Watt Avenue are shown in Table 7. All months showed very robust relationships with R^2 values between 0.90 and 0.99. The overall regression performance is shown in Figure 11 by plotting measured versus regression-based maximum daily temperatures at Watt Avenue. A time series comparison of the predicted and measured water temperatures from 2001-2011 at Watt Avenue is shown in Figure 12.

River Mile Locations

The monthly constants and regression coefficients used to predict daily maximum water temperatures at any specified RM along the LAR are shown in Table 8. The river mile portion of the multiple regression was non-linear (e.g., a*RiverMile^^{b}); therefore, interpolation of the "a" coefficient for application to daily modeling requires a special approach outlined at the bottom of Table 8. Predicted versus measured maximum daily water temperatures at the three locations along the river (Hazel Ave. RM 22.3, William B. Pond Park RM 13.6, Watt Ave. RM 9.2) are shown in Figure 13. A time series of predicted versus measured maximum daily temperatures at each location are shown in Figure 14, Figure 15, and Figure 16. Modeled maximum daily temperatures for these three locations are plotted together in Figure 17.

5.0 TABLES

Table 1. Data Sources for the Lower American River Water Temperature Regression Analyses.

Name	Data Collected	Operator	Station No.	Location		Period of Record Available	Period of Record Used in Regression Analyses
				Lat.	Long.		
Flow Stations							
Folsom Lake outflows	Daily Average Flow	US Bureau of Reclamation/ CDEC	CDEC-FOL	38.683	121.183	2/1/1995-present	1/1/2001-8/31/2009
Folsom South Canal	Diversion Flow	US Bureau of Reclamation/ CDEC	CDEC-FSC	38.650	121.183	7/11/2001-present	7/11/2001-8/31/2009
Water Temperature Stations							
American R. below Folsom Dam	Daily Water Temperature	USGS/ CDEC	USGS 11446220/ CDEC-AFD	38.688	121.166	10/24/1998-present	1/1/2001-8/31/2009
American R. at Hazel Ave. Bridge	Daily Water Temperature	USGS/ CDEC	USGS 11446220/ CDEC-AHZ	38.636	121.224	6/29/2001-present	6/29/2001-8/31/2009
American R. at William B. Pond Park	Daily Water Temperature	USGS/ CDEC	USGS 11446700/ CDEC-AWP	38.591	121.332	1/10/2001-present	10/1/2007-8/31/2009
American R. below Watt Ave. Bridge	Daily Water Temperature	USGS/ CDEC	USGS 11446980/ CDEC-AWB	38.567	121.387	11/30/1998-present	1/1/2001-8/31/2009[1]
Meteorological Station							
CIMIS at Fair Oaks	Daily Average Air Temperature	CIMIS	CIMIS at Fair Oaks	38.650	121.218	4/18/1997-present	4/18/1997-8/31/2009

Abbreviations:

CIMIS: California Irrigation Management Information System
USGS: United States Geological Survey
CDEC: California Data Exchange Center

[1] Location of gaging station was moved in 2009; only data prior to this were used in the development of the regressions.

Table 2. Coefficients Used for the Multiple Regression for Predicting Lower American River Average Daily Water Temperature at Hazel Avenue.

Month	Constant	A	B	C	R^2
Predicted Water Temp = Const. + A(Ave Air Temp) + B(Ave Water Temp below Folsom) + C(Log [Ave Flow])					
Jan	1.9464	0.0134	0.9398	-0.6182	0.838
Feb	3.0658	0.0634	0.8055	-0.8259	0.665
Mar	4.8402	0.0304	0.8408	-1.5306	0.859
Apr	8.0496	0.0490	0.6082	-1.7821	0.854
May	7.5008	0.0356	0.8387	-2.4903	0.934
Jun	9.2531	0.0257	0.7968	-2.9129	0.931
Jul	7.0760	-0.0156	0.8855	-1.9229	0.885
Aug	9.1246	0.0316	0.7682	-2.6583	0.751
Sep	9.7662	0.0845	0.6947	-3.2732	0.841
Oct	9.7572	0.0595	0.5984	-2.1663	0.865
Nov	8.1662	0.1901	0.5111	-1.8145	0.673
Dec	1.5390	0.0293	0.8908	-0.2236	0.925

Regression Variables:

Ave Air Temp = Daily average air temperature at CIMIS at Fair Oaks (CIMIS-131) (°C)

Ave Water Temp below Folsom = Daily water temperature below Folsom Data at USGS/CDEC station (USGS gage no. 11446220/ CDEC station AFD) (°C)

Ave Flow = Daily-averaged hourly flow below Folsom Reservoir (CDEC station FOL) – South Canal Diversion (CDEC station FSC) (cubic meters per second [cms])

Predicted Temp = Lower American River at Hazel Avenue (°C)

Table 3. Coefficients Used for the Multiple Regression for Predicting Lower American River Average Daily Water Temperature at Watt Avenue with Time Lagged Water Temperature.

Month	Constant	A	B	C	R^2
Predicted Water Temp = Const. + A(Ave Air Temp) + B(Lagged Ave Water Temp below Folsom) + C(Log[Ave Flow])					
Jan	1.818763	0.112641331	0.73259158	-0.147712419	0.57
Feb	3.539369	0.205141039	0.775380578	-1.499333534	0.45
Mar	4.987294	0.168695197	0.961301503	-2.512509452	0.91
Apr	8.855085	0.158340582	0.718969803	-3.034734768	0.91
May	11.86438	0.138534042	0.742039709	-4.371801735	0.95
Jun	12.62007	0.086480404	0.800890216	-4.43688051	0.95
Jul	13.08971	0.049031621	0.682266998	-3.293149439	0.94
Aug	16.90057	0.072653186	0.622758693	-5.222428569	0.91
Sep	15.26052	0.182748074	0.454786001	-4.508935727	0.84
Oct	2.757994	0.240015186	0.668043404	-0.344582923	0.82
Nov	-1.8198	0.231285327	0.828705359	0.703644524	0.96
Dec	-1.35138	0.167591589	0.685635625	1.786194262	0.87

Regression Variables:

Ave Air Temp = Daily average air temperature at CIMIS at Fair Oaks (CIMIS-131) (°C)

Ave Water Temp below Folsom = Daily water temperature below Folsom Data at USGS/CDEC station (USGS gage no. 11446220/ CDEC station AFD) (°C)

Ave Flow = Daily-averaged hourly flow below Folsom Reservoir (CDEC station FOL) – South Canal Diversion (CDEC station FSC) (cubic meters per second [cms])

Low Flows – water temperatures at low flows were modeled with HEC-5Q as described in the text.

Predicted Temp = Lower American River at Watt Avenue (°C)

[1]Low r-squared values are the result of a narrow range in flows in these months. These regressions represent the average water temperature.

Table 4. Coefficients Used for the Multiple Regression for Predicting Lower American River Average Daily Water Temperature at Watt Avenue without Time Lagged Water Temperature.

Month	Constant	A	B	C	R^2
Predicted Water Temp = Const. + A(Ave Air Temp) + B(Ave Water Temp below Folsom) + C(Log[Ave Flow])					
Jan	1.96471	0.112234	0.794124	-0.4599	0.59
Feb	2.807373	0.19099	0.859157	-1.40971	0.53
Mar	4.540722	0.158975	0.945175	-2.20309	0.88
Apr	8.476506	0.146524	0.686462	-2.57868	0.92
May	10.9384	0.15328	0.746008	-4.05553	0.93
Jun	12.99852	0.072963	0.790918	-4.44247	0.92
Jul	13.53072	0.058166	0.665339	-3.51614	0.87
Aug	16.56891	0.096824	0.602078	-5.15153	0.84
Sep	13.88743	0.186215	0.494713	-4.14767	0.85
Oct	3.846972	0.205693	0.685195	-0.77901	0.87
Nov	-4.20459	0.209982	0.960059	1.231348	0.93
Dec	1.040451	0.161682	0.754327	0.099866	0.89

Regression Variables:

Ave Air Temp = Daily average air temperature at CIMIS at Fair Oaks (CIMIS-131) (°C)

Ave Water Temp below Folsom = Daily water temperature below Folsom Data at USGS/CDEC station (USGS gage no. 11446220/ CDEC station AFD) (°C)

Ave Flow = Daily-averaged hourly flow below Folsom Reservoir (CDEC station FOL) – South Canal Diversion (CDEC station FSC) (cubic meters per second [cms])

Predicted Temp = Lower American River at Watt Avenue (°C)

[1]Low r-squared values are the result of a narrow range in flows in these months. These regressions represent the average water temperature.

Table 5. Coefficients Used for the River Mile Multiple Regression to Predict Average Daily Water Temperature at Specified Locations along the Lower American River.

Month	Constant	A	B	C	D	R^2
Predicted Water Temp = Constant + A(Ave Air T) + B(Ave Water T below Folsom) + C(Log[Ave Flow]) + D(RM)						
Jan	2.235497	0.055418	0.825738	-0.52645	0.008751	0.62
Feb	3.560284	0.136864	0.811086	-1.0953	-0.03644	0.56
Mar	6.527125	0.093312	0.85848	-1.95242	-0.08413	0.84
Apr	10.22137	0.100764	0.627146	-2.31341	-0.09348	0.87
May	10.58013	0.109122	0.845379	-3.40188	-0.12297	0.92
Jun	14.22662	0.048251	0.753645	-3.97143	-0.12483	0.92
Jul	13.63687	0.019043	0.760111	-3.24759	-0.1279	0.89
Aug	16.68644	0.062428	0.614724	-4.15399	-0.13937	0.84
Sep	14.90653	0.133762	0.548928	-4.02447	-0.11092	0.86
Oct	8.962731	0.133697	0.569276	-1.72354	-0.03133	0.81
Nov	7.706451	0.269051	0.453618	-1.73661	0.008454	0.68
Dec	0.97066	0.095728	0.836114	-0.16038	0.022549	0.90

Regression Variables:

Ave Air Temp = Daily average air temperature at CIMIS at Fair Oaks (CIMIS-131) (°C)

Ave Water Temp below Folsom = Daily water temperature below Folsom Data at USGS/CDEC station (USGS gage no. 11446220/ CDEC station AFD) (°C)

Ave Flow = Daily-averaged hourly flow below Folsom Reservoir (CDEC station FOL) – South Canal Diversion (CDEC station FSC) (cubic meters per second [cms])

RM = River Mile

Predicted Temp = Lower American River at RM "X" (°C)

Table 6. Coefficients Used for the Multiple Regression for Predicting Lower American River Maximum Daily Water Temperature at Hazel Avenue.

Month	Constant	A	B	C	R^2
Predicted Maximum Daily Water Temp @ Hazel = Const. + A(Ave Air Temp) + B(Ave Flow) + C(Ave Water Temp @ Hazel)					
Jan	0.17375	0.00003	0.00001	0.99449	0.99
Feb	-0.00264	0.00731	0.00018	1.01312	0.98
Mar	-0.07178	-0.00177	0.00001	1.03893	0.98
Apr	0.69535	0.00692	-0.00003	0.96403	0.96
May	0.48240	0.01581	-0.00008	0.97570	0.97
Jun	-0.18296	0.00659	0.00129	1.02190	0.98
Jul	-0.66568	0.00866	0.00336	1.03028	0.98
Aug	0.17533	0.01558	-0.00102	0.99770	0.97
Sep	0.60074	0.02433	-0.00225	0.96217	0.98
Oct	0.19623	0.00590	-0.00038	0.99600	0.99
Nov	0.35601	0.00128	-0.00107	0.98982	0.99
Dec	0.10980	-0.00370	0.00008	1.00387	1.00

Regression Variables:

Ave Air Temp = Daily average air temperature at CIMIS at Fair Oaks (CIMIS-131) (°C)

Ave Water Temp at Hazel Avenue

Ave Flow = Daily-averaged hourly flow below Folsom Reservoir (CDEC station FOL) – South Canal Diversion (CDEC station FSC) (cubic meters per second [cms])

Predicted Temp = Lower American River Daily Maximum at Watt Avenue (°C)

Table 7. Coefficients Used for the Multiple Regression for Predicting Lower American River Maximum Daily Water Temperature at Watt Avenue.

Month	Constant	A	B	C	R^2
Predicted Maximum Daily Water Temp @ Watt = Const. + A(Ave Air Temp) + B(Ave Flow) + C(Ave Water Temp @ Watt)					
Jan	1.00569	-0.00394	-0.00043	0.94919	0.93
Feb	0.71217	-0.00607	0.00007	1.00902	0.90
Mar	0.33731	0.05566	-0.00096	1.00540	0.96
Apr	0.89818	0.04517	-0.00142	0.99475	0.96
May	1.45530	0.03701	-0.00247	0.97258	0.97
Jun	1.04991	0.03389	-0.00424	1.02454	0.98
Jul	3.29308	0.00592	-0.00547	0.94674	0.98
Aug	2.73111	0.01389	0.00235	0.92145	0.97
Sep	2.05785	0.02953	0.00534	0.91187	0.97
Oct	0.29125	0.05054	0.01203	0.95499	0.96
Nov	-0.07404	0.00259	0.00280	1.03369	0.99
Dec	0.10571	-0.01679	-0.00017	1.04202	0.98

Regression Variables:

Ave Air Temp = Daily average air temperature at CIMIS at Fair Oaks (CIMIS-131) (°C)

Ave Water Temp at Watt Avenue

Ave Flow = Daily-averaged hourly flow below Folsom Reservoir (CDEC station FOL) – South Canal Diversion (CDEC station FSC) (cubic meters per second [cms])

Predicted Temp = Lower American River Daily Maximum at Watt Avenue (°C)

Table 8. Coefficients Used for the River Mile Multiple Regression to Predict Maximum Daily Water Temperature at Specified Locations along the Lower American River.

Month	Constant	A	B	C	D*	E
Predicted Maximum Daily Water Temp (@ specified RM) = Constant + A(Ave Air T) + B(Average Flow from Nimbus) + C(Ave Water T @ specified RM) - D*(RM)^E						
Jan	1.12655	-0.00390	-0.00088	0.95186	0.00010	3.87898
Feb	0.80414	0.00733	-0.00062	1.00411	1.56E-05	2.69554
Mar	0.47197	0.03883	-0.00133	1.03581	6.87E-05	3.42576
Apr	0.20330	0.02125	-0.00073	1.07582	2.91E-06	3.04489
May	0.20330	0.02125	-0.00073	1.07582	3.51E-06	4.08459
Jun	1.11537	0.01686	-0.00354	1.04520	0.00019	4.08459
Jul	3.24551	0.00501	-0.00661	0.96981	0.00094	2.83790
Aug	3.25360	0.01368	-0.00395	0.93010	9.72E-05	2.44781
Sep	2.89368	0.03580	-0.00306	0.89600	8.65E-07	3.13752
Oct	1.35000	0.04191	0.00271	0.93658	3.31E-08	4.58860
Nov	0.36491	0.00886	0.00059	1.01406	9.60E-08	5.50308
Dec	0.24219	-0.01729	-0.00020	1.03538	-5.35E-08	4.99985

Regression Variables:

Ave Air Temp = Daily average air temperature at CIMIS at Fair Oaks (CIMIS-131) (°C)

Ave Water Temp @ Specified RM = Daily average temperature recorded at any river mile location downstream of Nimbus.

Ave Flow = Daily-averaged hourly flow below Folsom Reservoir (CDEC station FOL) – South Canal Diversion (CDEC station FSC) (cubic meters per second [cms])

RM = River Mile

Predicted Temp = Lower American River at RM "X" (°C)

*Due to the non-linear nature of the scaled power component of the Maximum Daily Temperature Regression, the D coefficient was interpolated between months using a log transformation. The equation y=D*RME was transformed to log(y)=log(D)+E*log(RM). The log(D) component was linearly interpolated between months and the interpolated value was transformed back ($10^{log(D)}$= D) to be used for each daily calculation.

6.0 FIGURES

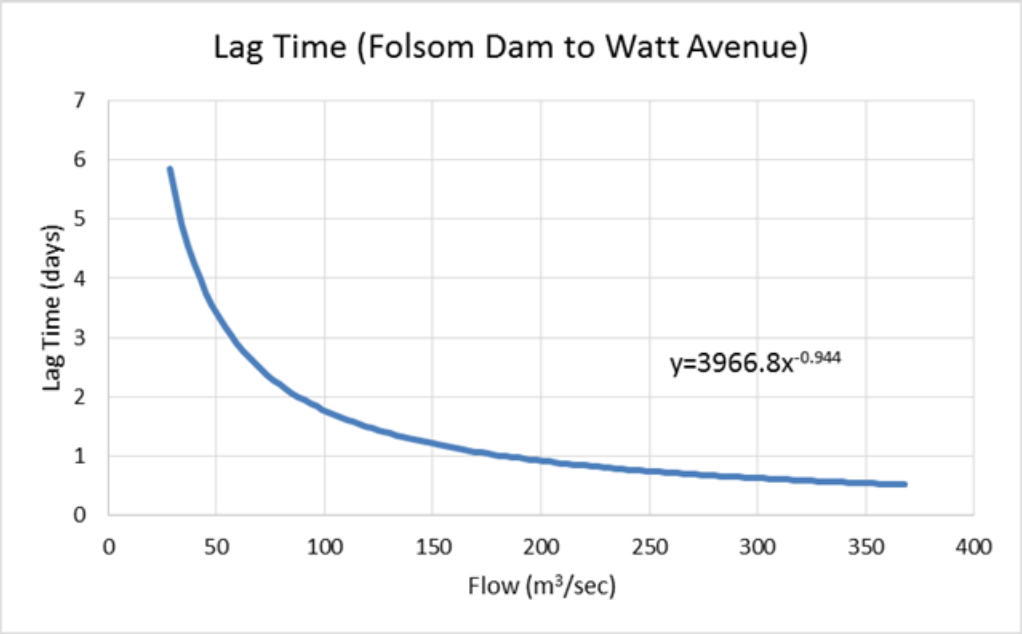


Figure 1. Flow Travel (Lag) time to Watt Avenue versus Flow.

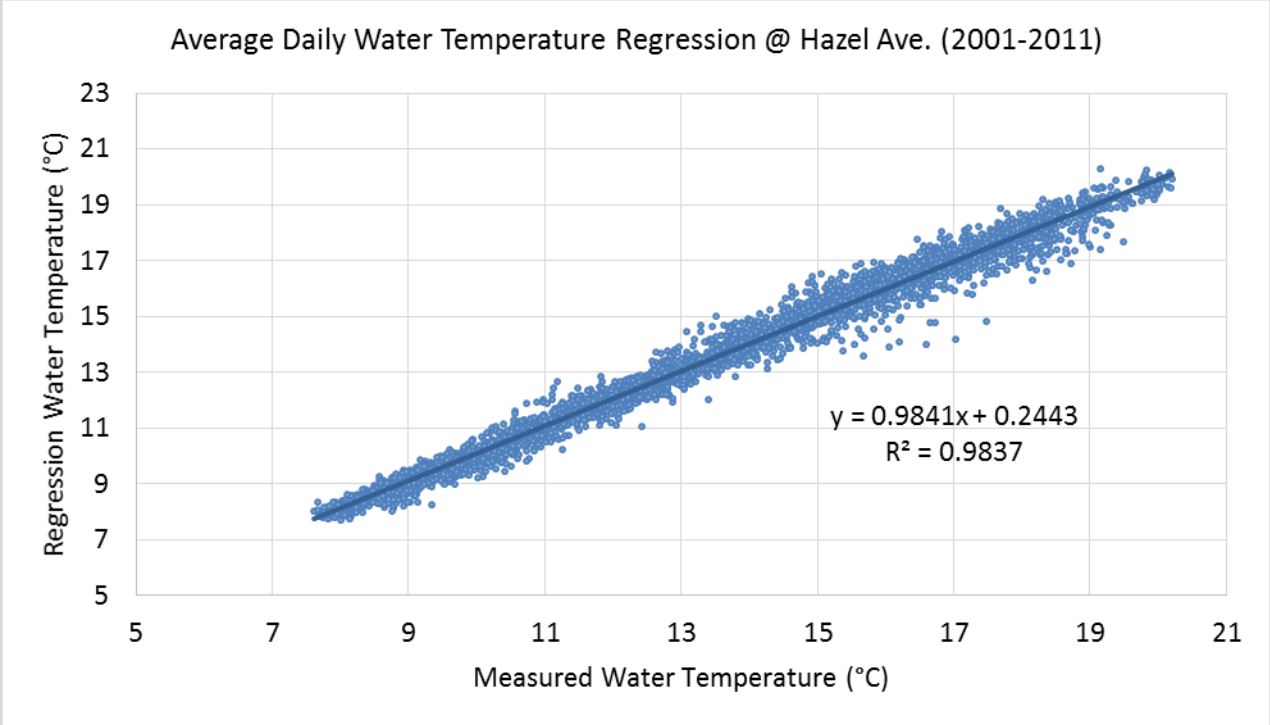


Figure 2. Measured versus Modeled (Regression) Average Daily Water Temperature at Hazel Avenue.

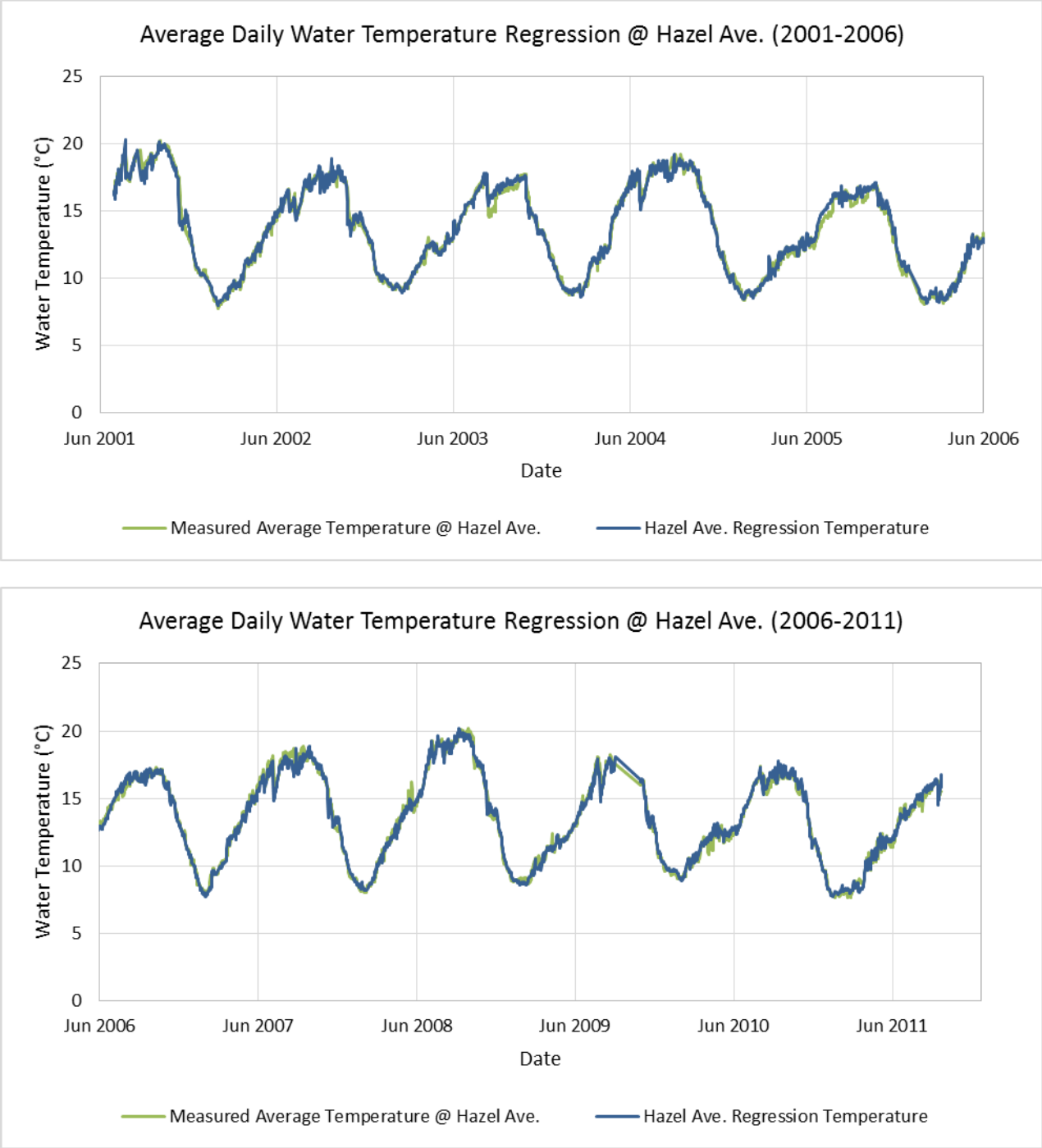


Figure 3. Comparison of Measured and Modeled (Regression) Average Daily Water Temperature Time Series on the Lower American River at Hazel Avenue (2001-2011).

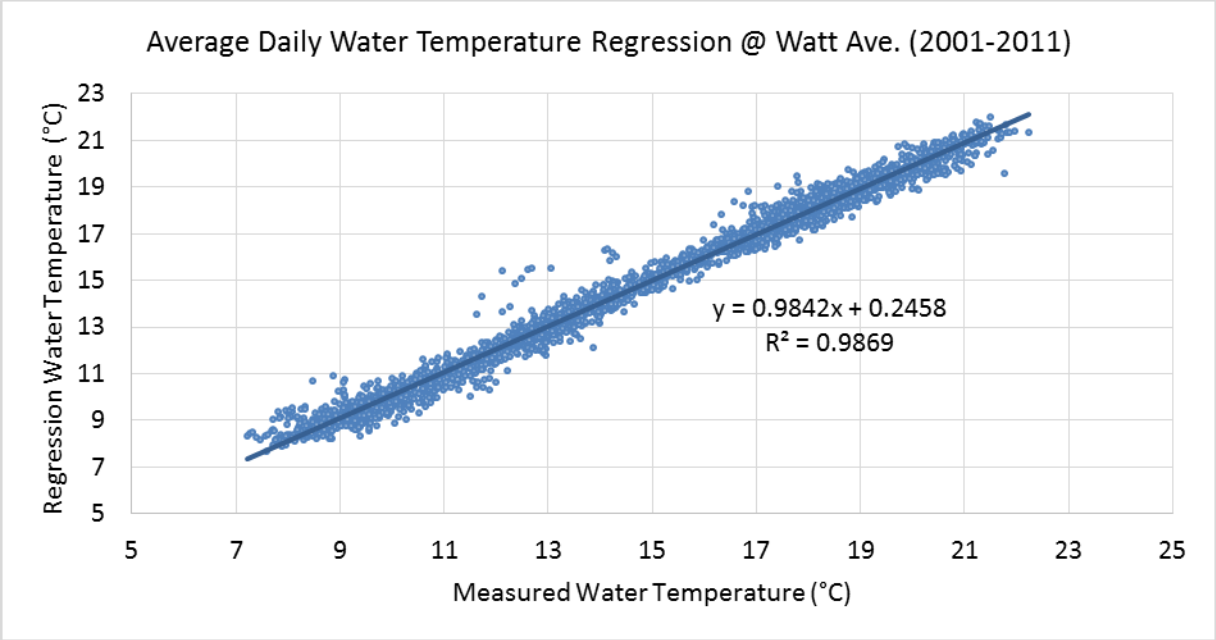


Figure 4. Measured versus Modeled (Regression) Average Daily Water Temperature at Watt Avenue.

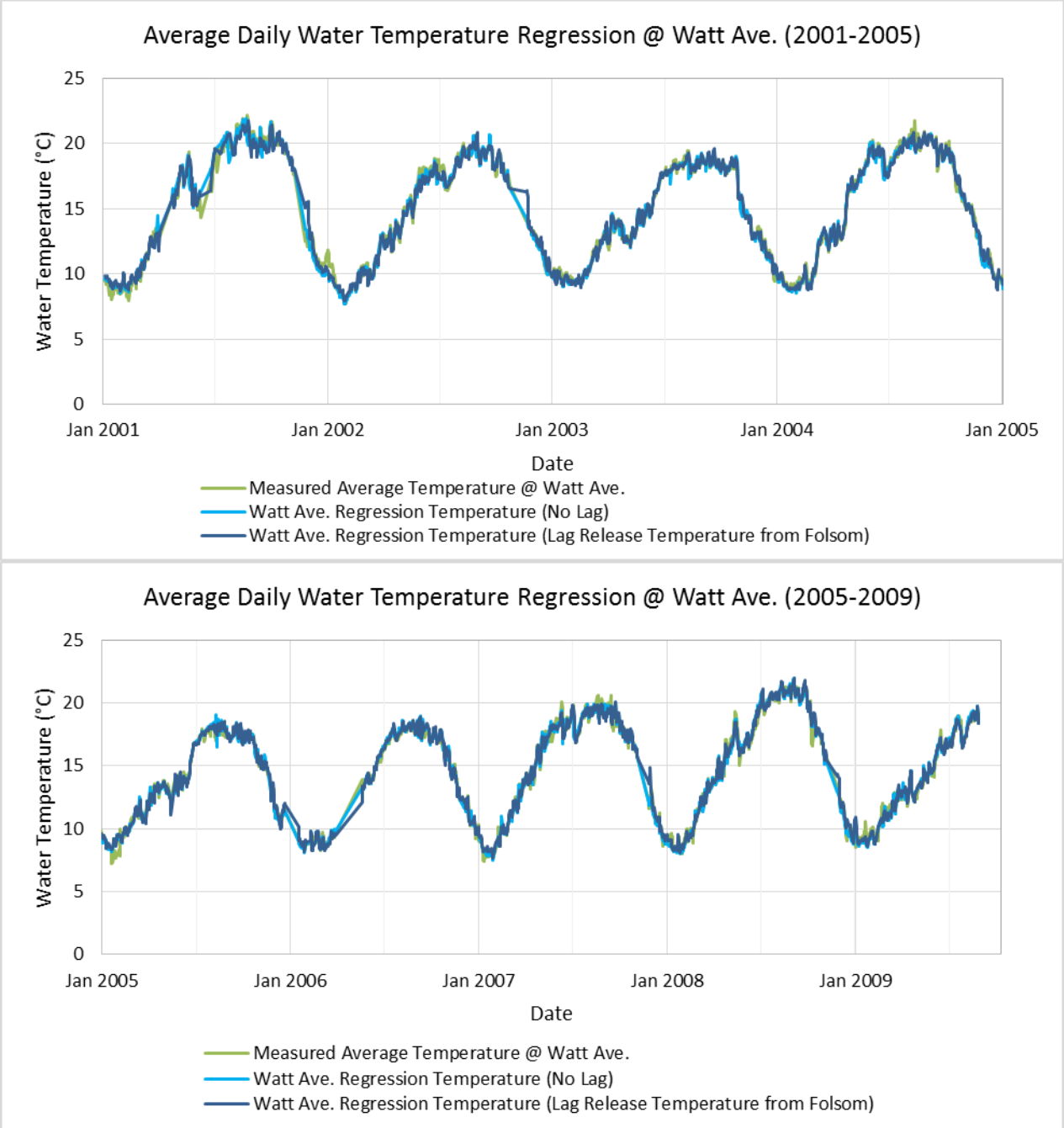


Figure 5. Comparison of Measured and Modeled (Regression) Average Daily Water Temperature Time Series on the Lower American River at Watt Avenue (2001-2009).

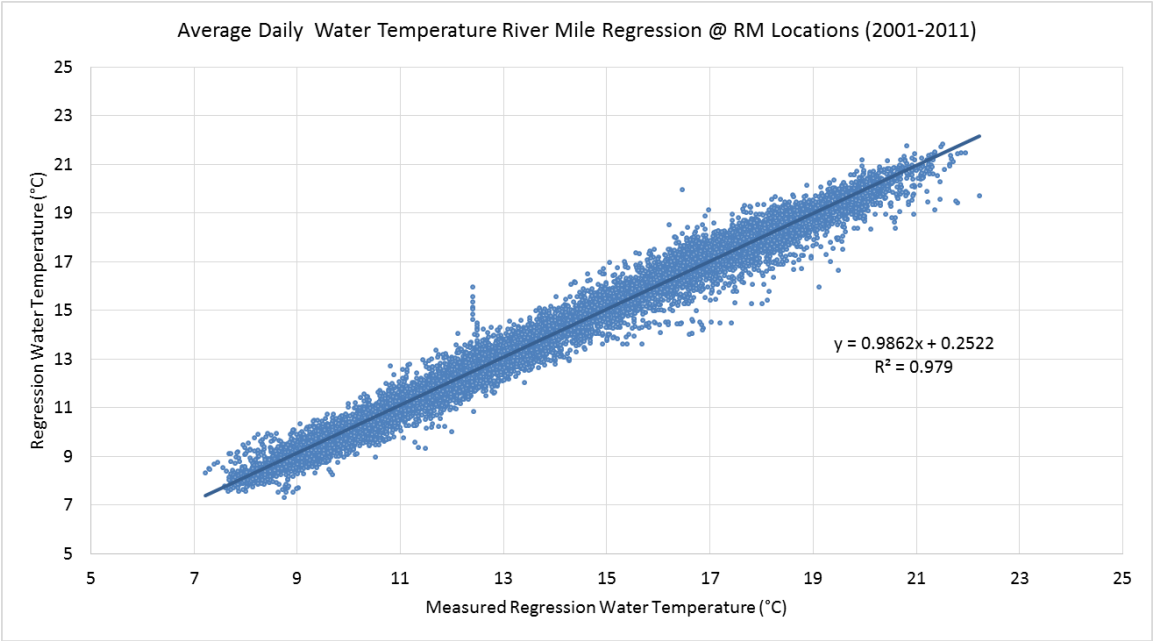


Figure 6. Measured versus Modeled (Regression) Average Daily Water Temperatures at Various River Mile Locations.

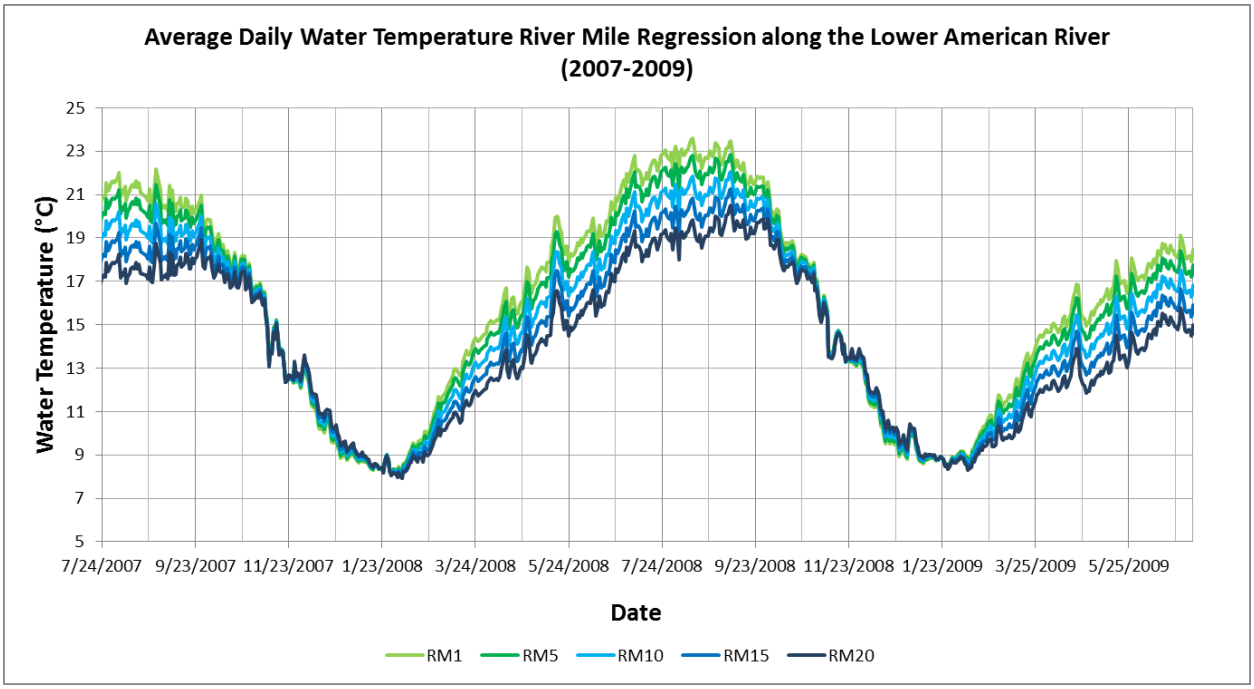
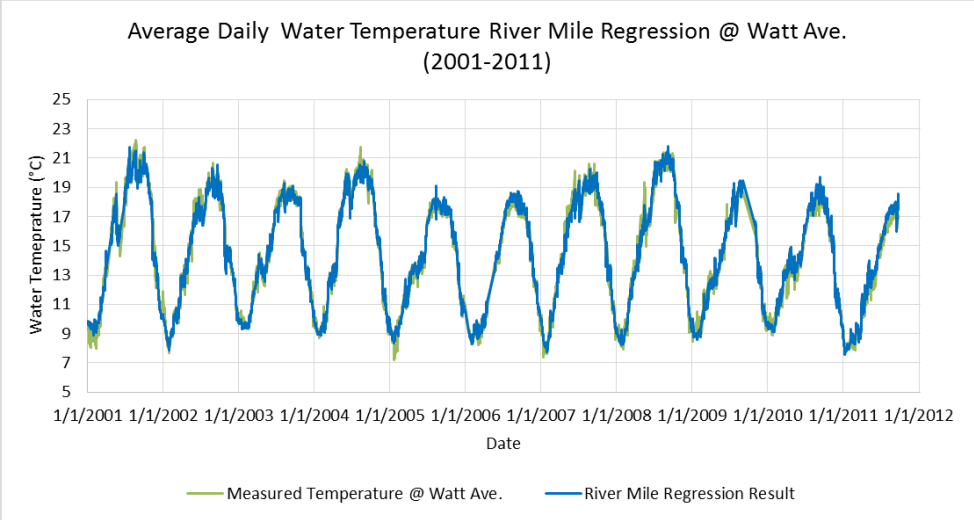
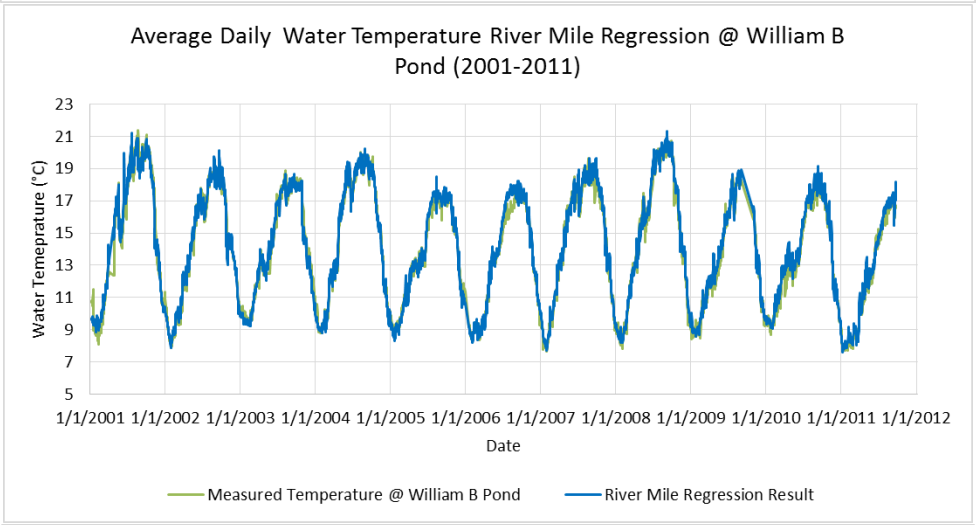


Figure 7. Regression-based Lower American River Water Average Daily Temperature Time Series by Five-Mile Increments for 2007-2009 (River Mile Regression Equation).





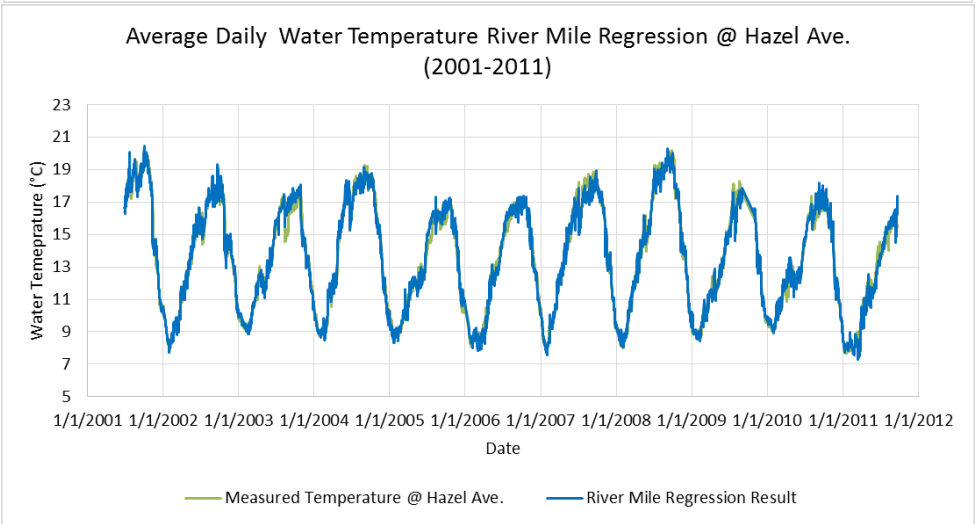


Figure 8. Measured versus (Regression) Lower American River Average Daily Water Temperature Time Series at Hazel Avenue, William B Pond, and Watt Avenue based on the River Mile Regression Equation (2001-2011).

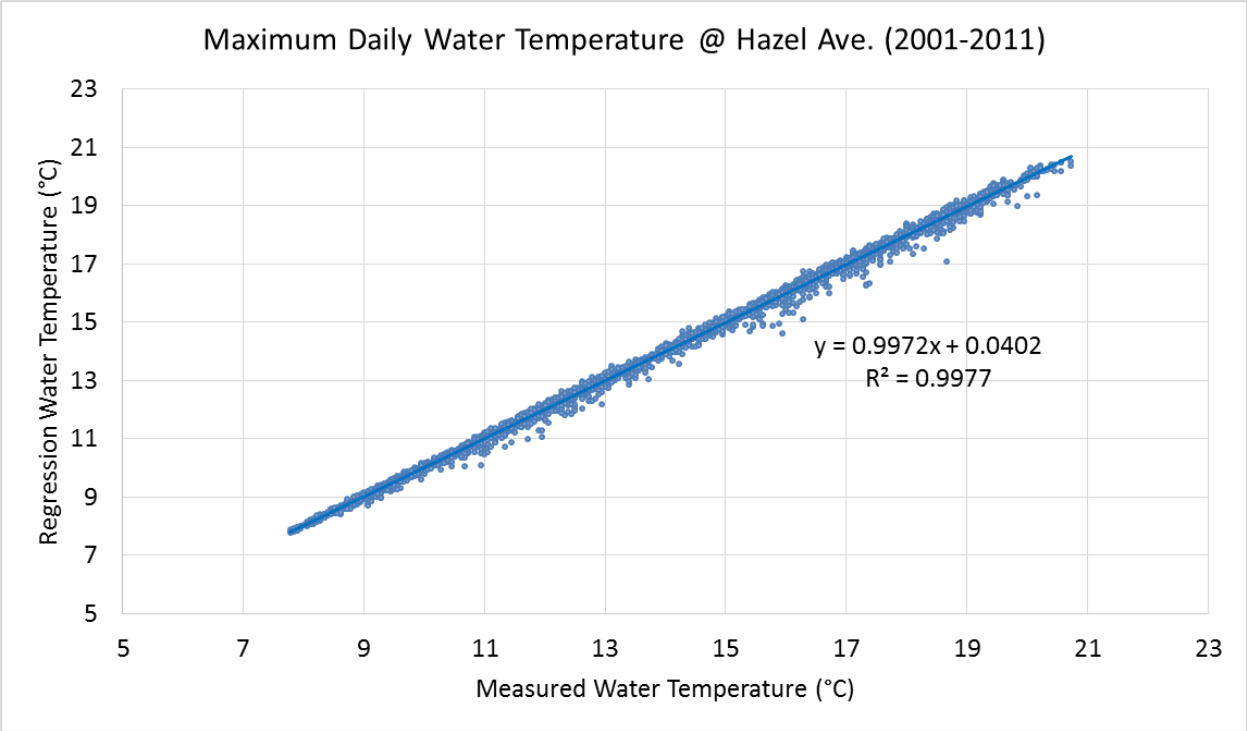


Figure 9. Measured versus Modeled (Regression) Maximum Daily Water Temperature at Hazel Avenue.

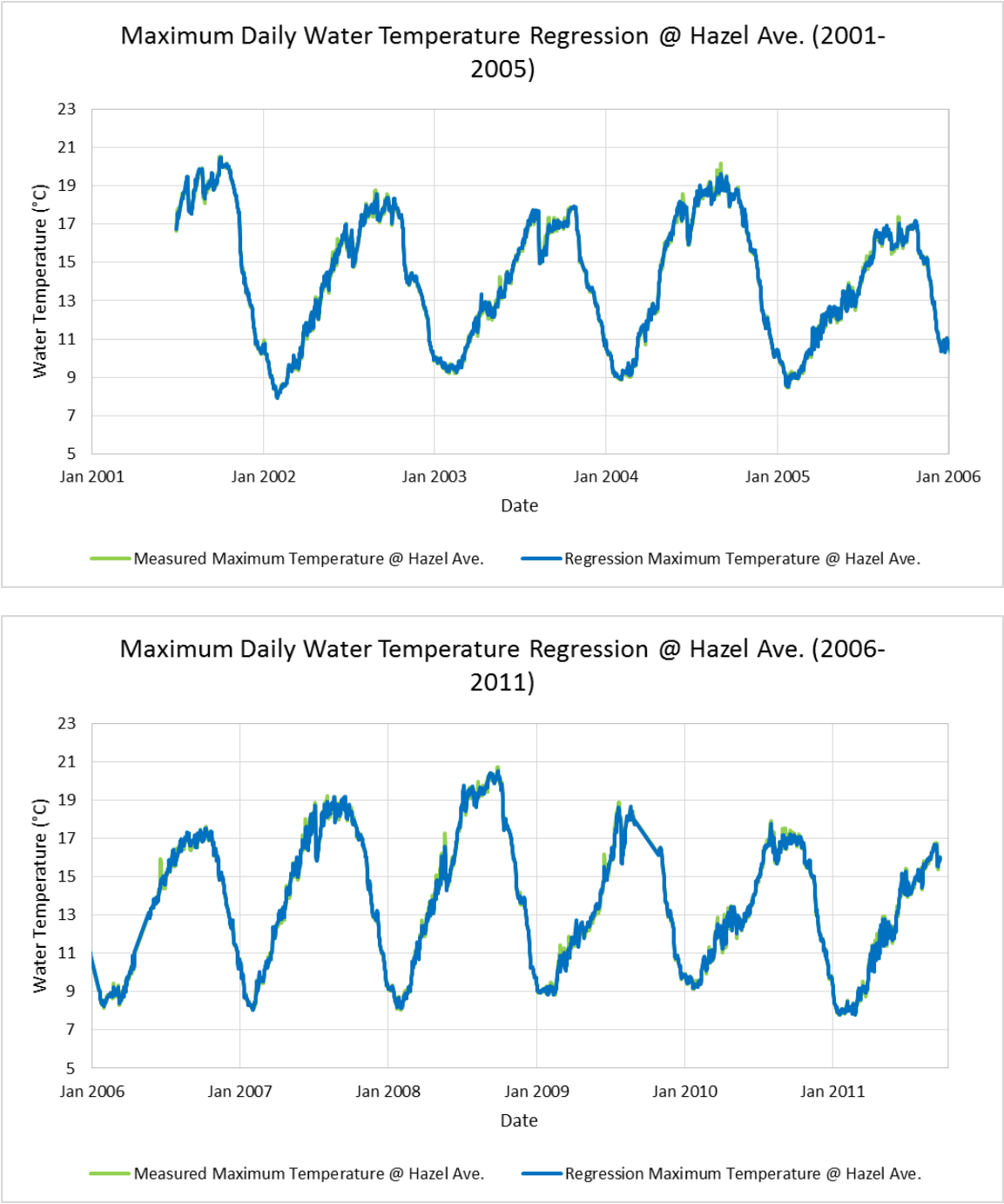


Figure 10. Comparison of Measured and Modeled (Regression) Maximum Daily Water Temperature Time Series on the Lower American River at Hazel Avenue (2001-2011).

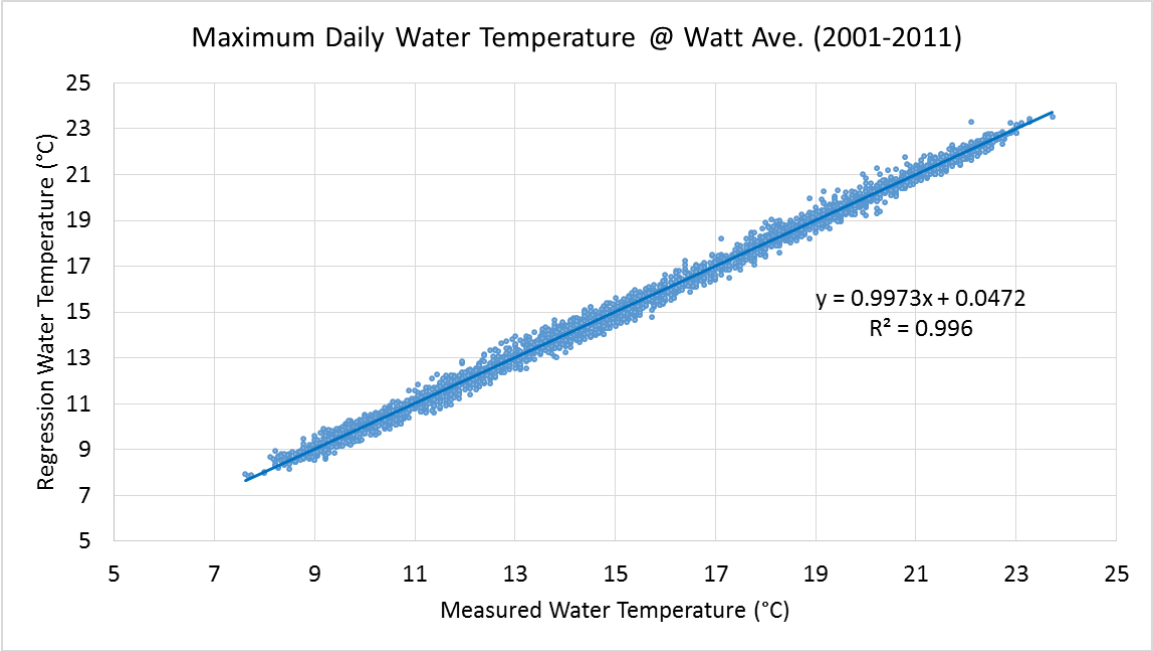


Figure 11. Measured versus Modeled (Regression) Maximum Daily Water Temperature at Watt Avenue.

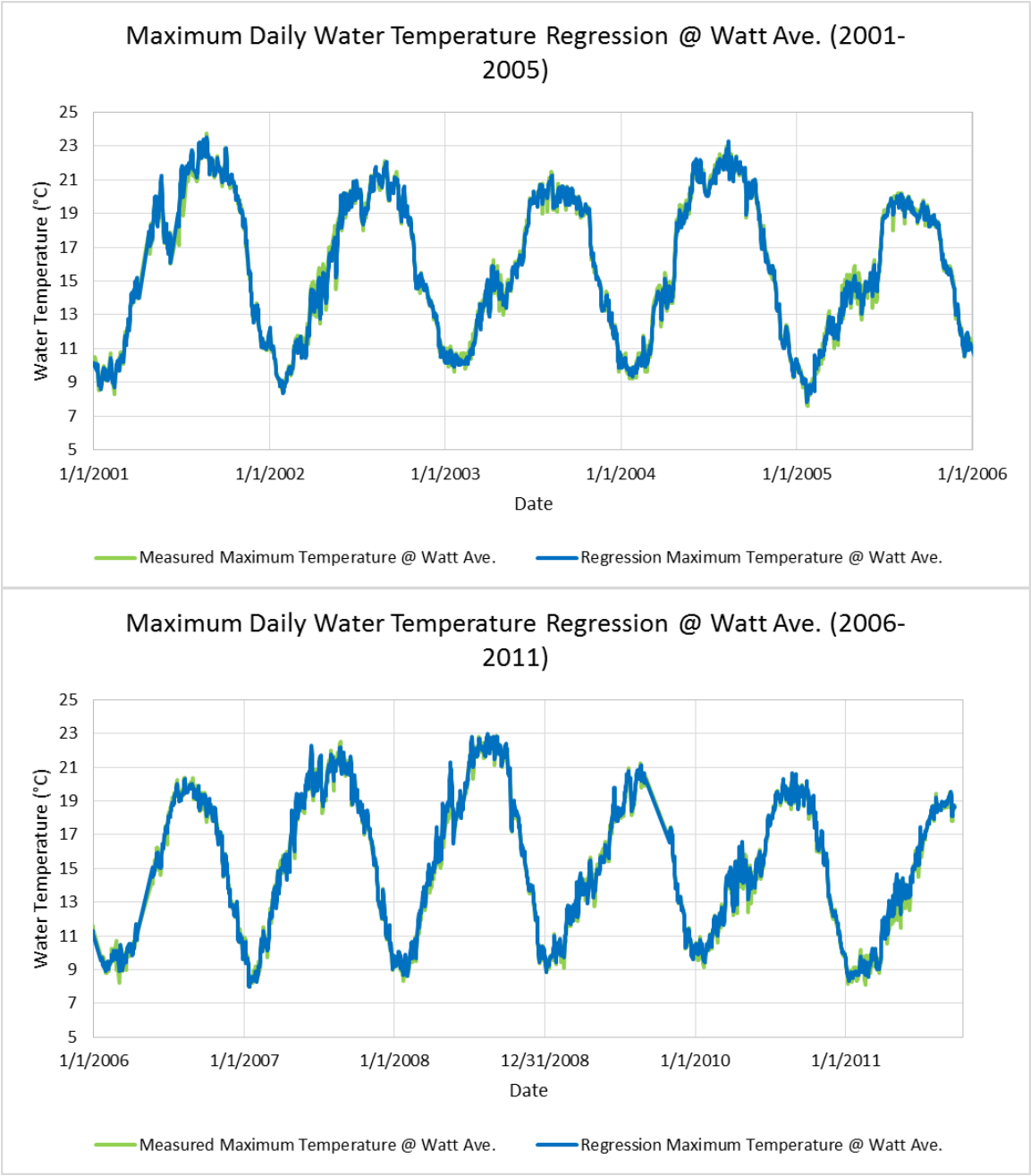


Figure 12. Comparison of Measured and Modeled (Regression) Maximum Daily Water Temperature Time Series on the Lower American River at Watt Avenue (2001-2011).

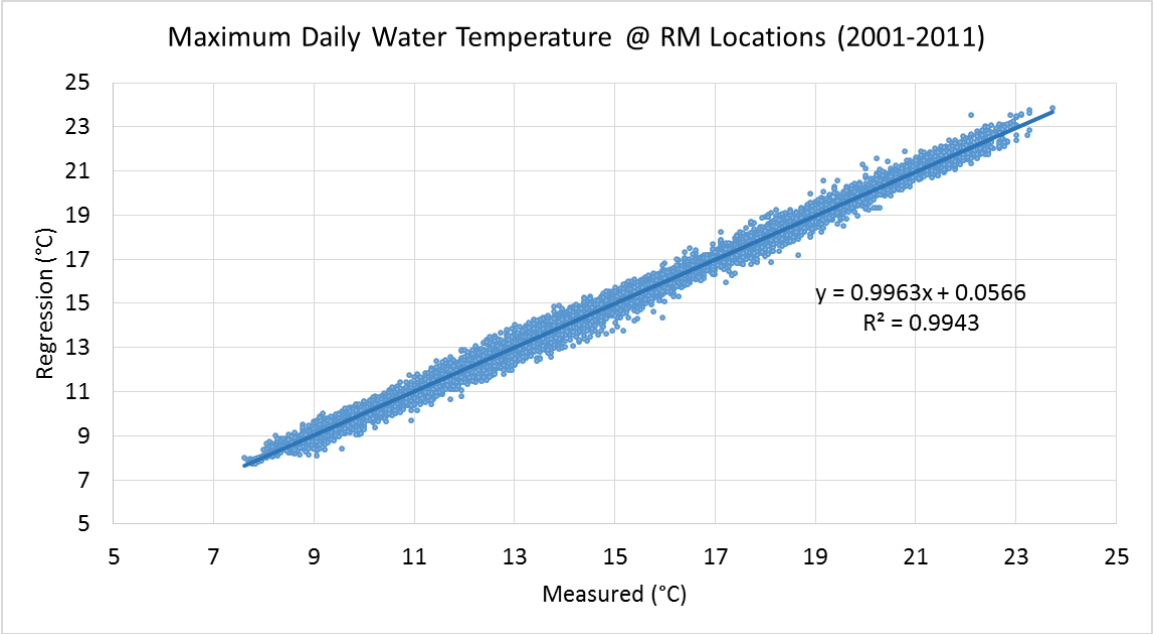


Figure 13. Measured versus Modeled (Regression) Maximum Daily Water Temperature at Various River Mile Locations.

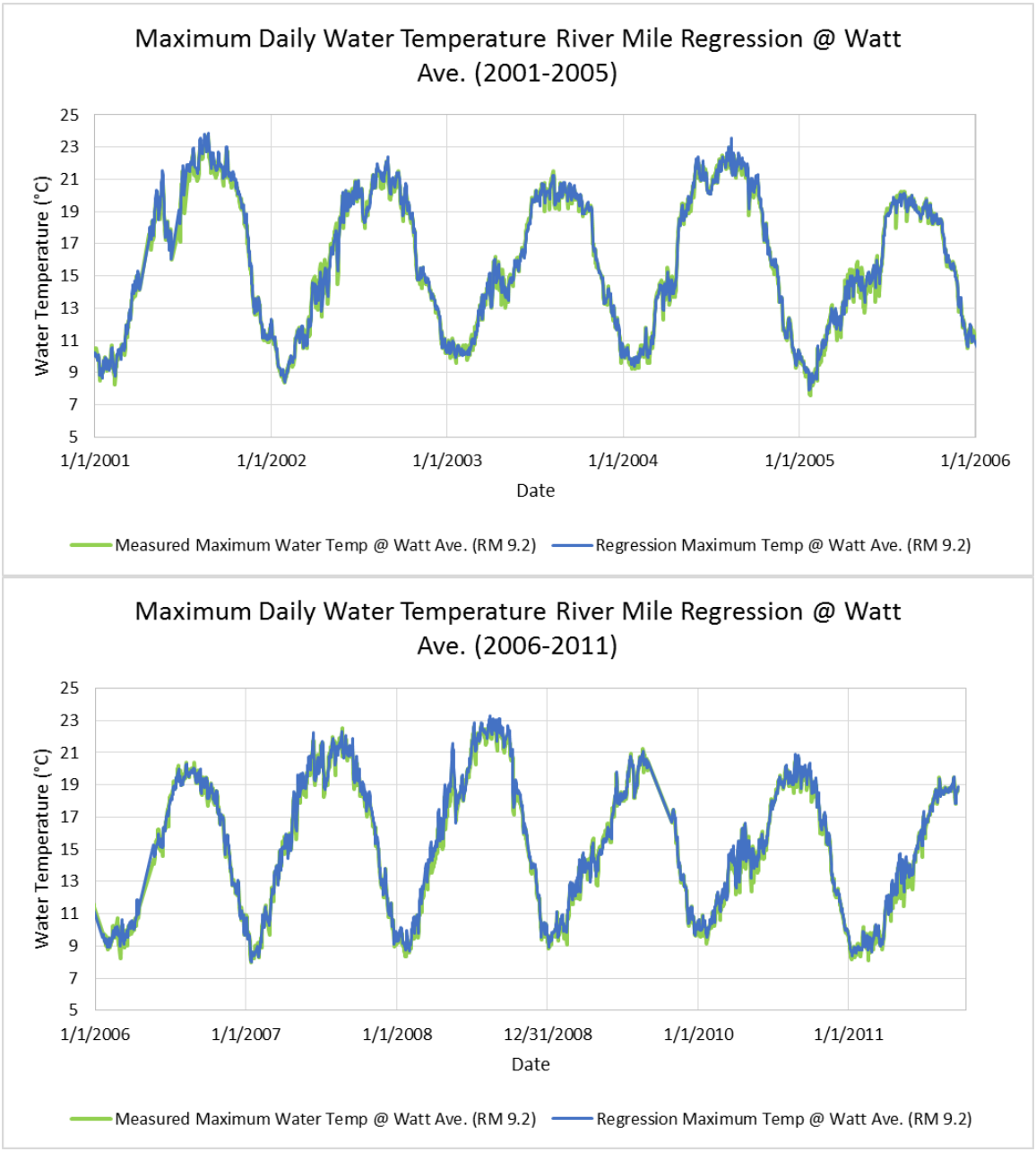


Figure 14. Comparison of Measured and Modeled (Regression) Maximum Daily Water Temperature Time Series on the Lower American River at Watt Avenue (RM 9.2) (2001-2011).

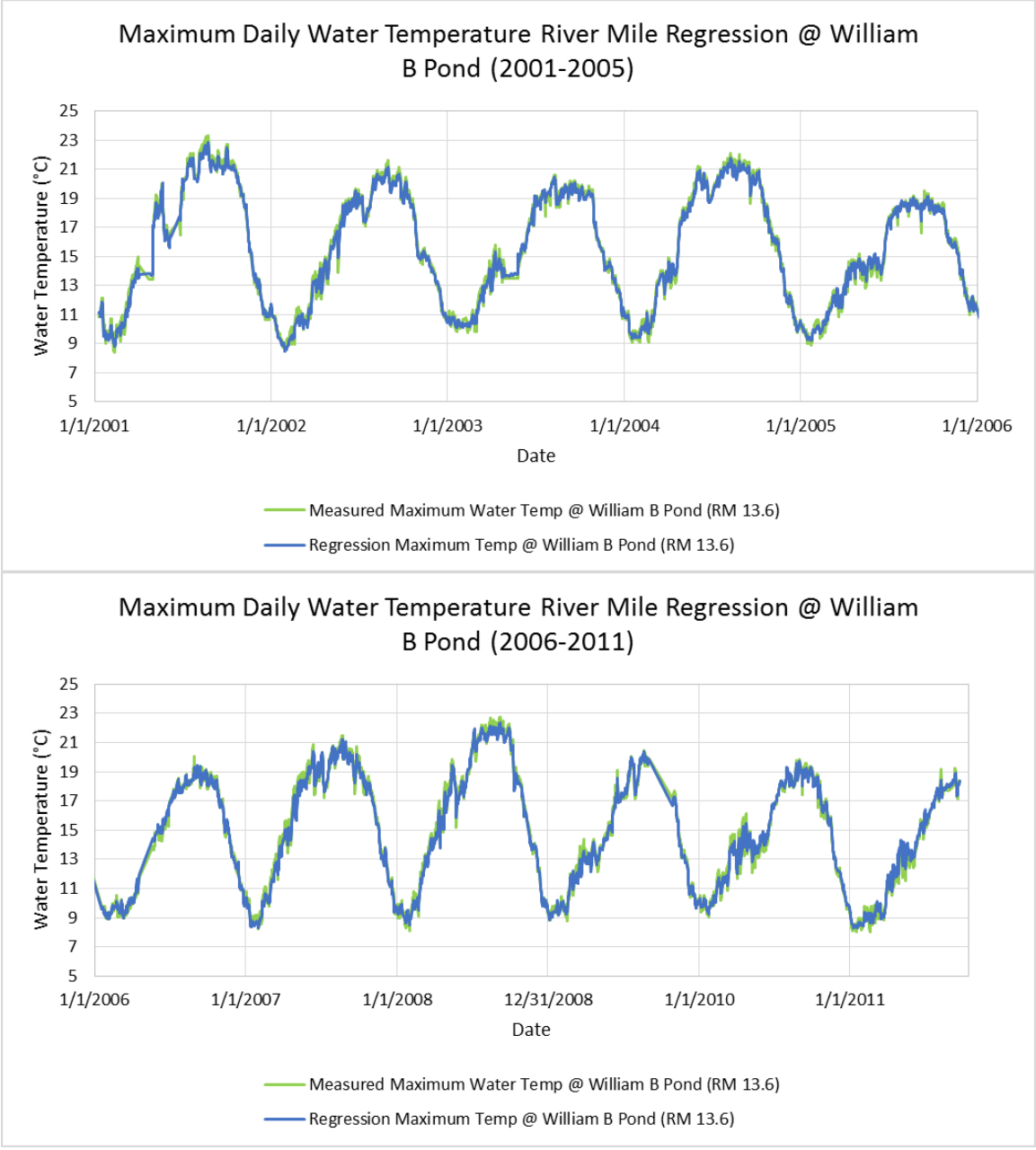


Figure 15. Comparison of Measured and Modeled (Regression) Maximum Daily Water Temperature Time Series on the Lower American River at William B Pond Park (RM 13.6) (2001-2011).

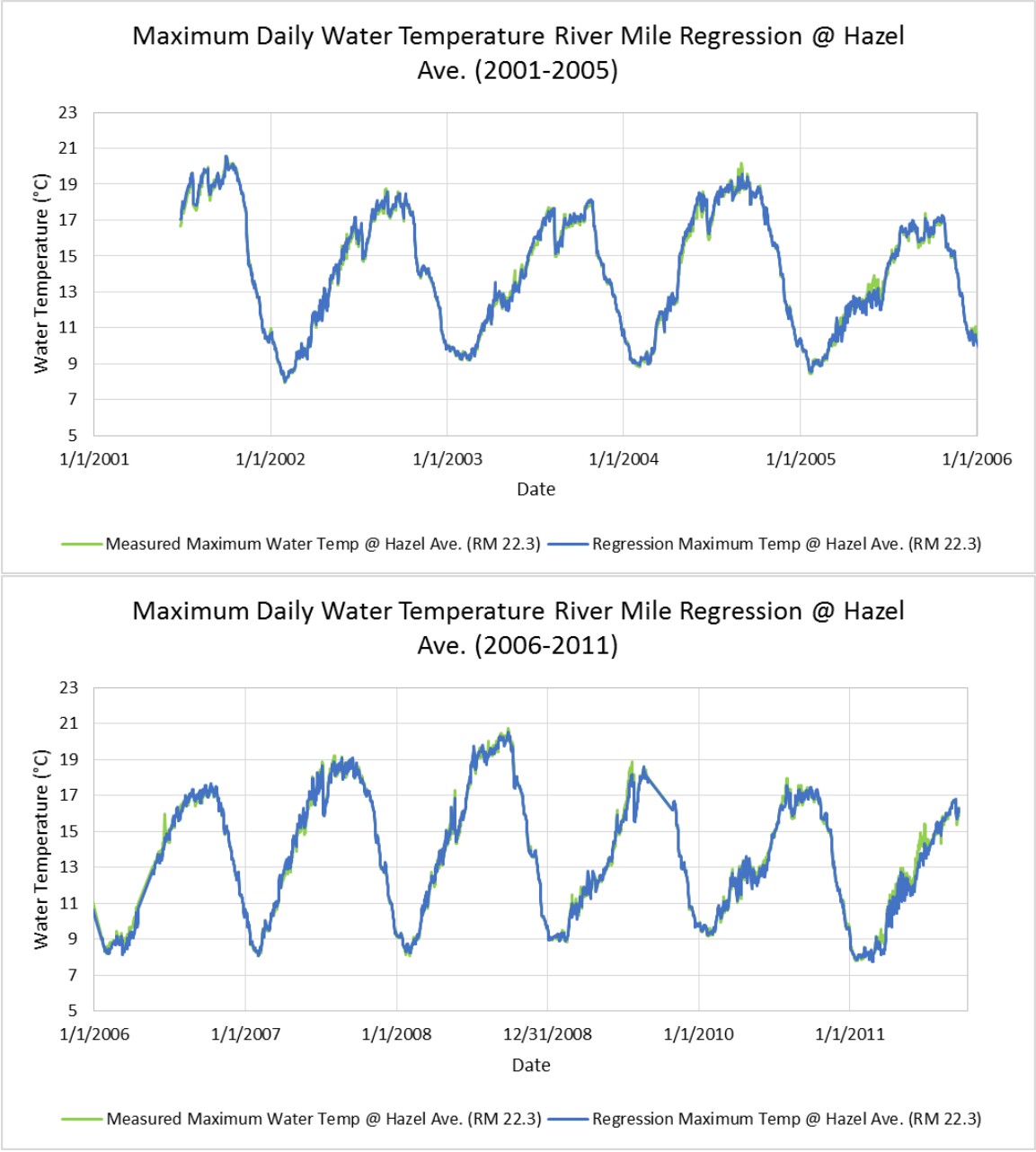
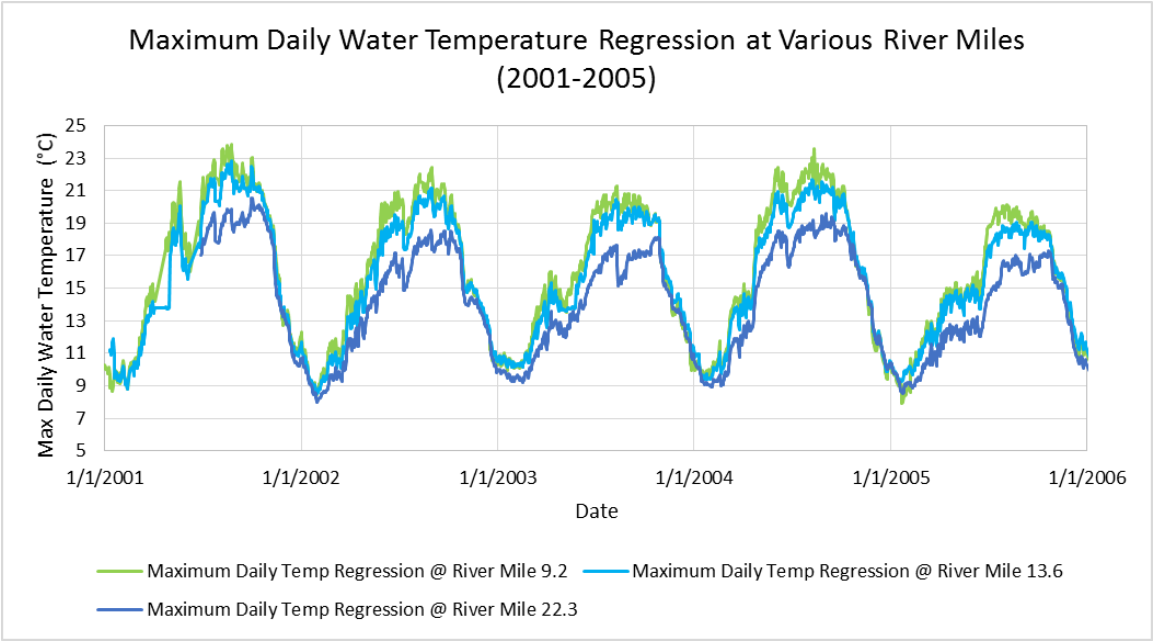


Figure 16. Comparison of Measured and Modeled (Regression) Maximum Daily Water Temperature Time Series on the Lower American River at Hazel Avenue (RM 22.3) (2001-2011).



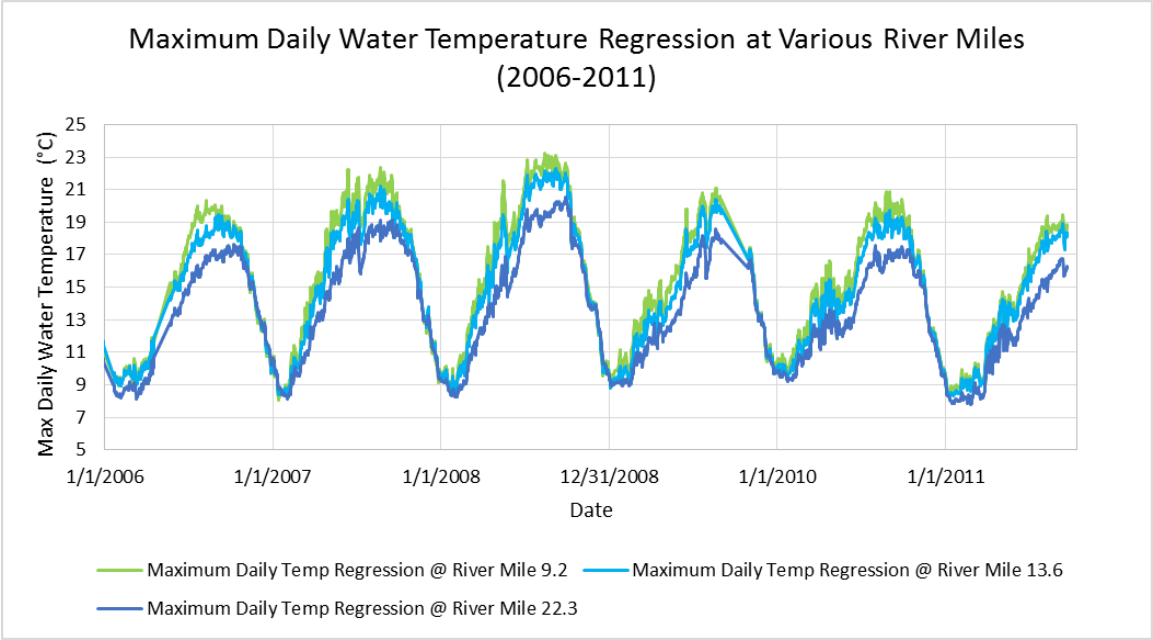
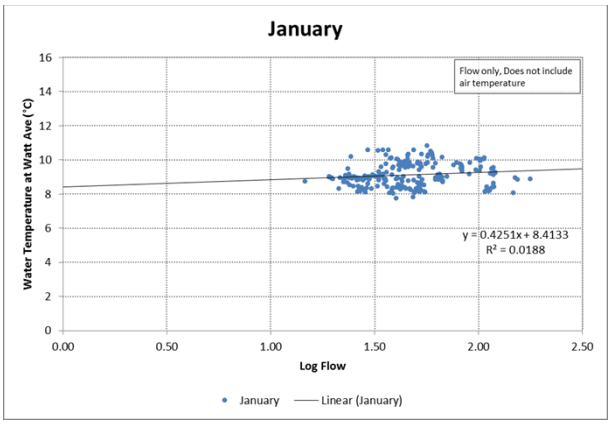


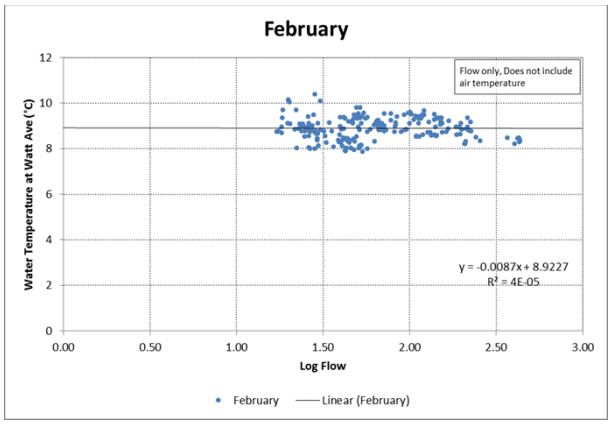
Figure 17. Modeled (Regression) Maximum Daily Water Temperature on the Lower American River Time Series at Locations Corresponding to Hazel Avenue (RM 22.3), William B Pond Park (RM 13.6) and Watt Avenue (RM 9.2) (2001-2011).

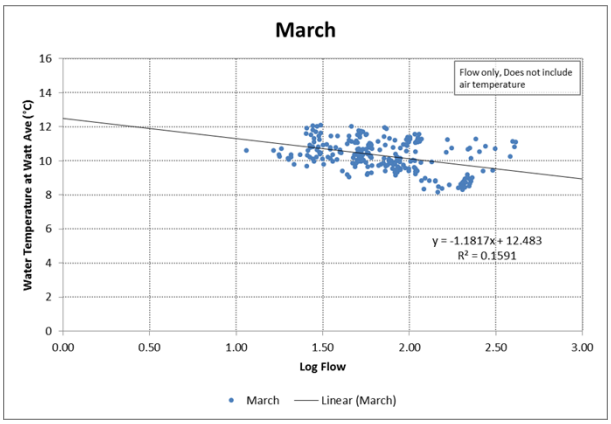
7.0 MAPS

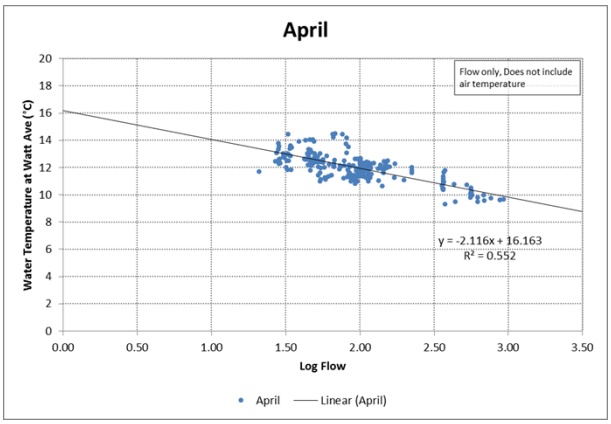
TECHNICAL MEMORANDUM 9 ATTACHMENT A

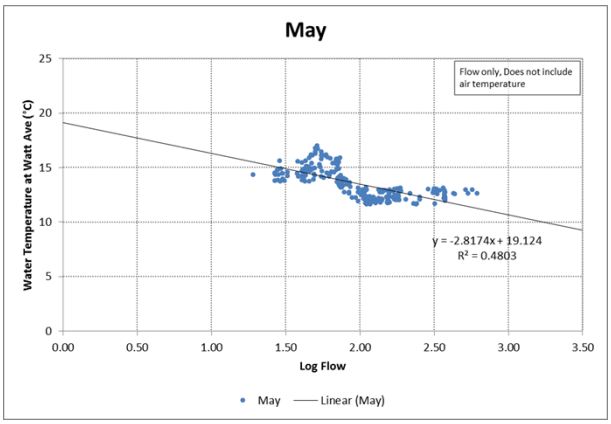
Flow vs. Water Temperature at Hazel and Watt Avenues

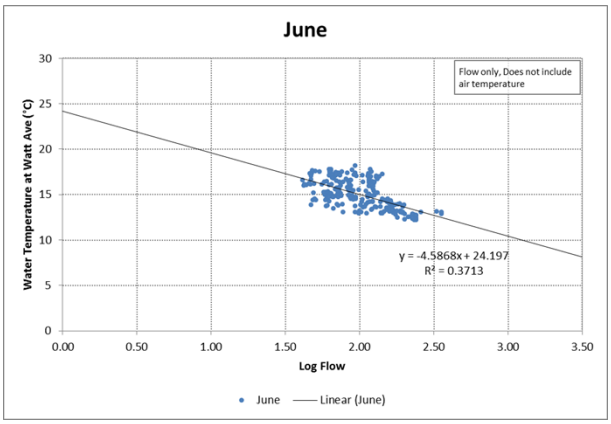

January
Flow only, Does not include air temperature
y = 0.4251x + 8.4133
R² = 0.0188
Water Temperature at Watt Ave (°C)
Log Flow
January
Linear (January)

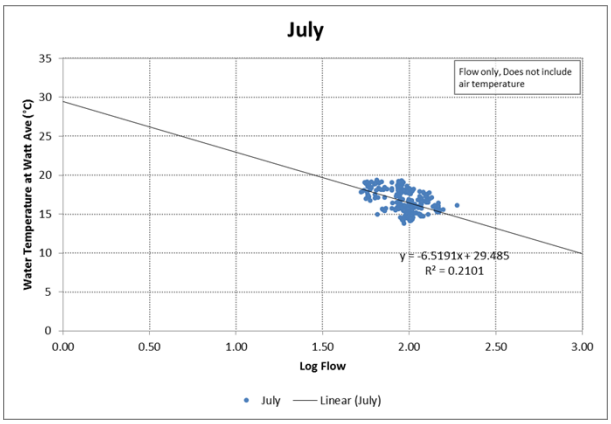

February
Flow only, Does not include air temperature
y = -0.0087x + 8.9227
R² = 4E-05
Water Temperature at Watt Ave (°C)
Log Flow
February
Linear (February)

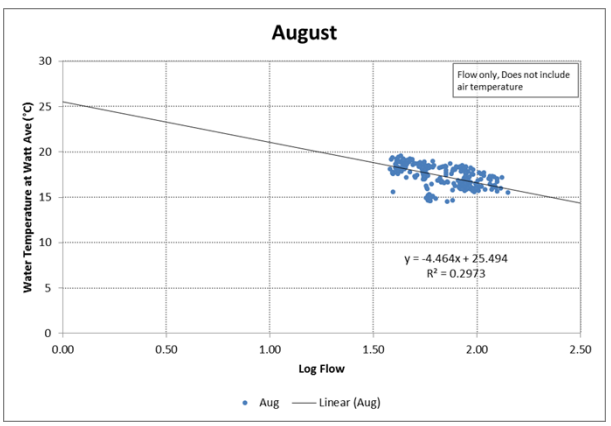

March
Flow only, Does not include air temperature
y = -1.1817x + 12.483
R² = 0.1591
Water Temperature at Watt Ave (°C)
Log Flow
March
Linear (March)

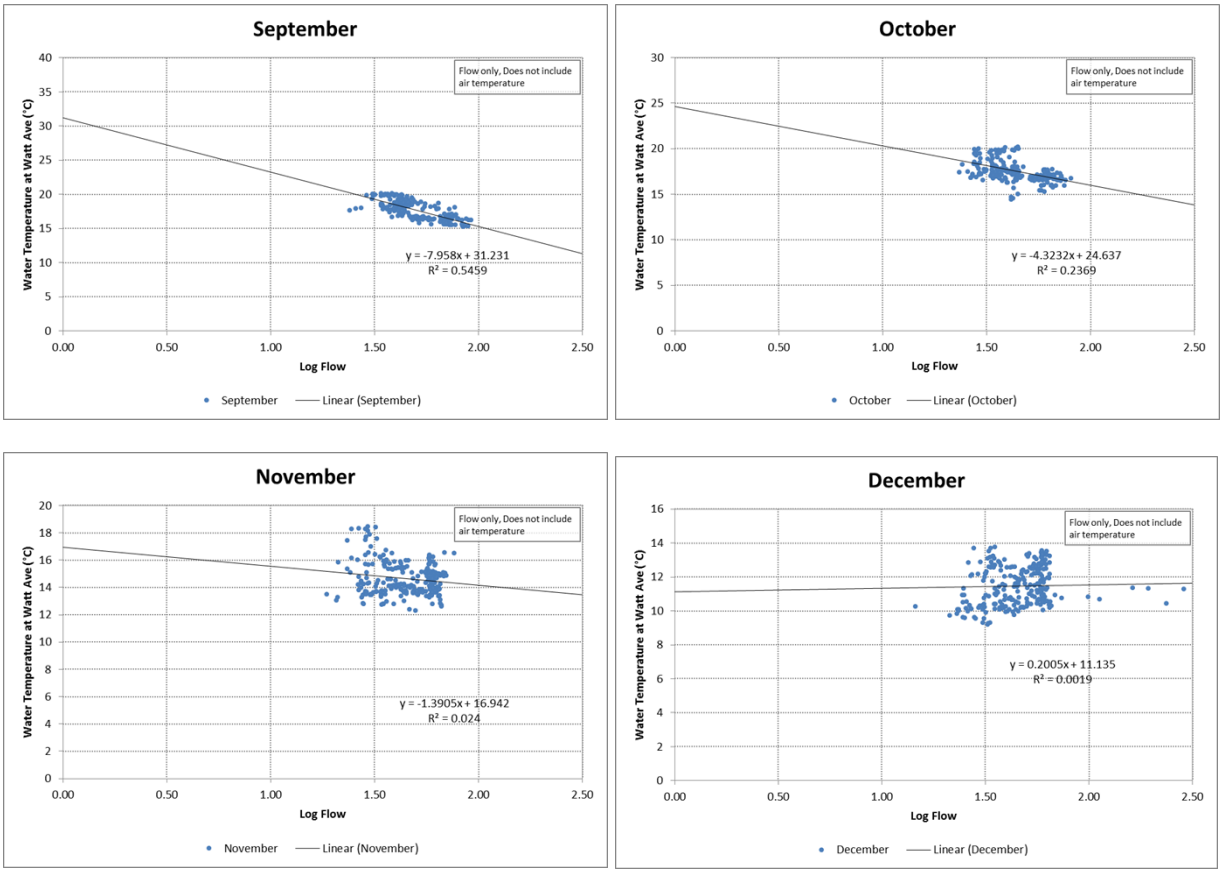

April
Flow only, Does not include air temperature
y = -2.116x + 16.163
R² = 0.552
Water Temperature at Watt Ave (°C)
Log Flow
April
Linear (April)


May
Flow only, Does not include air temperature
y = -2.8174x + 19.124
R² = 0.4803
Water Temperature at Watt Ave (°C)
Log Flow
May
Linear (May)

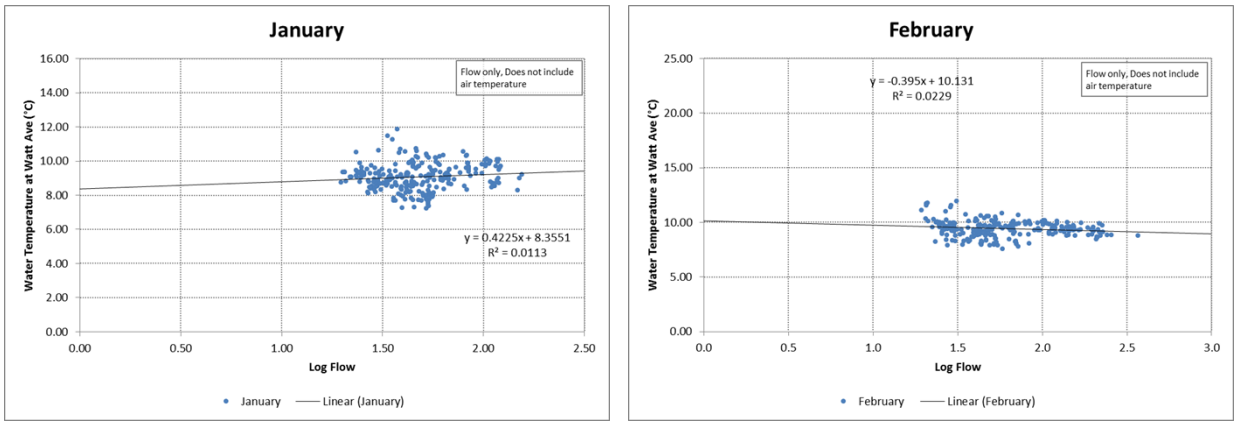

June
Flow only, Does not include air temperature
y = -4.5868x + 24.197
R² = 0.3713
Water Temperature at Watt Ave (°C)
Log Flow
June
Linear (June)

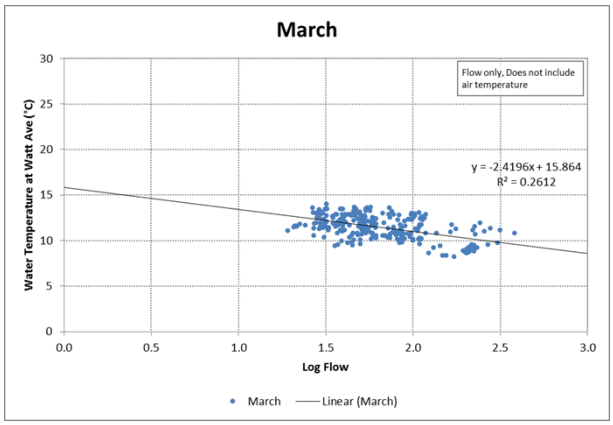

July
Flow only, Does not include air temperature
y = -6.5191x + 29.485
R² = 0.2101
Water Temperature at Watt Ave (°C)
Log Flow
July
Linear (July)

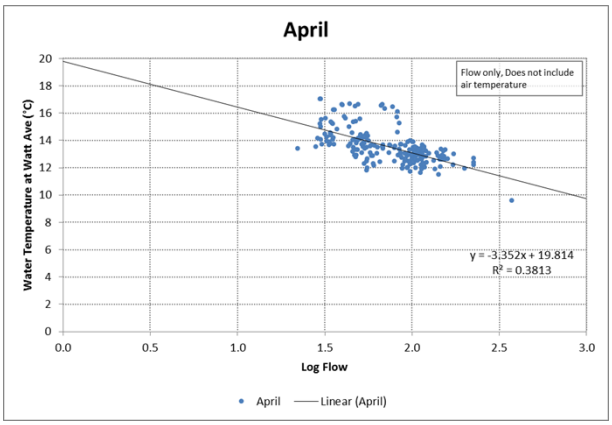

August
Flow only, Does not include air temperature
y = -4.464x + 25.494
R² = 0.2973
Water Temperature at Watt Ave (°C)
Log Flow
Aug
Linear (Aug)

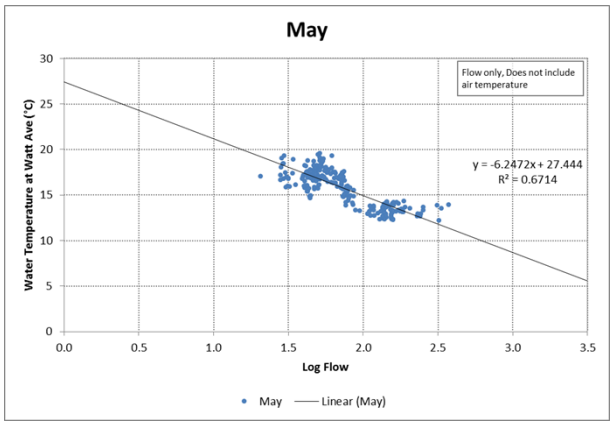


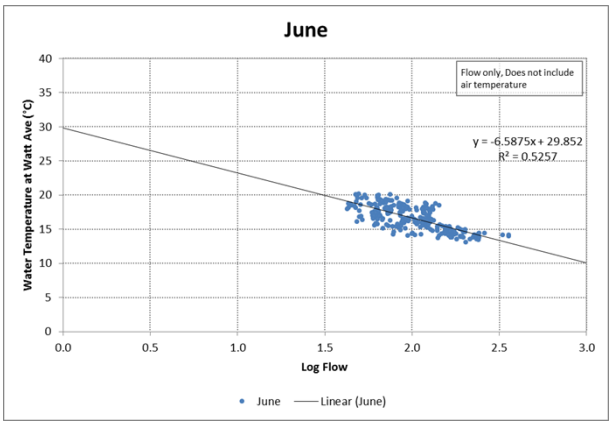
Attachment A Figure 1. Lower American River Flow only versus Water Temperature at Hazel Avenue Regression Relationships (2001-2009).

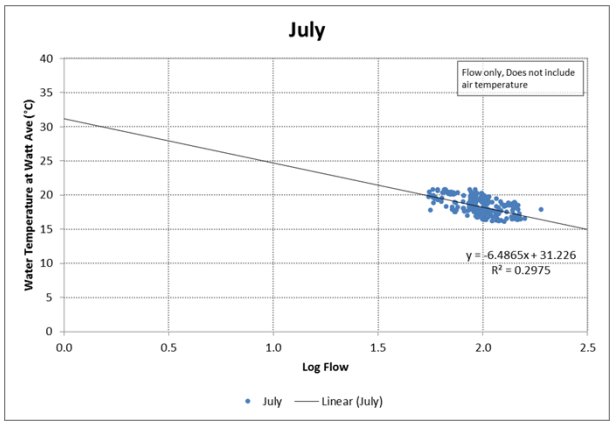


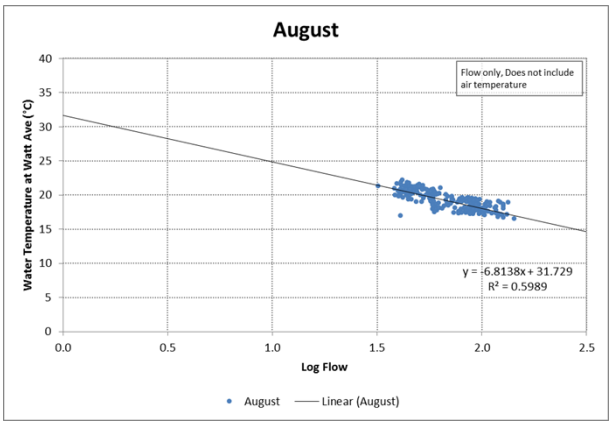

March
Flow only, Does not include air temperature
y = -2.4196x + 15.864
R² = 0.2612
Water Temperature at Watt Ave (°C)
Log Flow
March
Linear (March)

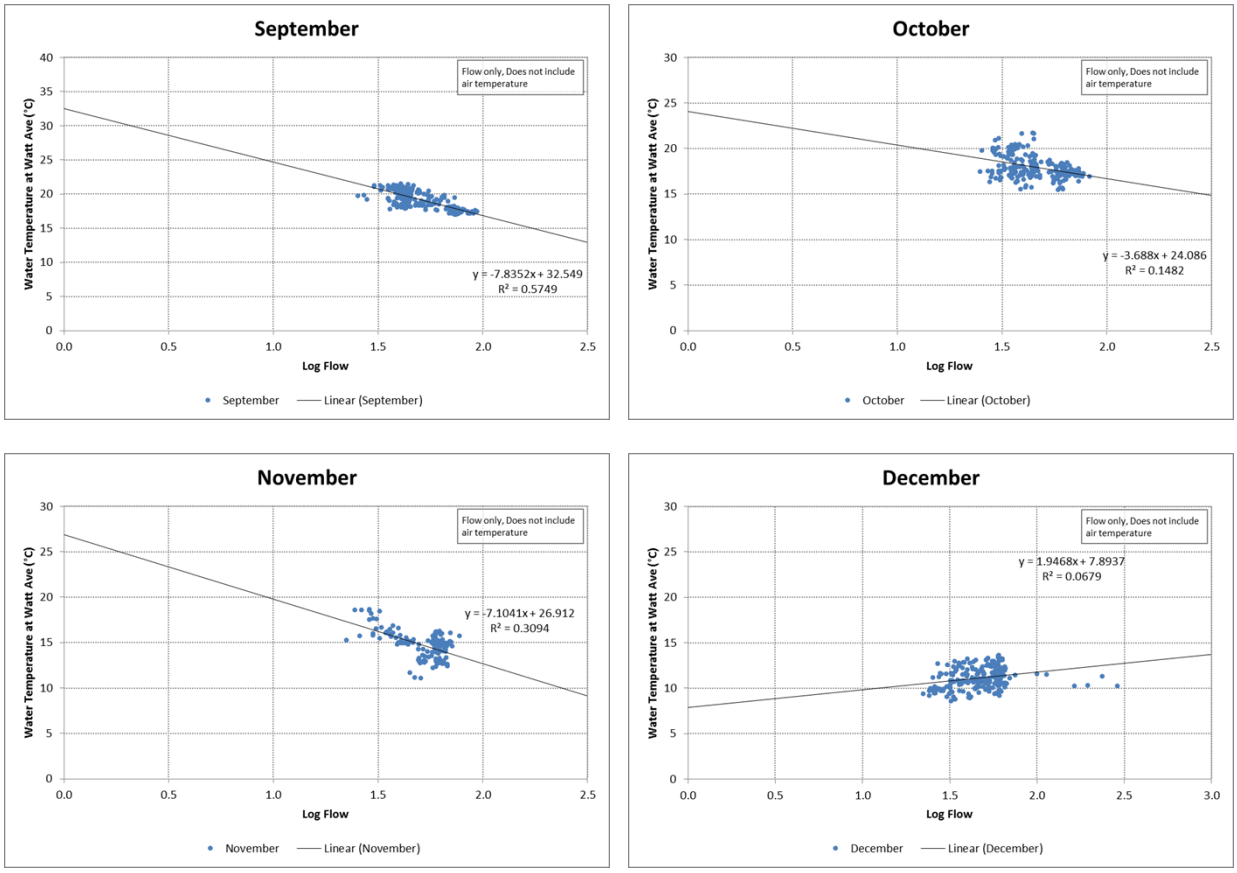

April
Flow only, Does not include air temperature
y = -3.352x + 19.814
R² = 0.3813
Water Temperature at Watt Ave (°C)
Log Flow
April
Linear (April)


May
Flow only, Does not include air temperature
y = -6.2472x + 27.444
R² = 0.6714
Water Temperature at Watt Ave (°C)
Log Flow
May
Linear (May)


June
Flow only, Does not include air temperature
y = -6.5875x + 29.852
R² = 0.5257
Water Temperature at Watt Ave (°C)
Log Flow
June
Linear (June)


July
Flow only, Does not include air temperature
y = -6.4865x + 31.226
R² = 0.2975
Water Temperature at Watt Ave (°C)
Log Flow
July
Linear (July)


August
Flow only, Does not include air temperature
y = -6.8138x + 31.729
R² = 0.5989
Water Temperature at Watt Ave (°C)
Log Flow
August
Linear (August)



Note: y-axis varies.

Attachment A Figure 2. Lower American River Flow only versus Water Temperature at Watt Avenue Regression Relationships (2001-2009).