

**Placer County Water Agency
Middle Fork American River Project
(FERC No. 2079)**

FINAL

**AQ 5 – BIOENERGETICS
TECHNICAL STUDY REPORT – 2011**



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1.0 INTRODUCTION

This report describes the AQ 5 – Bioenergetics study conducted by the Placer County Water Agency (PCWA) in accordance with the AQ 5 – Bioenergetics Technical Study Plan (AQ 5 – TSP). The AQ 5 – TSP was included in the Supporting Document (SD) H of the Pre-Application Document (PAD) for the Middle Fork American River Project (MFP or Project) (PCWA 2007).

The purpose of the study was to provide data to evaluate potential effects of Project operations on salmonid (trout) growth and habitat as a result of potential changes in flow, water temperature, and food resources (e.g., macroinvertebrates) in the Rubicon River bypass reach and in the peaking reach (Middle Fork American River below Oxbow Powerhouse). Rainbow trout are the primary salmonid management species and, thus, were used for the modeling (brown trout also exist in the Rubicon River and peaking reaches). A secondary purpose of the AQ 5 – TSP was to determine the feasibility of predicting the effects of changes in water temperature and food availability on hardhead growth and habitat.

The following sections provide a detailed description of the study objectives, study implementation, extent of the study area, study approach, study results, and literature cited.

2.0 STUDY OBJECTIVES

The objectives of the bioenergetics study in the AQ 5 – TSP are as follows:

- Determine factors limiting salmonid growth (food and/or water temperature).
- Predict the effects of changes in water temperature and food availability on salmonid growth and habitat.
- Determine the feasibility and appropriateness of predicting the effects of changes in water temperature and food availability on hardhead growth and habitat.

Figure AQ 5-1 shows the AQ 5 – TSP study objectives and the study elements associated with the objective. It also shows where information developed is documented.

3.0 STUDY IMPLEMENTATION

Study elements described in the AQ 5 – TSP (PCWA 2007) were initiated in 2007 and completed in 2011. A summary of the study elements that have been completed, outstanding study elements, and any deviations or proposed modifications to the AQ 5 – TSP are discussed in the following subsections.

3.1. STUDY ELEMENTS COMPLETED

The following study elements were completed:

- The Wisconsin Bioenergetics model (Hanson et al. 1997) was used to analyze salmonid growth and water temperature relationships in the Rubicon River and the peaking reach. An additional bioenergetics model (Addley 2006) was also used to corroborate the results.
- A bioenergetics foraging model (Addley 2006) that incorporated food availability, water temperature, depth, velocity, and fish size was used to quantify the amount and quality of habitat for salmonids in the Rubicon River and the peaking reach.
- The availability of bioenergetics data for hardhead (e.g., water temperature versus growth relationships) was evaluated to determine the feasibility of addressing water temperature and/or food availability through modeling.

3.2. DEVIATIONS FROM TECHNICAL STUDY PLAN

There were no deviations from the study plan.

3.3. OUTSTANDING STUDY ELEMENTS

There are no outstanding study elements for the AQ 5 – TSP.

3.4. PROPOSED MODIFICATION TO TECHNICAL STUDY PLAN

There are no proposed modifications to the AQ 5 – TSP.

4.0 EXTENT OF STUDY AREA

The study area for bioenergetics modeling and analysis includes the Rubicon River downstream of Hell Hole Reservoir and the peaking reach (Middle Fork American River and North Fork American River downstream of Oxbow Powerhouse).

5.0 STUDY APPROACH

The study approach addressed macroinvertebrate drift, water temperature scenarios, salmonid growth, salmonid habitat, and hardhead.

5.1. MACROINVERTEBRATE DRIFT

Macroinvertebrate drift sampling was conducted to document the seasonal density and size distribution of drifting macroinvertebrates in Rubicon River downstream of Hell Hole Reservoir and the peaking reach. Drifting macroinvertebrates are a primary food source for resident salmonids (e.g., Elliott 1973; Hughes and Dill 1990; Hayes et al. 2000; Addley 2006). Drift sampling was conducted at seven sampling sites on the bypass and peaking reaches in June, July/August, and September/October 2007 (Table AQ 5-1; Map AQ 5-1). At each sampling site, two representative riffles were identified for

sampling. At the downstream end of each riffle, three drift samples were collected using a sampling methodology similar to that used in Hayes et al. (2000). Drift samples were collected twice during the day (mid-morning and mid-afternoon). Drift nets consisted of three 0.5 mm mesh drift samplers (modified from Field-Dodgson 1985) stacked vertically in the water column at 0.1 m above the bed, at 0.4 of the water depth, and at the surface (only two nets were used in shallow water, <0.5 m) (Figure AQ 5-2). Three sets of nets were placed across the stream at each site: near mid-channel (or as close as possible depending on flows), mid-way between shore and mid-channel, and near shore.

Water velocity flowing into each of the stacked drift nets was measured at the start and end of each drift sample collection period. Duration of each sample period was approximately one hour. Samples were sorted and quantified by sub-sampling. Organisms in each sub-sample were measured for length. Abundance of organisms within each 2 mm length size class was determined. Mean drift density (number/m³) and size frequency results were summarized in tables/figures.

5.2. WATER TEMPERATURE SCENARIOS

Four flow/water temperature scenarios were developed for the bioenergetics analysis in the Rubicon River and one flow/temperature scenario was developed for the analysis in the peaking reach (Table AQ 5-2). The scenarios in the Rubicon River included existing instream flows; existing instream flows with anticipated increased South Fork Rubicon River flows as a result of the new SMUD License¹; Proposed Action instream flows; and Proposed Action instream flows plus an increase of 10 cubic feet per second (cfs) for sensitivity testing. In the peaking reach, the one flow/temperature scenario consisted of existing flows, but also represented other minimum flow/temperature scenarios because modifying minimum flows in the peaking reach did not change the water temperature (AQ 4 – Water Temperature TSR [PCWA 2011a; SD B]) (also see Appendix H [Table AQ 5-2]). Details of the scenarios are provided at the end of this section.

The water temperature scenarios were developed for seven locations on the Rubicon River (R28.8, R25.3, R22.5, R14.3, R5.3, R3.7, and R0.7) and for four locations in the peaking reach (MF23.1, MF14.3, MF8.9, and MF8.9) (Map AQ 5-2).

The flow/water temperature scenarios consisted of mean daily temperature and maximum daily temperature for 2005 – 2008 (above normal, wet, dry, and dry water year types, respectively). Four years of data were included in the scenarios to provide a time series long enough to analyze rainbow trout growth; these particular four years were selected because: (1) empirical water temperature data were available for each year; and (2) water temperature sensitivity modeling data were available for at least two of the years (2006 and 2007) (AQ 4 – TSR [PCWA 2011a; SD B]). Water temperature modeling was developed for 2006 and 2007 as part of the AQ 4 Water Temperature Modeling Study (AQ 4 – TSR [PCWA 2011a; SD B]). The 2006 (wet year) water

¹ The license for the Sacramento Municipal Utility District (SMUD) Upper American River Project (FERC No. 2101), when issued, will include increased minimum flows in the South Fork American River, which will increase flows in the Rubicon River.

temperature modeling data were used to represent 2005 (above normal year) and the 2007 (dry year) water temperature modeling data were used to represent 2008 (dry year).

The flow/water temperature scenarios were developed using a combination of measured and/or modeled temperature data. Where modeled or measured temperature data were missing for periods of time, temperature data were generated by using data from other years or data correlations from other sites. Water temperature modeling data were available only for May – September (AQ 4 – TSR [PCWA 2011a; SD B]). The flow regime scenarios, however, did not affect water temperature during the other months, so it was possible to use the measured existing temperature data to fill in the missing model data (late fall – spring data) and complete the annual temperature time series. The resulting water temperature scenarios were plotted, and where data were missing/filled by alternative means (e.g., other sites, correlation, etc.), the data were highlighted.

Details for each of the flow/water temperature for the Rubicon River scenarios are discussed below:

- **Rubicon River Existing (Existing)** – Measured water temperature data (AQ 4 – TSR [PCWA 2011a; SD B]) (Map AQ 5-2) from 2005 – 2008 were used to create the average daily and maximum daily water temperature time series in the Rubicon River. The streamflow releases that characterize Existing scenario are shown in Table AQ 5-2.
- **Rubicon River Existing + South Fork Rubicon Scenario (Existing + SF)** – This flow/water temperature scenario consisted of modeled existing flow releases from Hell Hole Dam with anticipated increased minimum flows from the South Fork Rubicon River in the new SMUD FERC license. The details of the water temperature modeling used for this scenario are provided in PCWA (AQ 4 – TSR [PCWA 2011a; SD B]). The streamflow releases that characterize Existing + SF scenario are shown in Table AQ 5-2.
- **Rubicon River Proposed Action (Proposed Action)** – The Proposed Action scenario is based on the minimum flows in the Proposed Action (Instream Flow and Reservoir Minimum Pool Measure [IFRM] PCWA 2011b; SD A), including increased SMUD flows in the South Fork Rubicon River. Water temperature modeling details are provided in PCWA (AQ 4 – TSR [PCWA 2011a; SD B]). The streamflow releases that characterize Proposed Action scenario are shown in Table AQ 5-2.
- **Rubicon River Proposed Action + 10 cfs (Proposed Action + 10 cfs)** – This scenario was developed to provide a wider range of flow/water temperatures in the analysis. The scenario is the Proposed Action scenario with a 10 cfs increase in minimum flow release from Hell Hole Reservoir. The scenario includes the increased South Fork Rubicon River flows (Table AQ 5-2). The water temperature data for 2007 and 2008 were obtained from the temperature modeling (AQ 4 – TSR [PCWA 2011a; SD B]). The temperature data for 2005

and 2006 were developed by linearly extrapolating temperature modeling results (AQ 4 – TSR [PCWA 2011a; SD B]) from lower flows (20 cfs and 30 cfs) to the higher flows (40 cfs).

Details for the peaking reach flow/water temperature scenario are discussed below:

- **Peaking Reach (All Flows)** – One flow/water temperature scenario was developed for the peaking reach (Table AQ 5-2). Previous water temperature modeling sensitivity analysis in the peaking reach (AQ 4 – TSR [PCWA 2011a; SD B], see Appendix H) showed that changes in minimum flows in the peaking reach did not alter water temperature due to the daily high flow releases (e.g., 1,000 cfs) in the peaking reach and the timing of the low flow releases. That is, cold minimum flow releases at the top of the reach occurred primarily at night when little warming of the water could occur along the length of the reach. The daily high flow releases were large enough such that little warming occurred in the reach. The streamflow releases that characterize the peaking reach flow scenario are shown in Table AQ 5-2.

5.3. SALMONID GROWTH

Rainbow trout growth was assessed for each flow/water temperature scenario and location (Section 5.1.2; Map AQ 5-2), except at the locations where maximum daily temperatures were greater than rainbow trout thermal maximum (maximum temperature criteria) (see below). The bioenergetics models were calibrated using observed growth and temperature data. Growth was then predicted for the alternative flow/temperature scenarios using the calibrated bioenergetics models. Rainbow trout growth was also assessed for two higher food regimes.

The methods for the maximum temperature criteria, observed rainbow trout growth, bioenergetics model calibration, and temperature and food growth scenarios are discussed below.

5.3.1. Maximum Temperature Criteria

Generally, daily maximum water temperatures in excess of 76°F (24.4°C) are too high to sustain rainbow trout. Hokanson et al. (1977) found that rainbow trout fed maximum rations could survive in a water temperature regime where the maximum daily water temperature was 76.6°F (24.8°C) (the mean temperature was 69.8°F [21°C] and the diel fluctuation was ± 6.8°F [3.8°C]). Upper incipient lethal (UILT) temperature estimates for rainbow trout in the literature for short exposures (24 hrs to 7 days) range from 75.2 – 80°F (24 – 26.7°C) (McCullough et al. 2001).

5.3.2. Observed Rainbow Trout Growth

Observed rainbow trout size by age in the Rubicon River and peaking reach are shown in Table AQ 5-3 (AQ 2 – Fish Population TSR [PCWA 2011c; SD B]). The average weight – length relationship for rainbow trout in the MFP is shown in Figure AQ 5-3.

5.3.3. Bioenergetics Model Calibration

The Wisconsin Bioenergetics model (Hanson 1997; Rand et al. 1993) was used to analyze salmonid growth and water temperature relationships in the Rubicon River and the peaking reach. An additional bioenergetics growth model (Addley 2006) was also used to corroborate the results.

Historical water temperature data and the average observed growth of rainbow trout for a 4-year period were used to calibrate the bioenergetics models. Calibration was accomplished by calculating the amount of food that a fish would require to achieve the observed growth under the existing water temperature scenarios. This amount of food by year was reported as a percent of maximum consumption (P-value).

Fish spawning was assumed to occur mid-April in Years 3 and 4 of the growth simulations. Energy loss at spawning was assumed to be 46% (Hayes et al. 2000).

5.3.4. Water Temperature and Food Growth Scenarios

Following calibration of the bioenergetics models, growth was modeled for each flow/water temperature scenario and location (Map AQ 5-2). The calibrated P-value for each year was used. The grouping of calibrated bioenergetics model sites and flow/temperature scenario locations is shown in Tables AQ 5-4a,b. For each location, growth (weight and length) for all of the flow/temperature scenarios were plotted together to show the relative effects of the scenarios on growth.

The same combinations of flow/temperature scenarios were modeled with a 10% and 20% increase in food consumption. These simulations were conducted to identify growth limiting factor at locations (i.e., water temperature and/or food). The simulations were also conducted to identify whether changes in physical habitat (wetted perimeter, reduced flow fluctuations), which could potentially increase food availability, would translate into increased fish growth (e.g., Moog 1993).

5.4. WATER TEMPERATURE AND FOOD EFFECTS ON SALMONID HABITAT

A bioenergetics foraging model (Addley 2005; Addley 2006) that incorporated food availability, water temperature, depth, velocity, and fish size was used to quantify how changes in water temperature and food availability affect habitat availability for adult (300 mm) rainbow trout.

Foraging model predictions of depth and velocity suitability for adult rainbow trout were compared to the habitat suitability criteria (PCWA HSC) used for instream flow habitat modeling (AQ 1 – Instream Flow Technical Study Report [TSR] [PCWA 2011d; SD B]). The base water temperature in the foraging model run was 59°F (15°C) and the base drift density was a moderately low drift density 1.4 prey/m³. Following this comparison, the foraging model was used to create velocity foraging model habitat suitability criteria (FM HSC) for a range of water temperatures and a range of drift densities. The temperature range was 42, 48, 54, 59, 64, and 68°F (5.5, 9, 12, 15, 18, and 20°C) and the drift density range was 1.1, 1.4, 2.1, 2.8, and 3.5 prey/m³. Because water

temperature and food primarily affect velocity habitat suitability (Addley 2006), the FM HSC for velocity were combined with the original MFP HSC for depth in habitat simulations.

At the instream flow study sites (Rubicon River and the peaking reach) (Map AQ 5-3), habitat versus flow relationships were developed using both the FM HSC and the MFP HSC. These relationships show the effects of water temperature and food availability on the amount of habitat available at the instream flow study sites.

5.5. HARDHEAD

The availability of bioenergetics data for hardhead (e.g., water temperature versus growth) was evaluated to determine the feasibility of addressing water temperature and/or food availability through bioenergetics modeling.

Bioenergetics data were not available for hardhead. Some limited literature data on water temperature preference was available; these data were used to make inferences regarding hardhead habitat in the Rubicon River and the peaking reach.

6.0 STUDY RESULTS

6.1. MACROINVERTEBRATE DRIFT

Macroinvertebrate drift density was relatively low at all of the study sites (Figure AQ 5-4a,b). The average drift density at all sites was 0.93 number/m³ (range 0.47 – 1.31 number/m³). This drift density was about 60% of the drift density in the Klamath River (Addley 2005) and less than 20% of that in highly productive trout streams (Filbert and Hawkins 1995; Hayes et al. 2000). It is on the low end of the typical drift density range reported by Allan (1987) of 0.01-1.0 to 5.0 + number/m³.

A consistent pattern in the drift density (Figure AQ 5-4b) was not present in the data. Within the Rubicon River and peaking reach there was a pattern of higher drift density at the top of the reach. The pattern of higher drift density at the top of the reaches may be related to the “tailwater” flow releases from Hell Hole Reservoir that occur at these two locations. There was no consistent seasonal trend in the drift density samples between the June sampling and the late September/early October samplings.

The size of the drifting macroinvertebrates was similar to that in other studies (e.g., Addley 2005) where most of the macroinvertebrates were relatively small, with few macroinvertebrates larger than 5 mm (Figure AQ 5-5; Tables AQ 5-5a,b). Trout gillraker spacing typically precludes fish from feeding on prey smaller than about 1 mm and larger fish have larger gillraker spacing. For example, gillraker spacing for a 300 mm salmonid can be on the order of 3.45 mm (Wankowski 1979) and can limit the amount of prey available to larger fish.

6.2. WATER TEMPERATURE SCENARIOS

Figures AQ 5-6a-d and Figures AQ 5-7a-b show the Existing (measured) mean daily water temperature for 2005 – 2008 along the length of the Rubicon River and the peaking reach, respectively. The figures show the dates where temperature data were measured and the dates where missing data were filled to create continuous temperature relationships. The methods used for filling missing data, by site and by date range, are shown in Tables AQ 5-6a and b.

During the summer, mean daily water temperature warms from approximately 46 – 47°F at the top of the Rubicon River (R28.8) to over 75°F at the bottom of the Rubicon River (R0.7) (Figures AQ 5-8). The greatest warming occurred from the top of the reach (R29.8) to approximately R14.3. Downstream of R14.3 there was limited warming (i.e., water temperature nearing/in equilibrium with air temperature).

In the peaking reach, water temperature warms gradually from a little under 55°F at the top of the reach (MF23.1) to 65 - 70°F at the lower end of the Middle Fork American River (MF0.1) (Figure AQ 5-9). Warming continued along the entire length of the reach, however, the increase in water temperature with distance was greater at the top of the reach and less at the bottom of the reach.

Maximum daily water temperature (Existing temperature scenario) was plotted with mean daily temperature at all of the temperature modeling/monitoring sites (Figures AQ 5-10a-g and AQ 5-11). The maximum daily temperature exceeded 76°F at all of the downstream Rubicon River modeling/monitoring sites from R5.3 (near Pilot Creek) to Ralston Afterbay (R0.7).

All of the Rubicon River flow/water temperature scenarios (Existing, Existing + South Fork Rubicon, Proposed Action, and Proposed Action + 10 cfs) at each location along the river are shown in Figures AQ 5-12a-d. The scenarios with increased minimum flow had limited effect on water temperature in the top of the reach (R28.8, R25.3, R22.5). In the middle of the reach there was decrease in summer temperature with increased flow (R14.3) and in the lower portion of the reach there was a small decrease in summer temperature with increased flow.

6.3. SALMONID GROWTH

6.3.1. Maximum Temperature Criteria

Because water temperature in the lower Rubicon River exceeded the 76°F maximum temperature criteria for rainbow trout (Section 5.3.1), the lower sites on the river (R3.7 and R0.7) were not modeled for rainbow trout temperature and food growth analyses. The R3.7 site was modeled for calibration purposes only, and to show that large amounts of weight loss occurred for fish in this temperature regime (possibly mortality). The R5.3 site was modeled for each of the flow/temperature scenarios to ascertain whether the lower portion of the river would benefit from an alternative flow/temperature scenario, even though maximum daily temperatures at this location were also greater than 76°F during the summer. It should be noted that small numbers of rainbow trout

were observed during fish population surveys conducted in the lower Rubicon River at R3.5 (AQ 2 – TSR [PCWA 2011c; SD B]).

6.3.2. Bioenergetics Model Calibration

The Wisconsin Bioenergetics model (Hanson 1997; Rand et al. 1993) calibration P-values for observed growth at R25.7, R20.9, R3.5, and MF14.1 are provided in Tables AQ 5-4a,b (Map AQ 5-3). Tables AQ 5-4a,b also show the other flow/water temperature modeling sites that used these P-values for the temperature/growth modeling scenarios. Calibration growth plots with the calibration fish sizes are provided in Figures AQ 5-13a,b for the Rubicon River and peaking reach sites. All sites calibrated with consistent P-values, except for the lower Rubicon River site (R3.7). At this site, for the last two years of growth, the P-value was relatively high (>0.93). A high P-value was required to match growth in the extremely high temperatures at the R3.7 location. During the last two years of the growth simulation, a large amount of weight loss occurred in the simulation during the summer (summer weight loss was offset by gains in the spring and fall).

6.3.3. Water Temperature and Food Growth Scenarios

The water temperature and food growth scenarios for the Rubicon River (Figures AQ 5-14a-e) and the peaking reach (Figure AQ 5-15, Figures AQ 5-16a-b) are discussed separately below.

Rubicon River

The different flow/water temperature scenarios had almost no effect on growth of rainbow trout in the upper portion of the reach from R28.8 downstream to below the South Fork Rubicon River at R22.5 (Figures AQ 5-14a-c, Figures AQ 5-12a-d). This occurred partly because the scenarios had limited effect on water temperature and partly because the water temperature during the primary growth season was in a range (48 – 62°F; Figures AQ 5-10a-c) where there is little effect of temperature on growth (see Figure AQ 5-17) (i.e., growth is similar in this range of temperature). The largest effects on growth were at R14.3 and R5.3. Summer water temperatures at these sites exceeded the optimum growth temperature for trout and the scenarios with increased flows resulted in decreased temperatures and, therefore, increased rainbow trout growth. Similar results we obtained using the Addley (2006) bioenergetics model (Appendix A).

The increased food scenarios (10% and 20% increase) resulted increased growth at all study sites (Figure AQ 5-14a-e). For example at R22.5 (below the South Fork Rubicon River), size at the end of the four-year analysis period increased from 200 g (150 mm) to 450 g (350 mm) with a 20% increase in food.

Peaking Reach

Growth in the peaking reach was greatest at the top of the reach (MF 23.1) and lowest at the bottom of the reach (MF0.1). This occurred because daily average water temperatures at the top of the reach were near 55°F (Figure AQ 5-9) during the summer (Figure AQ 5-9), which is in the optimal growth range for the Wisconsin Model (Figure AQ 5-17).

The increased food scenarios (10% and 20% increase) resulted increased growth at all study sites (Figure AQ 5-15). For example at MF23.1, size at the end of the four-year analysis period increased from a little under 425 g (330 mm) to 915 g (416 mm) with a 20% increase in food.

6.4. WATER TEMPERATURE AND FOOD EFFECTS ON SALMONID HABITAT

6.4.1. Habitat Suitability Criteria

The foraging model (Addley 2006) produced habitat suitability criteria similar to those developed using empirical fish observations (AQ 1 – TSR [PCWA 2011d; SD B]). Figures AQ 5-18a,b and Figures AQ 5-19a,b show the velocity HSC developed from empirical data (PCWA HSC) and those developed using the foraging model for different water temperatures and different drift densities. The foraging model daily energy intake (joules/day) predictions were scaled to percent of maximum to create the HSC. The MFP HSC include a broader range of velocities than any of the individual water temperature or drift density FM HSC; however, when the FM water temperature and drift density HSC are combined, the range of velocity is similar to the MFP HSC (Figures AQ 5-18a and AQ 5-19a).

Water Temperature

At the highest water temperature (68°F daily average), the foraging model HSC results showed that rainbow trout would have a positive daily net energy intake (i.e., exhibit positive growth) in a narrow range of velocities. High velocities required too much energy expenditure and lower velocities provided too little food. The largest energy intake and broadest range of velocity suitability occurred at 59°F. The coldest temperature modeled (42°F) had a board velocity range, but was shifted to lower velocities as a result of reduced swimming speed (food capture capability) at lower temperatures.

Food

The foraging model HSC showed that daily net energy intake increased with increased drift density and that the range of suitable velocities was broader. The foraging model HSC at the lowest drift density had the narrowest range of suitability. The foraging model HSC at the highest drift density showed both faster and slower water habitat became suitable. With higher drift density, adequate food was available in slow water habitat and in fast water habitat, the higher energy costs were offset by higher energy gains.

6.4.2. Habitat Versus Flow Relationships

Because the foraging model HSC were generally narrower than the MFP HSC it was expected that FM HSC modeling would show less habitat. The primary goal of the modeling, however, was to determine what effects flow/water temperature and increased food availability would have on adult rainbow trout habitat. Also the goal was to determine if water temperature and/or food availability control rainbow trout habitat availability in the MFP.

At all modeling sites, habitat was inversely correlated to water temperature (i.e., the lowest water temperature FM HSC resulted in the most habitat) (Figures AQ 5-20, AQ 5-21, AQ 5-22, AQ 5-23). These results occurred primarily because the FM HSC for warmer water temperature were narrower (lower range of suitable velocities) than the FM HSC for cooler temperatures (Figure AQ 5-19a). In addition, the lower water temperature FM HSC reached a peak in habitat at a lower discharge than the higher temperature FM HSC.

Drift density FM HSC was positively correlated to habitat (i.e., the highest drift densities resulted in the most habitat) (Figures AQ 5-20, AQ 5-21, AQ 5-22, AQ 5-23). These results occurred primarily because the FM HSC for higher drift densities were broader (larger range of suitable velocities) than the FM HSC for lower drift densities (Figure AQ 5-19a).

At all sites, the affect of increasing drift density have diminishing returns. For example, at 105 cfs at R25.7 (Figure AQ 5-20) a 27% increase in drift density at the low drift densities range (1.1 to 1.4 prey/m³) increased habitat by 38%, while a 25% increase in drift density at the high density range (2.8 to 3.5 prey/m³) resulted in only a 13% increase in habitat.

6.5. HARDHEAD

Hardhead have a much higher water temperature preference than rainbow trout. Knight determined that the preferred temperature for juvenile hardhead was 82°F (28°C). Hardhead tended to choose water temperatures above their acclimation temperature until reaching a thermal preferred maximum. Kimley et al. (2010) found similar results. Kimley et al. (2010) did not test hardhead acclimated to temperatures higher than 64°F (18°C), but found that hardhead acclimated to 64°F (18°C) preferred a temperature of 73°F (23°C). Presumably if Kimley et al. (2010) would have tested hardhead at higher temperatures their final preferred temperature would have been similar to that found by Knight (1985). All the hardhead acclimation groups avoided water <62°F (<17°C) (Kimley et al. 2010). In contrast, the reported optimum growth and preferred water temperature range for rainbow trout is much cooler (in the 59-64°F [15-18°C] range) (Kimley et al. 2010; McCullough et al. 2001).

The summer temperature in the lower Rubicon River was approximately 75°F (average daily) (Figures AQ 5-10a-g). This is approximately 7°F below the reported hardhead preferred temperature. The flow/water temperature scenarios with increased flow,

particularly Proposed Action + 10 cfs reduced summer temperature several degrees and, therefore, would reduce the quality of habitat in the lower Rubicon River for hardhead. Decreasing water temperatures in the lower Rubicon River improves rainbow trout growth, but likely decreases growth and habitat quality for hardhead.

Maximum summer water temperatures in the peaking reach (Figure AQ 5-9) is below the preferred temperature for hardhead (summer temperature <70°F).

7.0 SUMMARY

Macroinvertebrate drift was low in Rubicon River and peaking reach (0.4 – 1.3 number/m³). The average drift density was similar at the upper Rubicon River and upper peaking reach. Drift density was higher in the upper portion of the Rubicon River and the peaking reach than at the bottom of the reaches. The higher drift density at the top of the reaches may be related “tailwater” effects from the Hell Hole Reservoir releases.

The flow/water temperature scenarios with increased flow in the Rubicon River had little effect on temperature or rainbow trout growth in the upper Rubicon River (R28.8, R25.3, R22.5). Increased flow, however, decreased the temperature in the middle and lower Rubicon River (R14.3, R5.3) and increased rainbow trout growth. Maximum water temperatures in the lower Rubicon River (R5.3, R3.7, R0.7) exceeded the reported maximum temperature for rainbow trout survival (maximum daily 76°F), although low numbers of rainbow trout were observed in this reach during fish population surveys.

In the peaking reach, minimum flows in the ranges modeled did not affect water temperature. Summer water temperature was colder at the top of the peaking reach (e.g., 55-60°F) and warmer at the bottom (e.g., 60-70°F). The upper peaking reach (MF23.1) was near the optimal temperature for rainbow trout growth and the growth modeling showed the largest amount of growth at this location. The lower portion of the peaking reach was warmer and rainbow trout growth was lower (e.g., MF0.1).

Increased food availability increased growth at all study sites in the Rubicon River and the peaking reach. This suggests that food availability is a limiting factor for trout growth.

Habitat versus discharge modeling showed that increased drift density increased the amount of habitat available at all study sites (Rubicon River and peaking reach). Habitat suitability was generally inversely related to water temperatures, with the warmest modeled temperatures (68°F) resulting in the least amount of suitable habitat and the lower temperatures 42 – 59°F resulting in the largest amount of habitat.

Reported preferred hardhead water temperatures are much higher than rainbow trout (59-64°F versus 82°F). Summer water temperature in the lower Rubicon River is typically about 75°F (7°F below preferred). Reducing water temperature in the lower Rubicon River (i.e., flow scenarios with higher minimum flows) would decrease the quality of habitat for hardhead. Water temperatures in the peaking reach (summer temperature <70°F) are below the preferred temperature for hardhead.

8.0 LITERATURE CITED

- Addley, R. C. 2006. Habitat Modeling of river ecosystems: multidimensional spatially explicit and dynamic habitat templates at scales relevant to fish. PhD Dissertation, Utah State University, Logan, Utah.
- Addley, R. C., B. Bradford, and J. Ludlow. 2005. Klamath river bioenergetics report. Institute for Natural Systems Engineering, Utah Water Research Lab, Utah State University, Logan, UT.
- Allan, J.D. 1987. Macroinvertebrate drift in a Rocky Mountain stream. *Hydrobiologia* 144:261-268.
- Elliott, J.M. 1973. The food of brown and rainbow trout (*Salmo trutta* and *S. gairdneri*) in relation to the abundance of drifting invertebrates in a mountain stream. *Oecologia* 12:329-347.
- Field-Dodgson, M. S. 1985. A simple and efficient drift sampler. *New Zealand Journal of Freshwater Research*, 19: 167–172.
- Filbert, R.B. and C.P. Hawkins. 1995. Variation in condition of rainbow trout in relation to food, temperature, and individual length in the Green River, Utah. *Trans. Am. Fish. Soc.* 124:824-835.
- Hanson, P.C., T.B. Johnson, D.E. Schindler and J.F. Kitchell. 1997. Fish bioenergetics 3.0 for Windows. University of Wisconsin Sea Grant Institute, Madison.
- Hayes, J.W., J.D. Stark, K.A. Shearer. 2000. Development and test of a whole-lifetime foraging and bioenergetics growth model for drift-feeding brown trout. *Trans. Am. Fish. Soc.* 129:315-332.
- Hokanson, K.E.F., C.F. Kleiner, and T.W. Thorslund. 1977. Effects of constant temperatures and diel temperature fluctuations on specific growth and mortality rates and yield of juvenile rainbow trout, *Salmo gairdneri*. *Journal of the Fisheries Research Board of Canada*, 34:639-648.
- Hughes, N.F., and Dill, L.M. 1990. Position choice by drift-feeding salmonids: model and test for Arctic grayling (*Thymallus arcticus*) in subarctic streams, interior Alaska. *Can. J. Fish. Aquat. Sci.* 47: 2039-2048.
- Knight, N.J. 1985. Microhabitats and temperature requirements of hardhead (*Mylopharodon conocephalus*) and Sacramento squawfish (*Ptychocheilus grandis*), with notes for some other native California stream fishes. PhD Dissertation, University of California, Davis, Davis, California.
- Kimley, P.A., J.J. Cech, L.C. Thompson, S.A. Hamilton, D.E. Cocherell, G. Jones, J.B. Miranda. 2010. Experimental and field studies to assess pulsed water flow impacts on the behavior and distribution of fishes in the South Fork of the American River: second year. California Energy Commission, PIER Energy-Related Environmental Research Program. CEC-500-2009-067

- McCullough, D. A., S. Spalding, D. Sturdevant, and M. Hicks. 2001. Issue Paper 5: Summary of technical literature examining the physiological effects of temperature on salmonids. U.S. Environmental Protection Agency EPA 910-D-1-005.
- Moog, O. 1993. Quantification of daily peak hydropower effects on aquatic fauna and management to minimize environmental impacts. *Regulated rivers: Research and Management*, Vol.8: 5-14.
- Placer County Water Agency (PCWA). 2007. Placer County Water Agency – Middle Fork American River Project – Pre-Application Document.
- _____. 2011a. AQ 4 – Water Temperature Modeling Technical Study Report. Available in PCWA’s Application for New License – Supporting Document B.
- _____. 2011b. Instream Flow and Reservoir Minimum Pool Measure. Available in PCWA’s Application for New License – Supporting Document A.
- _____. 2011c. AQ 2 – Fish Population Technical Study Report (2007–2009). Available in PCWA’s Application for New License – Supporting Document B.
- _____. 2011d. AQ 1 – Instream Flow Technical Study Report. Available in PCWA’s Application for New License – Supporting Document B.
- Rand, P. S., D. J. Stewart, P. W. Seelbach, M. L. Jones, and F. R. Wedge. 1993. Modeling steelhead population energetics in lakes Michigan and Ontario. *Transactions of the American Fisheries Society* 122:977-1001.
- Wankowski, J. W. J. 1979. Morphological limitations, prey size selectivity, and growth response of juvenile Atlantic salmon *Salmo salar*. *Journal of Fish Biology* 14:89–100.

TABLES

Table AQ 5-1. Macroinvertebrate Drift Sampling Site Locations.

Study River and Site ID	Bypass Reach	Peaking Reach	Comparison Reach	Sample Date		
				1st	2nd	3rd
Middle Fork American River						
MF4.8		●		6/22/07, 6/25/07 ¹	7/30/07	10/8/07
MF14.1		●		6/20/07	8/1/07	10/9/07
MF19.1		●		6/27/07	8/2/07	10/15/07
MF26.2	●			6/15/07	8/8/07	10/2/07
Rubicon River						
R1.2	●			6/21/07	7/31/07	9/21/07
R20.9	●			6/26/07	8/7/07	9/25/07
R25.7	●			6/14/07	8/3/07	10/24/07
North Fork of the Middle Fork American River						
NFMF2.3			●	6/28/07	8/9/07	10/3/07
North Fork American River						
NF31.3			●	6/29/07	8/10/07	10/4/07

¹The afternoon sampling was not conducted on June 22, 2007 due to rising water levels. This sampling was completed on June 25, 2007.

Table AQ 5-2. Rubicon River and Peaking Reach Minimum Flows / Temperature Scenarios.

Flow Scenario	Year	Minimum Flow (cfs)							
		June		July		August		September	
		Hell Hole Release	SF Rubicon Flow	Hell Hole Release	SF Rubicon Flow	Hell Hole Release	SF Rubicon Flow	Hell Hole Release	SF Rubicon Flow
Rubicon River									
Existing	2005 - 2006	20	10	20	10	20	10	20	10
	2007 - 2008	20	10	20	10	20	10	20	10
Existing + South Fork Rubicon	2005 - 2006	20	28	20	19	20	18	20	18
	2007 - 2008	20	28	20	19	20	18	20	18
Proposed Action	2005 - 2006	50 / 40 ¹	28	30	19	30	18	30	18
	2007 - 2008	28 / 20 ¹	28	20	19	20	18	20	18
Proposed Action + 10 cfs	2005 - 2006	60 / 50 ¹	28	40	19	40	18	40	18
	2007 - 2008	38 / 30 ¹	28	30	19	30	18	30	18
Middle Fork American Peaking Reach		Oxbow Release		Oxbow Release		Oxbow Release		Oxbow Release	
Peaking Reach (All Flows)	2005 - 2006	75 - 300 ²	--	75 - 300 ²	--	75 - 300 ²	--	75 - 300 ²	--
	2007 - 2008	75 - 300 ²	--	75 - 300 ²	--	75 - 300 ²	--	75 - 300 ²	--

¹Minimum Flow June 1-14 / June 15-30.

²Minimum flow range (temperature model showed similar temperature for this range on minimum flows).

Table AQ 5-3. Average Fish Weight and Lengths by Age Class Measured in the Rubicon River and the Peaking Reach.

Date (Age)	Weight (g) / Length (mm)			
	R25.3	R22.5	R3.7	MF14.3
October 2005 (0+)	3 / 70	4 / 77	5 / 80	12 / 105
October 2006 (1+)	25 / 132	27 / 136	68 / 181	109 / 210
October 2007 (2+)	94 / 201	94 / 201	323 / 295	360 / 306
October 2008 (3+)	196 / 253	196 / 253	521 / 343	426 / 322

Table AQ 5-4a. Calculated P-Values in the Rubicon River from 2005-2008 (age 0+ to 3+) and P-Values with a 10% and 20% Increase.

Calculated P-Value					
Site	Fish Size / Age Data Site	2005 (0+)	2006 (1+)	2007 (2+)	2008 (3+)
R28.8	R25.7	0.360	0.339	0.455	0.483
R25.3					
R22.5	R20.9	0.403	0.361	0.484	0.525
R14.3					
R5.3	R3.5	0.558	0.551	0.935	0.951
R3.7					
Calculated P-Value + 10% Increase					
Site	Fish Size / Age Data Site	2005 (0+)	2006 (1+)	2007 (2+)	2008 (3+)
R28.8	R25.7	0.396	0.373	0.500	0.532
R25.3					
R22.5	R20.9	0.444	0.397	0.533	0.577
R14.3					
R5.3	R3.5	0.614	0.606	1.028	1.046
R3.7					
Calculated P-Value + 20% Increase					
Site	Fish Size / Age Data Site	2005 (0+)	2006 (1+)	2007 (2+)	2008 (3+)
R28.8	R25.7	0.432	0.406	0.546	0.580
R25.3					
R22.5	R20.9	0.484	0.433	0.581	0.630
R14.3					
R5.3	R3.5	0.670	0.662	1.122	1.141
R3.7					

Table AQ 5-44b. Calculated P-Values in the Peaking Reach from 2005-2008 (age 0+ to 3+) and P-Values with a 10% and 20% Increase.

Calculated P-Value					
Site	Fish Size / Age Data Site	2005 (0+)	2006 (1+)	2007 (2+)	2008 (3+)
MF23.1	MF14.1	0.555	0.446	0.600	0.507
MF14.3					
MF8.9					
MF0.1					
Calculated P-Value + 10% Increase					
Site	Fish Size / Age Data Site	2005 (0+)	2006 (1+)	2007 (2+)	2008 (3+)
MF23.1	MF14.1	0.611	0.490	0.660	0.558
MF14.3					
MF8.9					
MF0.1					
Calculated P-Value + 20% Increase					
Site	Fish Size / Age Data Site	2005 (0+)	2006 (1+)	2007 (2+)	2008 (3+)
MF23.1	MF14.1	0.666	0.535	0.720	0.609
MF14.3					
MF8.9					
MF0.1					

Table AQ 5-5a. Average Drift Density by Site (number/m³).

Length (mm)	Site									Average
	R25.7	R20.9	R1.2	MF26.2	MF19.1	MF14.1	MF4.8	NF31.3	NFMF2.3	
0-1	0.10	0.05	0.03	0.12	0.19	0.11	0.08	0.08	0.08	0.09
>1-3	0.88	0.33	0.36	0.65	0.72	0.50	0.20	0.77	0.81	0.58
>3-5	0.27	0.08	0.10	0.14	0.22	0.18	0.06	0.28	0.14	0.16
>5-7	0.04	0.01	0.02	0.02	0.03	0.03	0.00	0.04	0.02	0.02
>7	0.01	0.00	0.01	0.01	0.01	0.01	0.00	0.02	0.00	0.01
Total	1.31	0.47	0.52	0.93	1.16	0.82	0.35	1.19	1.06	0.87

Table AQ 5-5b. Average Macroinvertebrate Size (Percent of Total) at the Drift Sampling Locations.

Length (mm)	Site									Average
	R25.7	R20.9	R1.2	MF26.2	MF19.1	MF14.1	MF4.8	NF31.3	NFMF2.3	
0-1	7.0%	8.8%	5.0%	11.2%	15.8%	14.8%	25.1%	6.2%	8.6%	11.4%
>1-3	65.7%	70.0%	71.1%	70.0%	60.6%	61.2%	54.4%	65.6%	77.3%	66.2%
>3-5	23.5%	19.5%	19.4%	15.9%	20.1%	20.1%	18.4%	23.1%	12.0%	19.1%
>5-7	3.0%	1.3%	3.2%	2.1%	2.6%	2.7%	1.3%	3.6%	1.6%	2.4%
>7	0.8%	0.3%	1.3%	0.8%	0.9%	1.1%	0.7%	1.5%	0.5%	0.9%

Table AQ 5-6a. Rubicon River Water Temperature Missing and Filled Data Descriptions.

Missing Data	Site Used to Fill	Year Used to Fill	Method
R28.8			
Jan 1 - Jul 20, 2005	R28.8	2006	Fill In
Oct 29 - Dec 31, 2008	R28.8	2007	Fill In
R25.3			
Jan 1 - Sept 12, 2005	R25.3	2006	Fill In
Oct 29 - Dec 31, 2008	R25.3	2007	Fill In
R22.5			
Jan 1 - Jul 1, 2005	R22.5	2006	Fill In
Dec 5 - Dec 31, 2008	R22.5	2007	Fill In
R14.3			
Jan 1 - Apr 30, 2005	R5.3	2007/2005	Temperature Offset
May 1 - Sept 13, 2005	R14.3	2006	Calibrated Temperature Model
Oct 31 - Dec 31, 2005	R14.3	2006	Fill In
Jan 1 - Apr 30, 2006	R5.3	2007/2005	Temperature Offset
May 1 - Jul 23, 2006	R14.3	2006	Calibrated Temperature Model
Oct 29 - Dec 31, 2008	R14.3	2007	Fill In
R5.3			
May 1 - Sept 29, 2005	R5.3	2006	Calibrated Temperature Model
Sept 29 - Dec 31, 2005	R5.3	2006	Fill In
Jan 1 - Apr 30, 2006	R5.3	2005	Fill In
May 1 - Jul 10, 2006	R5.3	2006	Calibrated Temperature Model
Oct 29 - Dec 31, 2008	R5.3	2007	Fill In
R3.7 and 0.7			
Jan 1 - Apr 30, 2005	R5.3	2005	Temperature Offset
May 1 - Jul 1, 2005	R3.7 and 0.7	2006	Calibrated Temperature Model
Oct 27 - Dec 31, 2005	R3.7 and 0.7	2006	Fill In
Jan 1 - Apr 30, 2006	R5.3	2005	Temperature Offset
May 1 - Jul 14, 2006	R3.7 and 0.7	2006	Calibrated Temperature Model
Oct 28 - Dec 31, 2008	R3.7 and 0.7	2007	Fill In

Table AQ 5-6b. Peaking Reach Water Temperature Missing and Filled Data Descriptions.

Missing Data	Site Used to Fill	Year Used to Fill	Method
R23.1			
Oct 21 - Dec 31, 2005	MF23.1	2006	Fill In
Jan 1 - Jul 12, 2006	MF23.1	2005	Fill In
Nov 21 - Dec 31, 2008	MF23.1	2007	Fill In
R14.3			
Jan 1 - Aug 11, 2005	MF8.9	2007/2005	Temperature Offset
Feb 7 - Feb 26, 2006	MF8.9	2007/2006	Temperature Offset
Mar 9 - Mar 24, 2006	MF8.9	2007	Temperature Offset
May 23 - Jul 25, 2006	MF8.9	2007	Temperature Offset
Nov 21 - Dec 31, 2008	MF14.3	2007	Fill In
R8.9			
Nov 7 - Dec 31, 2008	MF8.9	2007	Fill In
R0.1			
Nov 7 - Dec 31, 2008	MF0.1	2007	Fill In

FIGURES

Figure AQ 5-1. Bioenergetics Study Objectives, Related Study Elements, and Reports.

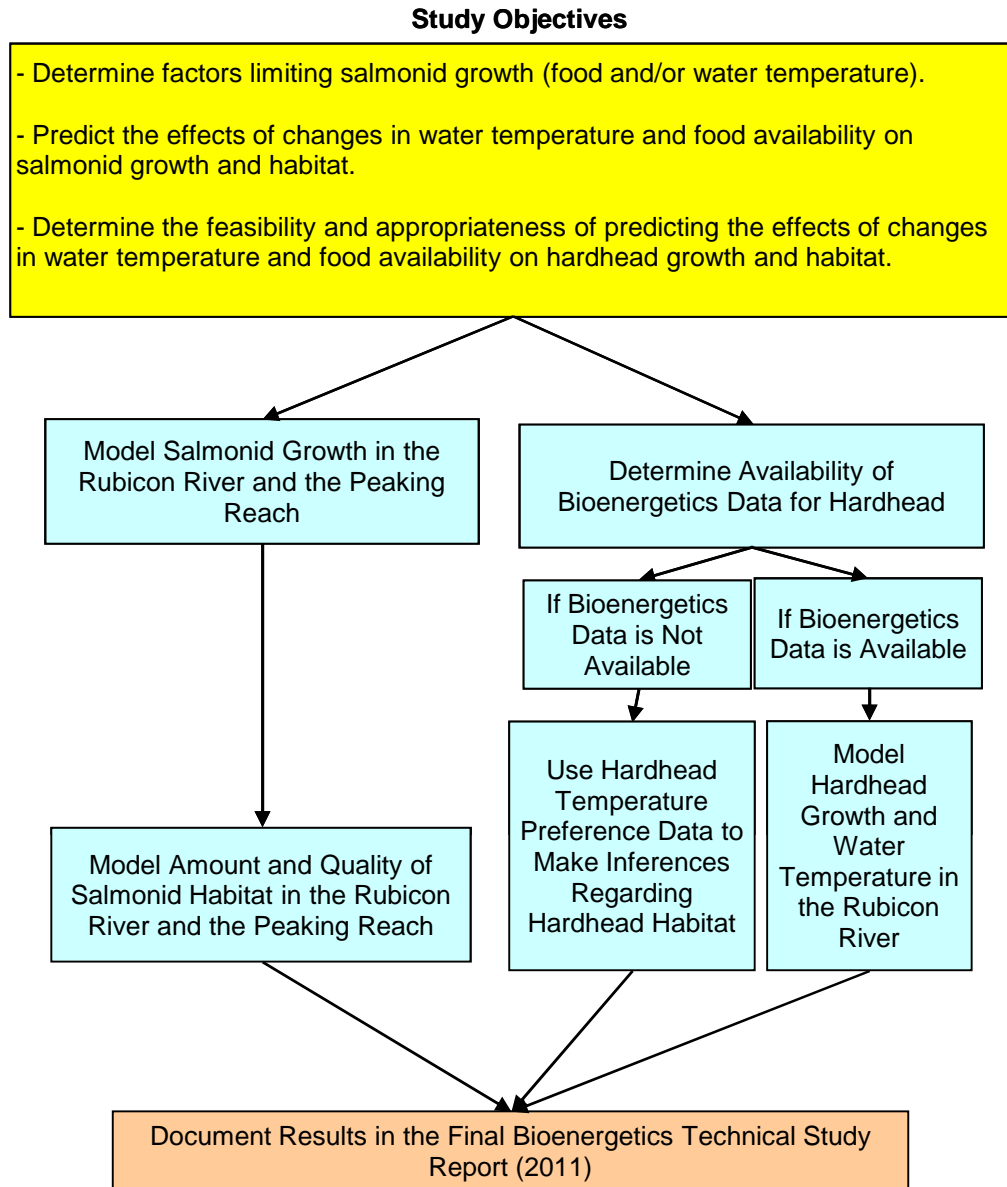


Figure AQ 5-2. Macroinvertebrate Drift Sampling (top) and Drift Sampling Nets (bottom).

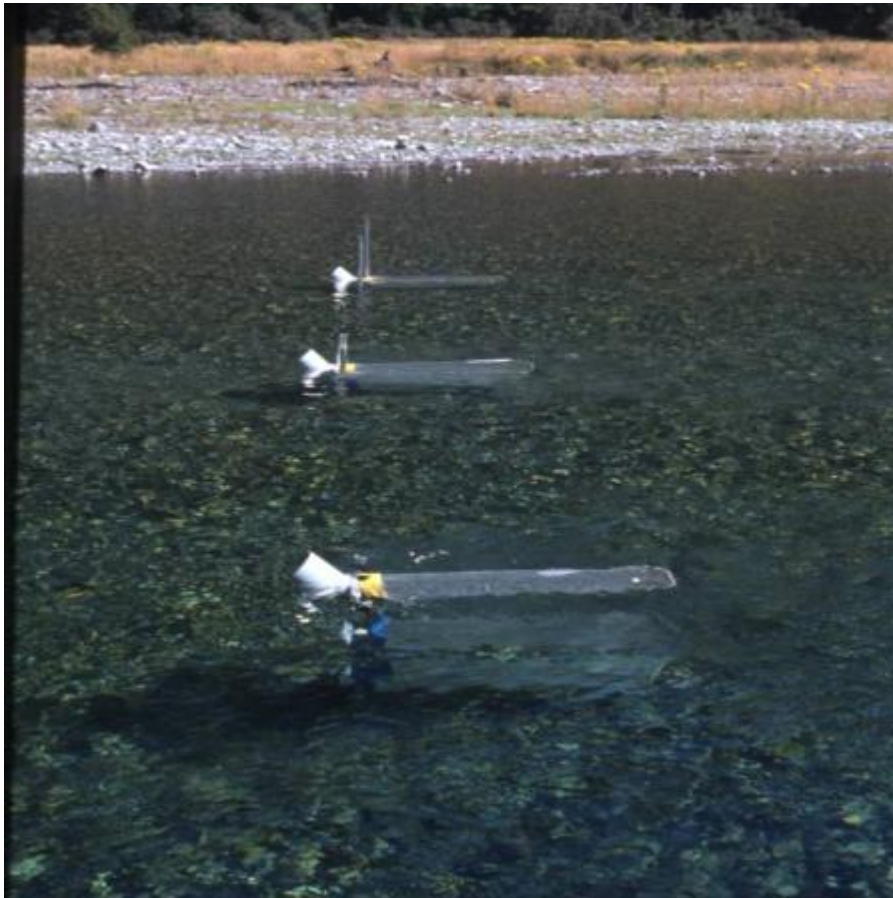
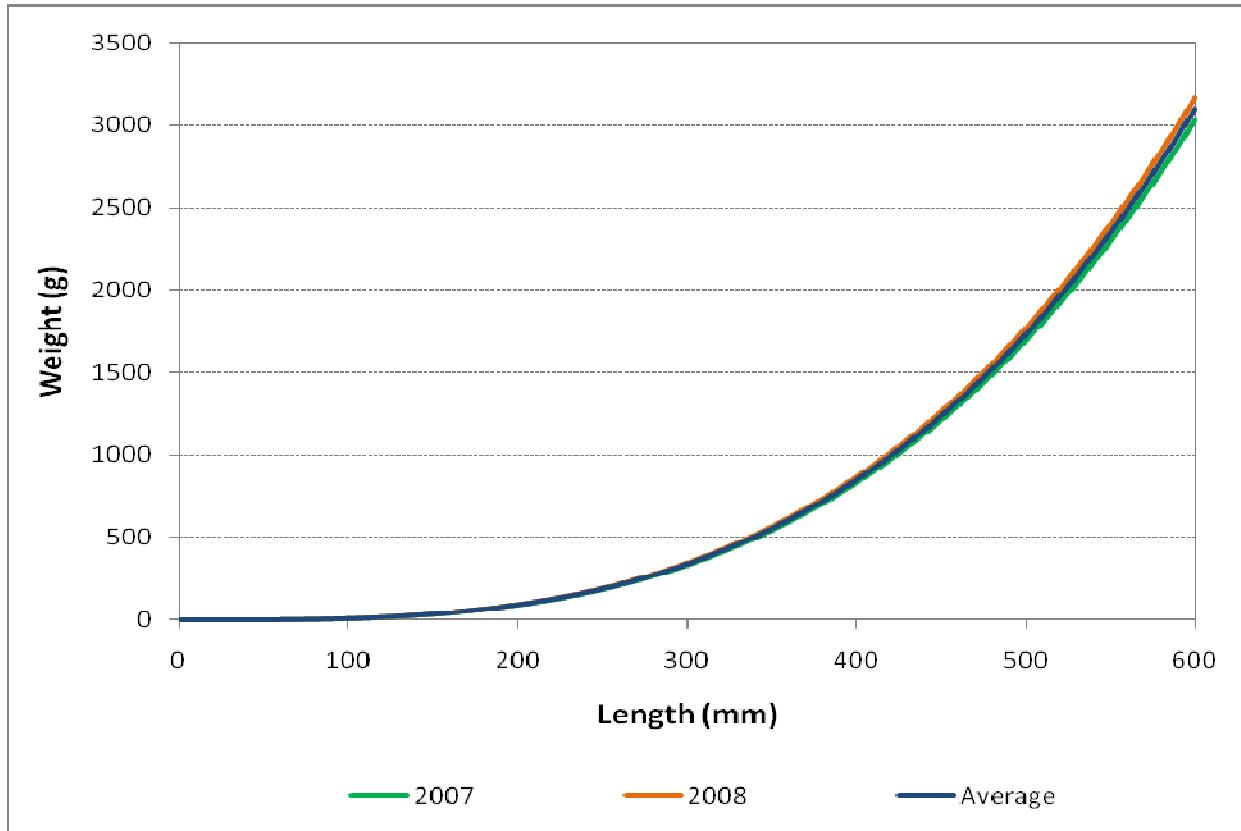


Figure AQ 5-3. Rainbow Trout Length-Weight Regression Equations.



Sample Year	W(g) = aL(mm) ^b		
	a	b	Number Sampled
2007	4.260E-06	3.187	2299
2008	4.243E-06	3.194	1888
Average	4.251E-06	3.190	--

Figure AQ 5-4a. Macroinvertebrate Drift Density (number/m³) by Sampling Location and Date.

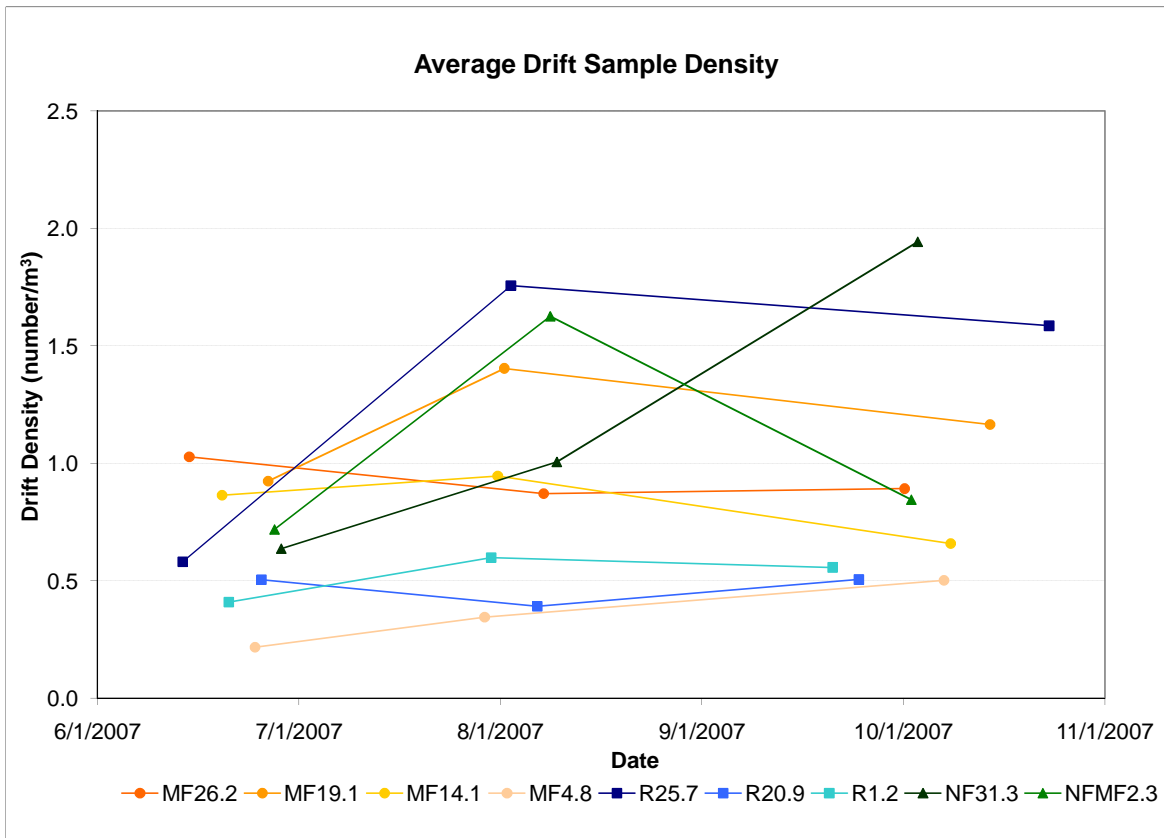


Figure AQ 5-4b. Average Macroinvertebrate Drift Density (number/m³) by Location.

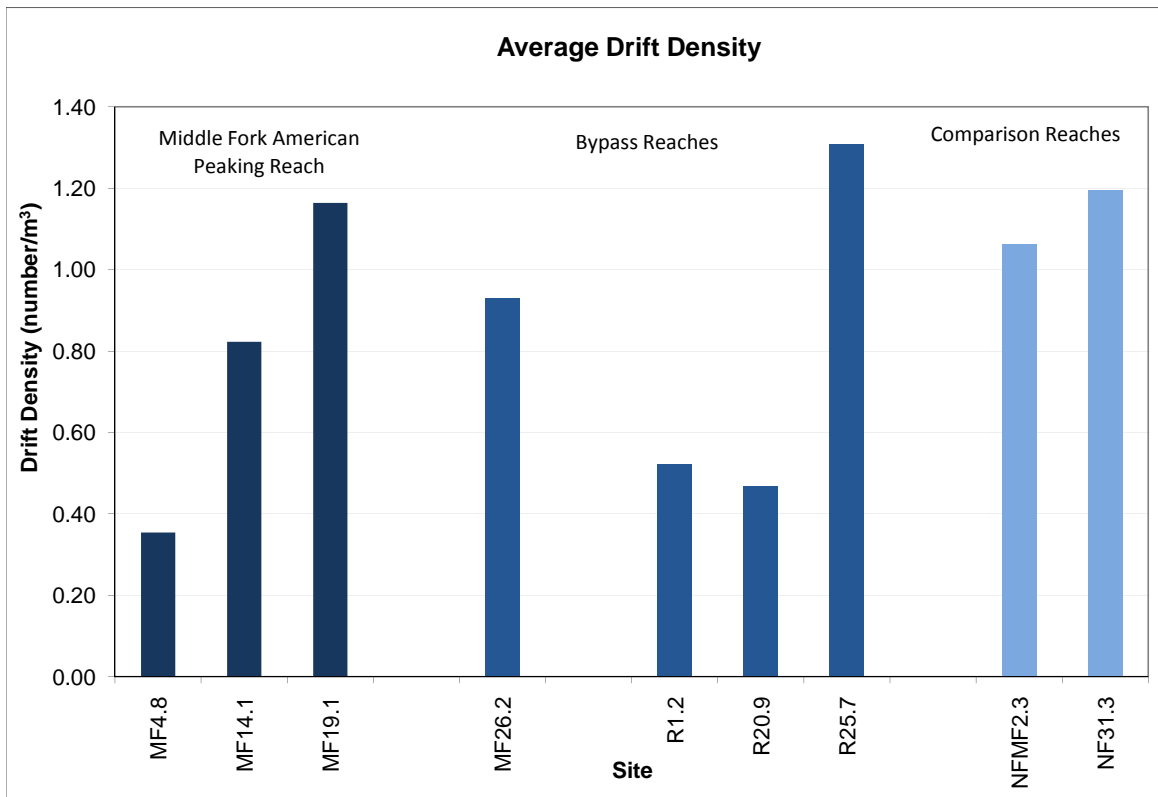


Figure AQ 5-5. Macroinvertebrate Drift Size (Percent of the Total) by Location.

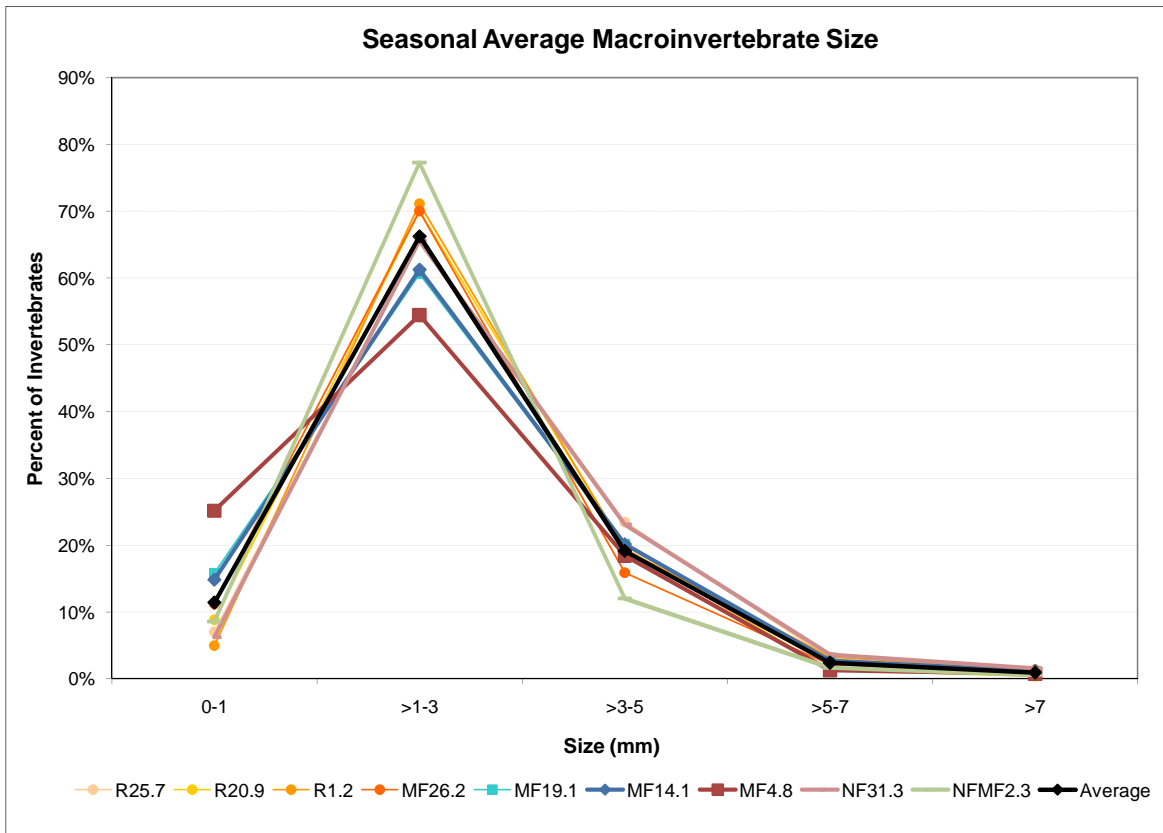


Figure AQ 5-6a. Rubicon River Average Daily Water Temperature at R28.8 (top) and R25.3 (bottom) (Solid line = Measured Data, Dotted line = Fill In Data).

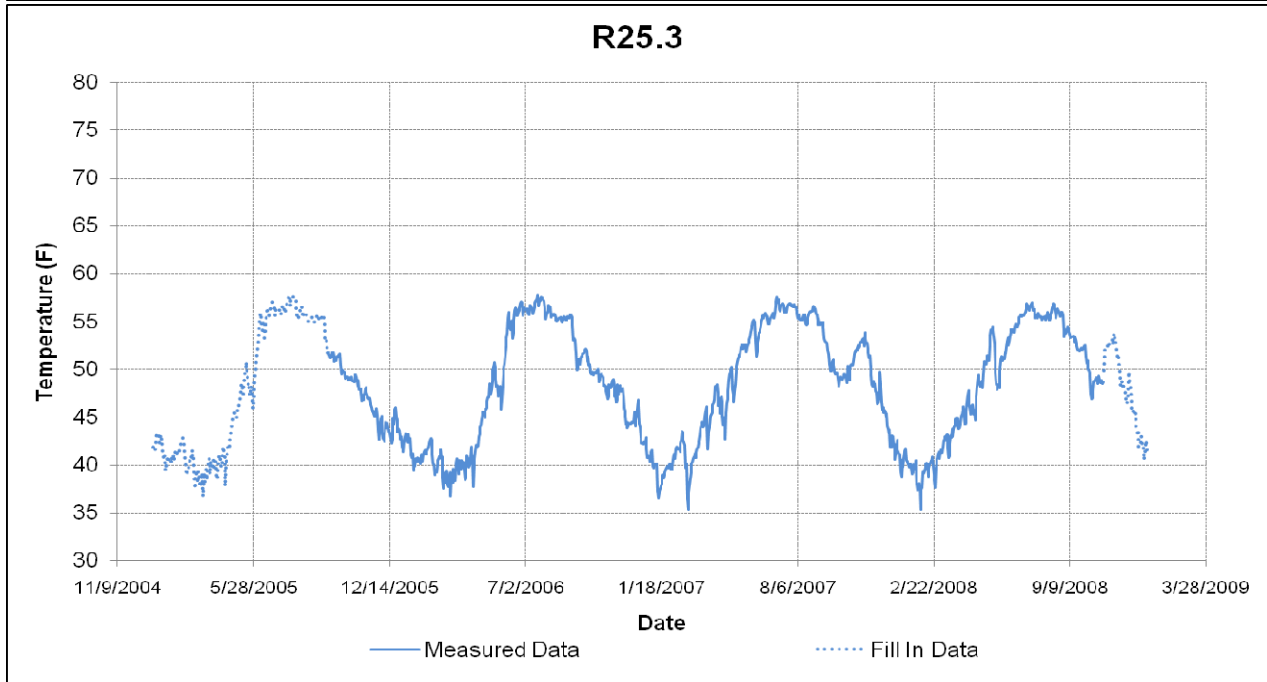
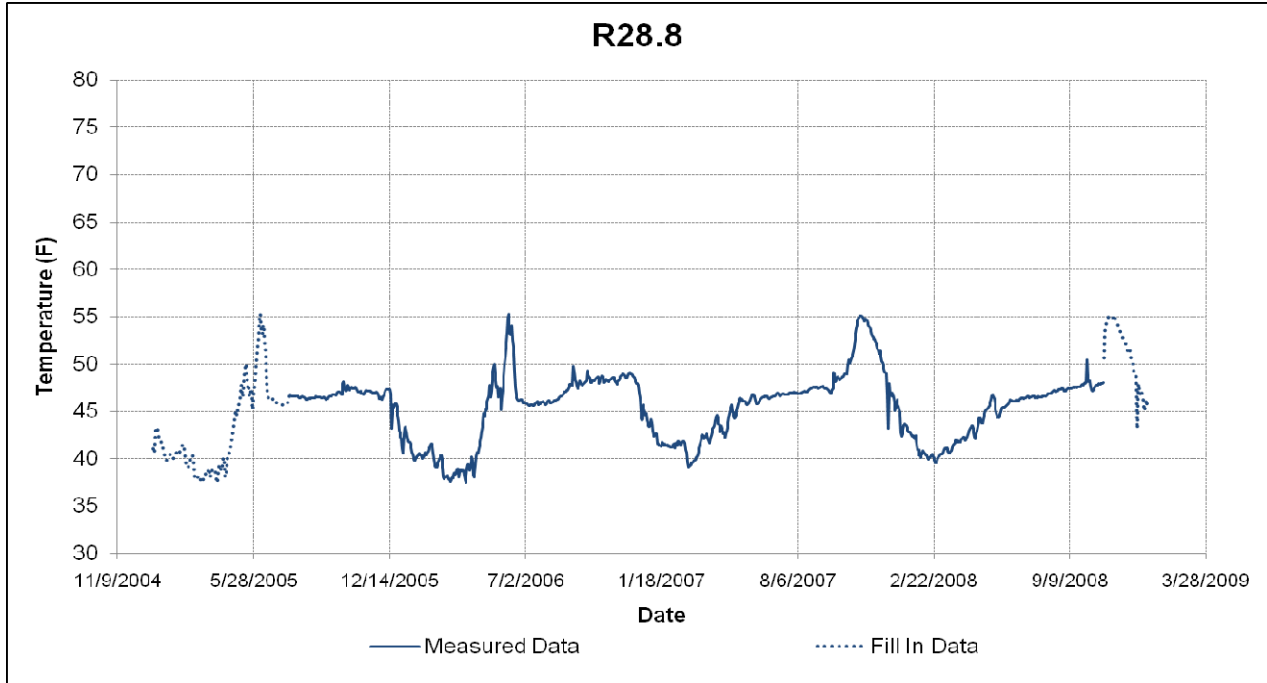


Figure AQ 5-6b. Rubicon River Average Daily Water Temperature at R22.5 (top) and R14.3 (bottom) (Solid line = Measured Data, Dotted line = Fill In Data).

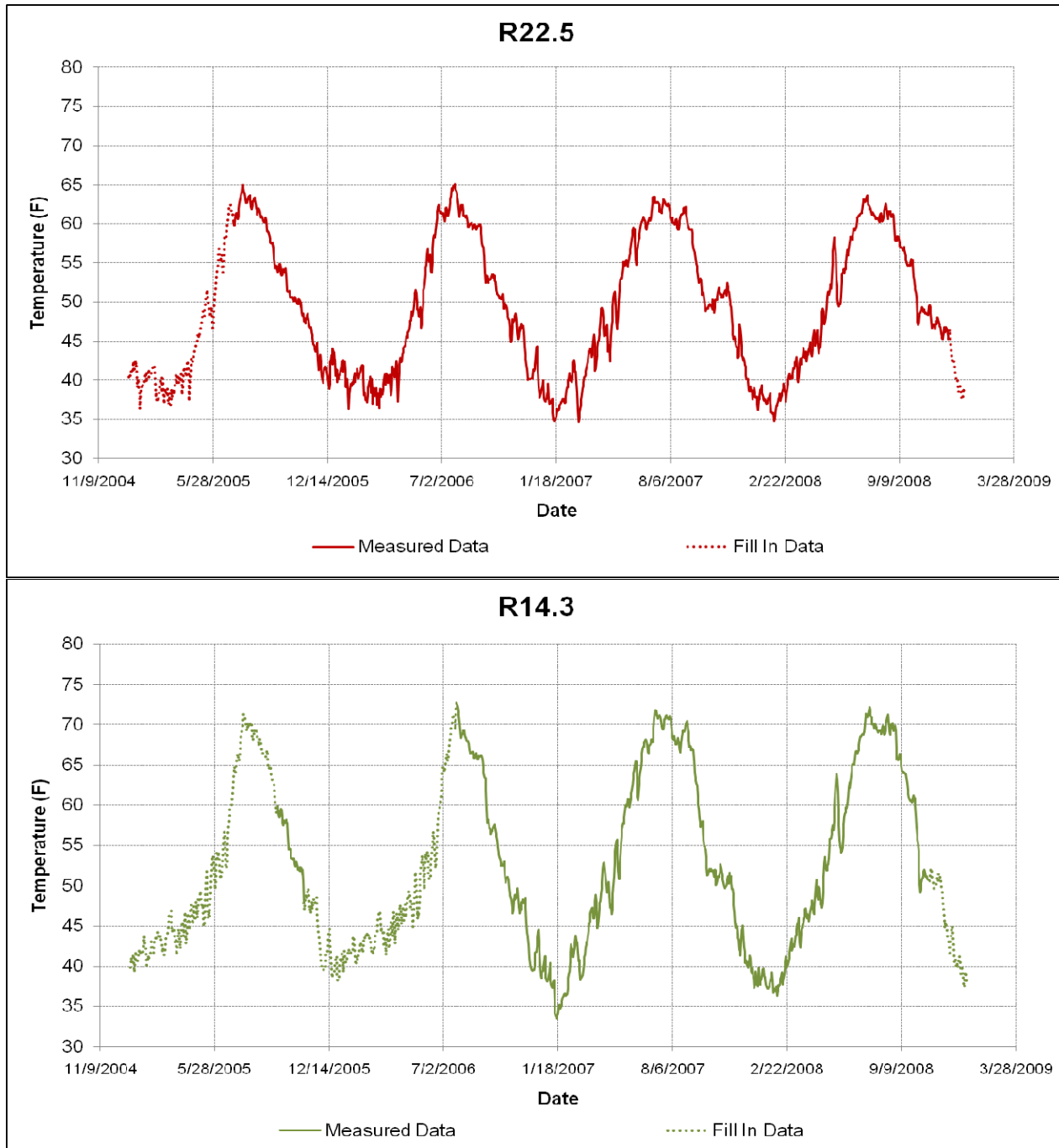


Figure AQ 5-6c. Rubicon River Average Daily Water Temperature at R5.3 (top) and R3.7 (bottom) (Solid line = Measured Data, Dotted line = Fill In Data).

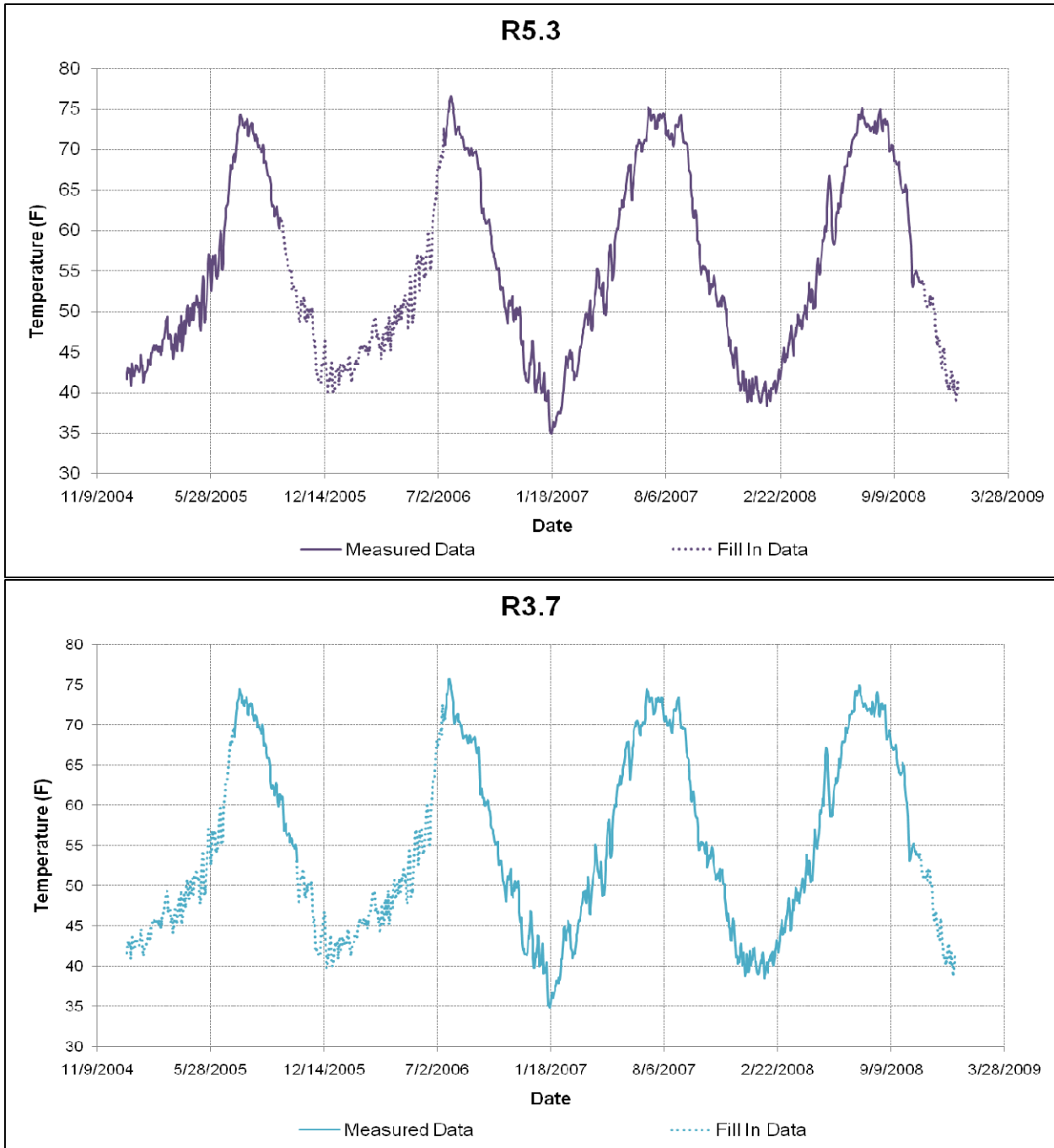


Figure AQ 5-6d. Rubicon River Average Daily Water Temperature at R0.7 (Solid line = Measured Data, Dotted line = Fill In Data).

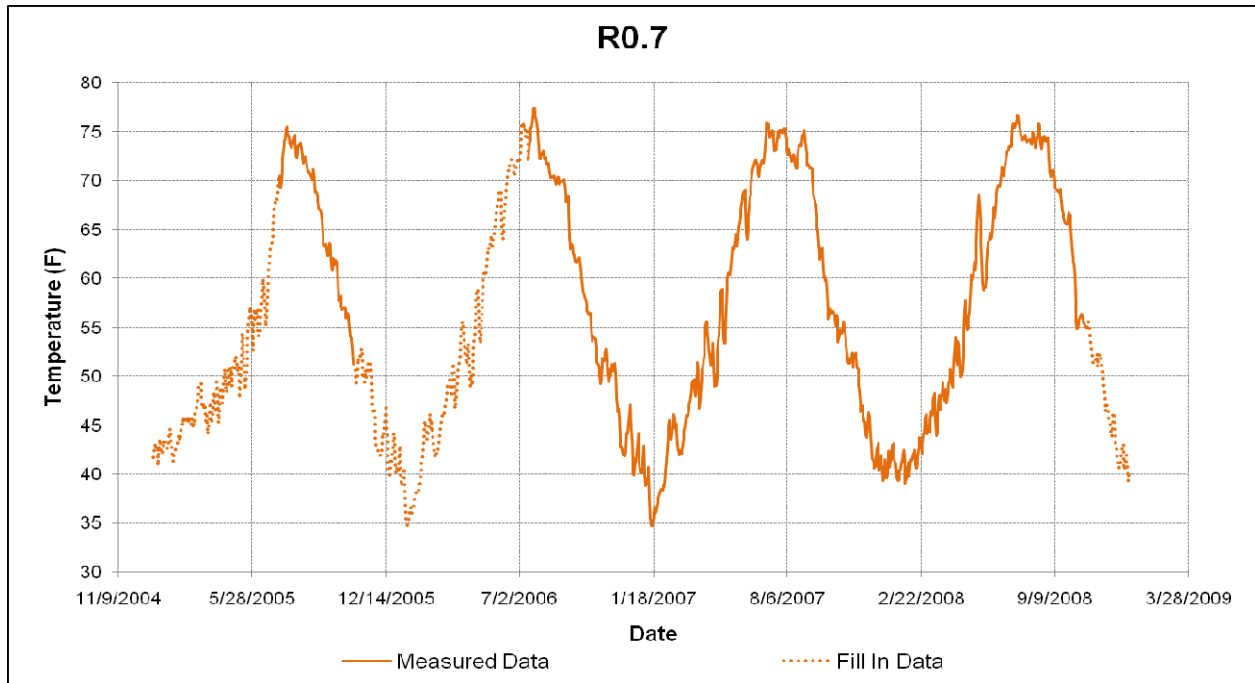


Figure AQ 5-7a. Peaking Reach Average Daily Water Temperature at MF23.1 (top) and MF14.3 (bottom) (Solid line = Measured Data, Dotted line = Fill In Data).

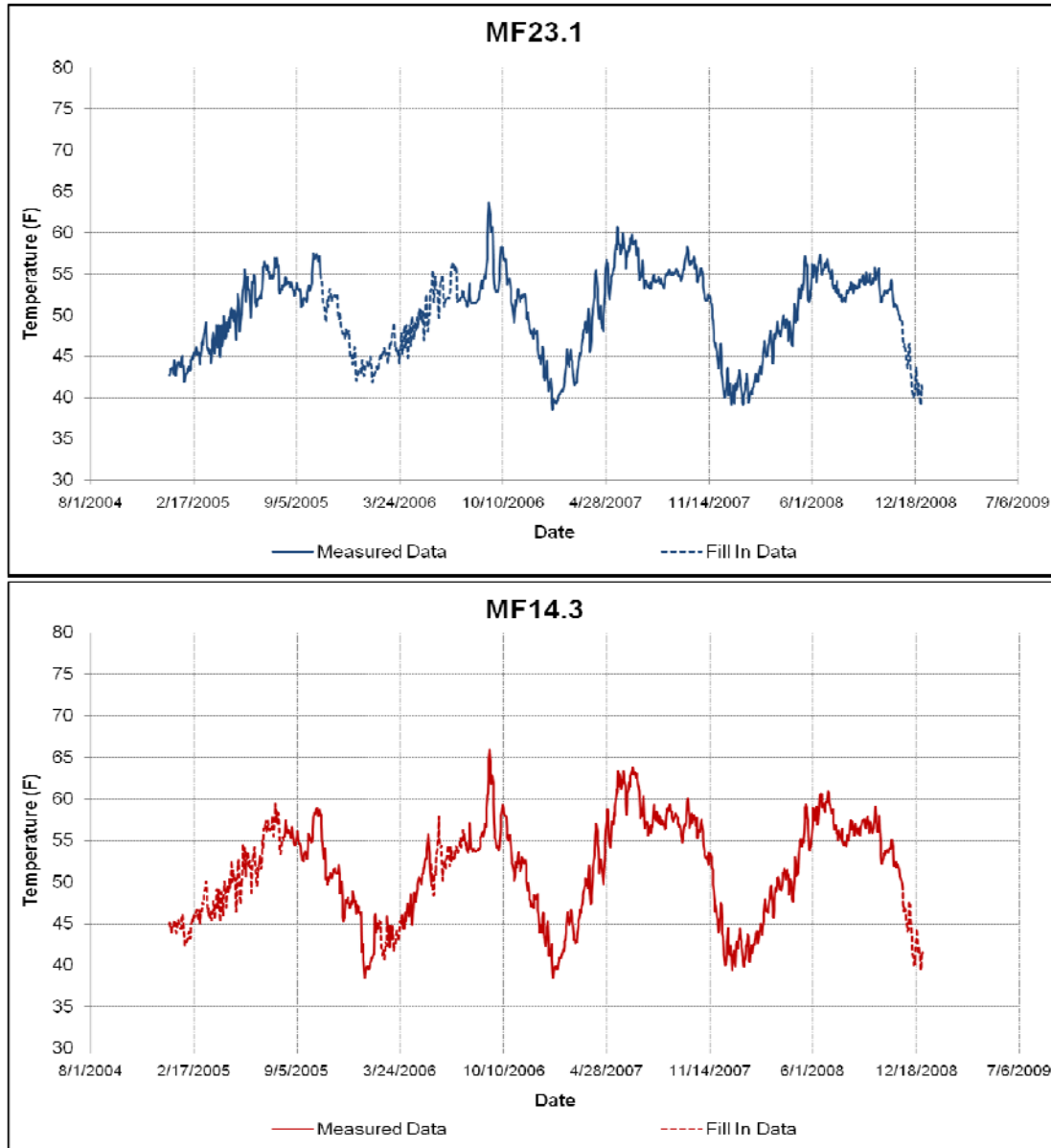


Figure AQ 5-7b. Peaking Reach Average Daily Water Temperature at MF8.9 (top) and MF0.1 (bottom) (Solid line = Measured Data, Dotted line = Fill In Data).

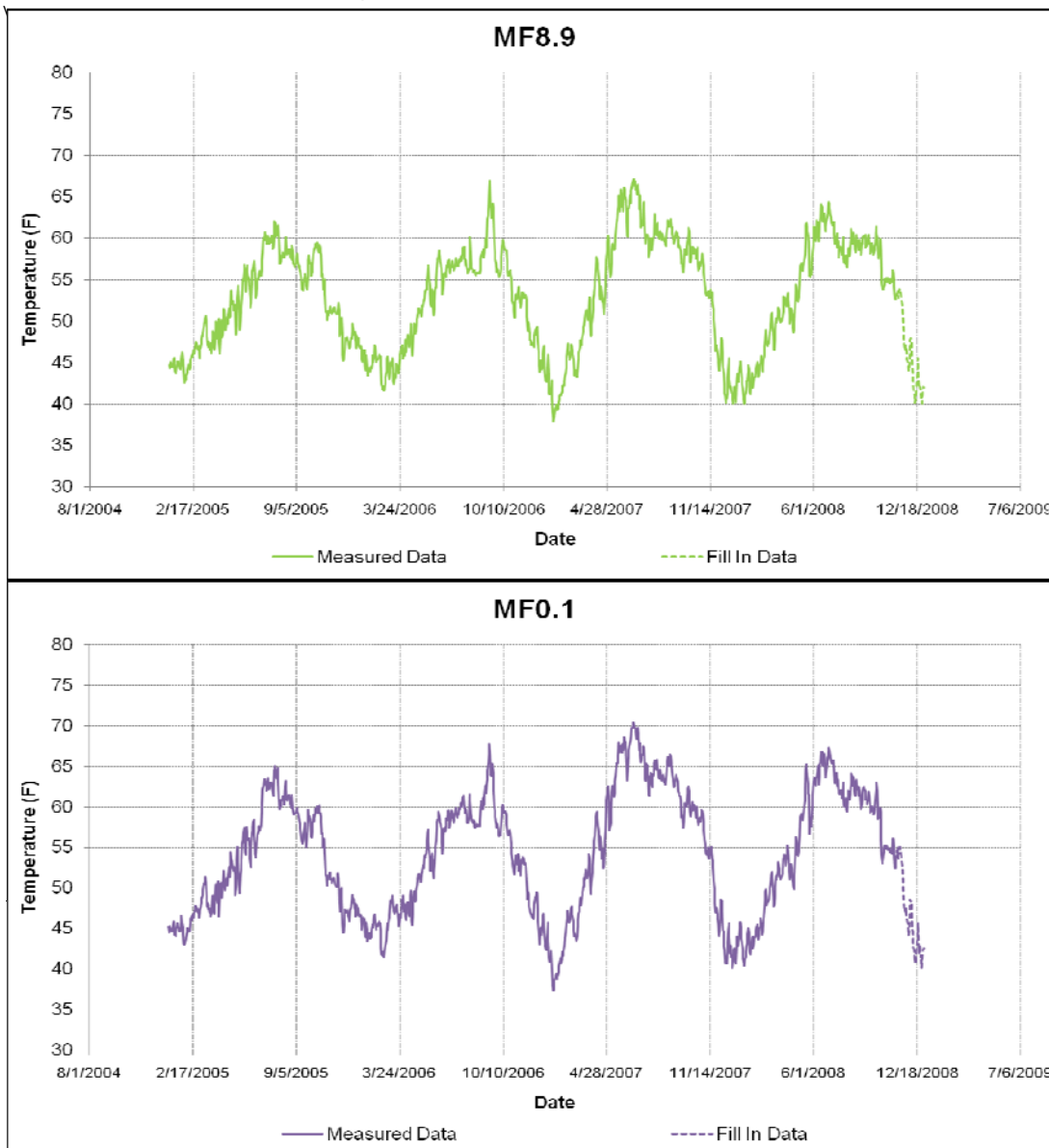


Figure AQ 5-8. Rubicon River Average Daily Water Temperature (2005-2008).

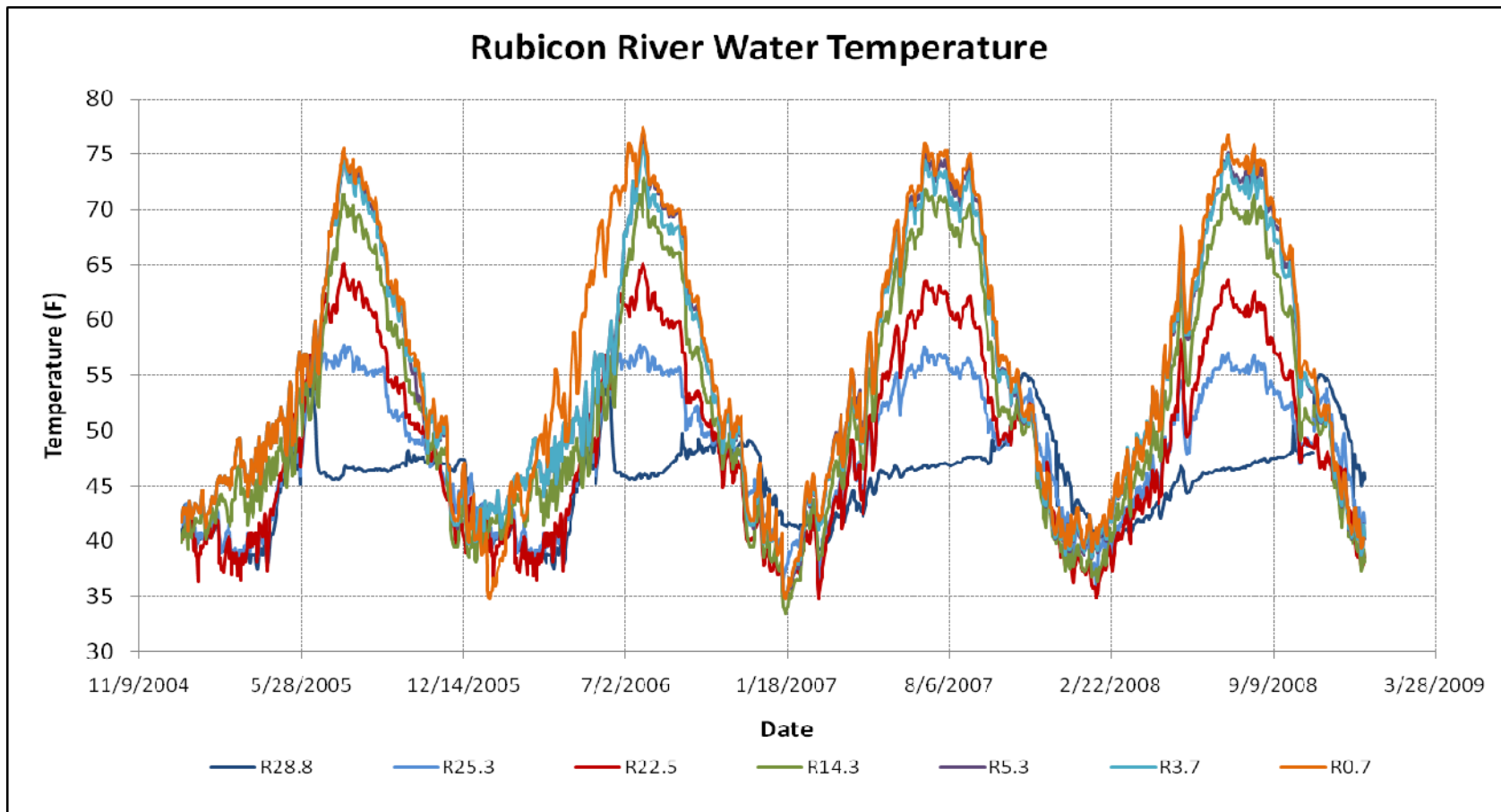


Figure AQ 5-9. Peaking Reach Average Daily Water Temperature (2005-2008).

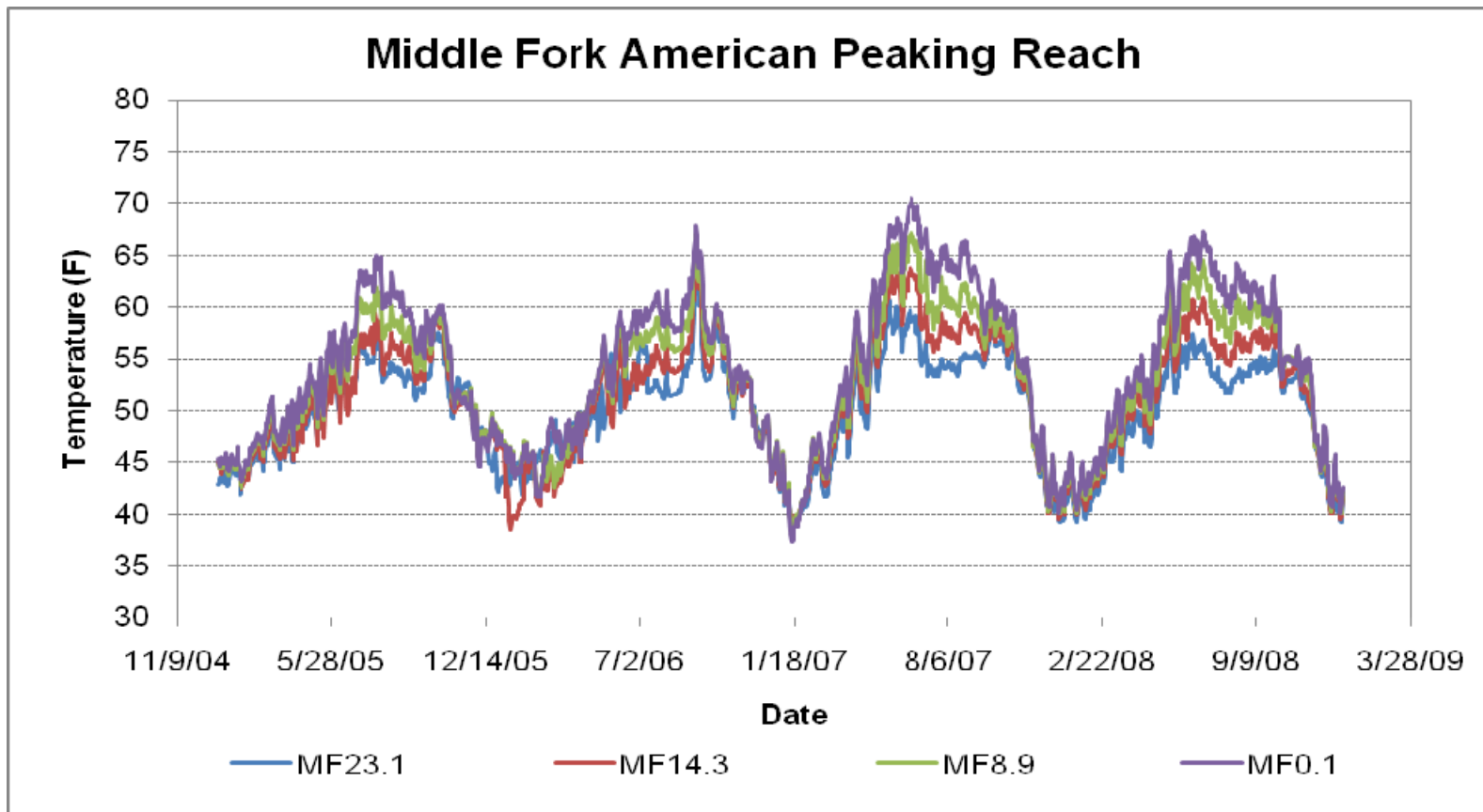


Figure AQ 5-10a. Rubicon River Maximum and Average Daily Water Temperature Scenarios at R28.8 (See Text for Description of Scenarios).

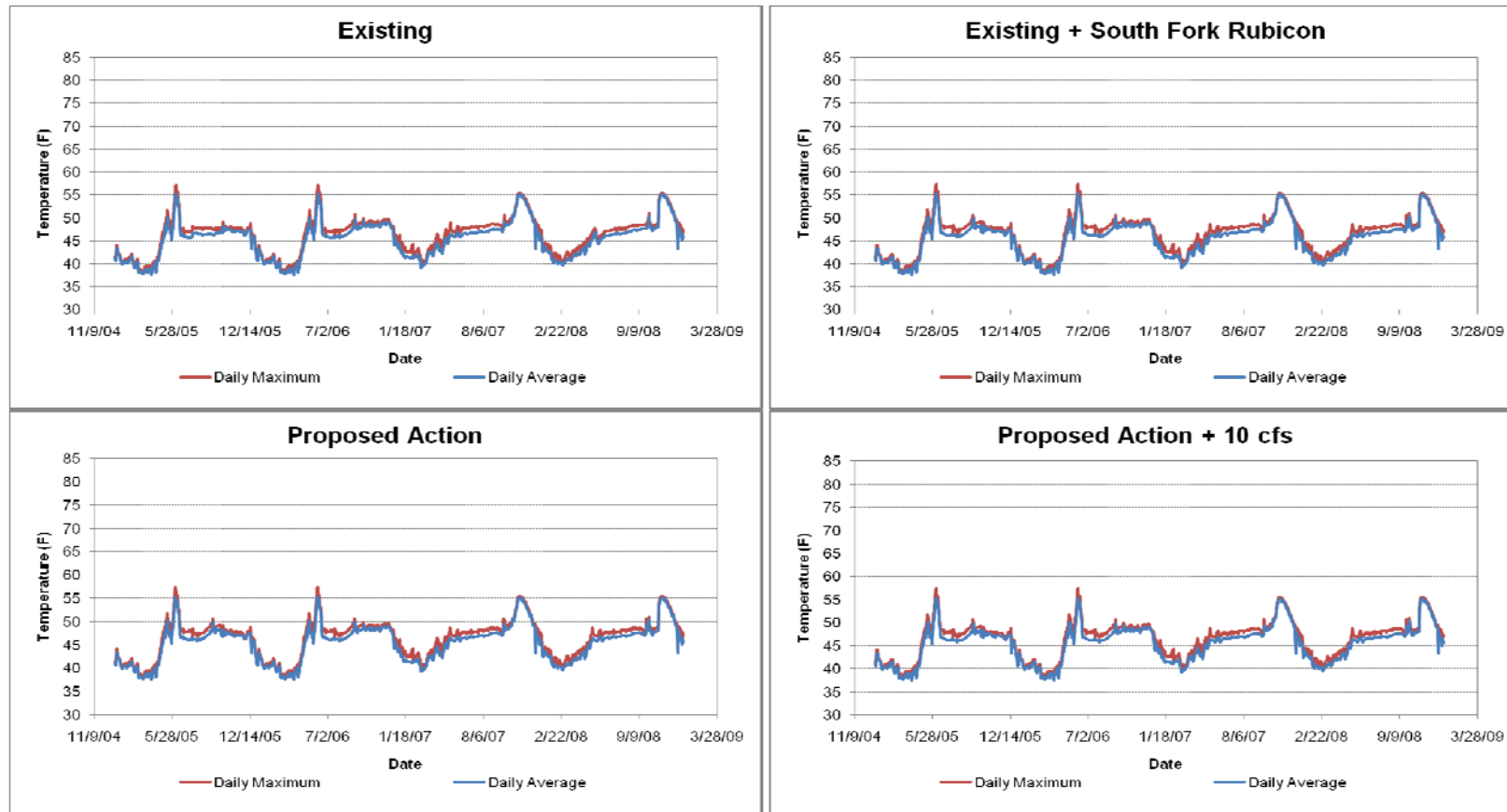


Figure AQ 5-10b. Rubicon River Maximum and Average Daily Water Temperature Scenarios at R25.3 (See Text for Description of Scenarios).

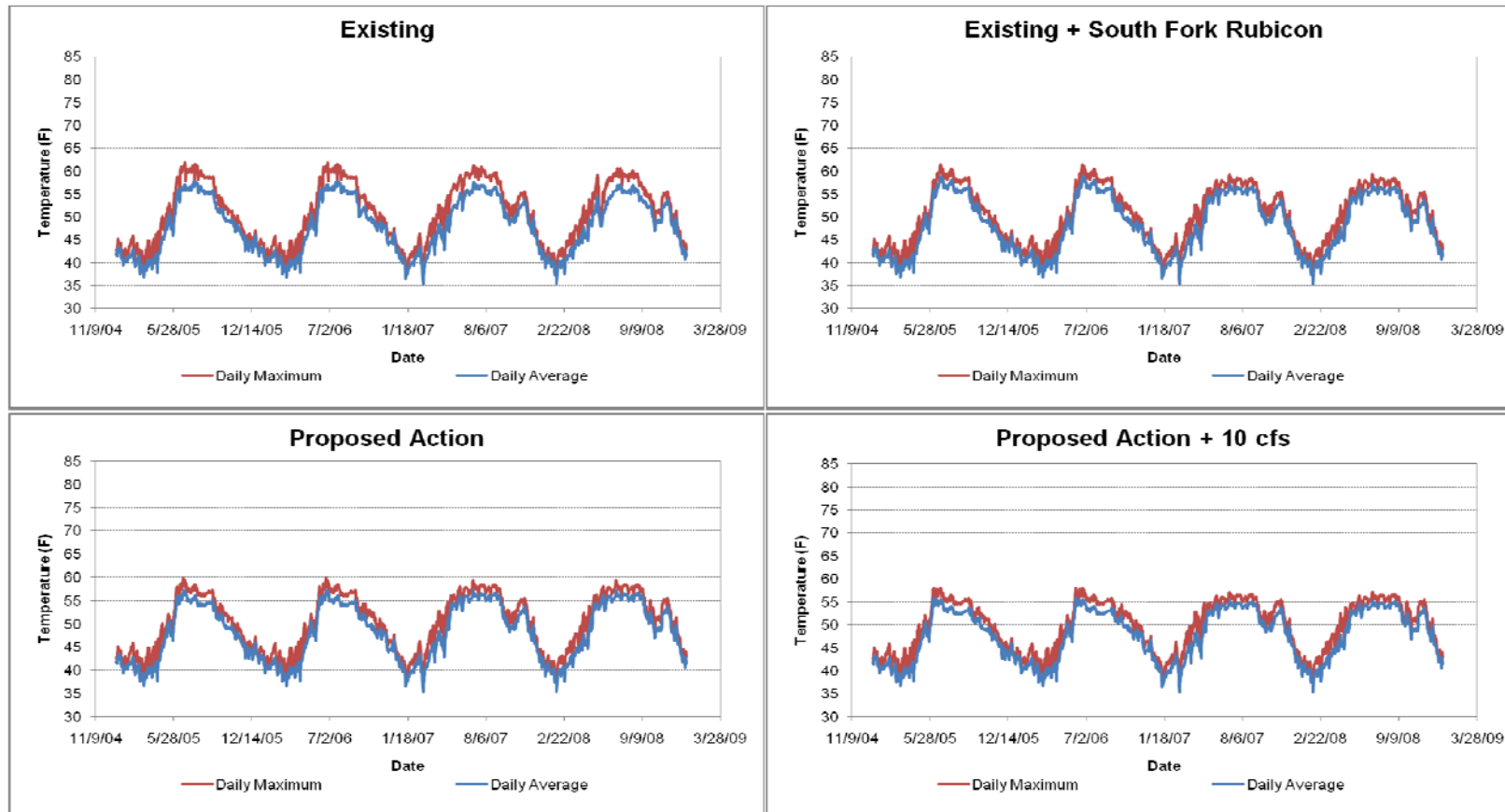


Figure AQ 5-10c. Rubicon River Maximum and Average Daily Water Temperature Scenarios at R22.5 (See Text for Description of Scenarios).

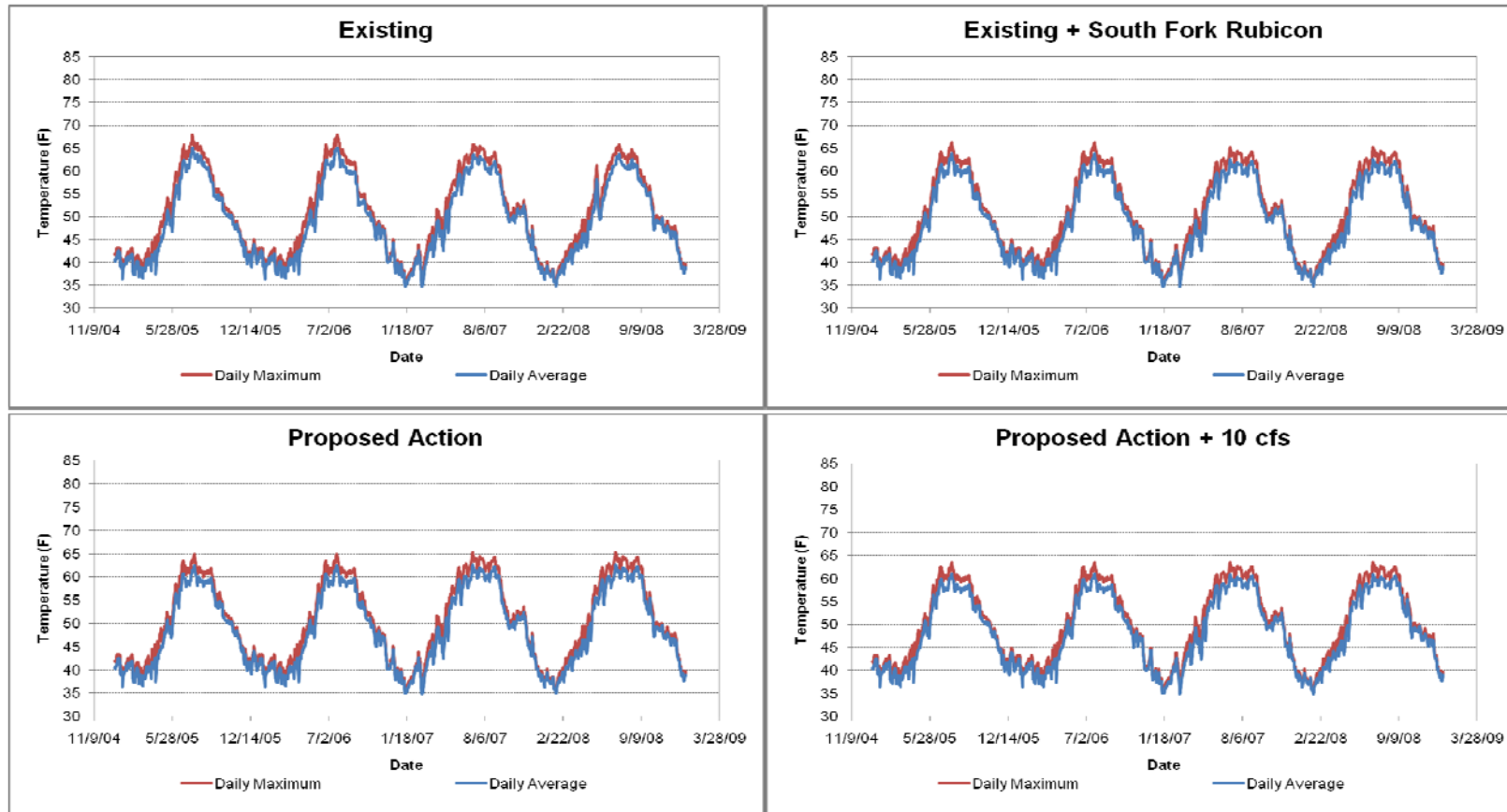


Figure AQ 5-10d. Rubicon River Maximum and Average Daily Water Temperature Scenarios at R14.3 (See Text for Description of Scenarios).

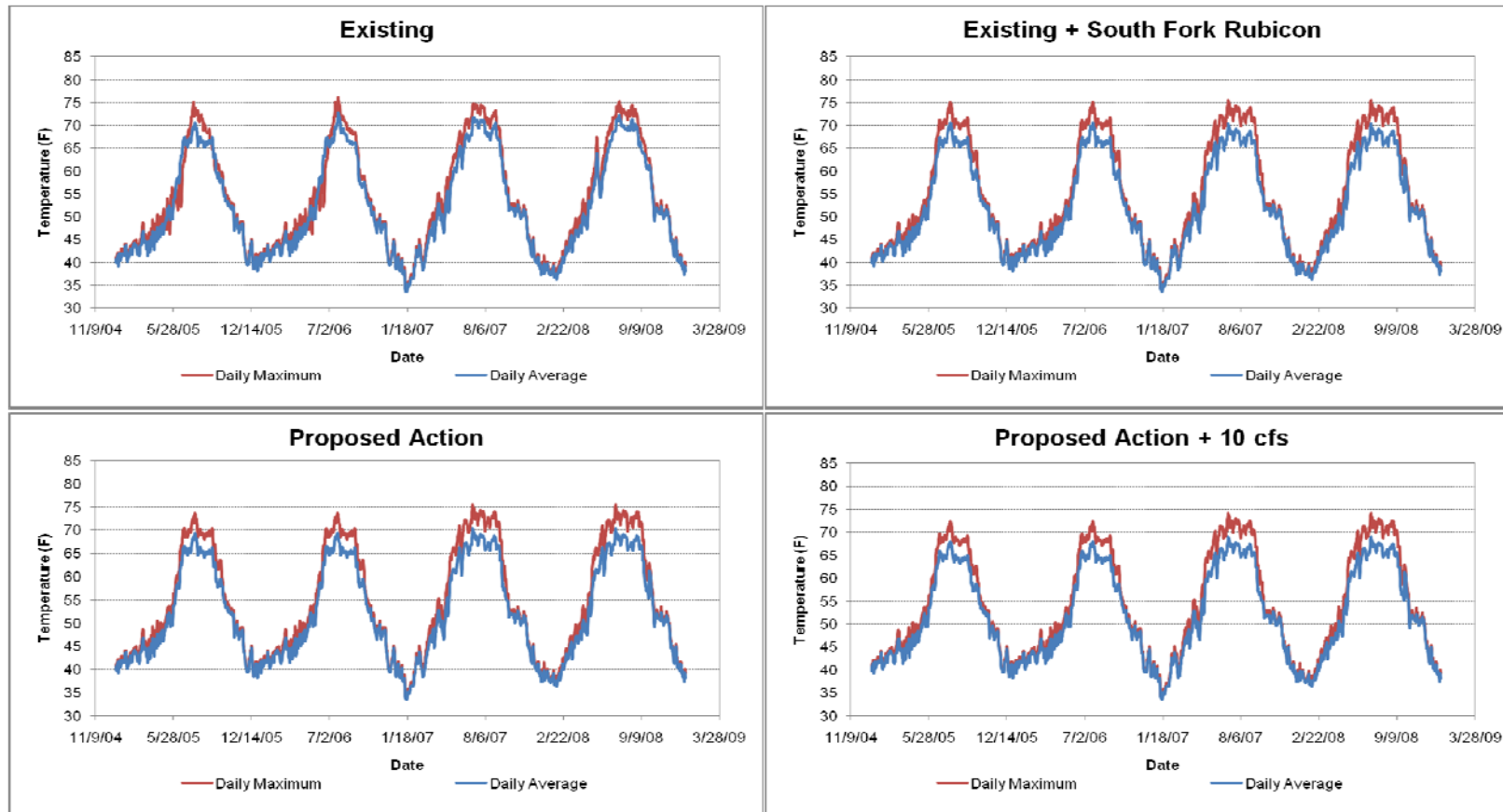


Figure AQ 5-10e. Rubicon River Maximum and Average Daily Water Temperature Scenarios at R5.3 (See Text for Description of Scenarios).

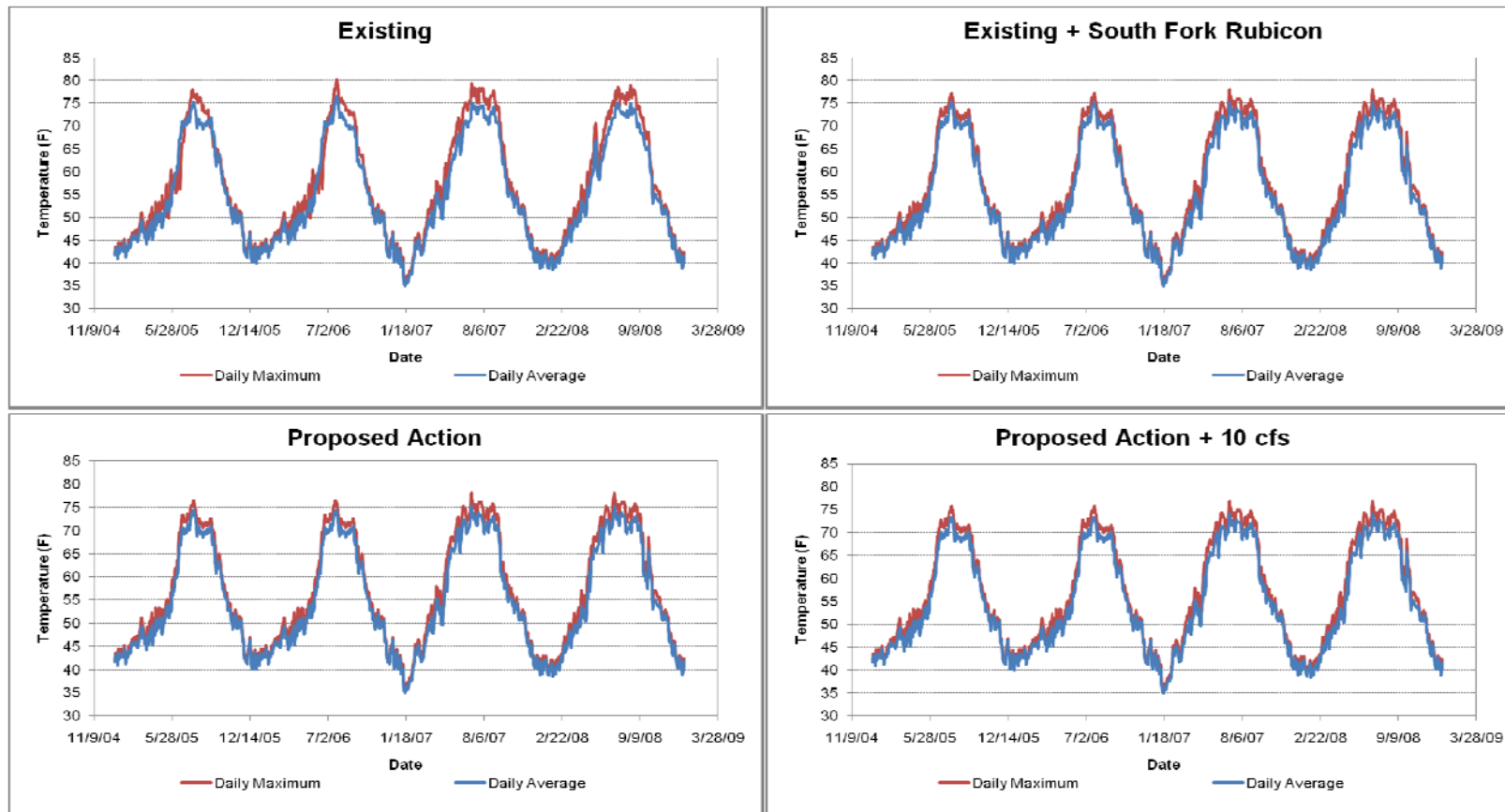


Figure AQ 5-10f. Rubicon River Maximum and Average Daily Water Temperature Scenarios at R3.7 (See Text for Description of Scenarios).

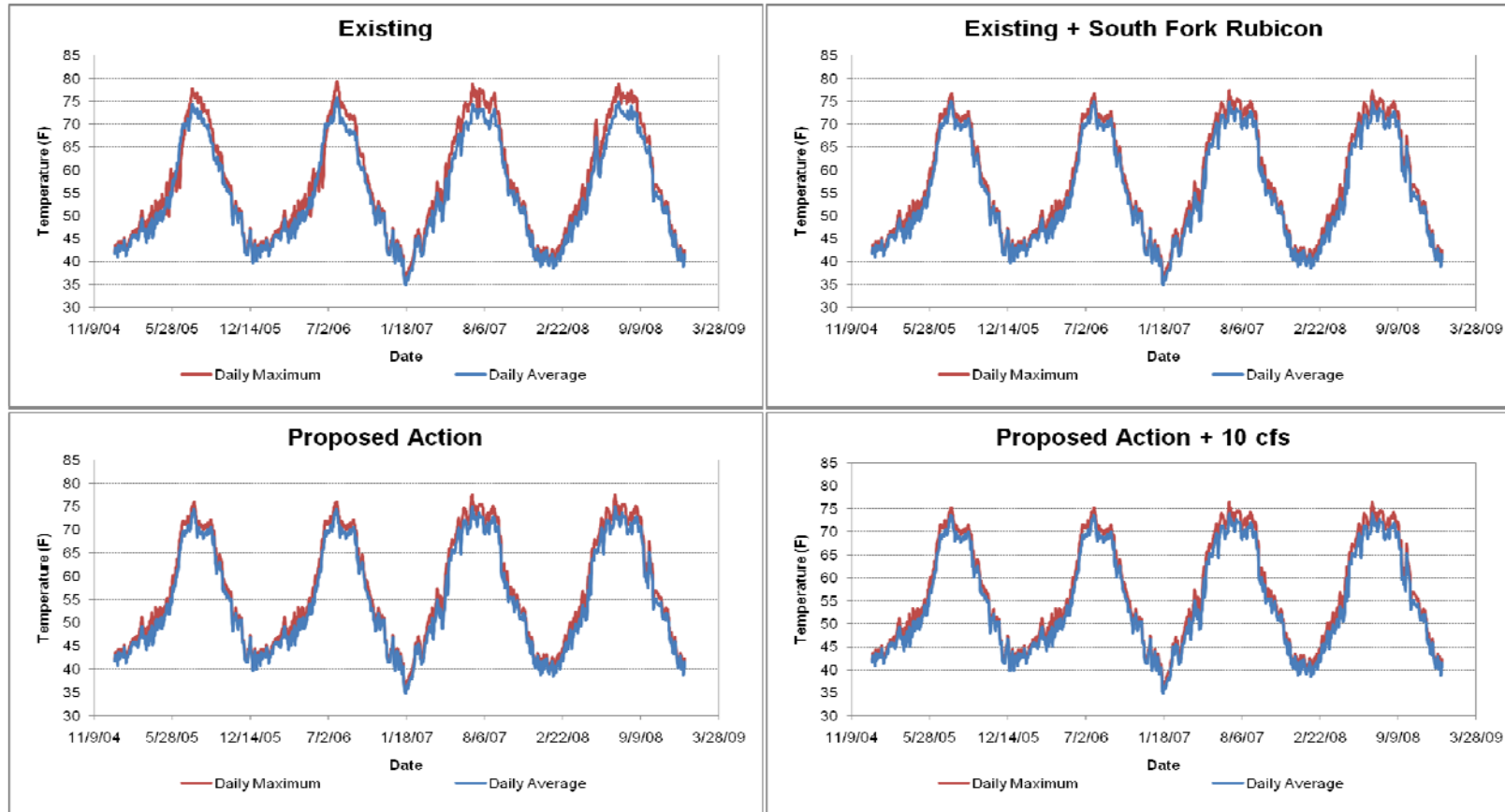


Figure AQ 5-10g. Rubicon River Maximum and Average Daily Water Temperature Scenarios at R0.7 (See Text for Description of Scenarios).

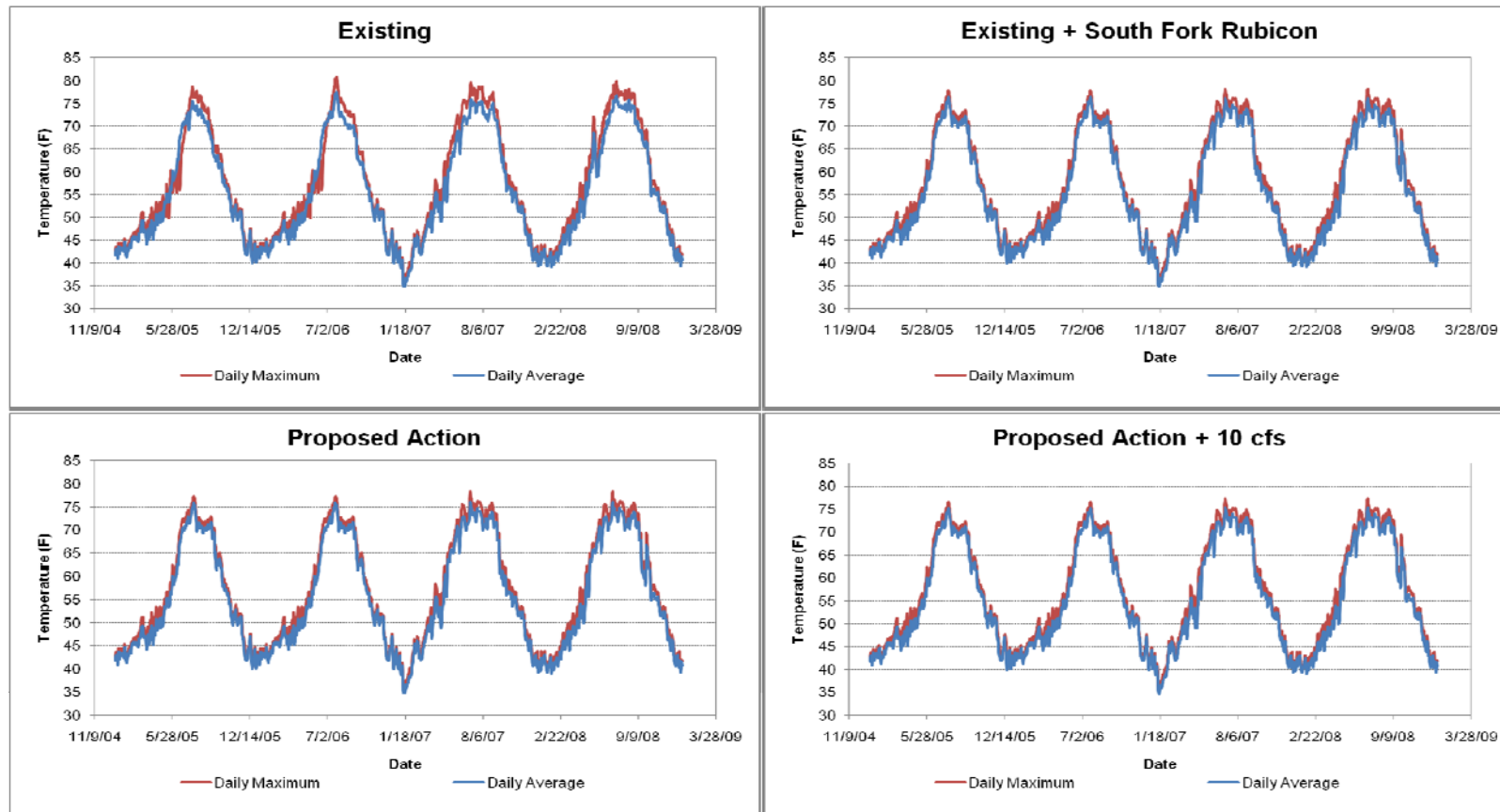


Figure AQ 5-11. Peaking Reach Maximum and Average Daily Water Temperature at MF23.1, MF14.1, MF8.9, and MF0.1.

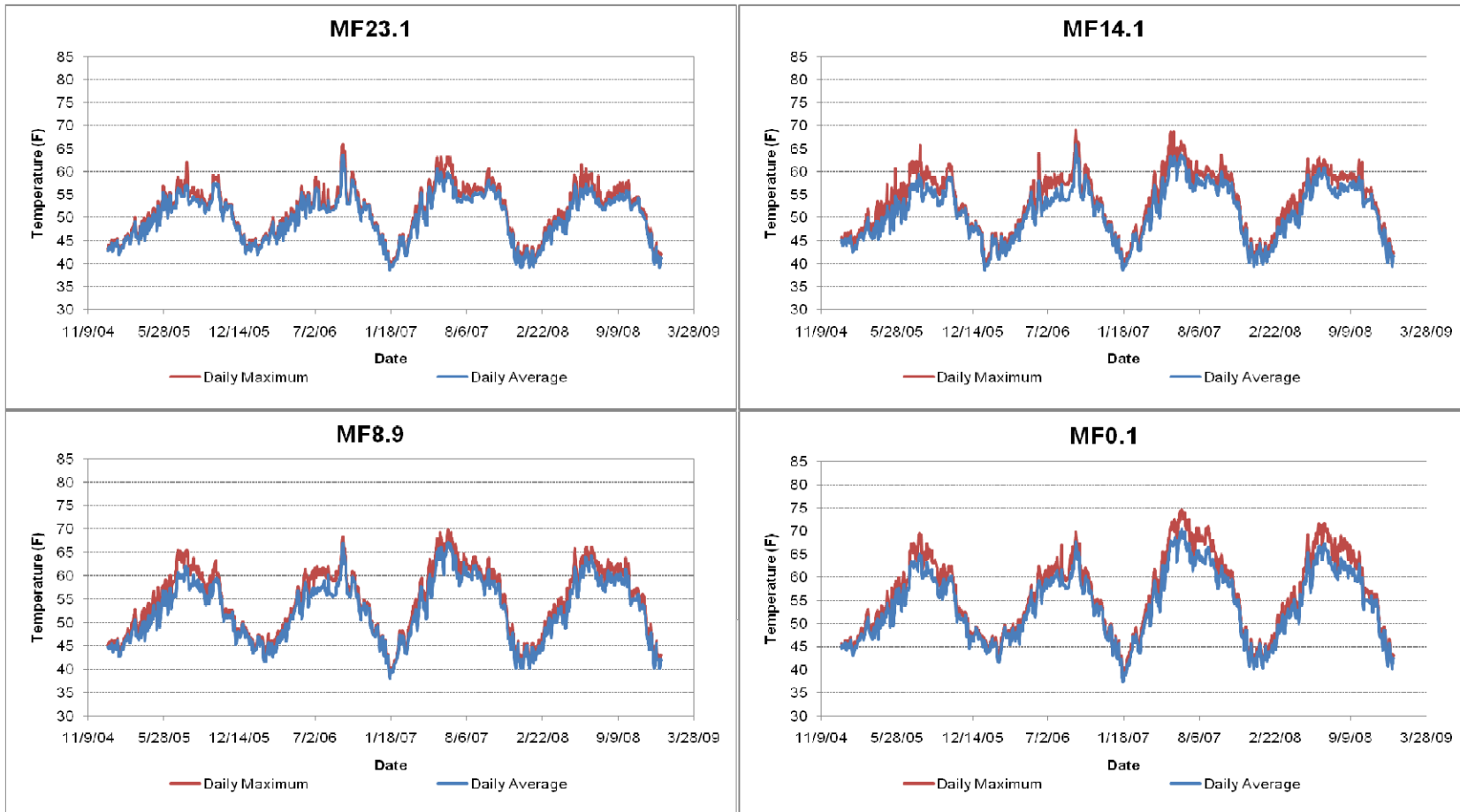


Figure AQ 5-12a. Rubicon River Average Daily Water Temperature Scenarios at R28.8 (top) and R25.3 (bottom) (See Text for Description of Scenarios).

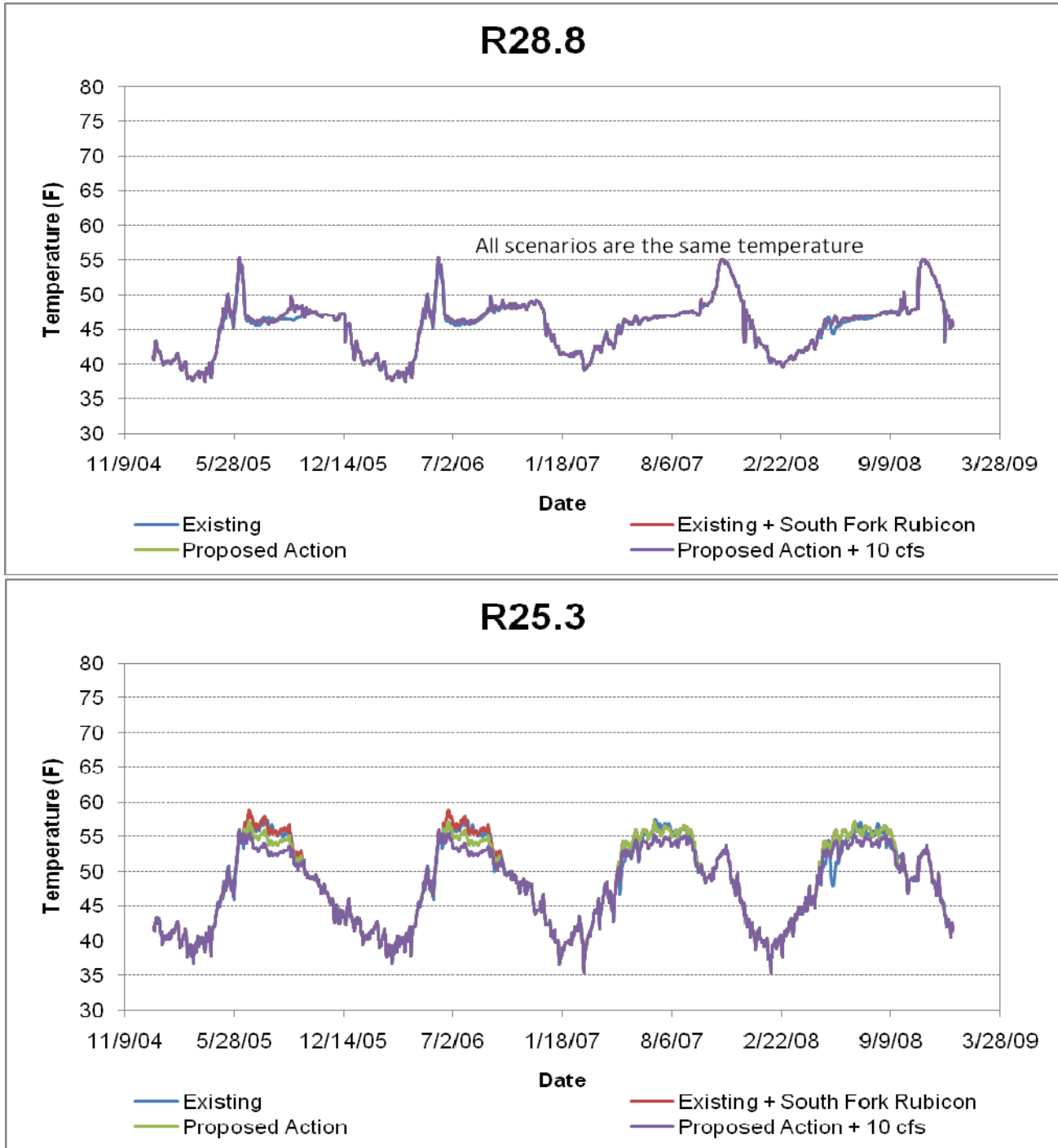


Figure AQ 5-12b. Rubicon River Average Daily Water Temperature Scenarios at R22.5 (top) and R14.3 (bottom) (See Text for Description of Scenarios).

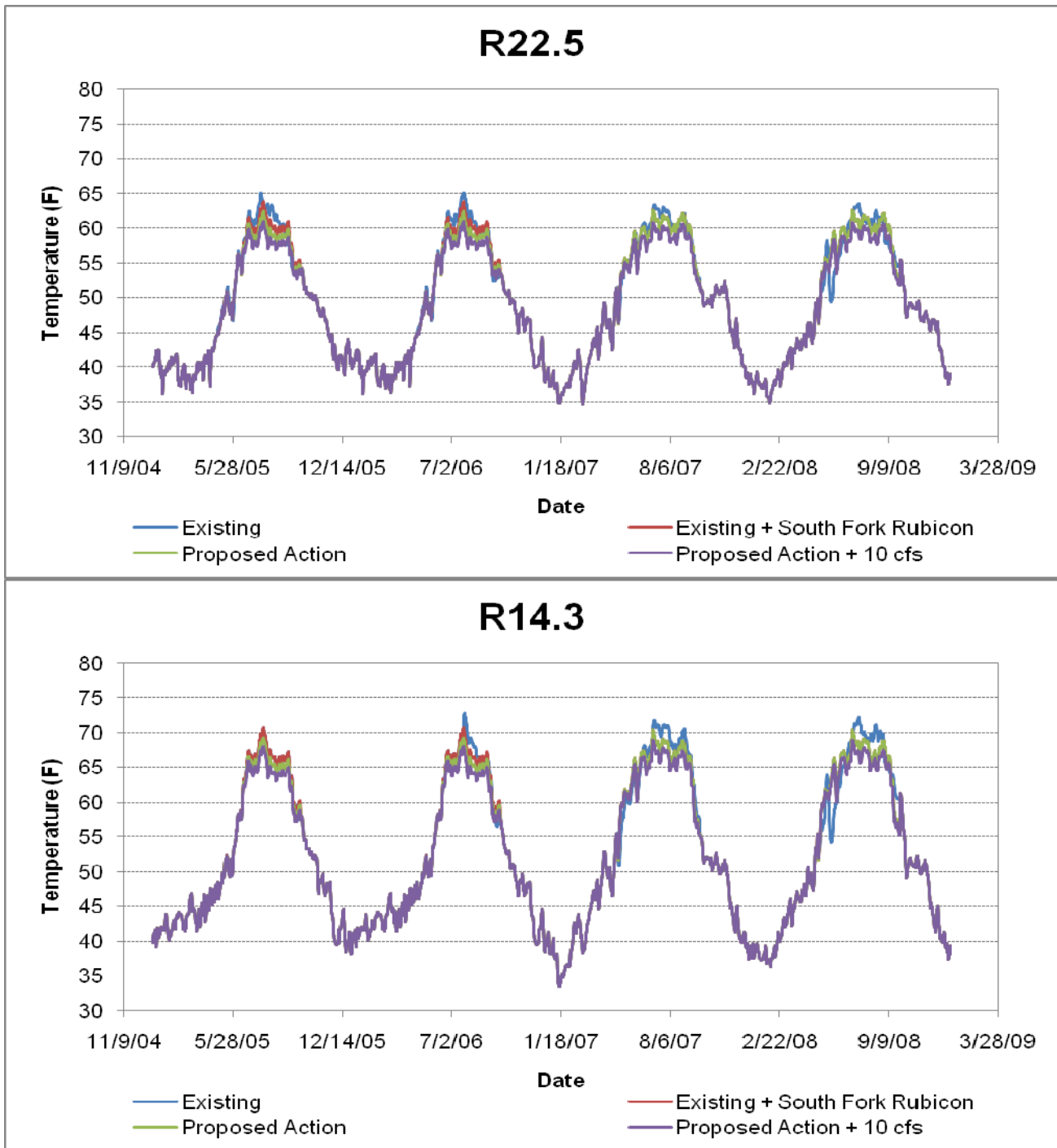


Figure AQ 5-12c. Rubicon River Average Daily Water Temperature Scenarios at R5.3 (top) and R3.7 (bottom) (See Text for Description of Scenarios).

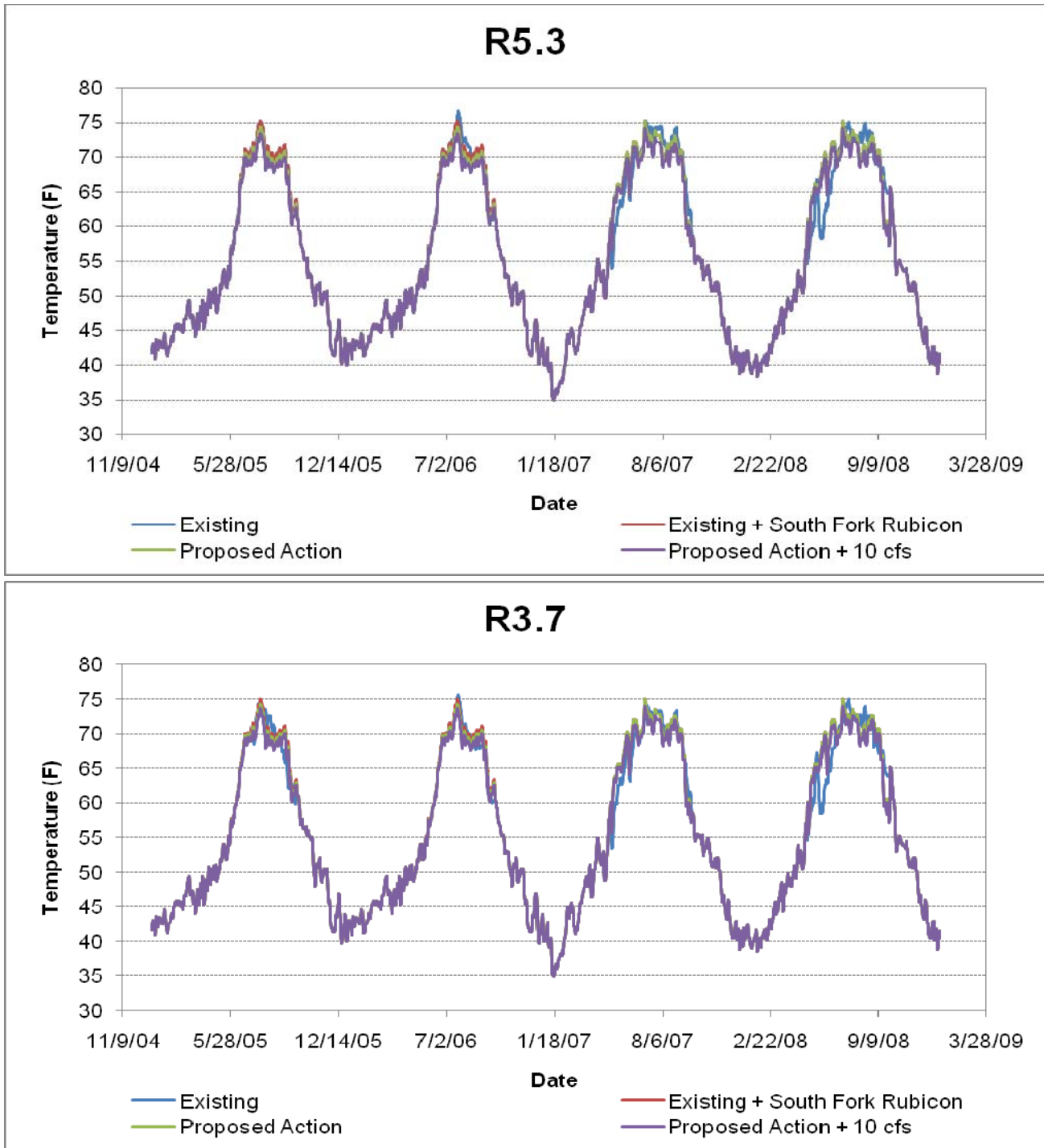


Figure AQ 5-12d. Rubicon River Average Daily Water Temperature Scenarios at R0.7 (See Text for Description of Scenarios).

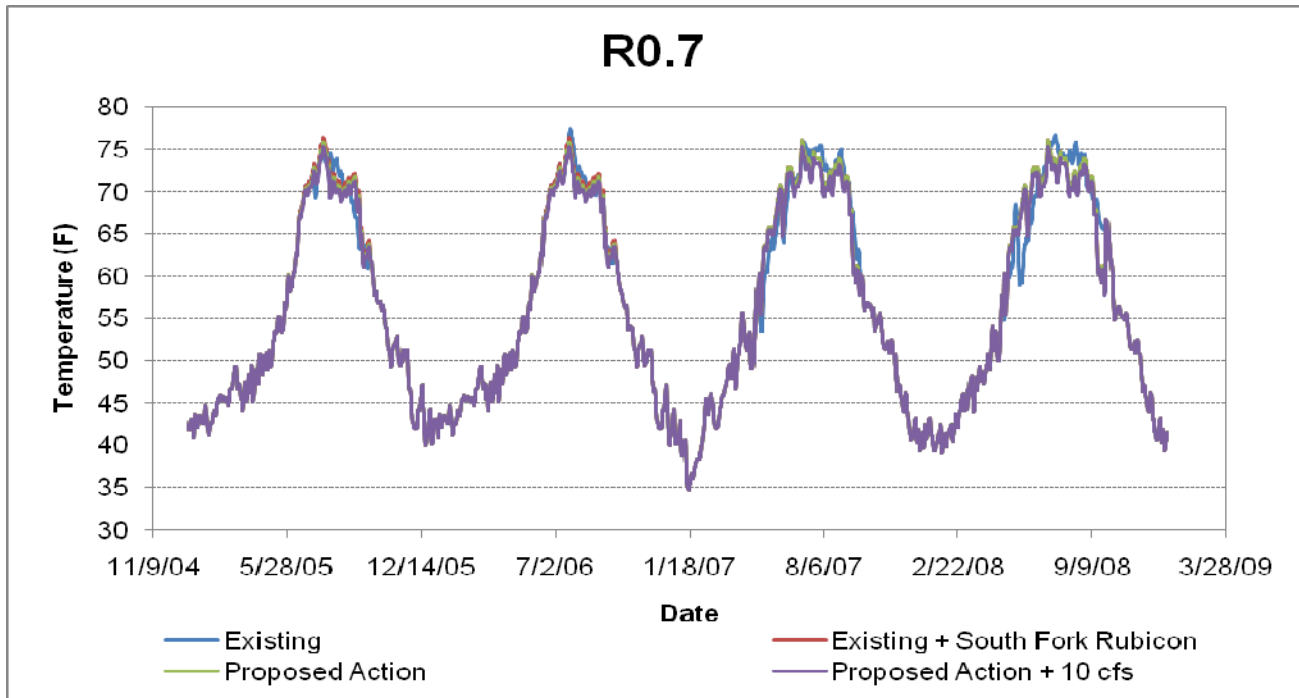


Figure AQ 5-13a. Calibrated Fish Growth at R25.3 (top) and R22.5 (bottom).

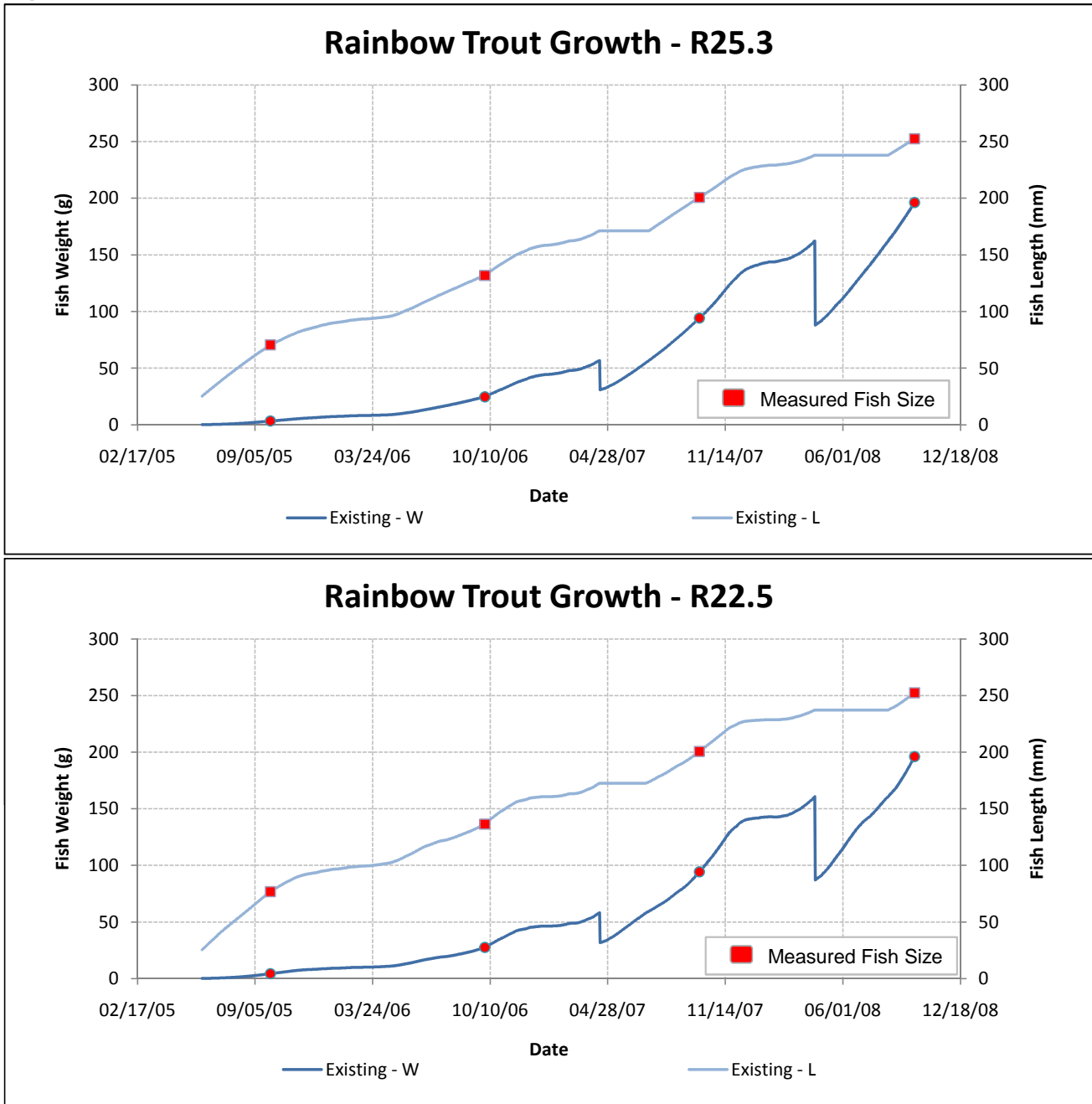


Figure AQ 5-13b. Calibrated Fish Growth at R3.7 (top) and the Peaking Reach MF14.1 (bottom).

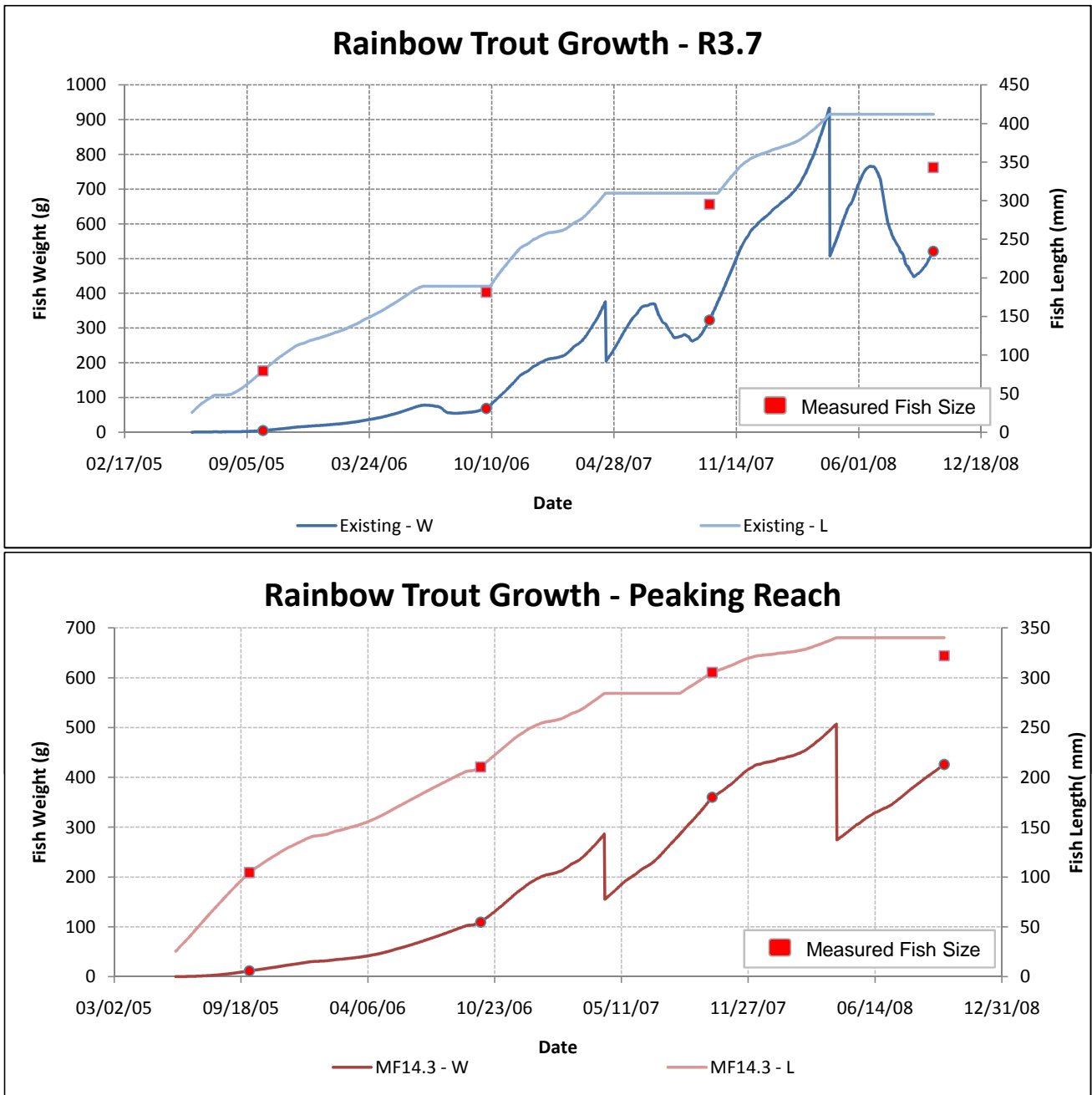


Figure AQ 5-14a. Rainbow Trout Growth for Each Flow/Temperature Scenario at R28.8 (Existing Growth [top], Plus 10% Food [middle], and Plus 20% Food [bottom]).

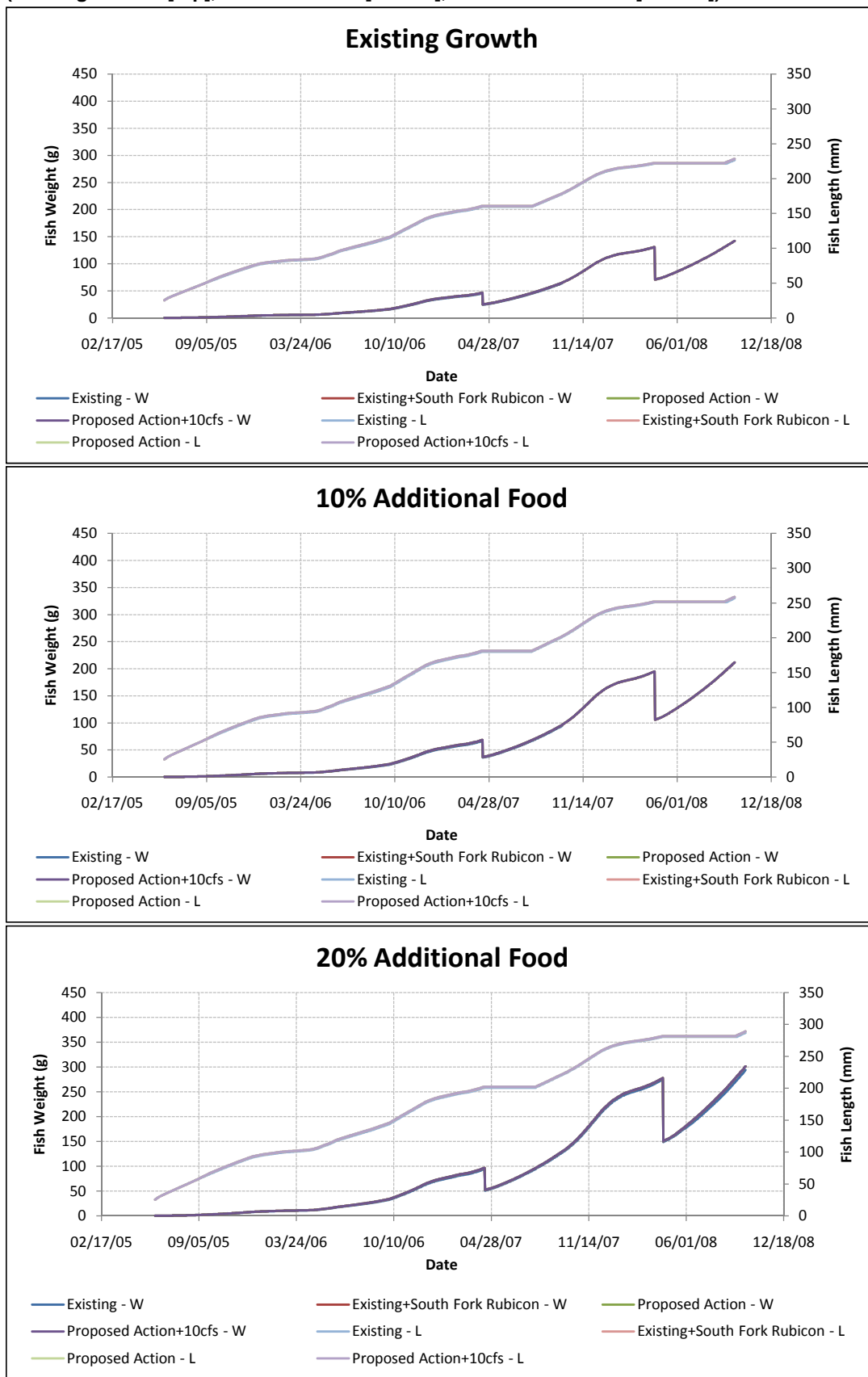


Figure AQ 5-14b. Rainbow Trout Growth for Each Flow/Temperature Scenario at R25.3 (Existing Growth [top], Plus 10% Food [middle], and Plus 20% Food [bottom]).

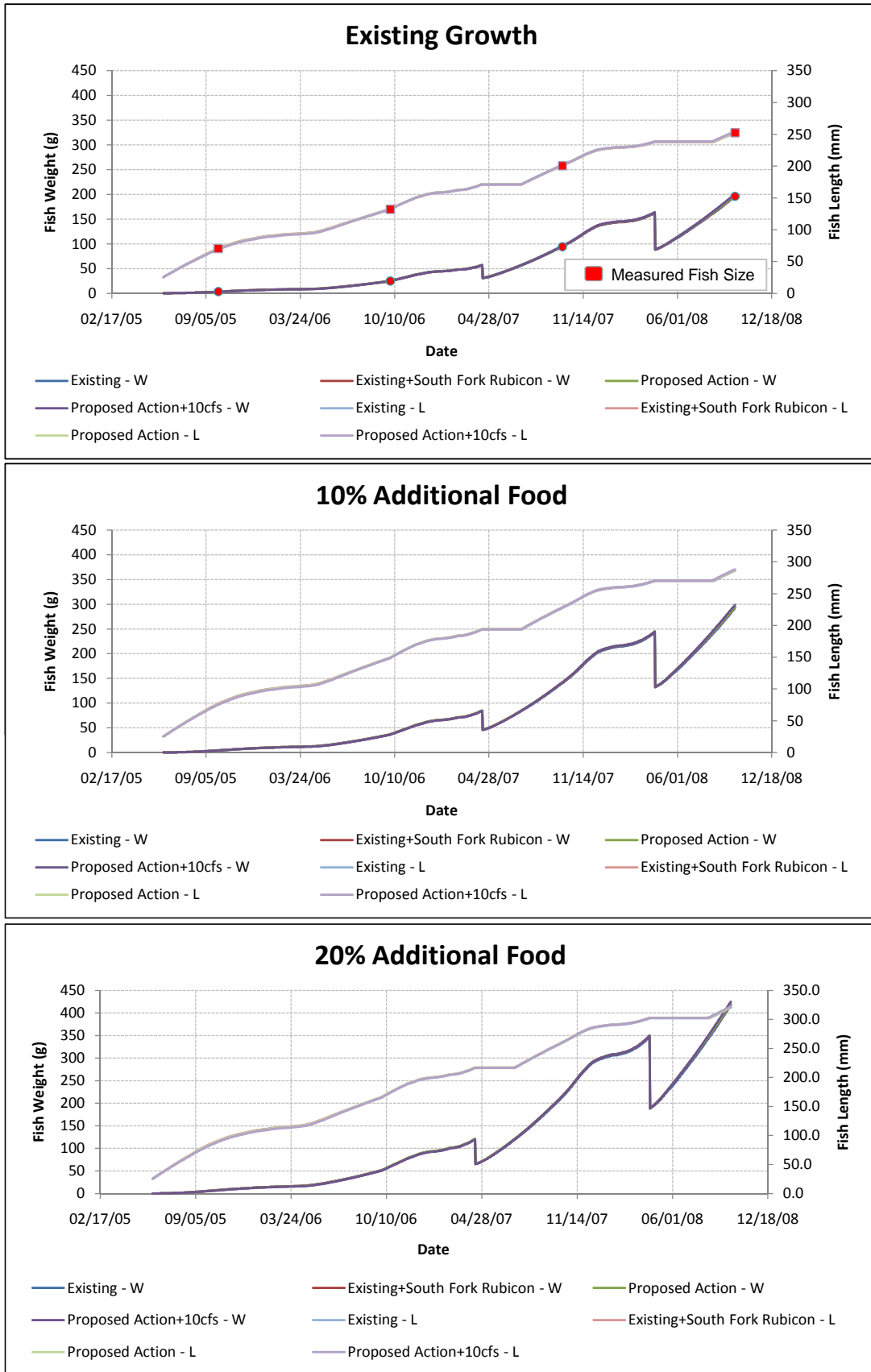


Figure AQ 5-14c. Rainbow Trout Growth for Each Flow/Temperature Scenario at R22.5 (Existing Growth [top], Plus 10% Food [middle], and Plus 20% Food [bottom]).

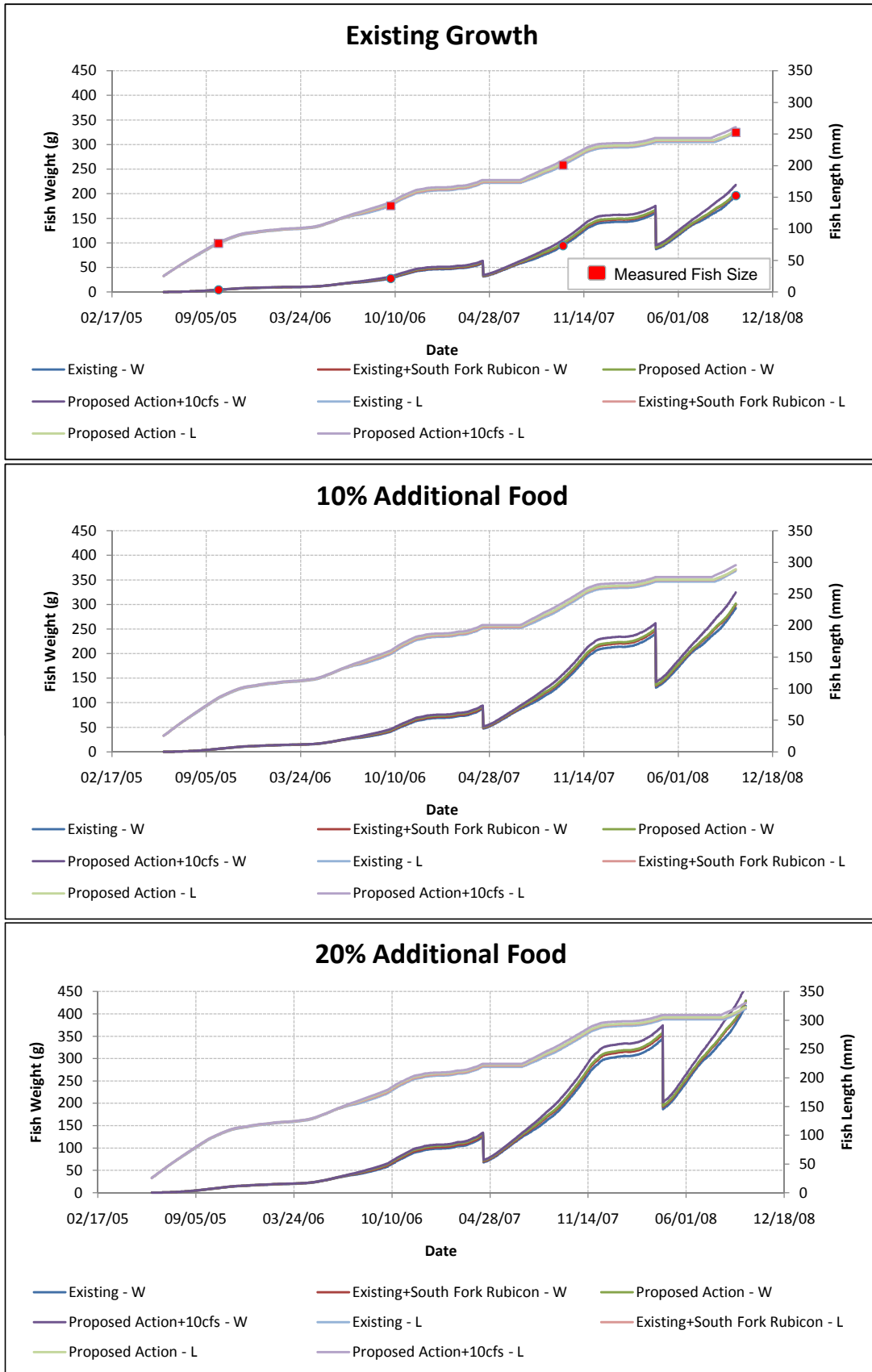


Figure AQ 5-14d. Rainbow Trout Growth for Each Flow/Temperature Scenario at R14.3 (Existing Growth [top], Plus 10% Food [middle], and Plus 20% Food [bottom]).

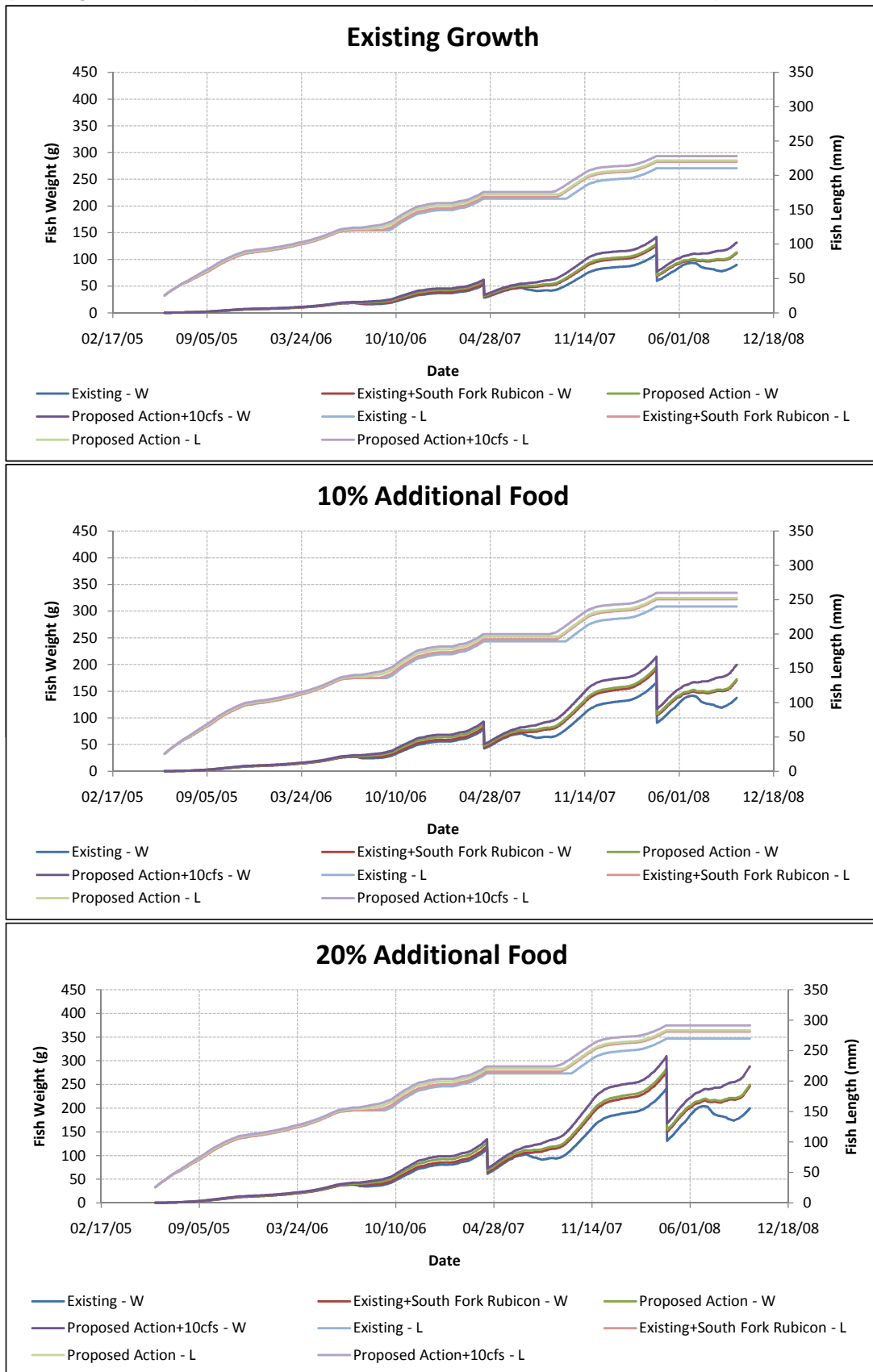


Figure AQ 5-14e. Rainbow Trout Growth for Each Flow/Temperature Scenario at R5.3 (Existing Growth [top], Plus 10% Food [middle], and Plus 20% Food [bottom]).

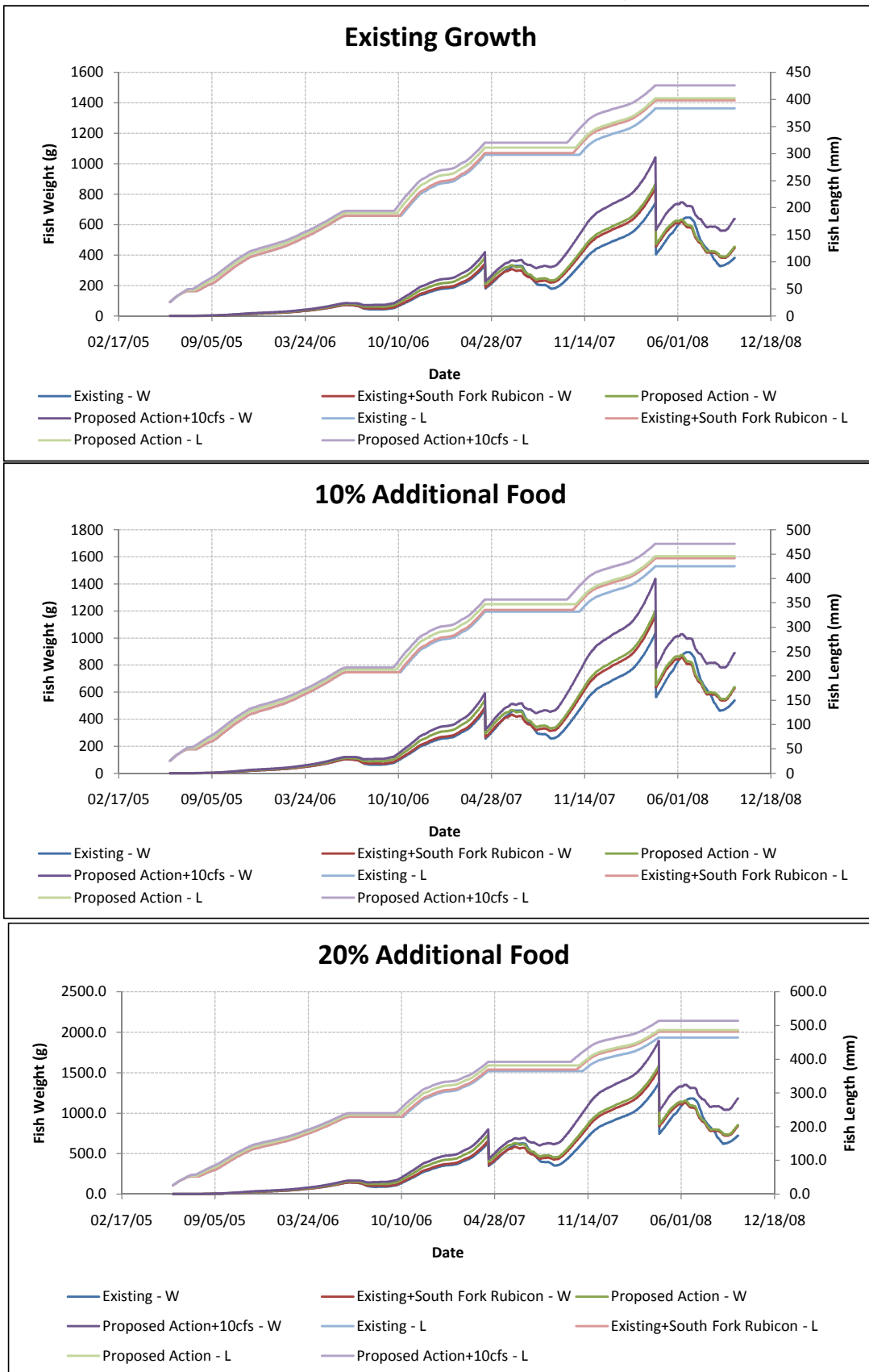


Figure AQ 5-15. Peaking Reach Rainbow Trout Growth at MF23.1, MF14.3, MF8.9, and MF0.1 (Existing Growth [top], Plus 10% Food [middle], and Plus 20% Food [bottom]).

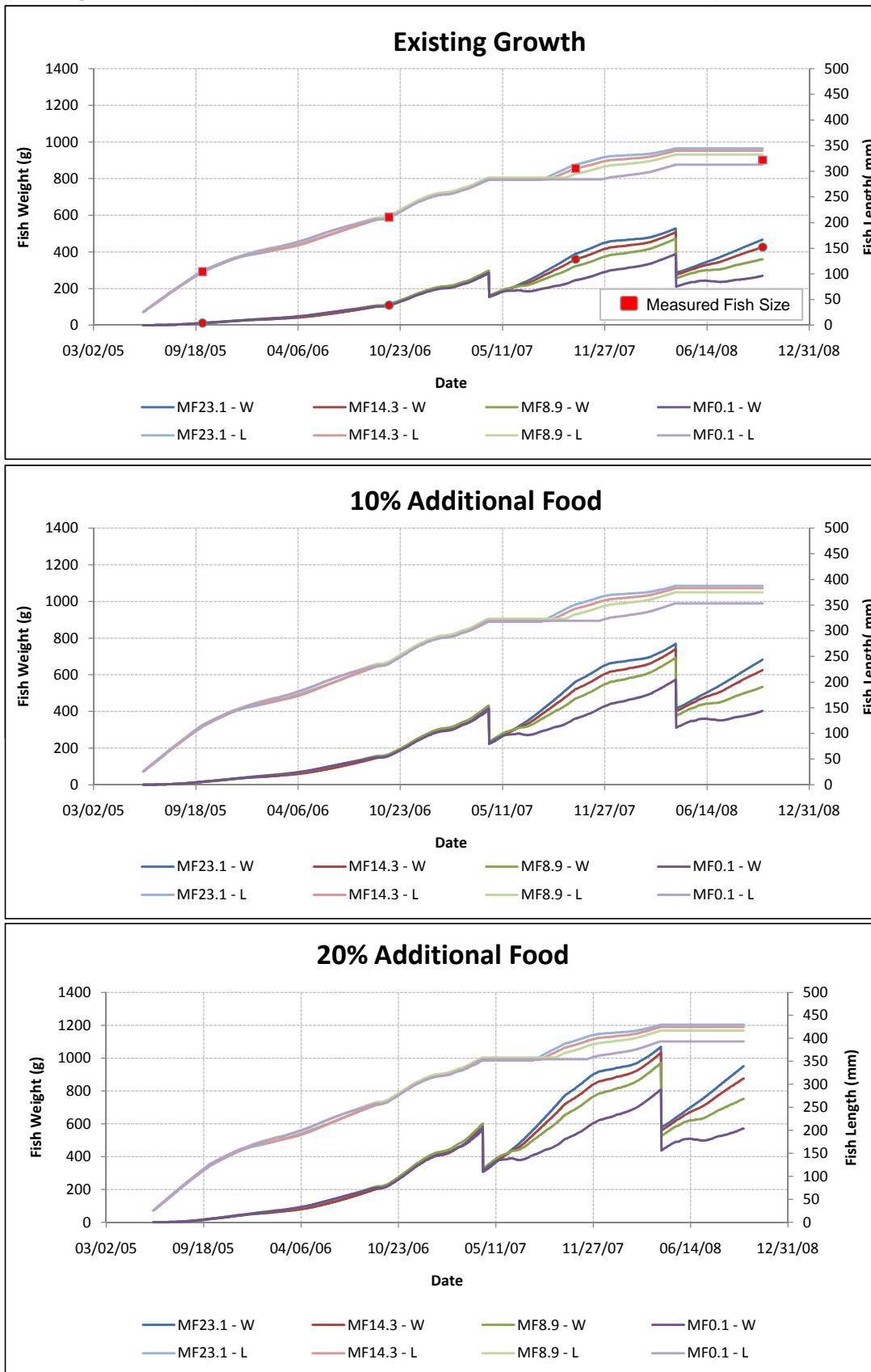


Figure AQ 5-16a. Rainbow Trout Growth at MF23.1 (top) and MF14.3 (bottom) (Existing Growth, Plus 10% Food, and Plus 20% Food).

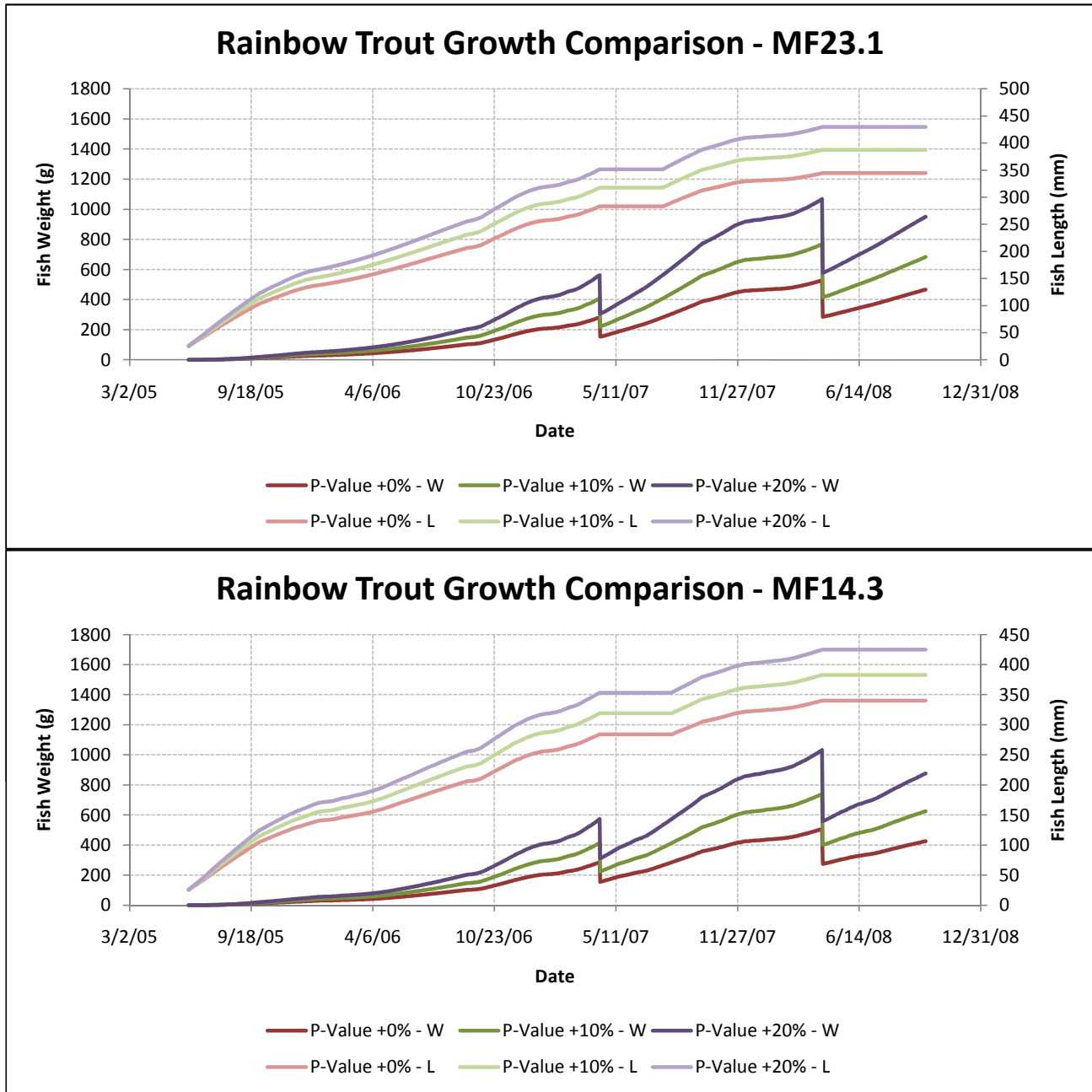


Figure AQ 5-16b. Rainbow Trout Growth at MF8.9 (top) and MF0.1 (bottom) (Existing Growth, Plus 10% Food, and Plus 20% Food).

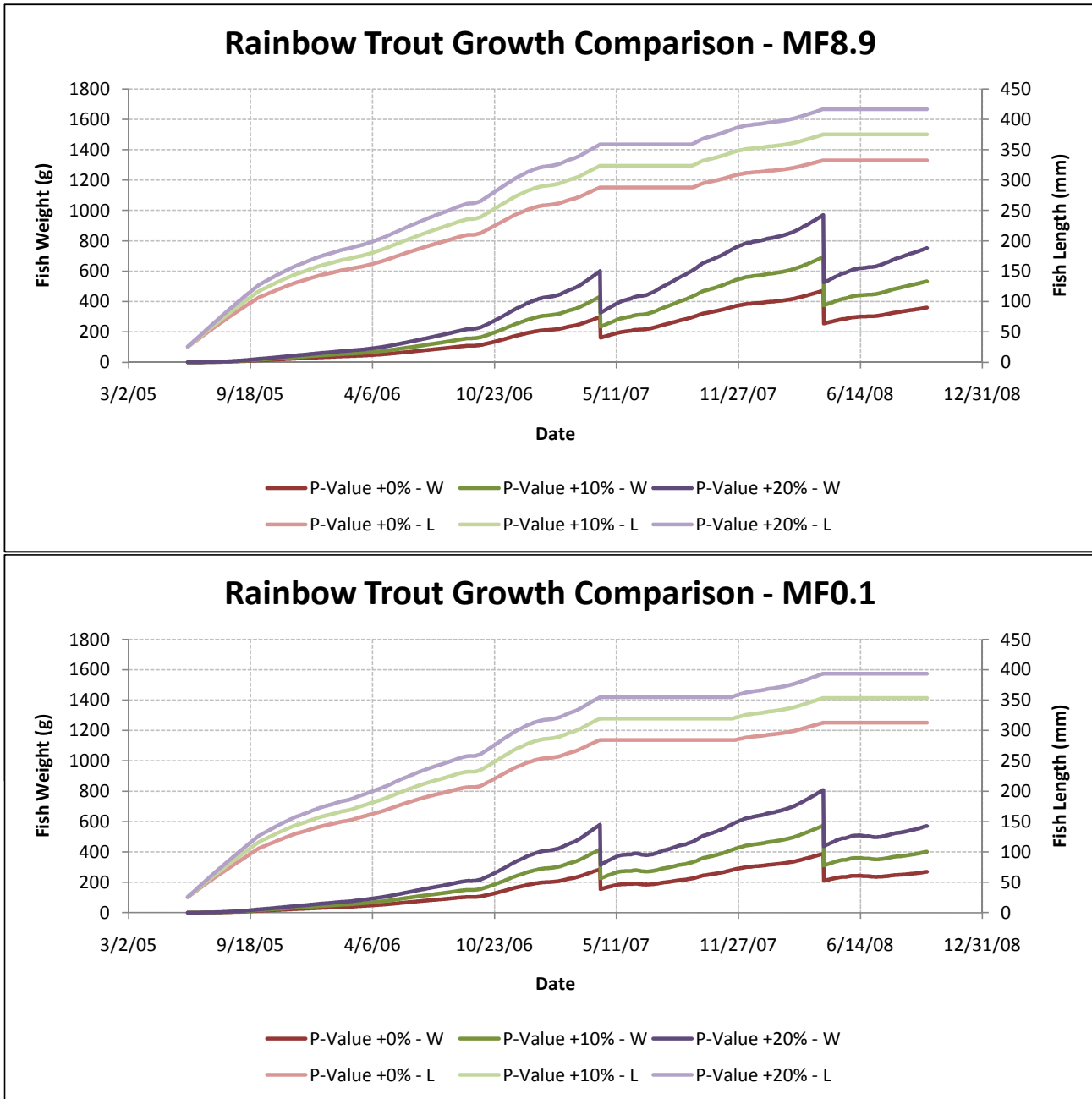


Figure AQ 5-17. Example of the Growth Versus Temperature Relationship (g/g/day) for the Wisconsin Model (Hanson 1997) and Addley (2006).

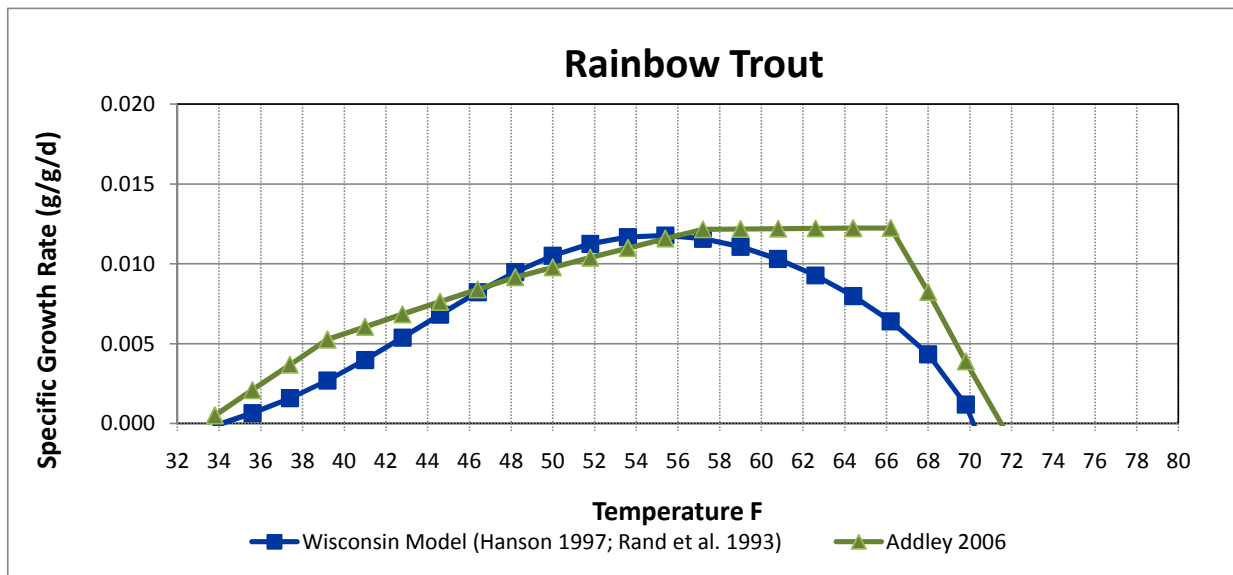


Figure AQ 5-18a. Rainbow Trout Velocity Habitat Suitability Criteria (HSC) for Average Water Temperature (42, 48, 54, 59, 64, 68oF) (Base Drift Density 1.4 number/m³) and the PCWA Instream Flow HSC.

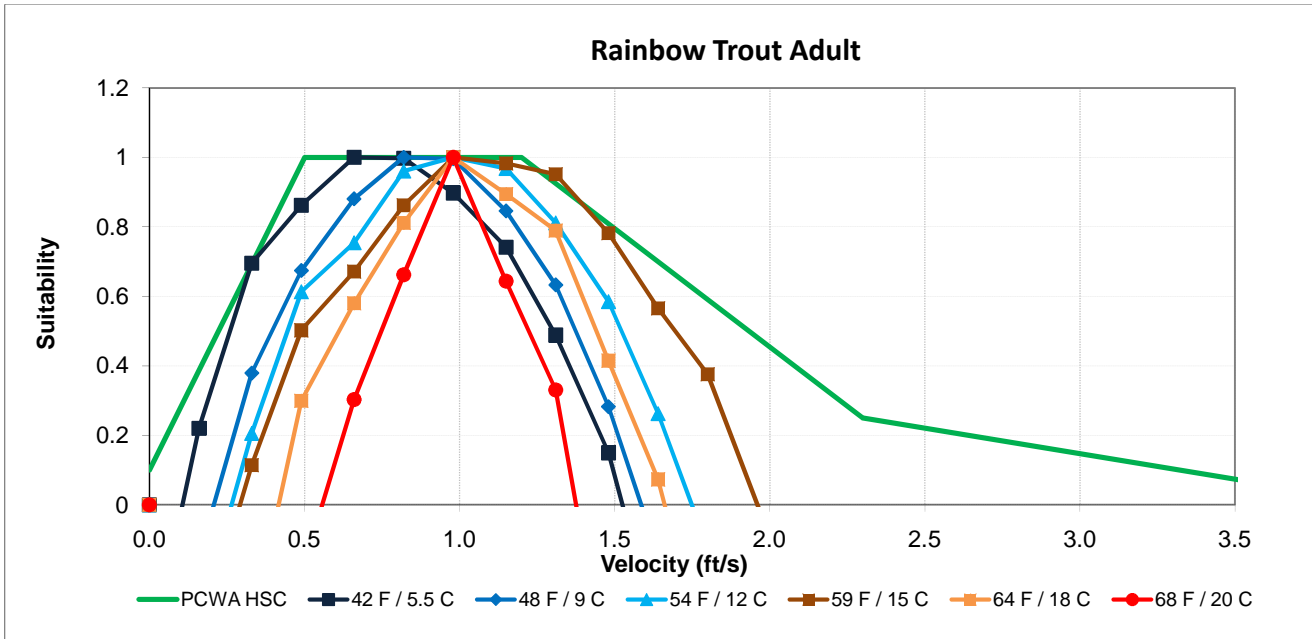


Figure AQ 5-18b. Rainbow Trout Foraging Model Data Used to Develop Temperature Habitat Suitability Criteria.

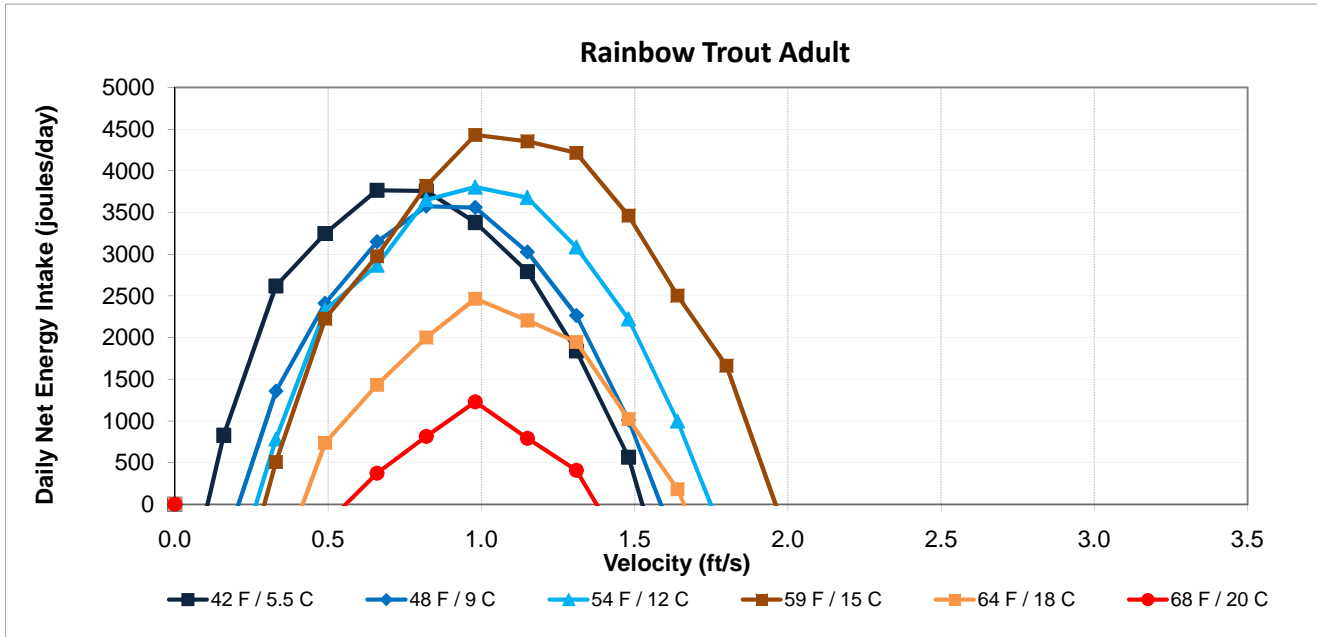


Figure AQ 5-19a. Rainbow Trout Velocity Habitat Suitability Criteria (HSC) for Different Drift Densities (1.1, 1.4, 2.1, 2.8, 3.5 number/m³) (Base Temperature 59°F) and the PCWA Instream Flow HSC.

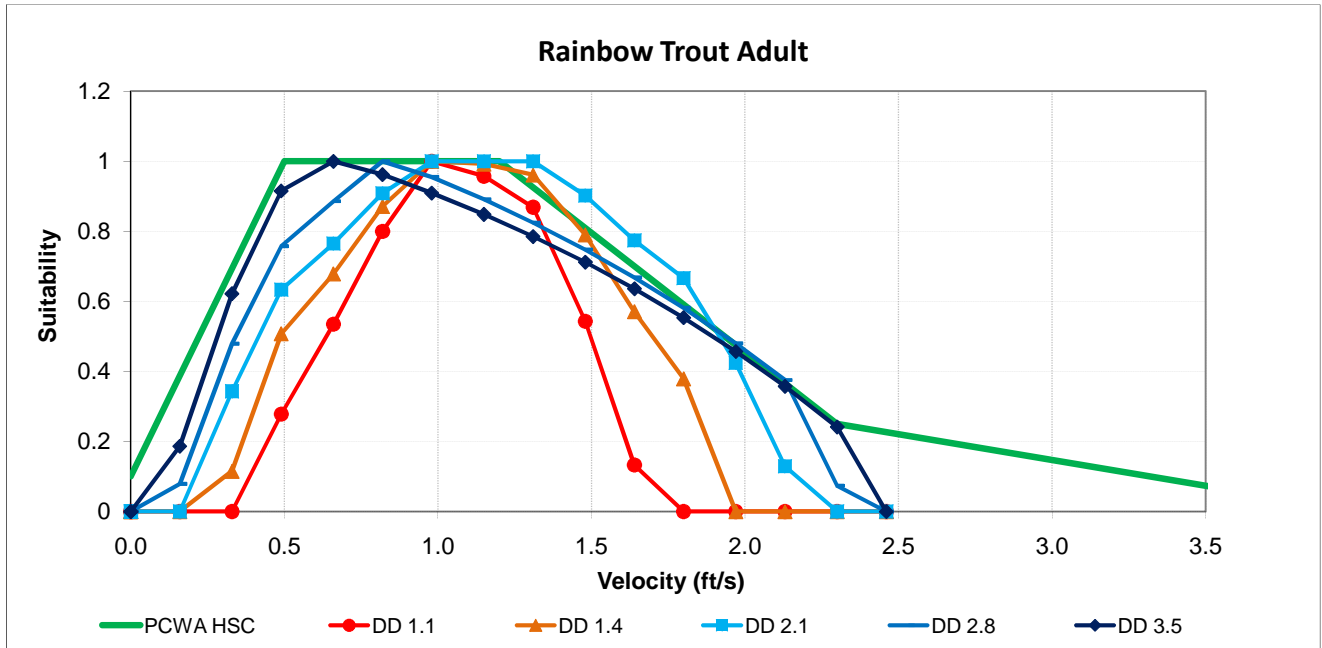


Figure AQ 5-19b. Rainbow Trout Foraging Model Data Used to Develop Drift Density Habitat Suitability Criteria.

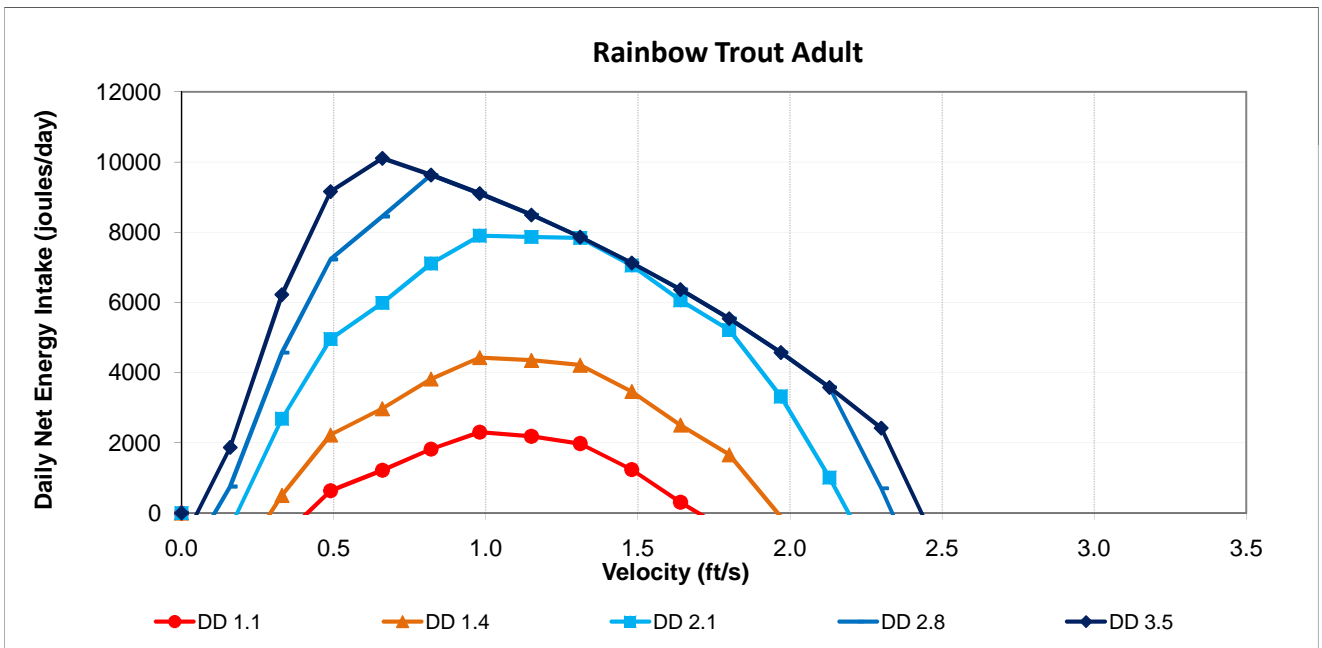


Figure AQ 5-20. Temperature (top) and Drift Density (bottom) Weighted Useable Area at the R25.7 Instream Flow Study Site.

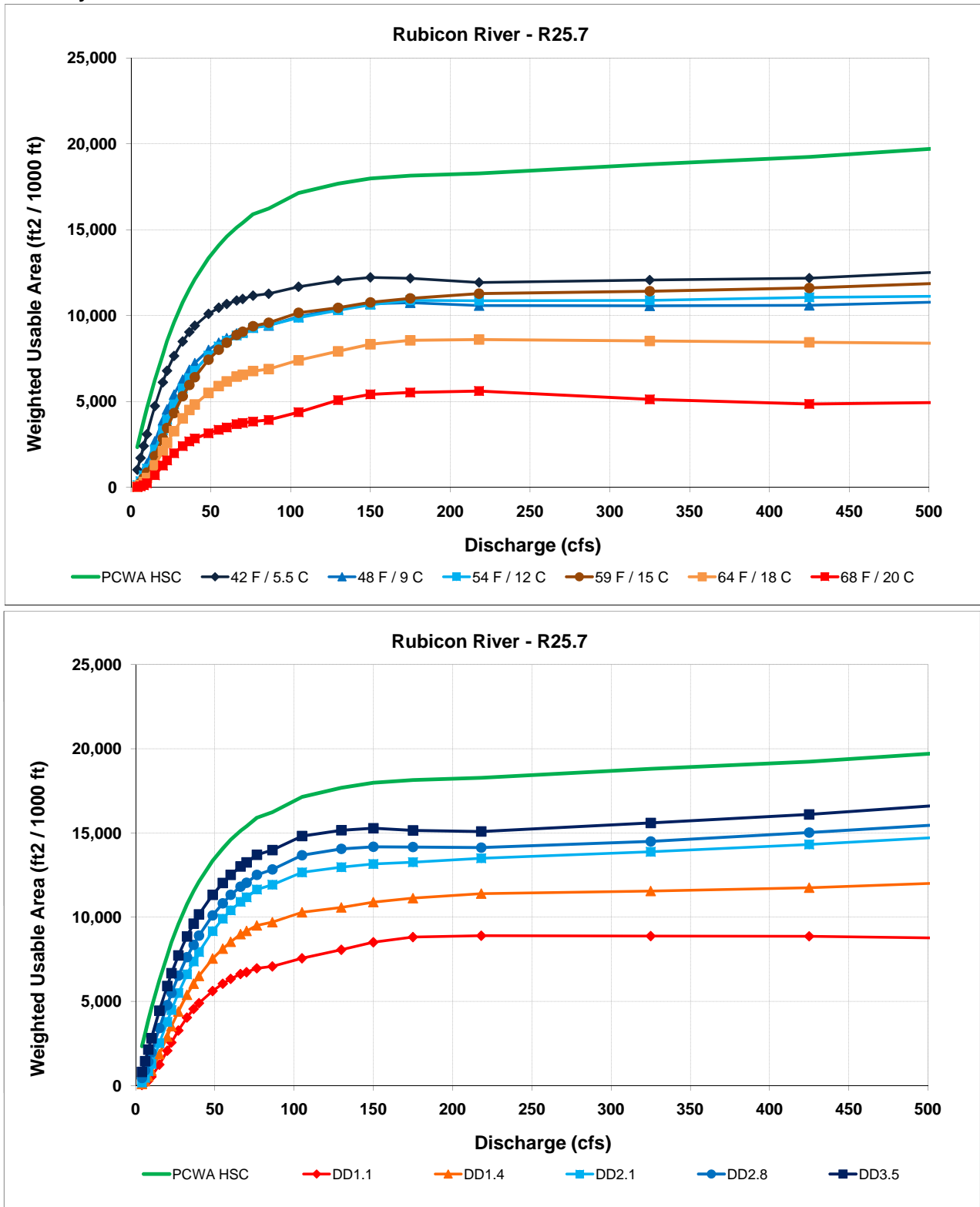


Figure AQ 5-21. Temperature (top) and Drift Density (bottom) Weighted Useable Area at the R20.9 Instream Flow Study Site.

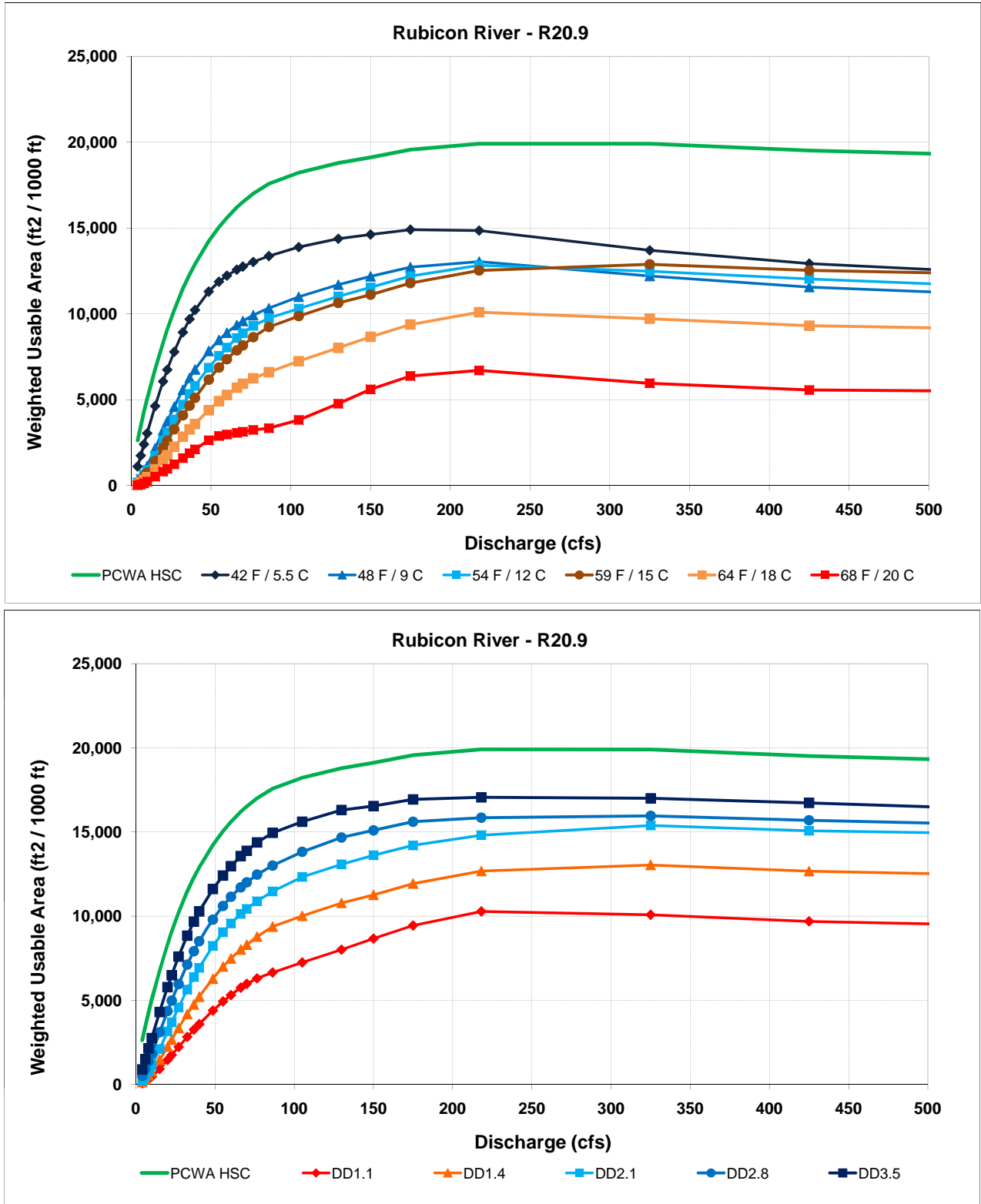


Figure AQ 5-22. Temperature (top) and Drift Density (bottom) Weighted Useable Area at the MF14.1 Instream Flow Study Site.

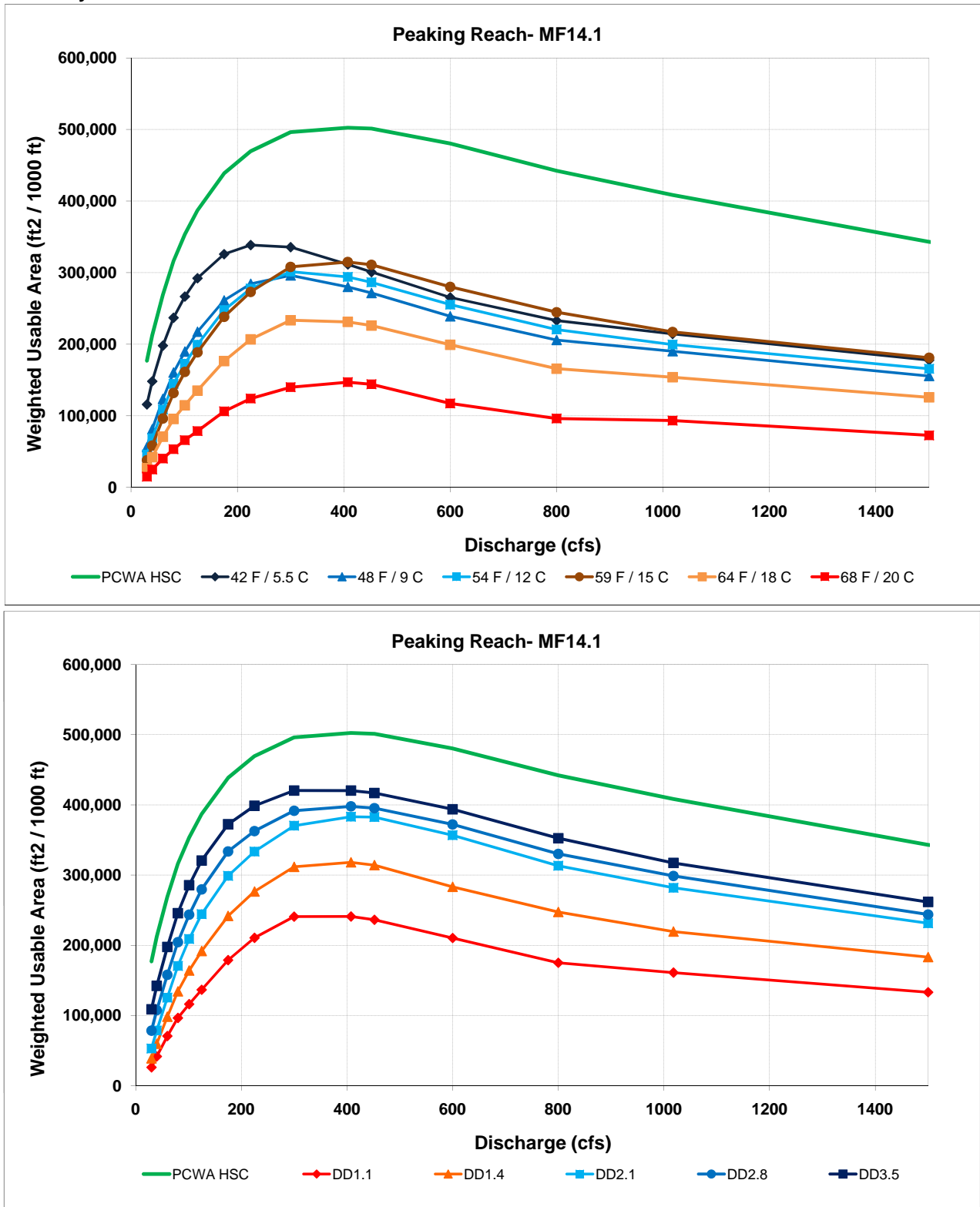
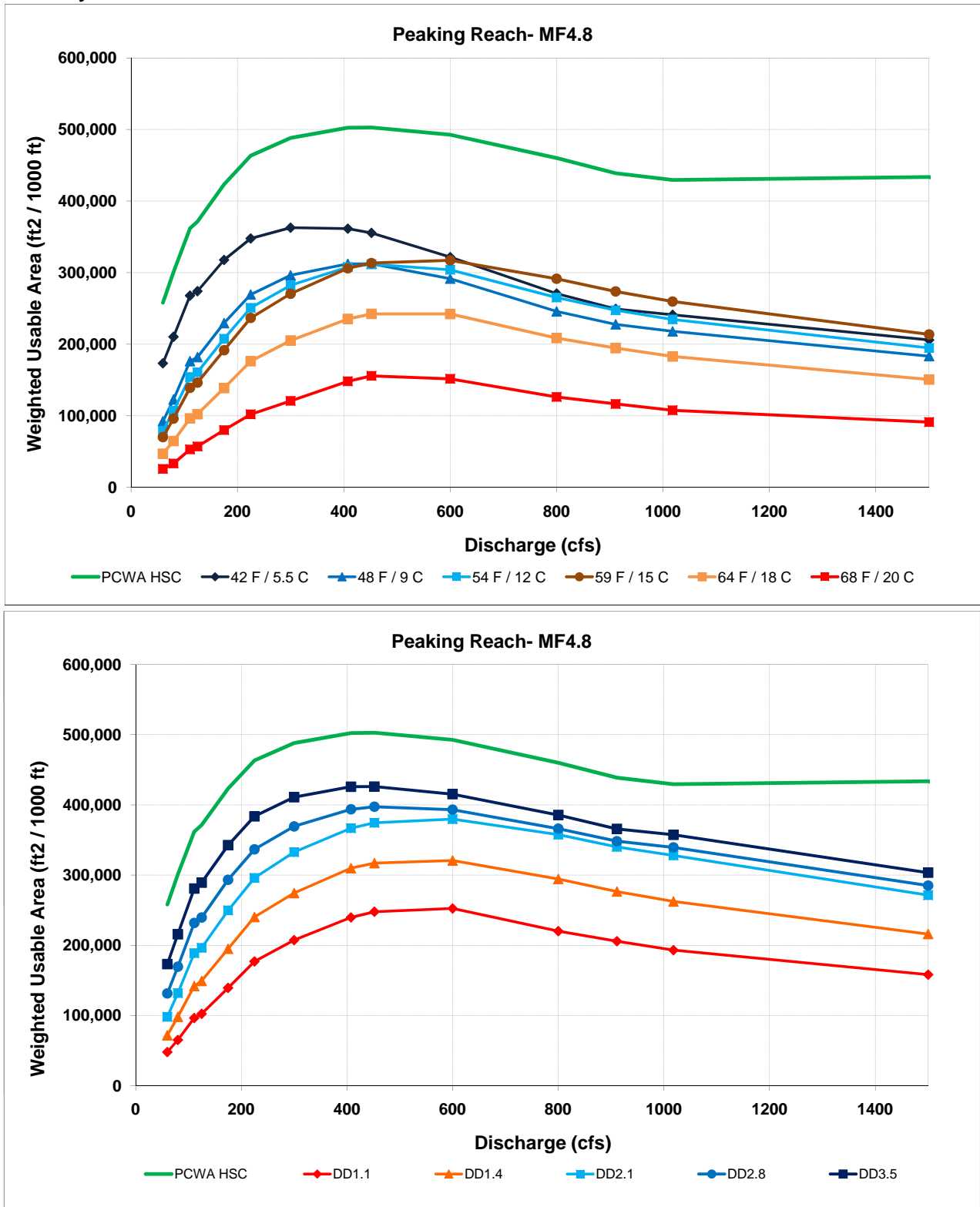


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Bioenergetics Model Verification

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- Figure A-3. Rainbow Trout Growth for Each Flow/Temperature Scenario at R5.3 (Existing Growth [top] and Plus 10% Food [middle]) with Addley (2006) Model.

Figure A-1. Rainbow Trout Growth for Each Flow/Temperature Scenario at R22.5 (Existing Growth [top] and Plus 10% Food [middle]) with Addley (2006) Model.

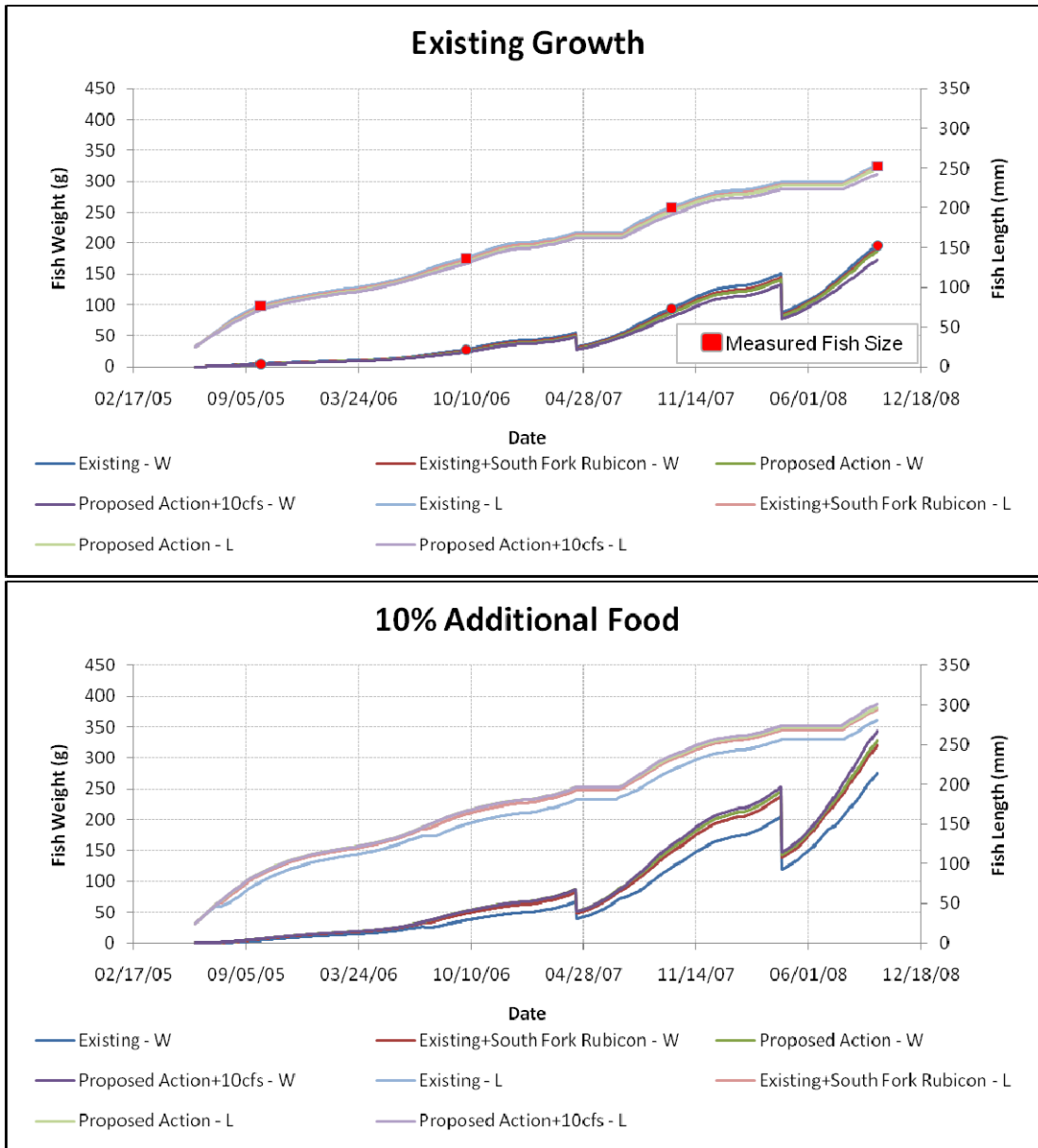


Figure A-2. Rainbow Trout Growth for Each Flow/Temperature Scenario at R14.3 (Existing Growth [top] and Plus 10% Food [middle]) with Addley (2006) Model.

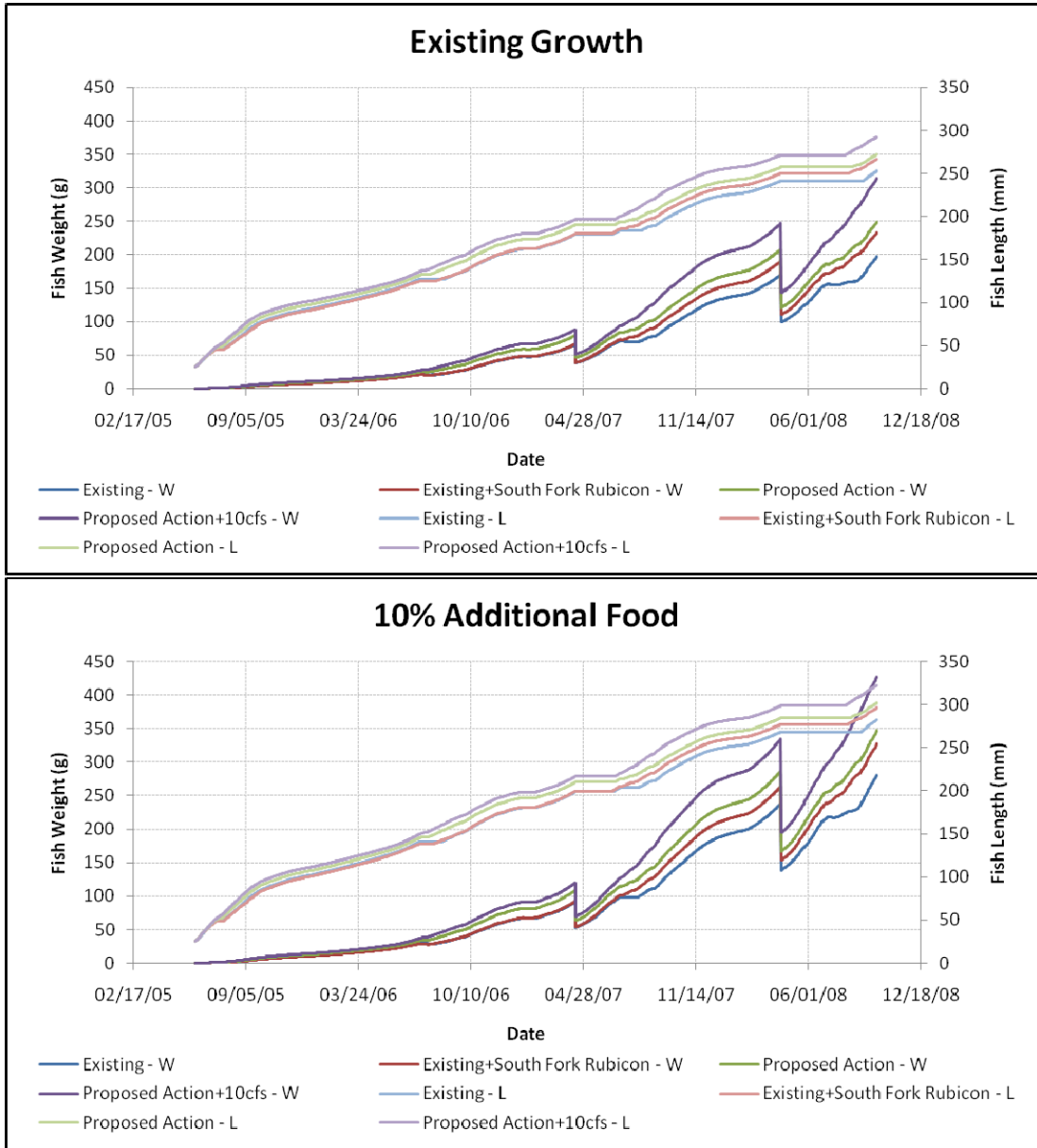


Figure A-3. Rainbow Trout Growth for Each Flow/Temperature Scenario at R5.3 (Existing Growth [top] and Plus 10% Food [middle]) with Addley (2006) Model.

