UNITED STATES OF AMERICA
BEFORE THE
FEDERAL ENERGY REGULATORY COMMISSION

Turlock Irrigation District	)	
	)	
and	)	Project No. 2299
	)	
Modesto Irrigation District	)	

2009 LOWER TUOLUMNE RIVER ANNUAL REPORT

Report 2009-6

Review of 2009 Summer Flow Operation

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March 2010

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Previous Dry Year Summer Flow Requirements and Operations

The Don Pedro Project Article 37 summer minimum flow requirement period at La Grange typically extends from about June 1 to September 30. That requirement was increased in 1996 to range from 50-250 cfs, with 50 or 75 cfs in drier year types, specified as about 50% of the years. The summer flow amount in dry years has at times been augmented by other water allocated from the total required annual volume. In drier years the annual flow volume is based on forecasted runoff until August, so there can be considerable change in forecasted available flow through part of the summer flow period. The Districts' also normally release a higher flow ("buffer flow") than in the schedule to help ensure minimum requirements are met.

The dry years of 2001-2004 and 2007 had summer requirements, including augmented flows, ranging from 75-95 cfs, with the exception of wetter conditions and much higher flows in 2003. That year a variable flow operation was used for the first time, with a higher flow targeted when higher air temperatures (AT) were forecasted (Ford and Kirihara 2004). The variable operation was intended to provide relatively cooler instream water temperature (WT) conditions during hot spells than would otherwise occur at a constant flow release, while using a similar total water volume in the period.

The 2008 hydrologic conditions became much drier after the April 1 runoff forecast, resulting in a lower forecast by late May. As a result, no water was available in the annual requirement to augment the 50 cfs summer flow requirement without reducing later base flow allocations. As actual releases were reduced toward 80 cfs in early June, Tuolumne River water managers decided to maintain instream conditions (e.g. wetted area, habitat availability, WT) more similar to those present in other recent dry years during which minimum required flow schedules had ranged from 75-95 cfs (not including buffer flows). That resulted in a supplemental flow averaging 100 cfs (using realtime values) from June 10 – September 30. There was also a variable flow operation implemented using an approximate 20-cfs range between high and low flow periods to account for changing AT conditions, similar in concept to the 2003 operation; target flow rates were either about 90-95 cfs or 110-115 cfs (Ford and Kirihara 2009).

2009 Summer Flow Operation

A late season increase in annual FERC flow volume similar to 2003 took place in 2009 when the nominal summer flow rate was 75 cfs. However, the flow schedule established with the fishery agencies included higher flows only for June 1-15 and in September (95 cfs). As was done in 2008, the summer water was supplemented by water managers to maintain instream conditions more similar to those in 2007-2008 than would be present with a 75 cfs base flow. In early June, a decision was made to target an average 105 cfs (using realtime values) and again use a variable operation. As in 2008, the flows were in an approximate 20-cfs range between high and low flow days to account for changing AT conditions during the June 16 – August 31 period.

2009 Criteria

- Average flow for the period of June 16 - August 31 was targeted to be about 105 cfs
- The lower flow target of 100 cfs applied on days when the National Weather Service (NWS) forecast for Modesto maximum AT was 99 degrees or lower
- The higher flow target of 120 cfs applied on days when the NWS forecast for Modesto maximum AT was 100 degrees or higher
- The actual flows were to be as operationally feasible
- The NWS 6 AM daily online forecast for maximum AT at Modesto (airport) was used to establish the daily flow target

2009 Operation and Implementation

The operation went reasonably smoothly, although several factors were again identified that can affect operations or instream conditions:

- mechanical constraints in making flow releases limit the ability to precisely operate at a specific flow target
- flow changes take time to affect conditions further downstream, so the earliest same-day changes would be most effective on a real-time basis
- the weather forecast location at Modesto was used as a predictor for the river reach many miles upstream where thermal conditions may not be relatively consistent with Modesto
- same-day temperature forecasts can be off several degrees, sometimes resulting in flow targets inconsistent with realtime conditions
- flow releases relative to the targets and flow measurements by USGS are imprecise due to the difficulties of a dynamic operational environment
- The “target flow day” at the USGS La Grange flow gage ran from morning to morning (not midnight to midnight), so daily flow averages on transition days were intermediate.
- hotter periods and higher thermal input mainly occur in mid-June through August based on historical patterns

The only realtime WT data was available at the USGS Modesto gage (RM 16.2), also reported by CDWR at their CDEC website, a river location too far downstream to have WT affected by these flow operation changes. Other WT data presented here are from manually downloaded thermographs.

Data/Results

The river thermograph data for the entire period have been posted to the TRTAC website at http://tuolumnerivertac.com/data.htm. The figures in this report include September for comparison, but the summary information refers mainly to the 77-day period of June 16 to August 31 which had the augmented and variable flow operation.

The daily range in AT at Modesto is in Figure 1 which shows the most extreme heat wave in 2009 was during June 27-29 with a peak AT of 111 F; a total of 18 of the 77 days (23.4%) were 100 F or higher. Figure 2 has the forecasted and actual maximum AT; a total of 21 of the 77 days (27.3%) were forecasted to be 100 F or higher. The deviation of the actual AT from the forecasts ranged from +7 to -5 F, with an average deviation of +0.7 F (Fig. 3); seven days would have had a different target flow with a perfect forecast during the 77-day period. September was not part of a variable flow operation and tracking of those daily forecasts during weekends/holidays was not done, so some daily deviations would have been different than shown.

Daily average flow, daily maximum AT, and the higher flow target days are in Fig. 4. There were four multi-day high flow target periods, ranging from 2-8 days in duration. The real-time flow average during June 16 – August 31 was 106 cfs and the daily average ranged from 95-131 cfs.

The recorded daily average WT at nine stations from La Grange gage at River Mile (RM) 51.8 down to Modesto gage at RM 16.2, with higher flow target days indicated, are in Fig. 5. Some general observations on the 2009 daily average WT are:

- WT increased in a downstream direction to RM 23.6
- WT recorded at RM 23.6 and at RM 16.2(Modesto - CDEC data) was similar
- WT at RM 51.8 (uppermost station) increased slightly throughout the 77-day period from about 51 F to 53 F
- The peak daily average WT for RM 50.8-42.9 occurred in late July – early August at lower flows, suggesting that the variable flow operation during heat waves was most effective for that reach
- The peak daily average WT for RM 39.6 and below was during the prolonged mid-July heat wave at higher flows
- The highest flows were during the highest AT in late June and appear to have been effective in reducing WT on a relative basis
- WT generally declined from RM 49.0 and below during August and continued in September

Another WT index, the 7-day average of daily maximum values (7DADM), for the first eight stations (Fig. 5) is in Fig. 6. Figures 7 to 9 show the flow, maximum AT, and average WT at RM 45.5, 42.9, and 39.6. Figure 10 has the daily minimum, average, and maximum WT at RM 49.0, 45.5, and 39.6

Comparison of Summer Conditions during 2007-2009

The dry years of 2007-2009 provide a comparison of WT with steady (2007) and variable (2008, 2009) flow operations in association with AT conditions.

Figure 11 has the June 16 – September 30 AT for those years, showing that heat waves with maximum AT of 109 F or higher occurred in each year, with the hottest days each year occurring in late June or early July. Figure 12 has the daily average flow at La Grange for the same period.

The associated daily average WT at three locations (RM 49.0, 45.5, and 39.6) are in Fig. 13. The average flow for the June 16 to August 31 period (77 days) was highest in 2007, next highest in 2009, and lowest in 2008. The peak water temperatures observed for those sites was highest in 2008. Each year had a general decline in WT during September.

References

Ford, T., and S. Kirihara. 2004. Review of 2003 summer flow operation. Prepared by Turlock and Modesto Irrigation Districts, California and Stillwater Sciences, Berkeley, California for Federal Energy Regulatory Commission, Washington, D.C.

Ford, T., and S. Kirihara. 2009. Review of 2008 summer flow operation. Prepared by Turlock and Modesto Irrigation Districts, California and Stillwater Sciences, Berkeley, California for Federal Energy Regulatory Commission, Washington, D.C.
http://tuolumnerivertac.com/Documents/2008SummerFlowOpsRpt.pdf

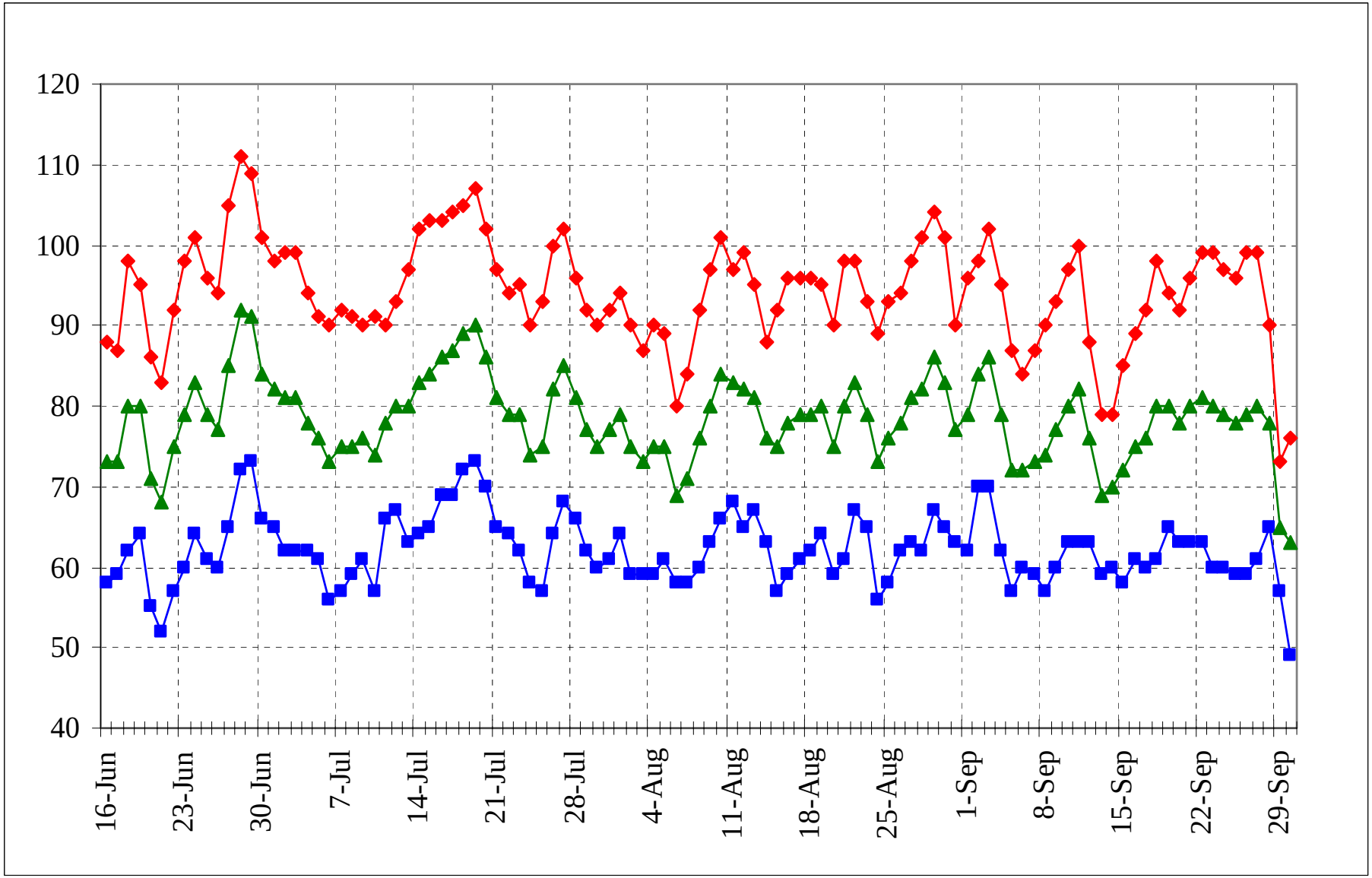

Figure 1. Minimum, average, and maximum air temperature (F) at Modesto in 2009

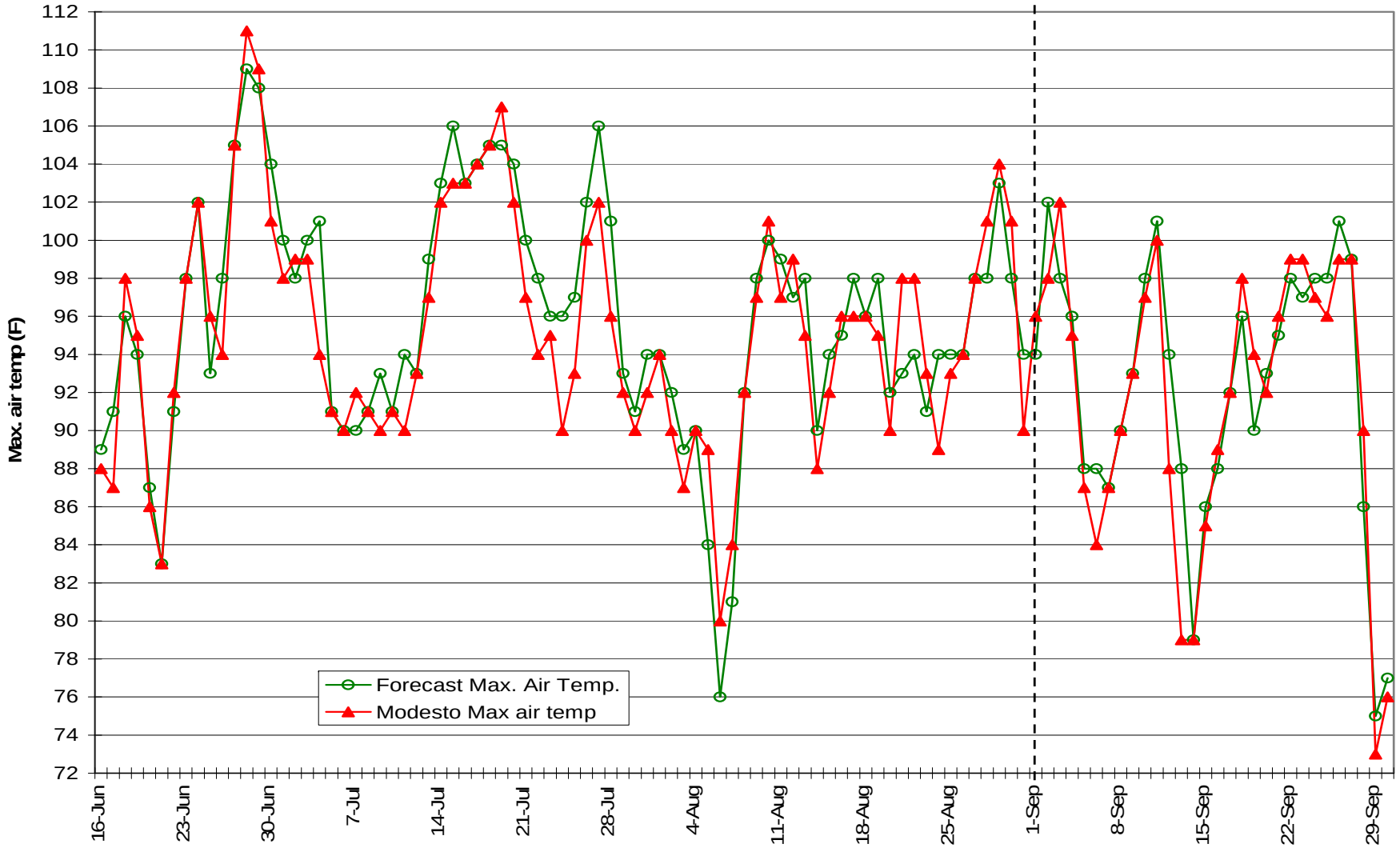

Figure 2. Forecasted and actual maximum air temperature in 2009

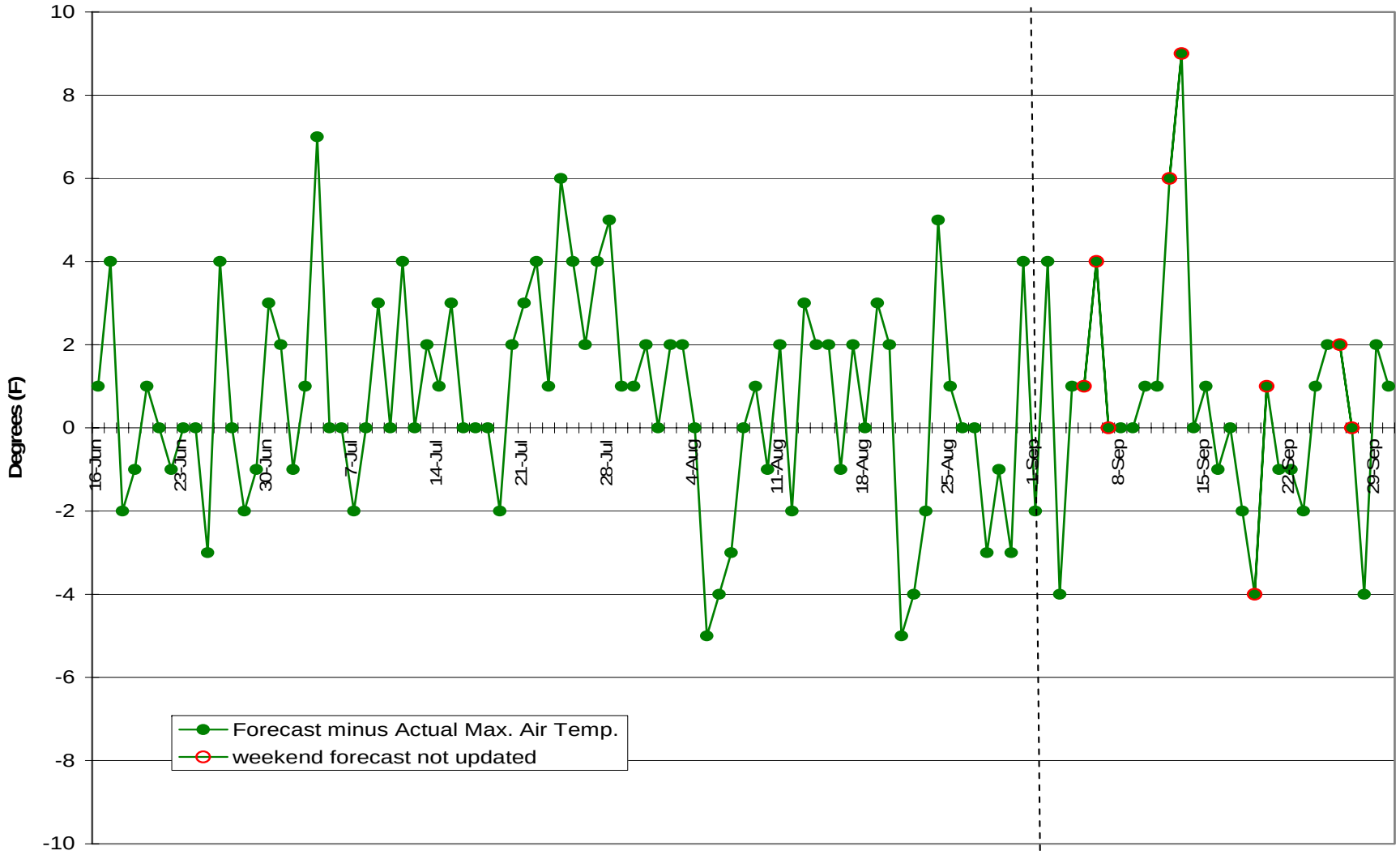

Figure 3. Deviation of forecasted and actual maximum air temperature in 2009

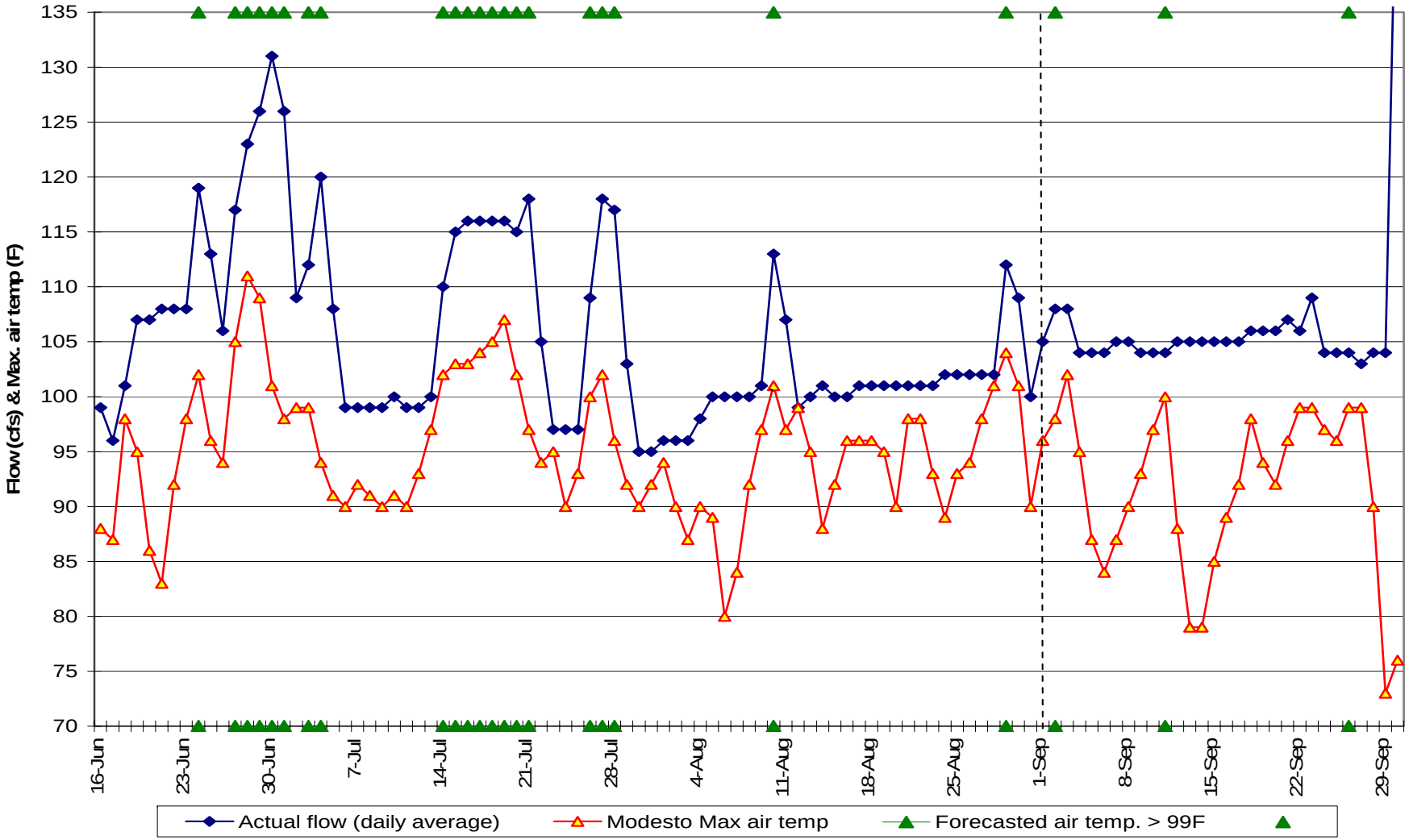

Figure 4. Daily average flow, daily maximum air temperature, and higher flow target days in 2009

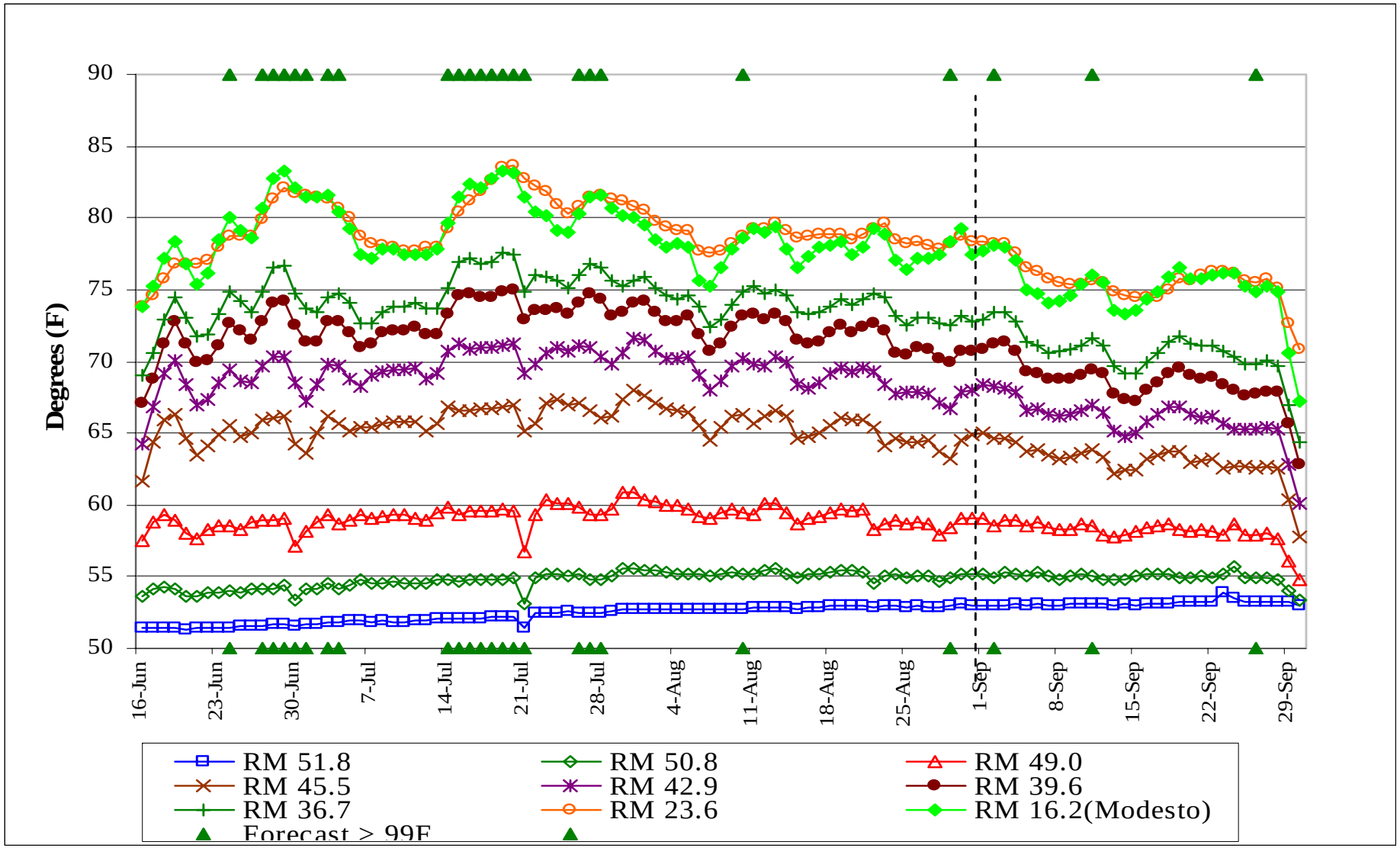

Figure 5. Daily average water temperature at nine stations from River Mile (RM) 51.8 to RM 16.2, with higher flow target days indicated

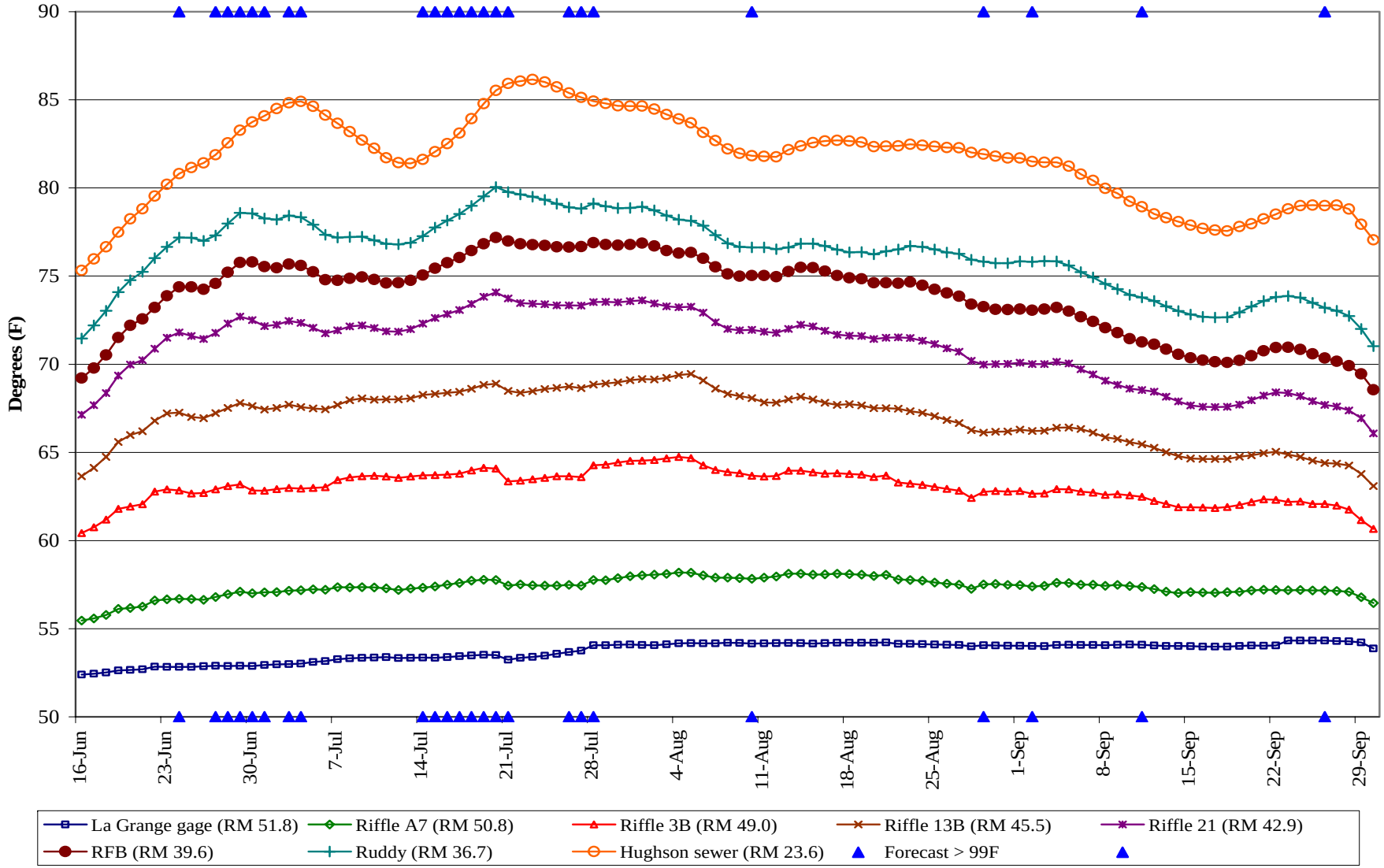

Figure 6. 7-day average of daily maximum water temperature at eight stations from La Grange gage at River Mile (RM) 51.8 to RM 23.6, with higher flow target days indicated

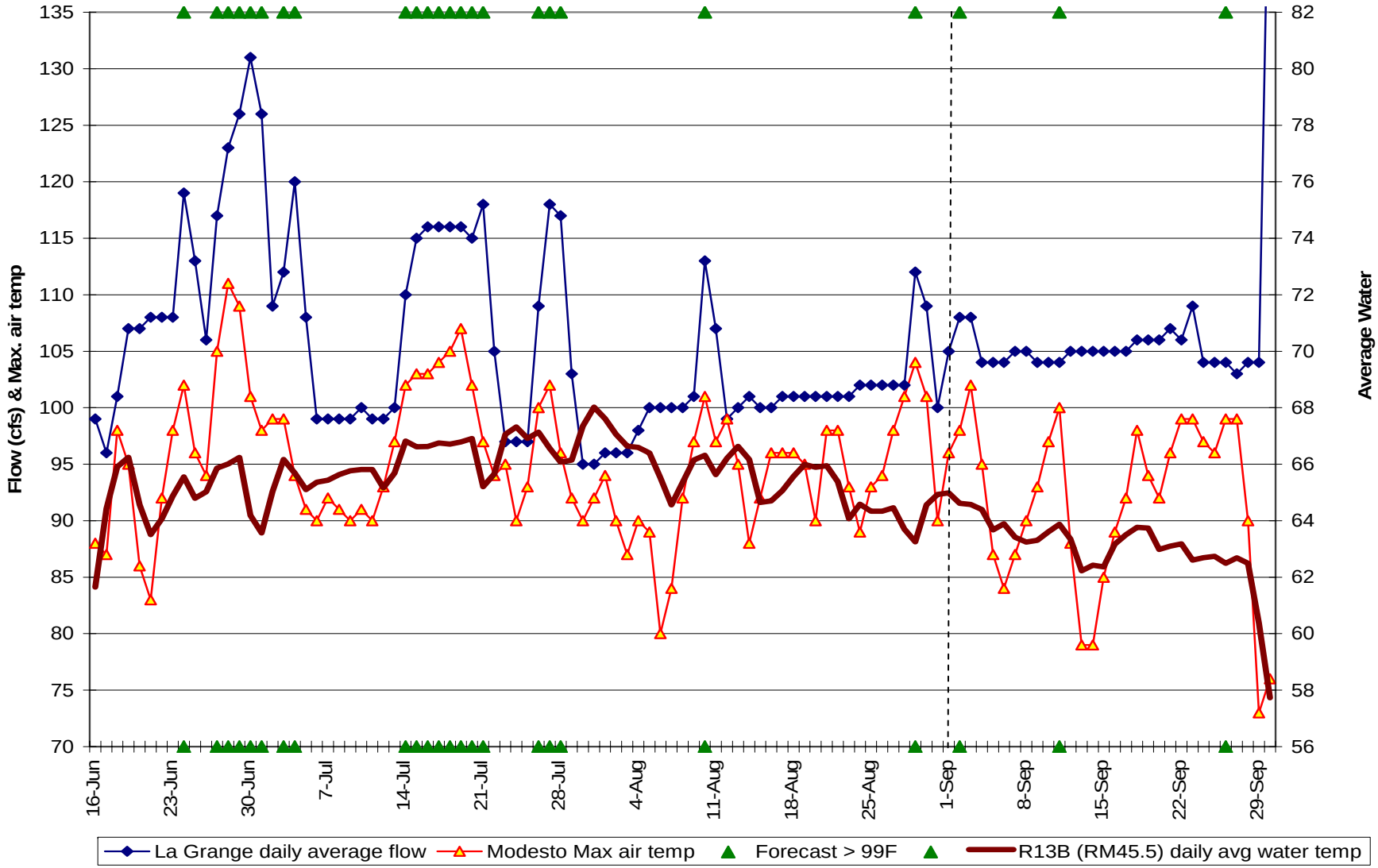

Figure 7. Flow, maximum air temperature, and average water temperature at River Mile 45.5

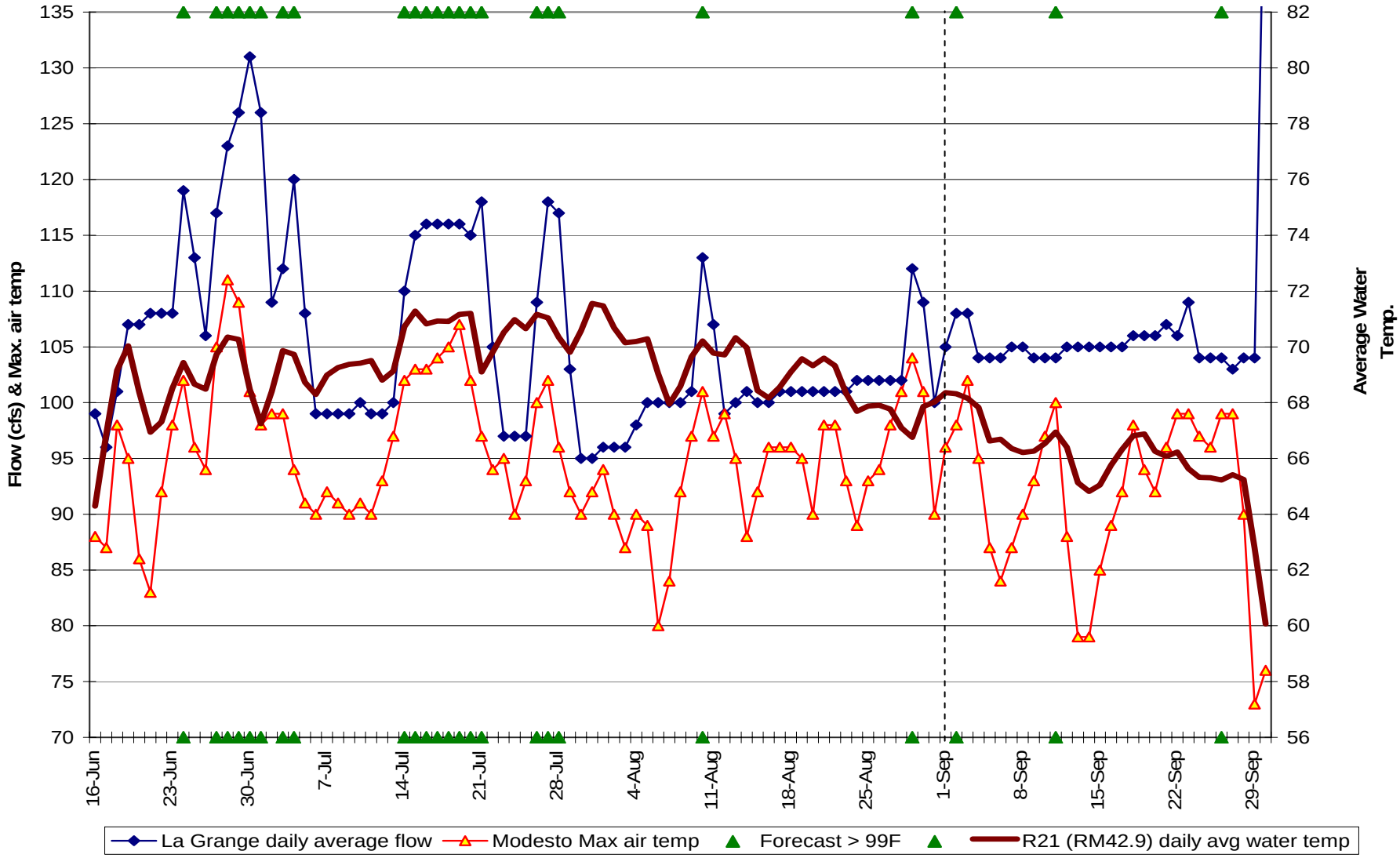

Figure 8. Flow, maximum air temperature, and average water temperature at River Mile 42.9

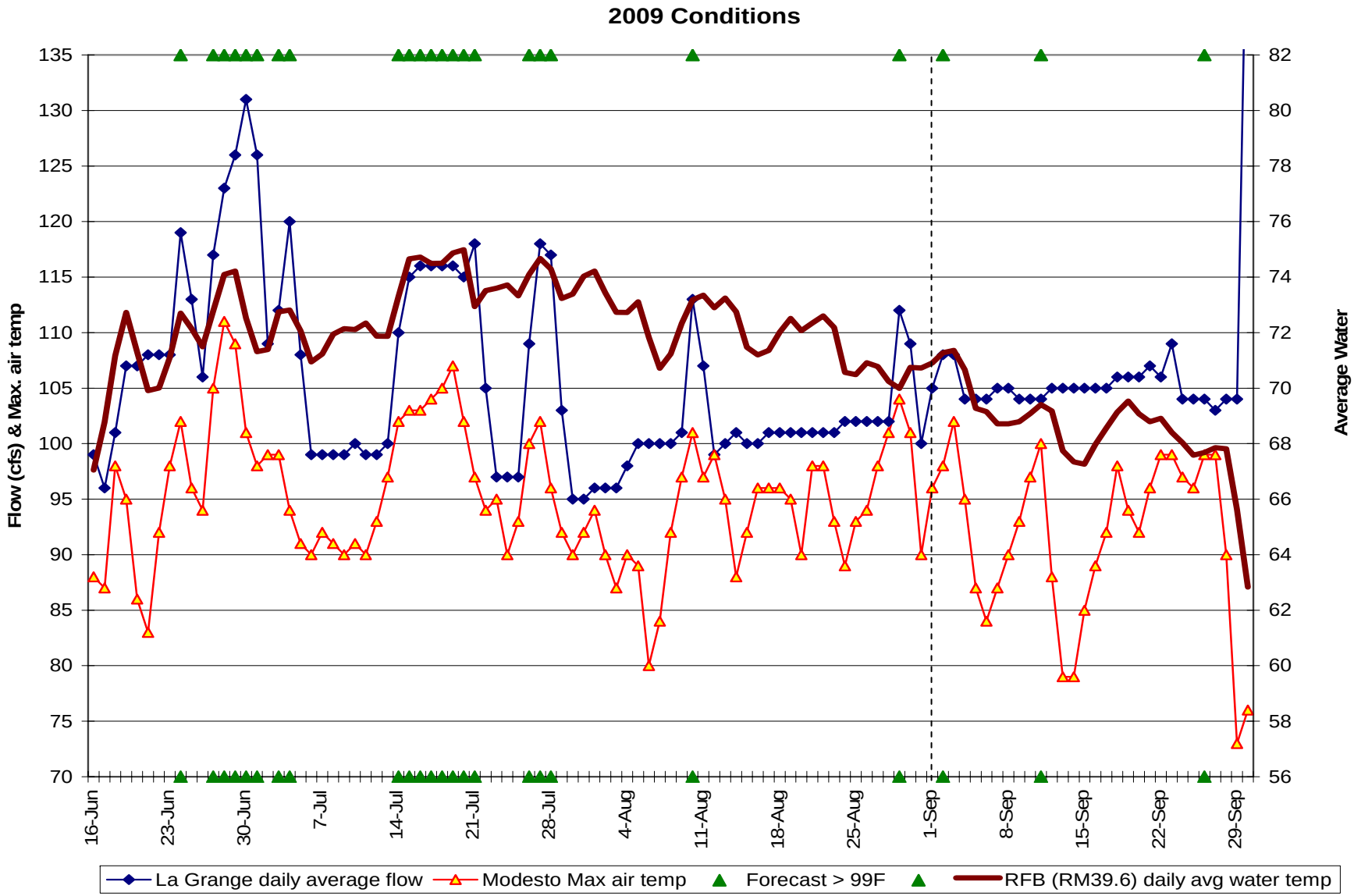

Figure 9. Flow, maximum air temperature, and average water temperature at River Mile 39.6

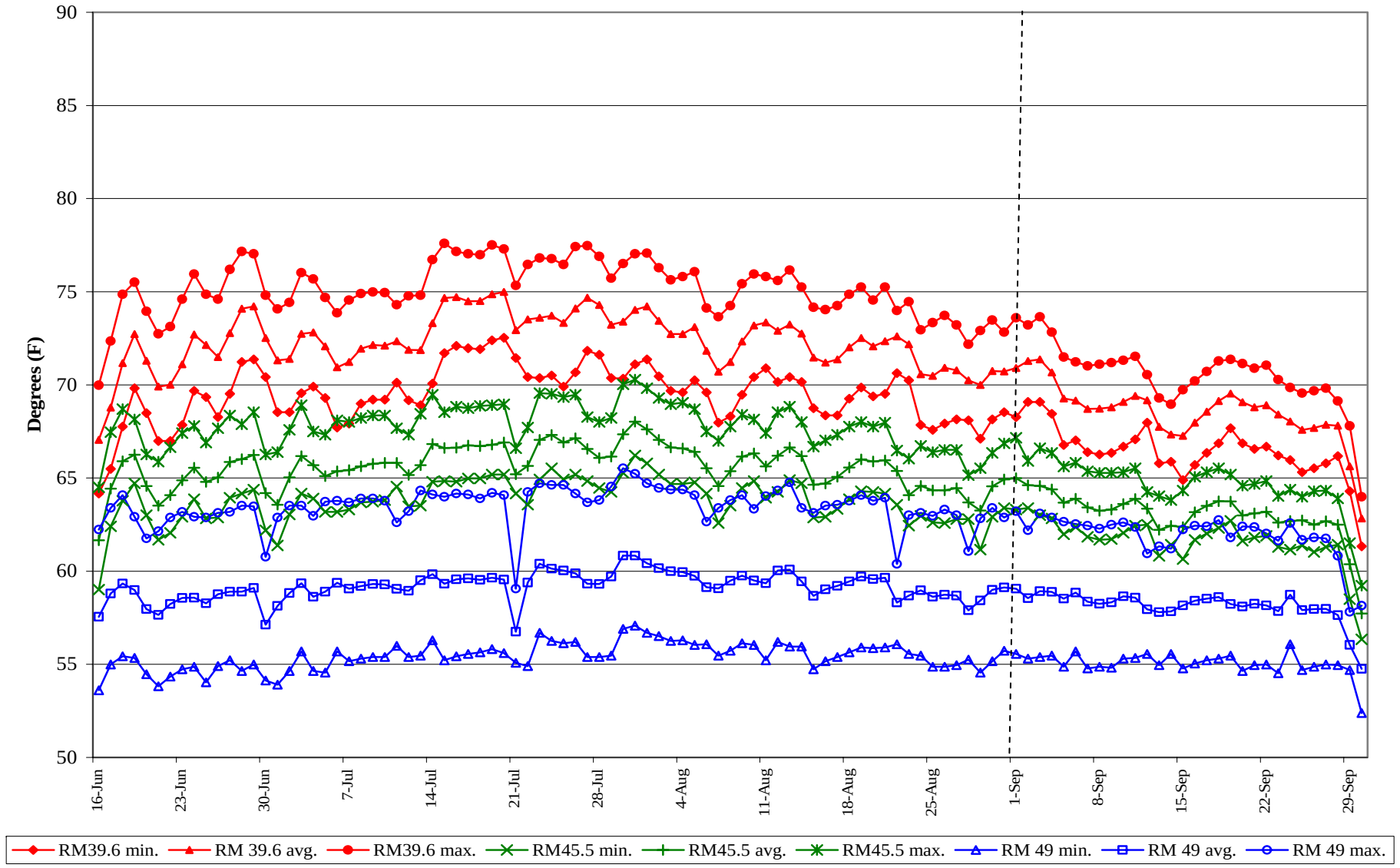

Figure 10. Daily minimum, average, and maximum WT at RM 49.0, 45.5, and 39.6

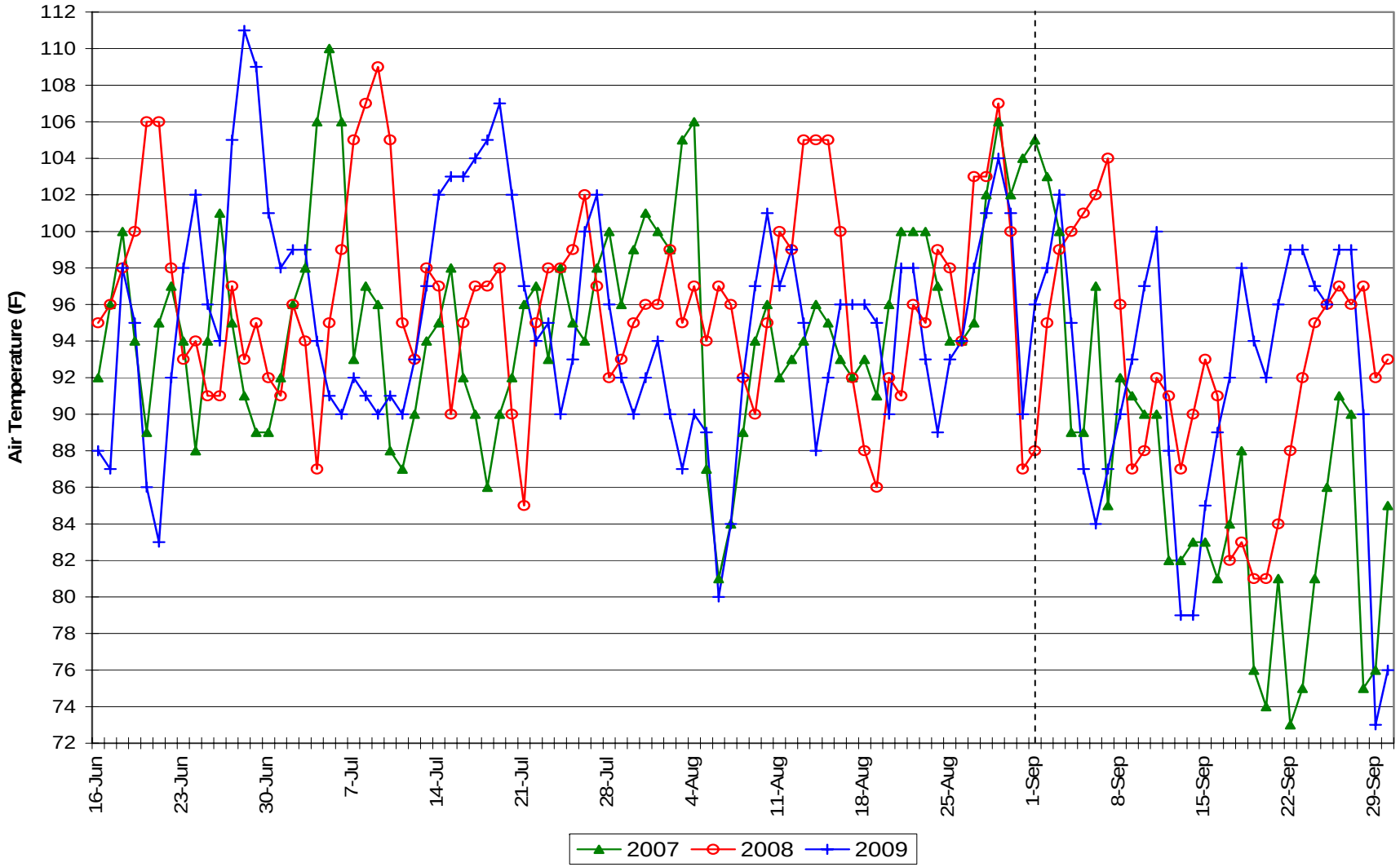

Figure 11. Maximum air temperature (F) at Modesto in 2007-2009 during June 16-September 30

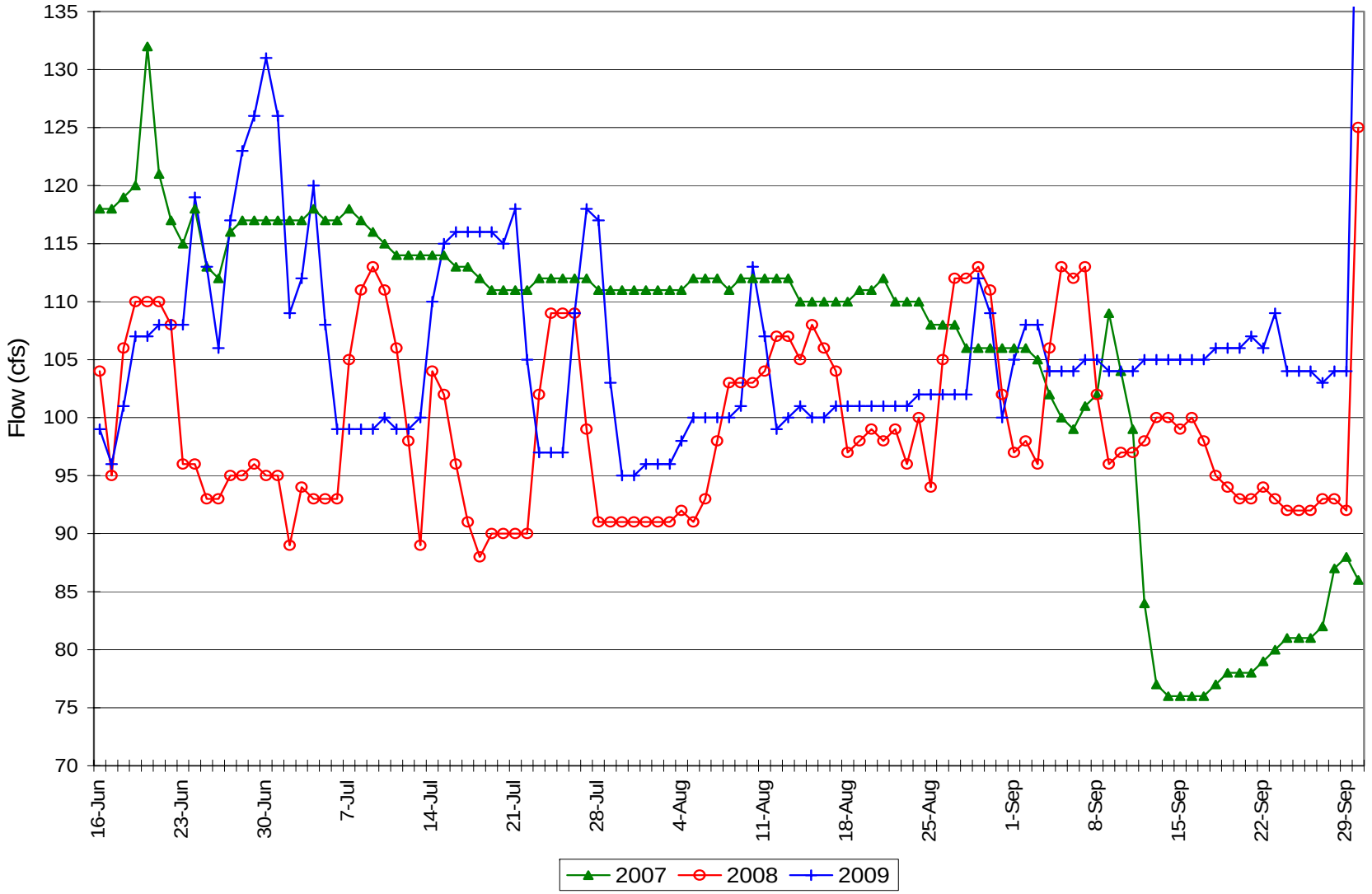

Figure 12. Daily average flow at La Grange in 2007-2009 during June 16-September 30

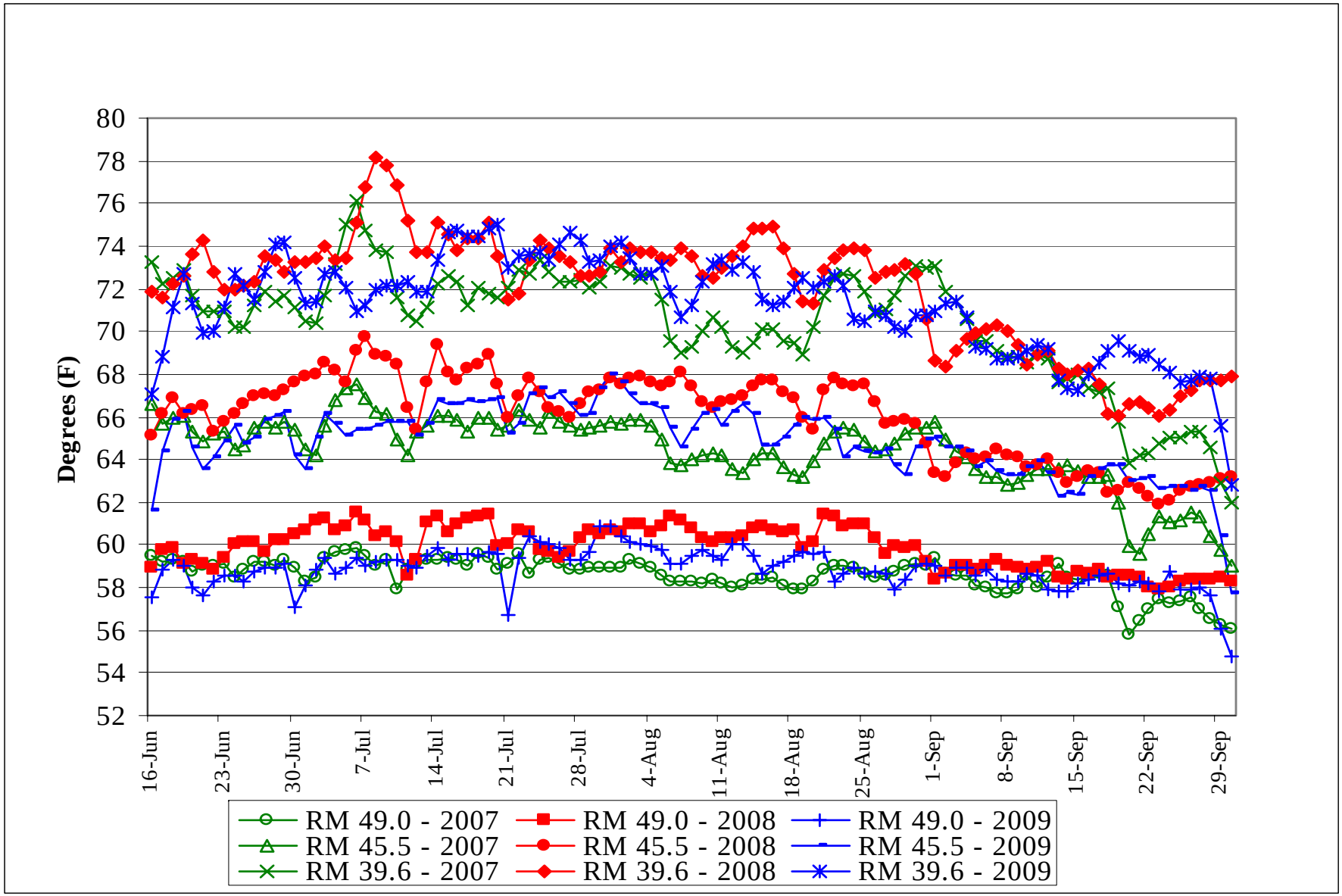

Figure 13. Daily average water temperature at RM 49.0, 45.5, and 39.6 in 2007-2009