# Simulated Water Temperature Effects of Bypassing Almaden Lake

*Prepared for:*

U.S. Army Corps of Engineers
333 Market Street
San Francisco, CA 94105
Contact: William DeJager

*Prepared by:*

Jones & Stokes
2600 V Street
Sacramento, CA 95818-1914
Contact: Anne Huber or Harry Oakes
916/737-3000

July 2004

Jones & Stokes. 2004. *Simulated water temperature effects of bypassing Almaden Lake.* July. (J&S 02-357.) Sacramento, CA.

# Contents

Page

# Tables

# Figures

**Follows Page**

# Simulated Water Temperature Effects of Bypassing Almaden Lake

## Introduction

The increase in water temperature in Almaden Lake has prompted this investigation into the potential cooling effects of bypassing the lake. The purpose of this report is to present estimates of the cooling effect on the upper Guadalupe River of altering Alamitos Creek so that it bypasses Almaden Lake, rather than flowing directly into the lake as occurs under existing conditions. This report provides estimated temperature effects associated with two alternative bypasses: a short bypass and a long bypass. As part of this evaluation, the JSATEMP stream temperature model performance was evaluated and improved for the simulation of water temperature at the Alamitos Drop Structure.

Almaden Lake is located at the downstream end of Alamitos Creek and is just upstream of the confluence of Alamitos and Guadalupe Creeks (Figure 1). The lake is a large depression in the river channel that was created by the inundation of a gravel-mining pit. Water flowing out of the lake is primarily from the lake's surface. The lake is more than 40 feet deep in places, and thermal stratification allows bottom temperatures to remain 10–20ºF cooler than surface temperatures.

The elevation of the lake surface is typically raised 5 feet in the summer when flashboards are installed at the drop structure. Installation of the flashboards allows the Santa Clara Valley Water District (SCVWD) to divert water to the offstream Alamitos Percolation Pond (Figure 1). In addition, the installation of the flashboards creates a backwater area in the section of river between Coleman Road and the drop structure and changes the flow characteristics from riverlike (i.e., fairly shallow, narrow, and fast moving) to lakelike (i.e., fairly deep, wide, and slow moving). Water from Guadalupe Creek flows into this backwater area.

Measured and simulated water temperatures indicate that water temperature increases as water passes through Almaden Lake and the backwater area. This warming occurs because water from the creeks (i.e., water flowing from Alamitos Creek into Almaden Lake and water flowing from Guadalupe Creek into the backwater area) has not yet reached temperatures that are in equilibrium with meteorological conditions. The long travel time through the lake and the backwater area allows the water to reach equilibrium values. In addition, the lake and backwater area have no shade, so the equilibrium water temperature is relatively high.

The JSATEMP stream temperature model has been used to simulate water temperatures in the Guadalupe River system for the environmental impact report/environmental impact statement for the upper Guadalupe River flood control project (upper project) (Santa Clara Valley Water District and U.S. Army Corps of Engineers 2001) and the downtown Guadalupe River flood control project (downtown project) (U.S. Army Corps of Engineers and Santa Clara Valley Water District 2001). In addition, the model is being used as part of the mitigation and monitoring performed for the downtown project (Jones & Stokes 2004). In the model, the Guadalupe River system is divided into 39 segments and includes reaches of:

- Alamitos Creek below Almaden Reservoir,
- Arroyo Calero below Calero Reservoir,
- Guadalupe Creek below Guadalupe Reservoir, and
- Guadalupe River from Almaden Lake to Trimble Road (Figure 2).

To simulate the stratification in Almaden Lake, the lake is represented by two horizontal layers: segment 17A represents the surface layer and segment 17B represents the bottom layer. The dividing plane between the surface and bottom layers of Almaden Lake is 10 feet below the lake surface.

The model is able to simulate seasonal changes in Almaden Lake temperature because the temperatures in the two layers vary as a result of the inflow of cool water from the creeks and surface heating of the top layer. The two-layer model is able to mimic the loss of thermal stratification in the fall because, when the surface water becomes cooler than the bottom temperature, the entire lake becomes a uniform temperature.

The backwater area between the drop structure and Coleman Road is represented by segment 18.

# Recalibration of Simulated Temperatures at the Alamitos Drop Structure

For the assessment of the Almaden Lake bypasses, the simulated water temperatures in the vicinity of the lake should be as accurate as possible. The JSATEMP stream temperature model was originally calibrated using water temperature data collected primarily in 1996 and 1997 (Jones & Stokes Associates 1999). Data collected from 2001–2003 are now available and have been used to improve model performance on other Guadalupe River projects.

- Recalibration was performed for Guadalupe Creek and the downtown project area using data collected in 2001, 2002, and 2003 as part of the mitigation and monitoring for the downtown project.
- Recalibration was performed for the upper project area using data measured in 2001. In 2001, however, temperatures were not measured at the drop structure; therefore, for the 2001 recalibration, no modifications were made to model parameters upstream of the drop structure.

Data collected in 2002 and 2003, which included measurements at the drop structure, were used for this project to reevaluate and improve model performance at the drop structure.

## Old Results of Model Calibration

For the purposes of this report, *original simulations* are the best and most recent simulations of historical conditions, prior to beginning the recalibration of water temperatures at the drop structure, and the results of these simulations are the *old results* or *old simulated temperatures*. Old results for the drop structure are compared to temperatures measured at the drop structure (Figures 3–6) in 1996, 1997, 2002, and 2003. Because temperatures were not measured at the drop structure in 2001, temperatures from the nearest downstream measurement site, which was 1.4 miles downstream at Branham Lane, are shown instead and are compared to simulated temperatures for Branham Lane (Figure 7).

The old results for the drop structure (1996, 1997, 2002, and 2003) and Branham Lane (2001) are summarized below.

- The 1996 simulated temperatures matched the measured temperatures fairly well from February through August. Simulated temperatures in September were too low, but measured temperatures in September were incomplete.
- For 1997 and particularly 2002 and 2003, simulated temperatures were too high.
- The 2001 simulated temperatures at Branham Lane were also too high, indicating a pattern similar to 1997, 2002, and 2003, although it is possible that the 2001 model mismatch at Branham Lane could have been related to vegetation removal in Reach 12, as described in the *Summary of JSATEMP Recalibration and Results for Accelerated Locally Preferred Project* (Jones & Stokes 2003a).

The goal of model recalibration was to reduce the temperatures simulated for the drop structure for 1997 and 2001–2003 without causing detrimental effects to model performance at other locations or for the drop structure in 1996. Unfortunately, as described later, this goal was not completely attainable.

# Parameter Modifications

There are multiple model parameters for the Almaden Lake area that have uncertain values. The following list describes the model assumptions that were reassessed and why parameter changes were or were not made.

- **Location of Guadalupe Creek Inflow—**In the original model simulations, the assumption was that, when the flashboards are absent, Guadalupe Creek water flows directly into the river upstream of the drop structure, and, when flashboards are installed, Guadalupe Creek water mixes with the lake water (segment 17).

  However, review of the aerial photographs (Figure 1) indicates that Guadalupe Creek water probably always enters the river at approximately the upstream end of segment 18 and does not flow into segment 17.

  In the recalibrated model, Guadalupe Creek flows are assumed to enter the upstream end of segment 18. This change caused the simulated Guadalupe Creek water to have a slight cooling effect at the drop structure. The effect is small because, when the flashboards are present, the travel time through segment 18 is long, allowing warming of the relatively cool creek water.

- **Diversion Values for Alamitos and Los Capitancillos Percolation Ponds—**In the original model simulations, diversion flows for offstream percolation were estimated using the measured flow values and model performance. In addition, for the 2001–2003 simulations, the diversions at Masson Dam on Guadalupe Creek were also estimated based on periodic flow measurements in the creek. (There are currently no stream gages downstream of Masson Dam or at the drop structure).

  These estimates were reassessed because greater diversions at Masson Dam (i.e., from Guadalupe Creek into the Los Capitancillos percolation ponds) reduce Guadalupe Creek flows. In contrast, when more water is diverted from segment 18 (i.e., from the backwater area into the Alamitos percolation pond), less water is lost from other segments, including lower Guadalupe Creek. Where flow is diverted is important because Guadalupe Creek flows cause the water at the drop structure to be cooler, whereas Alamitos Creek flows cause the water at the drop structure to be warmer. Alamitos Creek flows have a warming effect because Alamitos Creek water must pass through Almaden Lake prior to reaching the drop structure.

  In the recalibrated model, diversion values were not altered because such changes did not have a large enough effect on temperatures at the drop structure and were either detrimental to model performance for lower Guadalupe Creek or were contrary to the periodic flow measurements taken from lower Guadalupe Creek.

- **Channel Geometry for Segment 18—** In the original model simulations, segment 18 was estimated to have an average depth of 6.5 feet and a width of 180 feet when flashboards are installed.

Review of the diurnal temperature variation measured at the drop structure indicates that these estimates may be suitable for the 1996 and 1997 simulations. However, a shallower and narrower channel (average of 4 feet deep and 150 feet wide) produced better model performance for diurnal variation at the drop structure for 2002 and 2003. These changes were based on aerial photographs (Shay pers. comm.) and the model calibration process.

In the recalibrated model, the shallower, narrower channel was used. This change reduced the volume of segment 18, which reduced the travel time through the segment. The reduced travel time had only a slight cooling effect on the simulated temperatures at the drop structure. The diurnal variation measured at the drop structure in 2002 and 2003 could only be matched by reducing the depth of segment 18.

- **Accretions—** In the original model simulations, it was assumed that there were no accretions in Almaden Lake or segment 18. ( For the purposes of this report, accretions are local inflows that do not come from a specific tributary. They can come from seepage from offstream percolation ponds, groundwater, or small discharges to the river.)

  The effect of adding an accretion of 2 cubic feet per second (cfs) to the bottom of Almaden Lake was evaluated because the depth of the lake may allow it to intersect with groundwater. In the recalibrated model, these accretions were not added because the change had little beneficial effect on model performance.

  The effect of adding an accretion of 2 cfs to segment 18 was also evaluated. Water from the offstream percolation ponds is believed to seep back into Guadalupe Creek and the Guadalupe River at some unknown but low level. The Alamitos percolation pond is adjacent to segment 18 (Figure 1) and could be a source of accretions. The addition of a 2-cfs accretion at a temperature of 65ºF produced an improvement in model performance at the drop structure (i.e., the model matched the measurements better) for 2002 and 2003 but not for 1996. These accretions were added for the final recalibration.

- **Temperature of Accretions—**In the original model simulations, the temperature of the accretions is generally 65ºF for May–October.

  The reassessment considered varying the temperature of the segment 18 accretions from 61 to 65ºF for May–October (for November–April accretion temperatures are set to represent surface temperatures).

  This modification did not have a large effect on model performance and was not used in the recalibrated model.

- **Almaden Lake Mixing—** In the original simulations, 90% of the water leaving the lake was assumed to come from the surface layer, and the exchange flow was assumed to be zero. In the model, the user specifies the fraction of the water leaving the lake that comes from the surface and bottom layers because even though the outflow comes from the surface, some of the water may be pulled from the bottom. In addition, the user can specify a constant exchange flow between the two layers that simulates the effect of hydrodynamic mixing processes.

Decreasing the percent of water coming from the surface from 90 to 70% produced a relatively large improvement in model performance for 2002 and 2003 but not for 1996.

In the recalibrated model, this change was used, and it represents greater top to bottom mixing in the lake, either at the outflow location or throughout the lake.

- **Size of Almaden Lake—**Old and new model results indicate that there is sometimes a slight tendency for the simulated temperatures at the drop structure to be slower than the measured temperatures in responding to the cooling meteorological conditions of the fall. If portions of Almaden Lake have more through flow than other portions, it is possible that the effective volume of the lake for water temperature purposes is smaller than the actual volume of the lake. It might take less time for lake temperature to drop in the fall if the effective lake volume is small.

  However, a reduction in lake volume in the model did not have a large effect on the rate of cooling in the fall and, therefore, was not used in the recalibrated model.

In summary, the final parameter changes made for the recalibration were:

- Guadalupe Creek flows are assumed to enter the upstream end of segment 18,
- the dimensions of segment 18 were modified from 6.5 feet deep to 4 feet deep and from 180 feet wide to 150 feet wide,
- an accretion of 2 cfs at 65ºF was added to segment 18, and
- 30% of the outflow from Almaden Lake was assumed to come from the bottom of the lake, instead of 10%.

## New Model Calibration Results

For the purposes of this report, *new simulations* are simulations after the changes described above were made for recalibration of temperatures at the drop structure, the results of these simulations are the *new results* or *simulated temperatures*. The new results are shown in the bottom portions of Figures 3–7. For all years evaluated, the new simulations produced temperatures at the drop structure that were cooler and had more diurnal variation than the original simulations. This change resulted in a negative effect on model performance for 1996, did not cause much change in model performance for 1997, and improved model performance for 2001–2003.

The recalibration has the potential to affect model performance at other locations, so those results were also evaluated. The addition of the 2-cfs accretion to segment 18 caused the calculated flow at upstream locations to be modified slightly in order to maintain the proper flow balance between upstream and downstream gage locations. As a result, temperatures upstream of the Guadalupe River had the potential to be altered by the recalibration. However, evaluation of results showed little change in model performance for segment 16, Alamitos Creek upstream of Almaden Lake (temperatures were measured in 1996 and 1997), or segment 6, the downstream end of Guadalupe Creek (measured in 1996, 1997, and 2001–2003).

Temperatures were measured in Almaden Lake in 1997 near the surface, at a depth of 5 feet, and at 15–25 feet below the surface. The variable depth of the deeper measurements was the result of entanglement of the probe line. The new simulated temperatures for Almaden Lake are slightly warmer than the old simulated temperatures, which reduces the model performance for the lake temperatures. However, because the Almaden Lake temperature probes represent temperatures at particular depths at one location in the lake, and the simulated Almaden Lake temperatures represent average temperatures for the entire surface and bottom layers of the lake, the measured temperatures can only be used as a general guideline for whether the Almaden Lake temperatures are simulated correctly. The new simulated temperatures for Almaden Lake during 1997 correctly match the measured seasonal trends (Figure 8).

Temperatures were measured at Branham Lane approximately 1.4 miles downstream of the drop structure in 1996, 1997, and 2001. The effect of the model changes on model performance at Branham Lane was similar to the effect on the performance for the drop structure: Branham Lane performance was made worse for 1996, about the same for 1997, and improved for 2001 (Figures 7, 9, and 10). In 2002 and 2003, temperatures were not measured at Branham Lane but were measured farther downstream, and the model changes had little effect on temperatures at these locations.

It is difficult to say why model performance for drop structure temperatures is different in 1996-1997 than in 2002-2003. The measured temperatures for these two sets of years are different because the 1996-1997 measured temperatures have a smaller diurnal temperature variation than the 2002-2003 temperatures (2ºF versus 5ºF during the summer). One possible explanation for the differences is that changes were made in 1999 in association with the installation of the fish ladder at the drop structure. The changes include the following.

- Prior to 1999, an open pipe connected the Alamitos percolation pond to segment 18, causing the two water bodies to maintain the same elevation. After 1999, the intake for the Alamitos percolation pond was left in segment 18, but the overflow pipe for the percolation pond emptied into the river immediately downstream of the drop structure. It is unclear how much back and forth flow occurred prior to 1999 through the open pipe, but water balance calculations performed by the SCVWD (Nam pers. comm.) indicate that there is seldom any overflow from the percolation pond to the river.
- Prior to 1999, flow was measured at the drop structure. After the installation of the fish ladder, flow could no longer be measured at the drop structure,

and model flows for segment 18 have been estimated based on historical differences between flows at the drop structure and flows at gage 23B.

- Prior to 1999, flow passed over the flashboards, whereas flow now passes through the fish ladder. However, there has been minimal change in the water surface elevation behind the flashboards (Aguilera and Bozzo pers. comm.).
- Prior to 1999, water temperature was measured on the downstream side of the drop structure. It is now measured 300–400 feet downstream of the drop structure. Based on observations and simulations, such a change is unlikely to make a significant difference in the diurnal variation of the water temperature. It is possible that there are some significant local accretions just downstream of the drop structure that could have affected the water temperature measurements, but they would not cause an increase in diurnal variation.

For the assessment of the Almaden Lake bypasses, it is more important that the model match the current conditions than past conditions. For this reason, the new simulation parameters were used for the evaluation of the Almaden Lake bypasses. The changes that were made for model recalibration were estimates of what could be producing the temperatures that were measured. If additional information becomes available, the model calibration for drop structure temperatures could be fine tuned.

# Simulated Temperature Effects of Almaden Lake Bypasses

## Modeling Assumptions

The purpose of the Almaden Lake bypass simulations is to estimate the cooling effect on the upper Guadalupe River of altering Alamitos Creek so that it bypasses Almaden Lake, rather than flowing directly into the lake as occurs under existing conditions. Figure 1 identifies one possible location for a bypass channel and an approximate area of soil fill placement. This alignment is conceptual in nature and has been developed so that the reviewer can more easily comprehend the proposed bypass alignment and corresponding assumptions.

Two types of bypasses were simulated: a short bypass and a long bypass.

- The short bypass would bypass Almaden Lake (segment 17) but not the backwater area (segment 18) that is created when flashboards are inserted at the drop structure, as occurs annually under existing conditions. The short bypass would affect segment 17 but not segment 18. The simulation of this bypass helps to evaluate the warming effect of Almaden Lake separately from the warming effect of the backwater area.

- The long bypass would bypass Almaden Lake and the backwater area. Alamitos Creek flows would mix with Guadalupe Creek flows in the bypass channel near the current confluence point at the upstream end of segment 18. This bypass would affect both segments 17 and 18. The existing channel in segment 18 would be modified, or a new channel would be constructed adjacent to the existing channel.

Both the short and the long bypasses would be placed in the eastern portion of Almaden Lake (Figure 1). For the temperature simulations, the location of the bypass is not important, but the length of the bypass could be important. The length of the bypass through the lake would be approximately 0.4 mile.

Simulations were run with the dry/median flows and the 1994 meteorology. These are the same conditions used to assess other upper and downtown Guadalupe River project actions.

The following modeling assumptions were made.

- The hydraulic capacity is, or will be, suitable to allow riparian vegetation to exist upstream of the drop structure (segment 18) and along the constructed bypass channel in segment 17.
- The SCVWD will divert water for offstream percolation ponds at the same rate used for the dry/median year (i.e., the same rate used for prior simulations) (Table 1). Water will be diverted from the bypass upstream of the drop structure (segment 18), even though it is possible that the SCVWD might want this water to flow into the new Almaden Lake and not through the bypass.
- No water will be diverted from Alamitos Creek or Guadalupe Creek to maintain the water elevation in Almaden Lake, and no water will be released from Almaden Lake back into the river.
- The vegetation density, distance from the channel, and growth rates for the vegetation along the bypass channel in segments 17 and 18 will be the same as those assumed for the lower Guadalupe Creek mitigation plantings (Table 2).
- The bypass channel in segments 17 and 18 will have the same channel geometry as the existing recontoured channel in lower Guadalupe Creek (Table 2).
- Riparian vegetation that has established along the edge of the low-flow channel in Reach 12 (segments 19 and 20) will remain, but there will be no additional planting. Future growth of this vegetation is not included in the simulations.
- Guadalupe Creek will continue to flow into the area upstream of the drop structure (i.e., it will not be rerouted to enter the river downstream of the drop structure).

# Bypass Scenarios and Their Assumptions

Six bypass scenarios were simulated. The scenarios and their assumptions are described below.

- **Scenario 1A (No Bypass under Existing Conditions).** This scenario represents existing (baseline) conditions for the Guadalupe River and its tributaries. The scenario captures the effects of mitigation vegetation and channel grading on lower Guadalupe Creek, which was planted by the SCVWD in 2001. The scenario assumes:
    - existing (2003) vegetation and channel geometry conditions for lower Guadalupe Creek,
    - no bypass in segments 17 and 18, and
    - the same function of the flashboard system (i.e., as it has functioned historically).
- **Scenario 1B (No Bypass with Mature Vegetation along Lower Guadalupe Creek).** This scenario represents postmitigation (year 40) conditions for Guadalupe Creek and shows the predicted benefits of lower Guadalupe Creek mitigation plantings. The scenario assumes:
    - year 40 vegetation conditions in lower Guadalupe Creek are the same as those used in previous model runs, although the new vegetation growth rates were used (Jones & Stokes 2003b);
    - no bypass in segments 17 or 18; and
    - the same function of the flashboard system (i.e., as it has functioned historically).
- **Scenarios 2A (Unvegetated Short Bypass) and 2B (Unvegetated Long Bypass).** These two scenarios represent conditions immediately following bypass construction. These scenarios assume:
    - the bypass would be constructed fairly soon (i.e., before the lower Guadalupe Creek mitigation plantings become more established and provide more significant shade benefits),
    - existing (2003) conditions for lower Guadalupe Creek, and
    - the new bypasses have no vegetation cover because vegetation would consist of recently planted seedlings.

    These scenarios estimate year 1 conditions for the new bypasses.
- **Scenarios 3A (Vegetated Short Bypass) and 3B (Vegetated Long Bypass).** These two scenarios represent postmitigation (year 40) conditions for Guadalupe Creek and the bypasses. These scenarios assume the same year 40 vegetation conditions for the bypasses as those used for lower Guadalupe Creek in Scenario 1B.

The assumptions for these six scenarios are summarized in Table 3.

# Results

As described below, even before vegetation becomes established along the bypass channels, the bypass channels are expected to reduce average water temperatures in the upper reaches of the upper project area (i.e., between the drop structure and stream gage 23B) during the late spring through early fall, with the long bypass being more effective than the short bypass. The cooling effects of the unvegetated bypasses on maximum temperatures, however, are small, and for some months there are temperature increases. The cooling effect of the bypass channels following full growth of vegetation is large, with average temperatures in Scenario 3B (vegetated long bypass) being up to 5.8ºF cooler than Scenario 1B (no bypass with mature vegetation along lower Guadalupe Creek).

Scenario 1A (no bypass under existing conditions) should be compared to Scenarios 2A and 2B (the unvegetated-bypass scenarios [i.e., unvegetated short bypass and unvegetated long bypass]). The comparison of Scenario 1A to Scenarios 2A and 2B is shown in Figures 11–16. This comparison shows the estimated immediate effect of creating a bypass, prior to the growth of vegetation along the bypass channels and prior to any additional growth of the vegetation along lower Guadalupe Creek.

Scenario 1B (no bypass with mature vegetation along Guadalupe Creek) represents the same conditions as Scenario 1A, except that mitigation plantings along Guadalupe Creek are fully grown. Scenario 1B should be compared to Scenarios 3A and 3B (the vegetated-bypass scenarios [i.e., vegetated short bypass and vegetated long bypass]). This comparison shows the estimated long-term effects of creating a bypass.

## Longitudinal Plots for August and April

Longitudinal results are shown for Guadalupe Creek (segments 4–6) through Almaden Lake (segment 17), the area upstream of the drop structure (segment 18), and the upper project area (segments 19–29) for August and April (Figures 11 and 12). The values shown represent temperatures at the downstream end of the segments. August represents one of the hottest months, when temperature effects are likely to be relatively large. August is also a month of concern for juvenile steelhead. April represents a month of concern for out-migrating steelhead smolts. For the dry/median year, flashboards are assumed to be present for May–October, so April represents a month with no flashboards.

The simulated temperatures for August show that lower Guadalupe Creek (segments 5 and 6) is expected to be cooler once the mitigation plantings are fully grown (Figure 11 and Table 4). For August, average temperatures were 3.6ºF cooler, and the average maximum temperatures were 6.9ºF cooler with the full growth.

The segment 17 results represent the temperatures in the surface layer of Almaden Lake or the temperatures in the bypass around the lake, depending on the scenario. The August results show that, in segment 17, temperatures are highest under the no-bypass scenarios, intermediate with the unvegetated-bypass scenarios, and coolest with the vegetated-bypass scenarios. At this location, there is no difference between the short-bypass and long-bypass scenarios. Bypassing Almaden Lake has a larger effect on average temperatures than maximum temperatures because the diurnal temperature variation is much smaller in the lake than in the bypass channel because of the differences in depth.

In segment 18 in August, there is only a small cooling effect (0.5ºF) attributable to the growth of the mitigation plantings in Guadalupe Creek, which can be seen by comparing the no-bypass scenarios (1A and 1B) (Figure 11). Differences between the short and long bypasses appear in this segment. Under full-growth conditions, the long-bypass temperatures are much cooler than the short-bypass temperatures. Under unvegetated conditions, the long bypass has cooler average temperatures but warmer maximum temperatures than the short bypass. This difference between the average and maximum temperatures is caused by the large diurnal variation associated with the shallow channel of the long bypass in segment 18 compared to the relatively deep channel of the short bypass.

By the downstream end of segment 19, however, both the maximum and average temperatures for August are cooler in the unvegetated-long-bypass scenario (2B) than they are in the unvegetated-short-bypass scenario (2A). The trend for the long-bypass temperatures (both average and maximum) to be cooler than the short-bypass temperatures is carried downstream of segment 19. For August, there is a noticeable difference in temperatures between the scenarios through segment 23, which is 2.8 miles downstream of the drop structure.

Segment 24 (Reach 10B) is relatively warm because it is shallow and poorly shaded (Figures 11 and 12). Mitigation plans are being finalized for Reach 10B. It is expected that mitigation planting will occur in fall 2005. Once the mitigation becomes effective, temperatures in this reach should be reduced and, if a bypass were created, there would be better continuity of cooler temperatures.

The April temperature patterns (Figure 12) differ from the August patterns because of seasonal differences and because the flashboards were not in place in April as they were in August. In the Almaden Lake area (segment 17), the maximum temperatures in the unvegetated-bypass scenarios are warmer than the maximum temperatures in Scenario 1A (no bypass), although the average temperatures under the unvegetated bypass conditions are cooler. This difference occurs because of the small diurnal variation in Almaden Lake.

In April, the full growth of mitigation plantings in Guadalupe Creek has a relatively large cooling effect (1.4ºF) on segment 18 temperatures because the volume of segment 18 is reduced, even when there is no bypass, by the absence of flashboards. The smaller volume allows the Guadalupe Creek water to warm less as it passes through segment 18.

The bypass channel in segment 18 is shallower and has less volume than the existing channel when the flashboards are out, hence the relatively high maximum temperatures but cool average temperatures for the unvegetated-long-bypass scenario in April.  The average segment 18 temperatures for the unvegetated-short-bypass are warmer in April than the no-bypass temperatures, even though they were cooler in segment 17.  The explanation is that some of the cool water from the bottom of Almaden Lake contributes to the segment 18 temperatures under the no-bypass scenarios but not under the bypass scenarios. The average and average maximum temperatures in April are coolest for the vegetated bypass scenarios and remain noticeably cooler through segment 23.

## Temperature Effects at Individual Segments through the Dry/Median Year

Figures 13–16 show monthly temperature patterns through the dry/median year for segments 6, 17, 18, and 23.  Differences between the scenarios are shown in Tables 4–6.  As a result of vegetation growth, temperatures in segment 6 are expected to be cooler by up to 4.5ºF for monthly average temperatures and 8.1ºF cooler for the monthly average of the daily maximum temperatures.  This cooling in lower Guadalupe Creek is expected to reduce temperatures in segment 18 by up to 1.4ºF, with the largest cooling effect occurring in the spring, when the flashboards are not in place (Figure 13 and Table 4).

In segment 17, the vegetated-bypass temperatures (both average and average maximums) are cooler than for Scenario 1B through most of the year (Figure 14 and Tables 5 and 6).  In addition, the average unvegetated-bypass temperatures are cooler than for Scenario 1A, but the diurnal variation under the unvegetated conditions is high enough to make the maximum temperatures similar to the maximums for the no-bypass scenario.  Under the no-bypass scenarios, the simulated temperatures shown for segment 17 represent only surface temperatures.  Fish passing through the lake could access cooler temperatures by swimming deeper.

In segment 18 (Figure 15 and Tables 5 and 6), there are large reductions in temperature under Scenario 3B (vegetated long bypass), particularly during the summer months.  Compared to Scenario 1B (no bypass), the average temperatures of Scenario 3B were up to 5.8ºF cooler, and maximum temperatures were up to 5.5ºF cooler (Tables 5 and 6).  Average temperatures for Scenario 3B are also significantly cooler than for Scenario 1B (i.e., multiple months with a temperature reduction of more than 3ºF).  Average and average maximum temperatures for Scenario 3A (vegetated short bypass) provide a moderate temperature reduction (multiple months with a temperature reduction of more than 1ºF).  The maximum temperatures for Scenario 2B (unvegetated long bypass) and the average and average maximum temperatures for Scenario 2A (unvegetated short bypass) do not offer a clear cooling benefit.

By the downstream end of segment 23, which is 2.8 miles downstream of the drop structure, the simulated temperature benefits of the bypasses is 1.1ºF or less (Figure 16 and Tables 5 and 6).

# Additional Considerations

An Almaden Lake bypass could benefit fish in several ways. The temperature reductions described in this report could benefit Chinook salmon or steelhead that may pass through or reside in the upper reaches of the upper project area and Almaden Lake. The greatest temperature reductions are expected to occur in the summer, when the anadromous fish life stage most likely to occur in the Guadalupe River system is juvenile steelhead. Other potential anadromous fish benefits associated with a bypass are reduced predation and a more direct route to upstream tributaries.

There would be clear temperature benefits associated with a shaded Almaden Lake bypass. However, prior to determining whether a bypass should be constructed, project design and cost would need to be evaluated. In addition, potential use of the deep portion of the lake by anadromous fish should be assessed. Further evaluation should also include the other ecological benefits and constraints that might be associated with an Almaden Lake bypass.

Furthermore, alternatives to a bypass should be considered. One possible alternative could be cooling water in the upper portion of the Guadalupe River by increasing the amount of water being withdrawn from the bottom of Almaden Lake. Water could be pumped from the bottom of the lake through a pipe, or a temperature curtain could be installed to reduce the amount of water coming from the surface of the lake. Another possible alternative would include diverting water for offstream percolation from the surface of Almaden Lake instead of segment 18. The relocation of the diversion point could allow water levels in the area between the drop structure and the lake to be lowered, allowing segment 18 to become more riverine. A riverine channel at this location could allow vegetation to shade the water and allow the Guadalupe Creek water to stay cool for a longer distance once it enters the river.

# Conclusions

Recalibration of the JSATEMP stream temperature model improved the model's ability to match the 2002 and 2003 temperatures measured at the drop structure. Recalibration had little effect on model performance for 1997 but caused a reduction in the model's ability to match the 1996 measured drop structure temperatures. A number of changes occurred in the operations and measurements at the drop structure in 1999 as a result of the installation of the fish ladder. These changes may be the cause of the apparent differences between the 1996-1997 and 2002-2003 temperatures.

The changes made to improve model ability to match the 2002-2003 temperatures at the drop structure were routing the Guadalupe Creek flow into segment 18, adding a local accretion of 2 cfs to segment 18, increasing the amount of Almaden Lake outflow coming from the bottom layer, and changing the dimensions of segment 18. Additional information could help determine whether the changes made for recalibration accurately portray the real physical conditions. Such additional information could include temperature measurements of the Almaden Lake outflow at the upstream end of segment 18, flow and temperature measurements at the old and new temperature probe locations for the drop structure, and improved water balance information for the inflows to the channel upstream of the drop structure.

The magnitude of the simulated benefits of creating a bypass depends somewhat on model inputs. The presence of local accretions can dampen the effect of warming in Almaden Lake and can dampen the effect of using a bypass. For this reason, the addition of the 2-cfs accretion to segment 18 has the effect of reducing the estimated benefit of a bypass. The local accretions are unlikely to be much more than 2 cfs because flows over the drop structure can be fairly low (average flow of 2.3 cfs for July 1996 and 3.9 cfs for July of 1997). The effect of the bypasses also depends on conditions in the bypasses. The conditions modeled here should be attainable; they represent a fairly shallow and narrow channel with good, but not complete, shade.

Temperatures from Alamitos Creek and Guadalupe Creek also play a role in the temperature effects of the bypasses. The creek temperatures have less effect when Almaden Lake is present than when there is no lake or backwater area (i.e., backwater created by the installation of flashboards at the drop structure). The simulated creek temperatures are considered to be fairly accurate because the model has been able to match temperatures at the downstream ends of Alamitos and Guadalupe Creeks.

The flows used for simulating the dry/median year represent fairly low-flow conditions at the drop structure because these flows have been altered to represent the low flows that have been going over the drop structure since 1995. Flows over the drop structure are low because the SCVWD has been diverting more water upstream of the drop structure in response to their inability to use instream percolation since 1995. Dry/median year flows at the drop structure are set at 3.5 cfs for most months. Higher flows would likely reduce the cooling effect of the bypasses but carry the cool water farther downstream before warming to no-bypass temperatures.

In the short term, before trees would have a chance to grow along the bypass channels, the creation of either one of the bypasses is unlikely to have a deleterious effect on water temperatures. The maximum effect of the bypasses is best assessed at the downstream end of segment 18, just before the water leaves the area of modification. Under the worst-case condition for the bypasses, maximum temperatures are occasionally warmer than under the no-bypass condition (by up to 2.6ºF at segment 18), but average temperatures are generally cooler (by up to 4.0ºF at segment 18).

After vegetation along the bypasses has grown, the potential benefits of the long bypass are much greater than the potential benefits of the short bypass. During the summer months, average temperatures at the downstream end of segment 18 are cooled only 1–2ºF with the short bypass but 5–6ºF with the long bypass. Summer maximum temperatures at the drop structure are cooled 1–2ºF with the short bypass but 4–6ºF with the long bypass.

# References Cited

## Printed References

Jones & Stokes Associates. 1999. *Simulation of water temperature for the Guadalupe River flood control project located in downtown San Jose, California.* Preliminary Draft. December 21. (J&S F019). Sacramento, CA. Prepared for U.S. Army Corps of Engineers, Sacramento, CA.

Jones & Stokes. 2003a. *Summary of JSATEMP recalibration and results for accelerated locally preferred project.* July 23. Memo to Santa Clara Valley Water District and U.S. Army Corps of Engineers, San Francisco District.

———. 2003b. *Upper Guadalupe: soil–vegetation growth memo for 4/30 GWIWG meeting.* April 28, memo to Upper Guadalupe flood protection project design review team participants.

———. 2004. Water year 2003 mitigation monitoring report for the Guadalupe River Project, downtown San Jose, California. Final. April. (J&S 03-319.) Sacramento, CA. Prepared for U.S. Army Corps of Engineers, Sacramento District, Sacramento, CA, in coordination with Santa Clara Valley Water District, San Jose, CA.

Santa Clara Valley Water District and U.S. Army Corps of Engineers. 2001. *Environmental impact report/environmental impact statement for the upper Guadalupe River flood control project, volume IX, additional information.* Final. March.

U.S. Army Corps of Engineers and Santa Clara Valley Water District. 2001. *Final integrated general re-evaluation report/environmental impact report-supplemental environmental impact statement for proposed modifications to the Guadalupe River Project, downtown San Jose, California.* Vol. 1. February. State Clearinghouse # 199902056, filed with U.S. EPA April 2001.

## Personal Communications

Aguilera, Joe, and John Bozzo. 2004. Operations and maintenance. Santa Clara Valley Water District. July 8, 2004—e-mail.

Nam, Judy. Hydrologist. Santa Clara Valley Water District. June 25, 2004—water balance calculations received in an Excel file.

Shay, John. 2004. Water Quality Specialist. Santa Clara Valley Water District. May 17, 2004—phone call.

**Table 1.** Flow Conditions for Dry/Median Year

| Month | Flow upstream of Masson Dam (cfs) | Diversions at Masson Dam (cfs) | Flow in Alamitos Creek at Gage 70 (cfs) | Diversions upstream of Alamitos Drop Structure (cfs) |
|---|---|---|---|---|
| January | 1 | 0.3 | 0.5 | 0 |
| February | 3.5 | 0.5 | 6 | 0 |
| March | 1 | 0.3 | 1 | 0 |
| April | 1 | 0.3 | 1 | 0 |
| May | 7.1 | 6.1 | 11.1 | 8 |
| June | 8.2 | 6.2 | 6.5 | 4.5 |
| July | 5 | 3 | 6.4 | 4.5 |
| August | 3.4 | 1.4 | 7.4 | 5.5 |
| September | 1.4 | 0.4 | 4.5 | 1.5 |
| October | 1 | 0.3 | 2.8 | 0 |
| November | 1 | 0.3 | 2.5 | 0 |
| December | 1 | 0.3 | 1.5 | 0 |

Notes: cfs = cubic feet per second.

For the dry/median year, accretions of 1 cfs are assumed to enter lower Guadalupe Creek from the Los Capitancillos percolation ponds.

Refer to Figures 1 and 2 for the locations of features identified in the table.

**Table 2.** Shade and Channel Geometry Parameter Values for Existing and Altered Channels

| | Existing Channel by Segment | | | Bypass/Postmitigation by Segment | | |
|---|---|---|---|---|---|---|
| Parameter | 6 | 17 | 18 | 6 | 17 | 18 |
| Length (miles) | 0.85 | 0.4 | 0.32 | 0.85 | 0.4 | 0.32 |
| Trunk offset (feet) [a] | 20 | 350 | 115 | 17 | 17 | 17 |
| Tree height (feet) | 30 | 15 | 10 | 58 | 58 | 58 |
| Crown diameter (feet) | 26 | 15 | 10 | 44 | 44 | 44 |
| Linear vegetation fraction [b] | 0.5 | 0.05 | 0.05 | .7 to .8 | 0.75 | 0.75 |
| Shade density [c] | 0.87 | 0.8 | 0.8 | 0.87 | 0.87 | 0.87 |
| Average depth (feet) at 1 cfs | 1.1 | 6.4[d] | 4 [e] | 1.1 | 1.1 | 1.1 |
| Width (feet) at 1 cfs | 19 | 683.0 | 150 [e] | 19 | 19 | 19 |

Notes: Segments 5 and 6 cover the length of the lower Guadalupe Creek mitigation area. Parameters for segment 5 are similar to those for segment 6 and, therefore, are not shown in this table. Model segment 17 covers the length of Almaden Lake. The lake is represented by a surface layer and a bottom layer. With a bypass, segment 17 becomes a single layer representative of a riparian channel. Segment 18 extends from Almaden Lake to the Alamitos Drop Structure.

There are separate vegetation parameters for the east and west banks. The values for both banks are similar except for the linear vegetation fractions for lower Guadalupe Creek (where a range of values is provided).

cfs = cubic feet per second.

[a] *Trunk offset* is the average distance from the center of the channel to the trees closest to the water.

[b] *Linear vegetation fraction* is the fraction of a segment that is lined with vegetation.

[c] *Shade density is the fraction* of sunlight that is blocked from reaching the water in areas that are shaded.

[d] Average depth of surface layer.

[e] The average depth and width values of 4 feet and 150 feet, respectively, for segment 18 under existing conditions are the dimensions assumed when flashboards are in place. When the flashboards are absent, the channel is shallower and narrower (2.4 feet deep and 52 feet wide at 1 cfs). For the dry/median year, the flashboards are assumed to be in place from May through October.

**Table 3.** Assumptions for the Scenarios to Simulate the Temperature Effects of an Almaden Lake Bypass

| | Shade Parameters in Segments | | | Channel Geometry Parameters in Segments | | |
|---|---|---|---|---|---|---|
| Scenarios | 6 | 17 | 18 | 6 | 17 | 18 |
| 1A: No Bypass under Existing Conditions | E | E | E | E | E | E |
| 1B: No Bypass with Mature Vegetation along LGC | N | E | E | E | E | E |
| 2A: Unvegetated Short Bypass | E | 0 | E | E | N | E |
| 2B: Unvegetated Long Bypass | E | 0 | 0 | E | N | N |
| 3A: Vegetated Short Bypass | N | N | E | E | N | E |
| 3B: Vegetated Long Bypass | N | N | N | E | N | N |

Notes: Lower Guadalupe Creek has already been recontoured. Therefore the existing channel represents postmitigation conditions.

E = Existing conditions.

N = New channel geometry or full growth of new vegetation.

0 = New vegetation, provides no shade benefit following planting.

LGC = Lower Guadalupe Creek.

**Table 4.** Simulated Reduction in Average and Average Maximum Water Temperatures in Lower Guadalupe Creek (Segment 6) and in the Guadalupe River upstream of the Alamitos Drop Structure (Segment 18) Resulting from the Full Growth of Mitigation Plantings along Lower Guadalupe Creek

| | Average by Segment | | Average Maximum by Segment | |
|---|---|---|---|---|
| Month | 6 | 18 | 6 | 18 |
| January | -0.2 | -0.1 | -0.4 | -0.1 |
| February | -0.2 | -0.1 | -0.4 | -0.1 |
| March | -1.9 | -0.8 | -3.5 | -0.8 |
| April | -3.3 | -1.4 | -5.8 | -1.4 |
| May | -4.2 | -0.2 | -7.2 | -0.2 |
| June | -4.5 | -0.4 | -8.1 | -0.4 |
| July | -4.2 | -0.5 | -7.9 | -0.5 |
| August | -3.6 | -0.5 | -6.9 | -0.5 |
| September | -3.3 | -0.5 | -5.7 | -0.4 |
| October | -2.4 | -0.3 | -3.8 | -0.3 |
| November | -0.3 | -0.1 | -0.5 | -0.1 |
| December | -0.2 | -0.1 | -0.3 | -0.1 |
| Largest Drop | -4.5 | -1.4 | -8.1 | -1.4 |

**Table 5.** Change in Average Monthly Temperature in Model Segments 17, 18, and 23 Associated with the Creation of a Short and Long Almaden Lake Bypass

| | Short Bypass by Segment | | | Long Bypass by Segment | | |
|---|---|---|---|---|---|---|
| Month | 17 | 18 | 23 | 17 | 18 | 23 |
| **Unshaded Bypasses (Scenarios 2A and 2B) Compared to No-Bypass Scenario 1A** | | | | | | |
| January | -0.1 | 0.4 | 0.1 | -0.1 | 0.3 | 0.1 |
| February | -1.0 | 0.1 | 0.0 | -1.0 | 0.0 | 0.0 |
| March | -1.9 | 0.7 | 0.2 | -1.9 | 0.0 | 0.1 |
| April | -2.7 | 0.5 | 0.1 | -2.7 | -0.5 | -0.1 |
| May | -5.2 | -0.7 | -0.1 | -5.2 | -2.4 | -0.3 |
| June | -6.1 | -0.5 | -0.1 | -6.1 | -3.3 | -0.5 |
| July | -6.3 | -0.8 | -0.1 | -6.3 | -3.7 | -0.6 |
| August | -6.7 | -1.2 | -0.2 | -6.7 | -4.0 | -0.6 |
| September | -4.8 | -0.6 | -0.1 | -4.8 | -3.5 | -0.7 |
| October | -4.3 | -0.4 | -0.1 | -4.3 | -1.9 | -0.4 |
| November | -4.9 | -2.2 | -0.6 | -4.9 | -2.4 | -0.6 |
| December | -1.7 | -0.5 | -0.1 | -1.7 | -0.4 | -0.1 |
| Largest Drop | -6.7 | -2.2 | -0.6 | -6.7 | -4.0 | -0.7 |
| **Shaded Bypasses (Scenarios 3A and 3B) Compared to No-Bypass Scenario 1B** | | | | | | |
| January | -0.5 | 0.3 | 0.1 | -0.5 | 0.0 | 0.0 |
| February | -1.2 | 0.0 | 0.0 | -1.2 | -0.1 | -0.1 |
| March | -4.2 | 0.1 | 0.1 | -4.2 | -1.9 | -0.3 |
| April | -6.5 | -0.5 | -0.1 | -6.5 | -3.6 | -0.5 |
| May | -6.2 | -1.3 | -0.2 | -6.2 | -3.7 | -0.6 |
| June | -7.9 | -1.3 | -0.2 | -7.9 | -5.6 | -0.8 |
| July | -8.1 | -1.5 | -0.2 | -8.1 | -5.8 | -0.9 |
| August | -8.3 | -1.8 | -0.3 | -8.3 | -5.8 | -1.0 |
| September | -7.2 | -1.1 | -0.2 | -7.2 | -5.6 | -1.1 |
| October | -7.4 | -0.7 | -0.2 | -7.4 | -3.7 | -0.8 |
| November | -5.1 | -2.3 | -0.6 | -5.1 | -2.7 | -0.8 |
| December | -2.0 | -0.6 | -0.2 | -2.0 | -0.7 | -0.2 |
| Largest Drop | -8.3 | -2.3 | -0.6 | -8.3 | -5.8 | -1.1 |

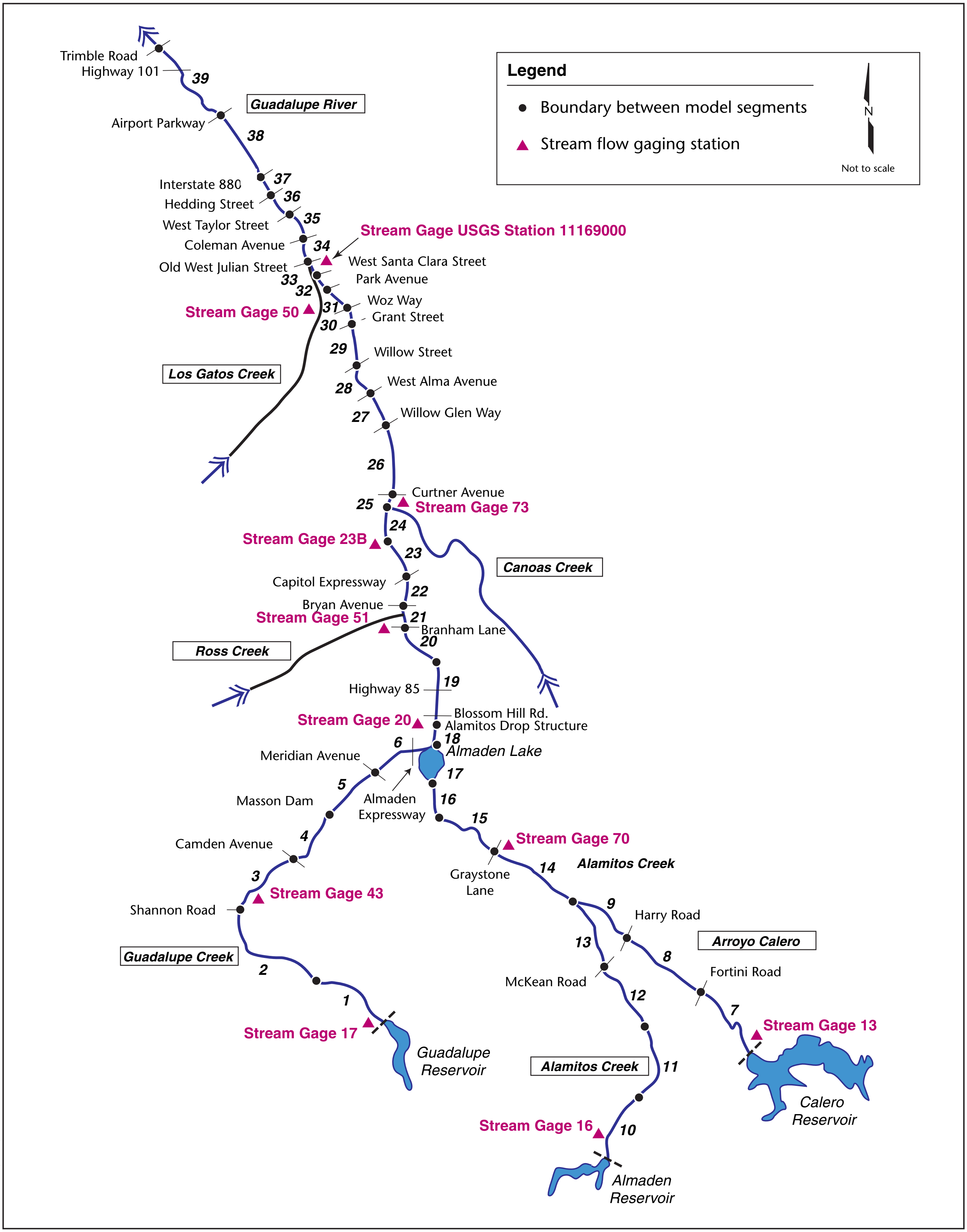
**Table 6.** Change in Average Maximum Temperatures in Model Segments 17, 18, and 23 Associated with the Creation of a Short and Long Almaden Lake Bypass

| | Short Bypass by Segment | | | Long Bypass by Segment | | |
|---|---|---|---|---|---|---|
| Month | 17 | 18 | 23 | 17 | 18 | 23 |
| **Unshaded Bypasses (Scenarios 2A and 2B) Compared to No-Bypass Scenario 1A** | | | | | | |
| January | 2.6 | 0.5 | 0.1 | 2.6 | 2.1 | 0.1 |
| February | 1.1 | 0.4 | 0.1 | 1.1 | 1.6 | 0.0 |
| March | 2.1 | 0.9 | 0.2 | 2.1 | 2.6 | 0.1 |
| April | 1.6 | 0.6 | 0.1 | 1.6 | 2.3 | -0.1 |
| May | -0.3 | -0.5 | -0.1 | -0.3 | 0.9 | -0.3 |
| June | -0.7 | -0.4 | -0.1 | -0.7 | 0.0 | -0.5 |
| July | -0.7 | -0.7 | -0.1 | -0.7 | -0.2 | -0.6 |
| August | -1.3 | -1.1 | -0.2 | -1.3 | -0.5 | -0.6 |
| September | 0.0 | -0.5 | -0.1 | 0.0 | -0.6 | -0.6 |
| October | 0.0 | -0.4 | -0.1 | 0.0 | 0.5 | -0.4 |
| November | -2.7 | -2.0 | -0.6 | -2.7 | -0.8 | -0.6 |
| December | 0.2 | -0.5 | -0.1 | 0.2 | 1.0 | -0.1 |
| Largest Drop | -2.7 | -2.0 | -0.6 | -2.7 | -0.8 | -0.6 |
| **Shaded Bypasses (Scenarios 3A and 3B) Compared to No-Bypass Scenario 1B** | | | | | | |
| January | 1.8 | 0.4 | 0.1 | 1.8 | 1.5 | 0.0 |
| February | 0.8 | 0.3 | 0.0 | 0.8 | 1.2 | -0.1 |
| March | -2.6 | 0.1 | 0.1 | -2.6 | -1.6 | -0.3 |
| April | -5.4 | -0.5 | -0.1 | -5.4 | -4.1 | -0.5 |
| May | -2.2 | -1.2 | -0.2 | -2.2 | -1.9 | -0.6 |
| June | -4.3 | -1.3 | -0.2 | -4.3 | -4.8 | -0.8 |
| July | -4.2 | -1.5 | -0.2 | -4.2 | -4.9 | -0.9 |
| August | -4.5 | -1.9 | -0.3 | -4.5 | -4.8 | -0.9 |
| September | -5.0 | -1.1 | -0.2 | -5.0 | -5.5 | -1.0 |
| October | -5.9 | -0.7 | -0.2 | -5.9 | -3.7 | -0.8 |
| November | -3.3 | -2.2 | -0.6 | -3.3 | -1.4 | -0.8 |
| December | -0.4 | -0.7 | -0.2 | -0.4 | 0.4 | -0.2 |
| Largest Drop | -5.9 | -2.2 | -0.6 | -5.9 | -5.5 | -1.0 |

02357.02 003 (07/04)

Jones & Stokes

Figure 1
Confluence of Guadalupe Creek, Alamitos Creek, and Guadalupe River
with the Assumed Alignment for the Almaden Lake Bypass



02357.02 014 (07/04)

Jones & Stokes

**Figure 2**
**JSATEMP Model Segments and Stream Flow Gages in the Guadalupe River Watershed**

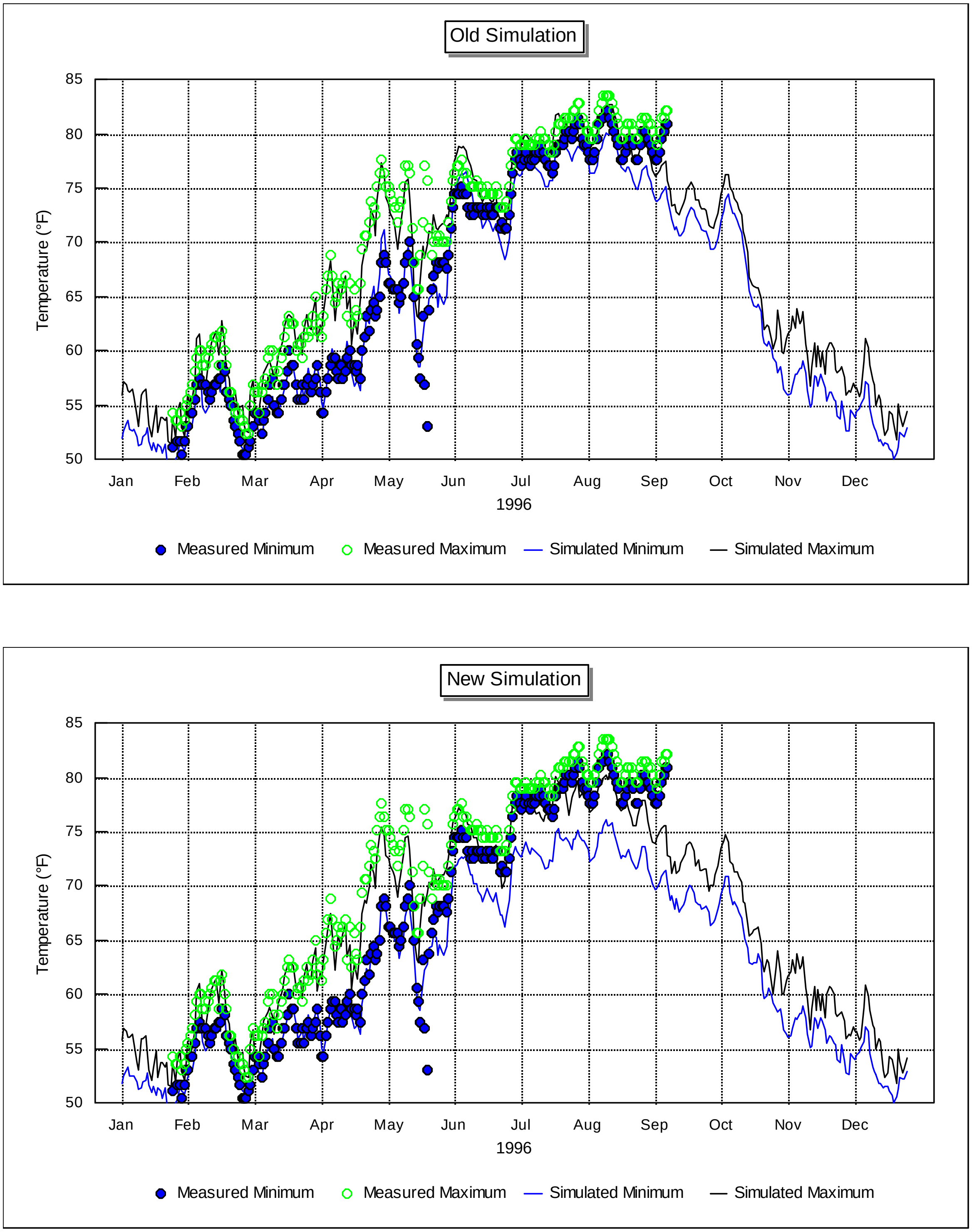


Figure 3. Water Temperature at the Alamitos Drop Structure during 1996, Comparison of Measured Temperatures to Old and New Simulated Temperatures

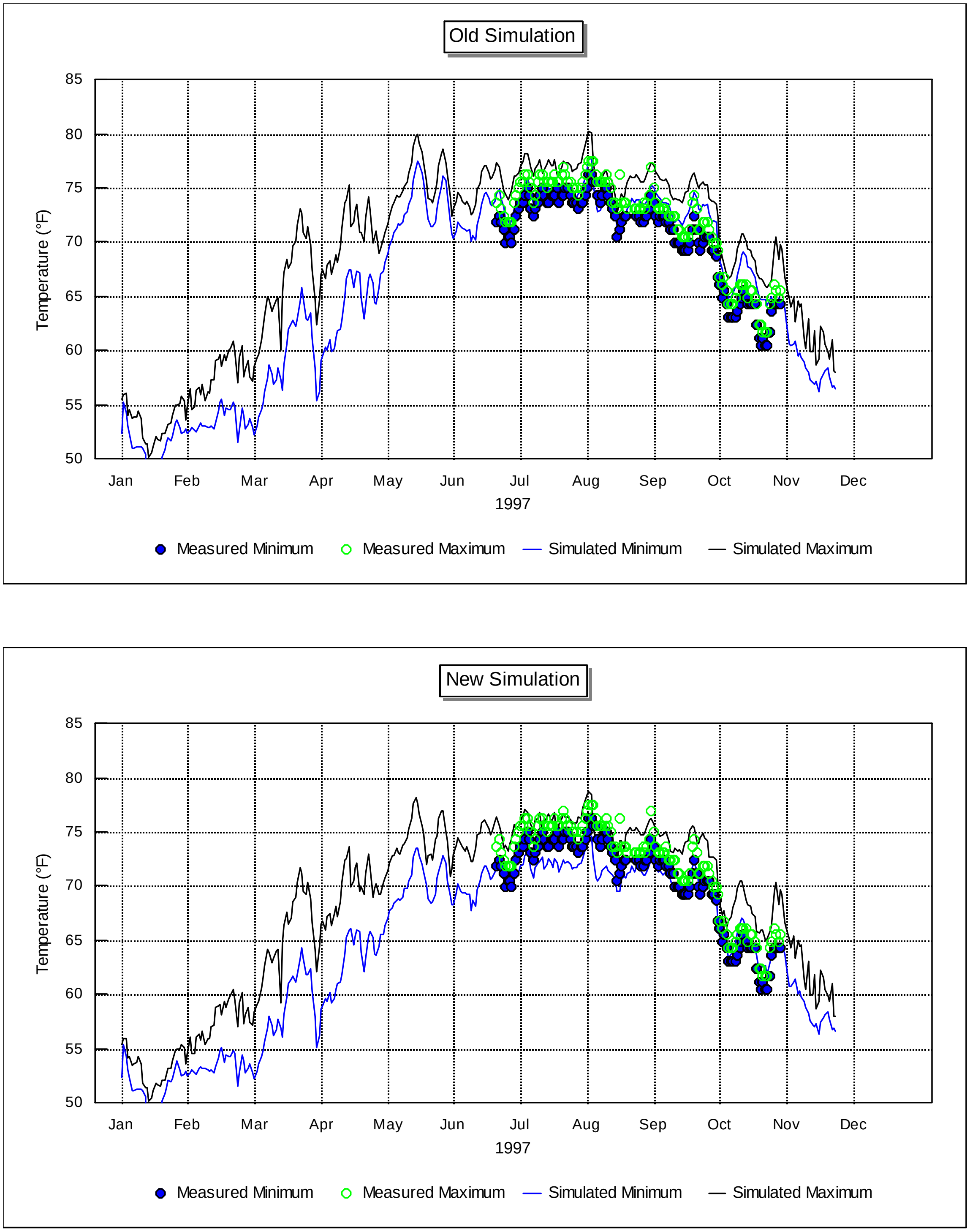
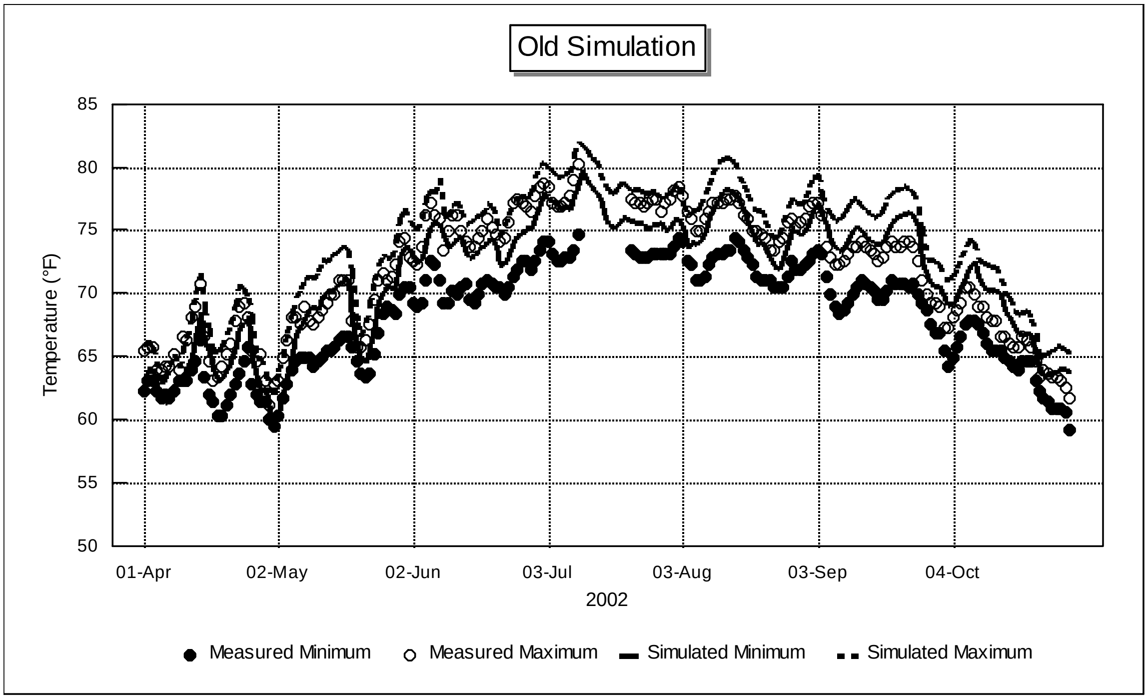


Figure 4. Water Temperature at the Alamitos Drop Structure during 1997, Comparison of Measured Temperatures to Old and New Simulated Temperatures



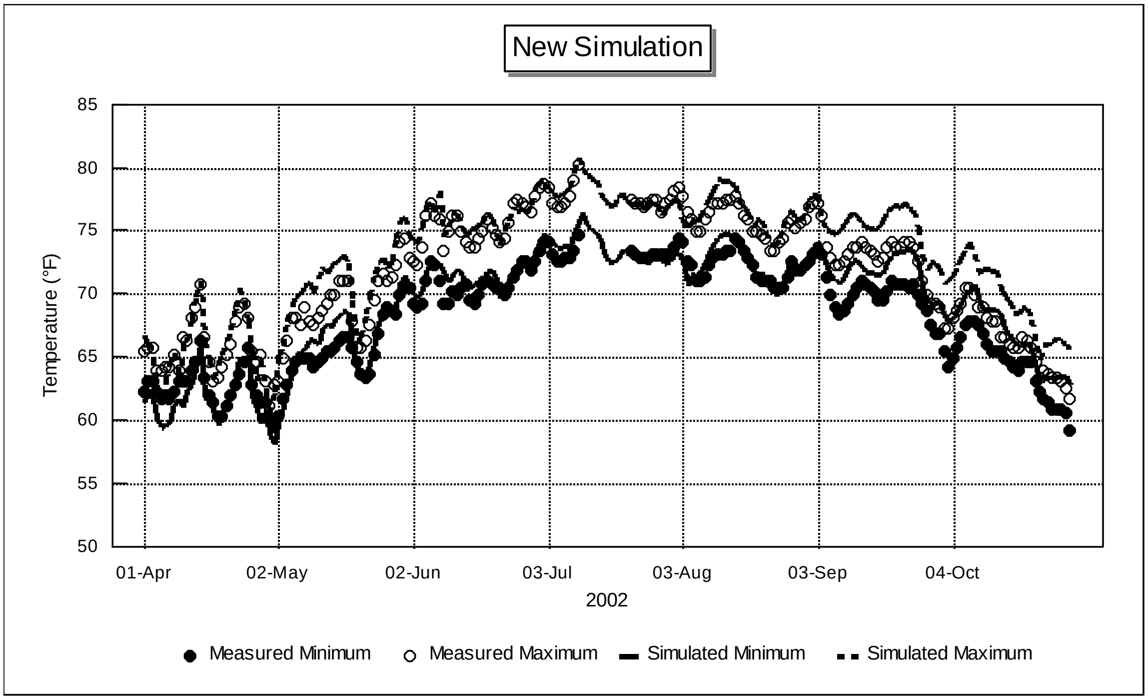
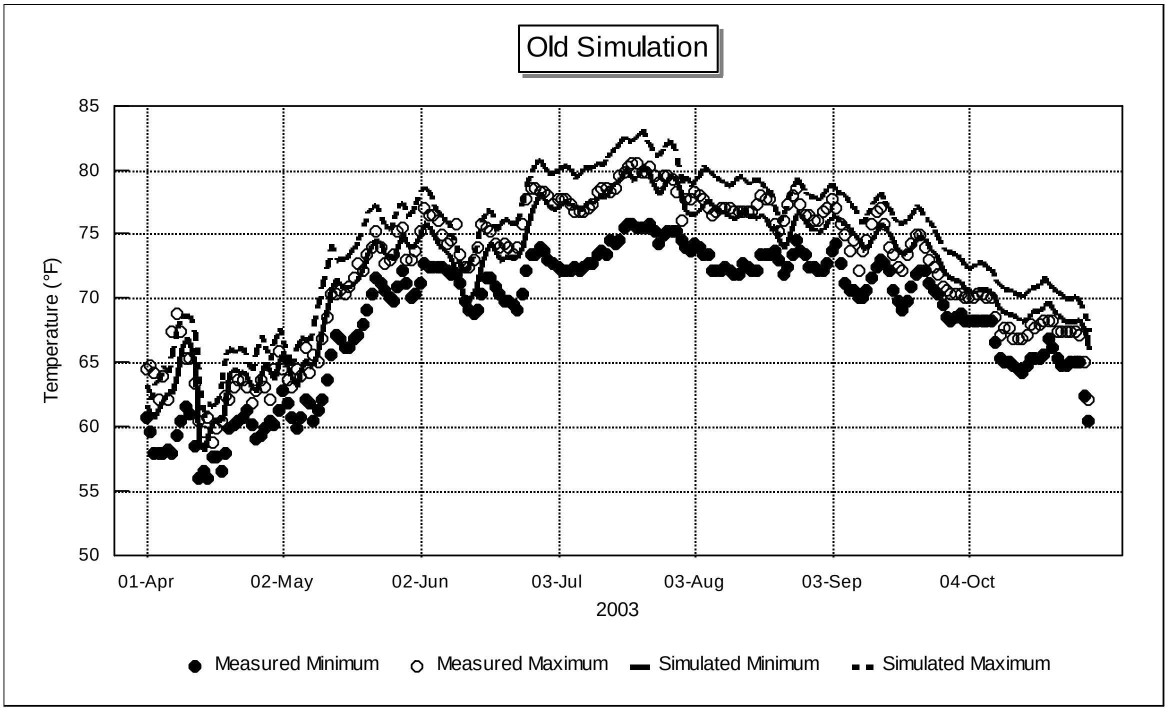


Figure 5. Water Temperature at the Alamitos Drop Structure during 2002, Comparison of Measured Temperatures to Old and New Simulated Temperatures



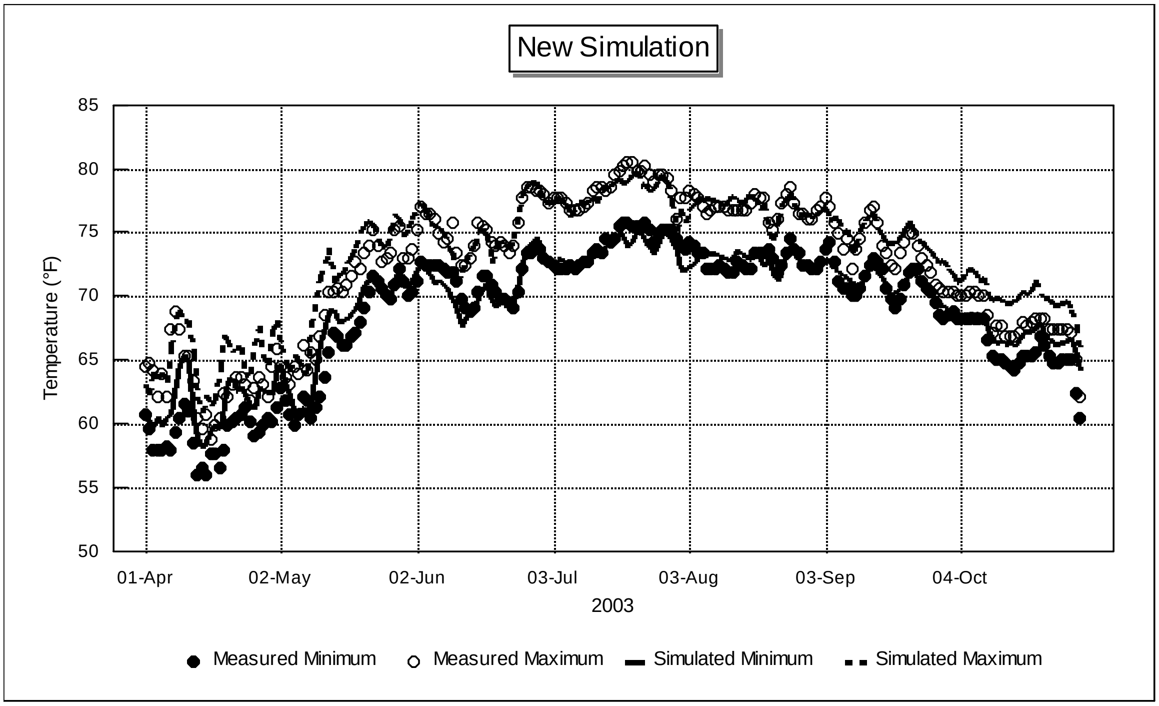
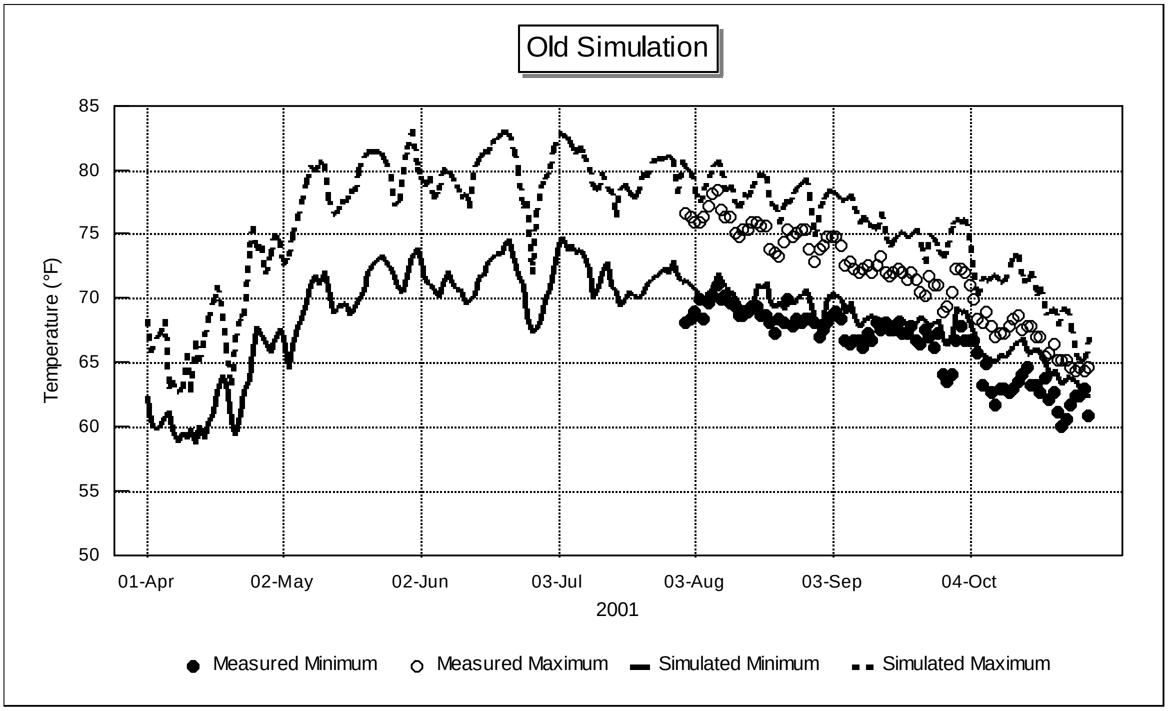


Figure 6. Water Temperature at the Alamitos Drop Structure during 2003, Comparison of Measured Temperatures to Old and New Simulated Temperatures



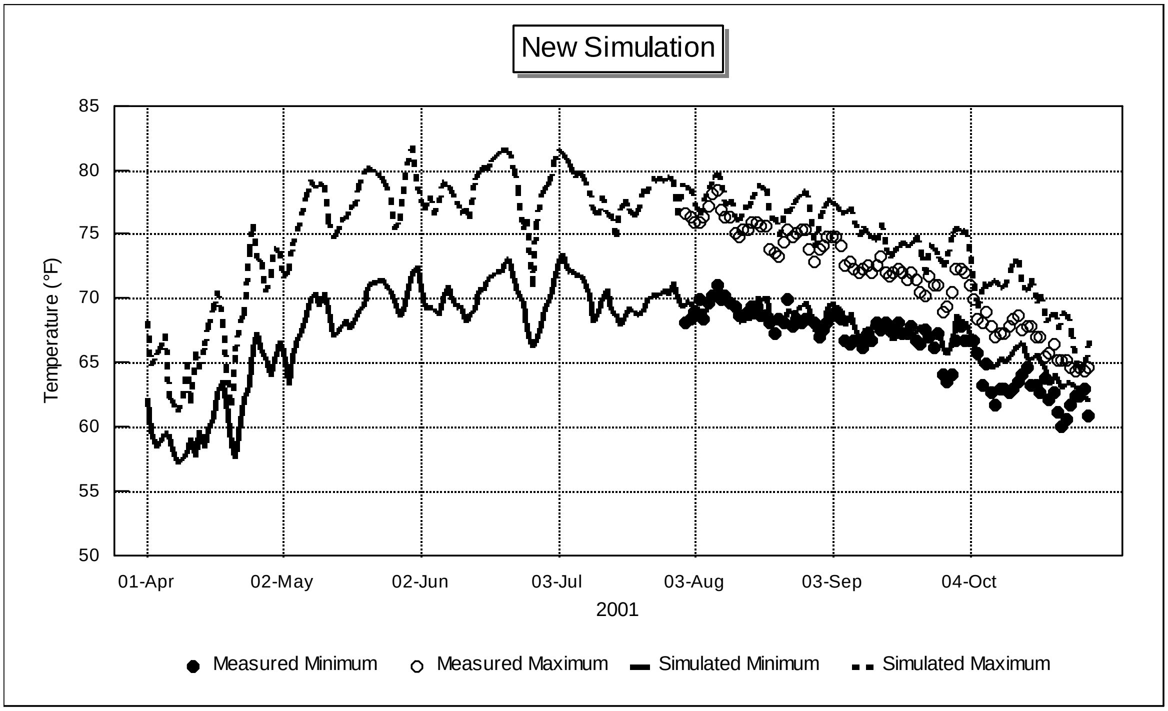


Figure 7. Water Temperature at Branham Lane during 2001, Comparison of Measured Temperatures to Old and New Simulated Temperatures

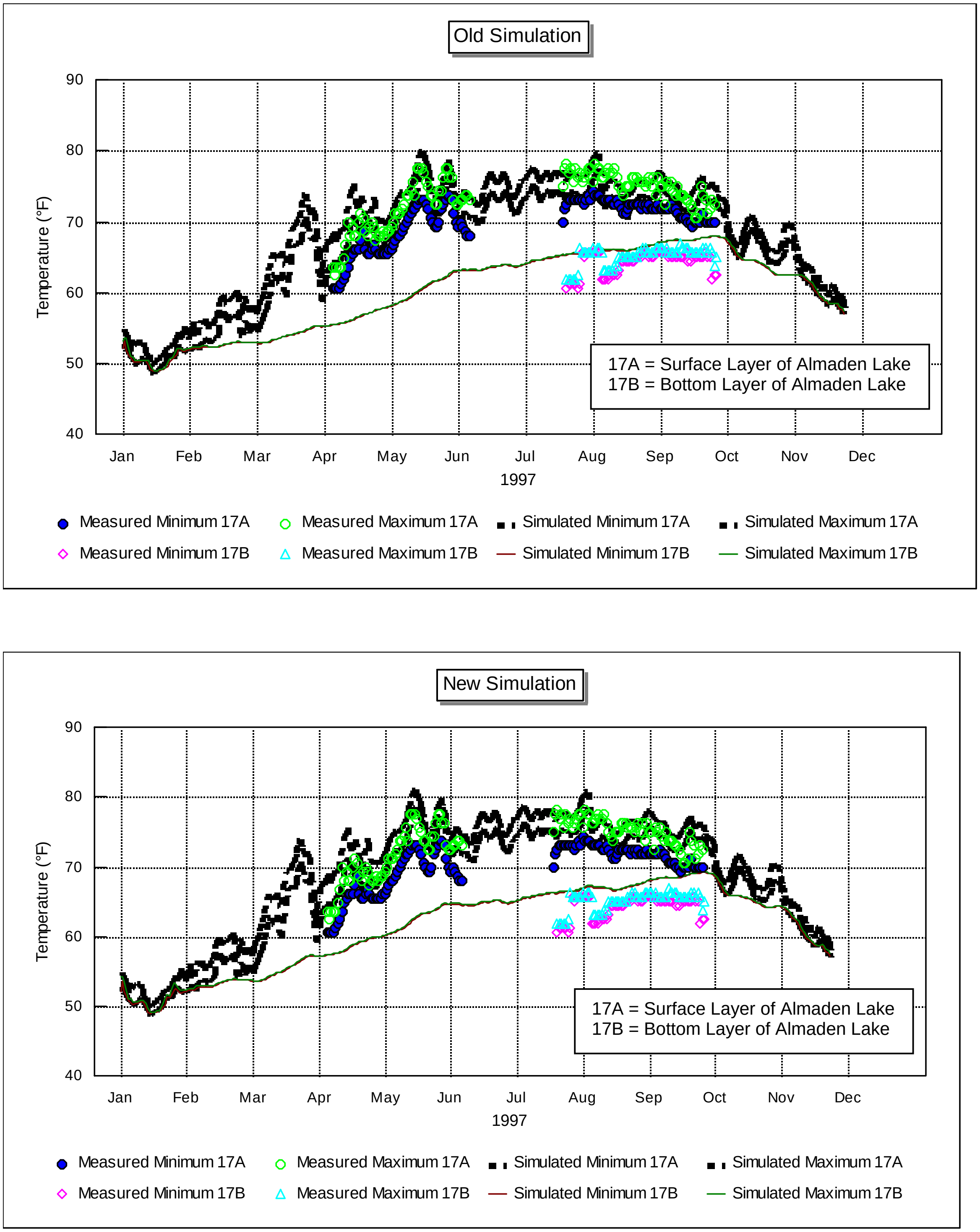
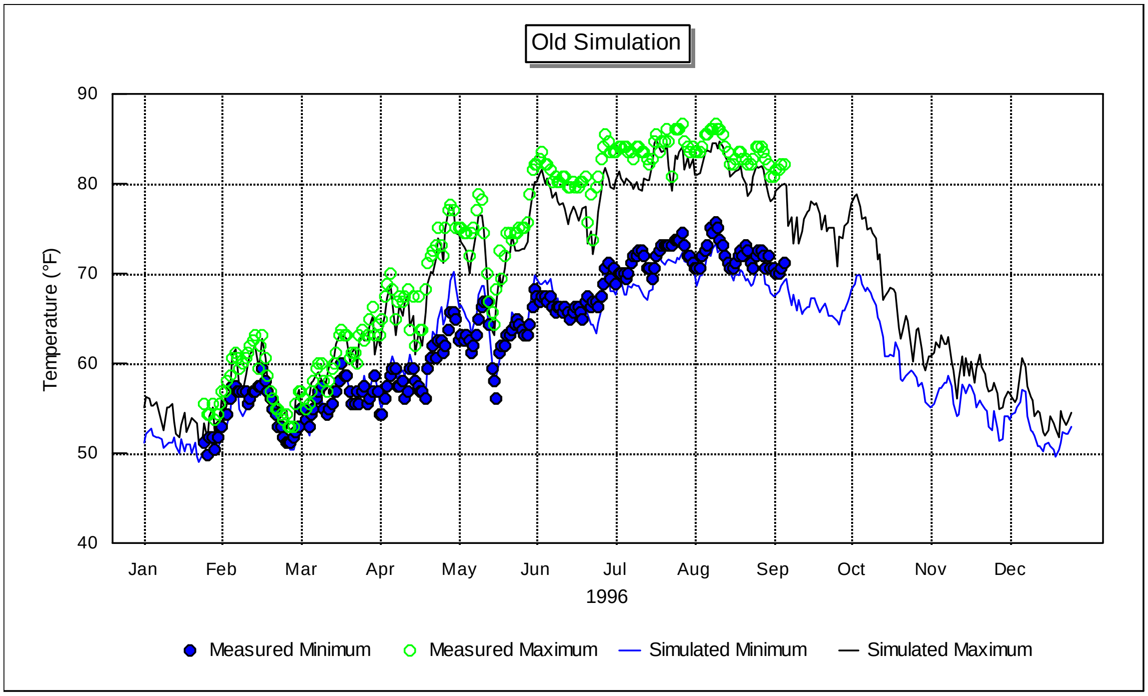


Figure 8. Water Temperature in Almaden Lake during 1997, Comparison of Measured Temperatures to Old and New Simulated Temperatures



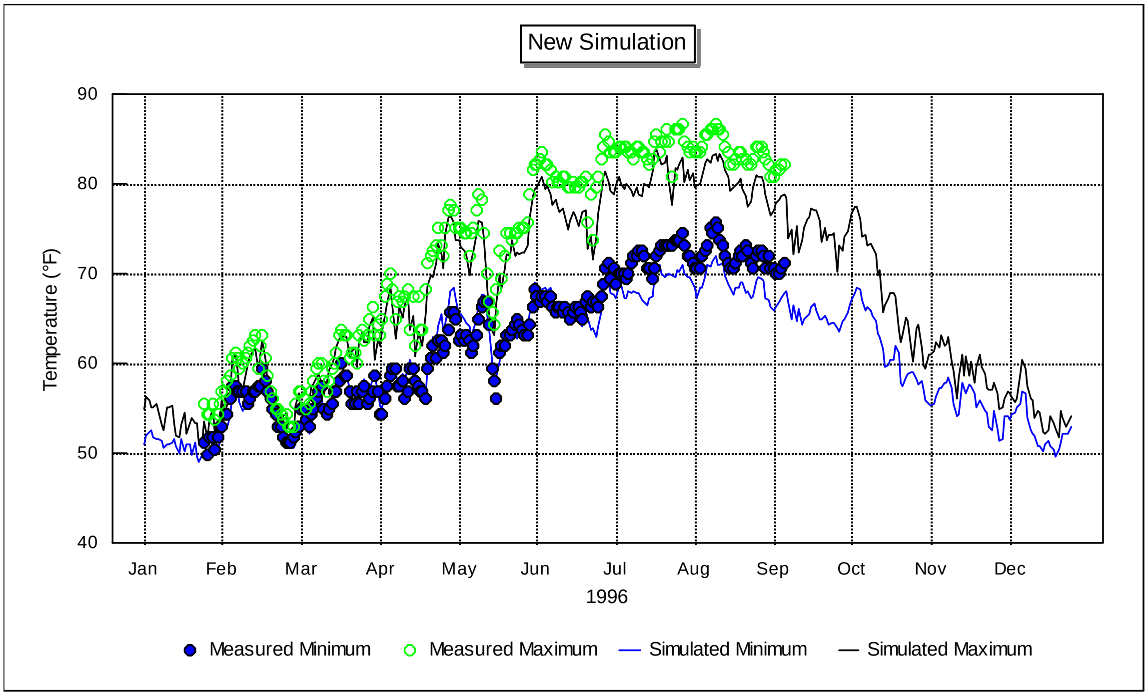


Figure 9. Water Temperature at Branham Lane during 1996, Comparison of Measured Temperatures to Old and New Simulated Temperatures

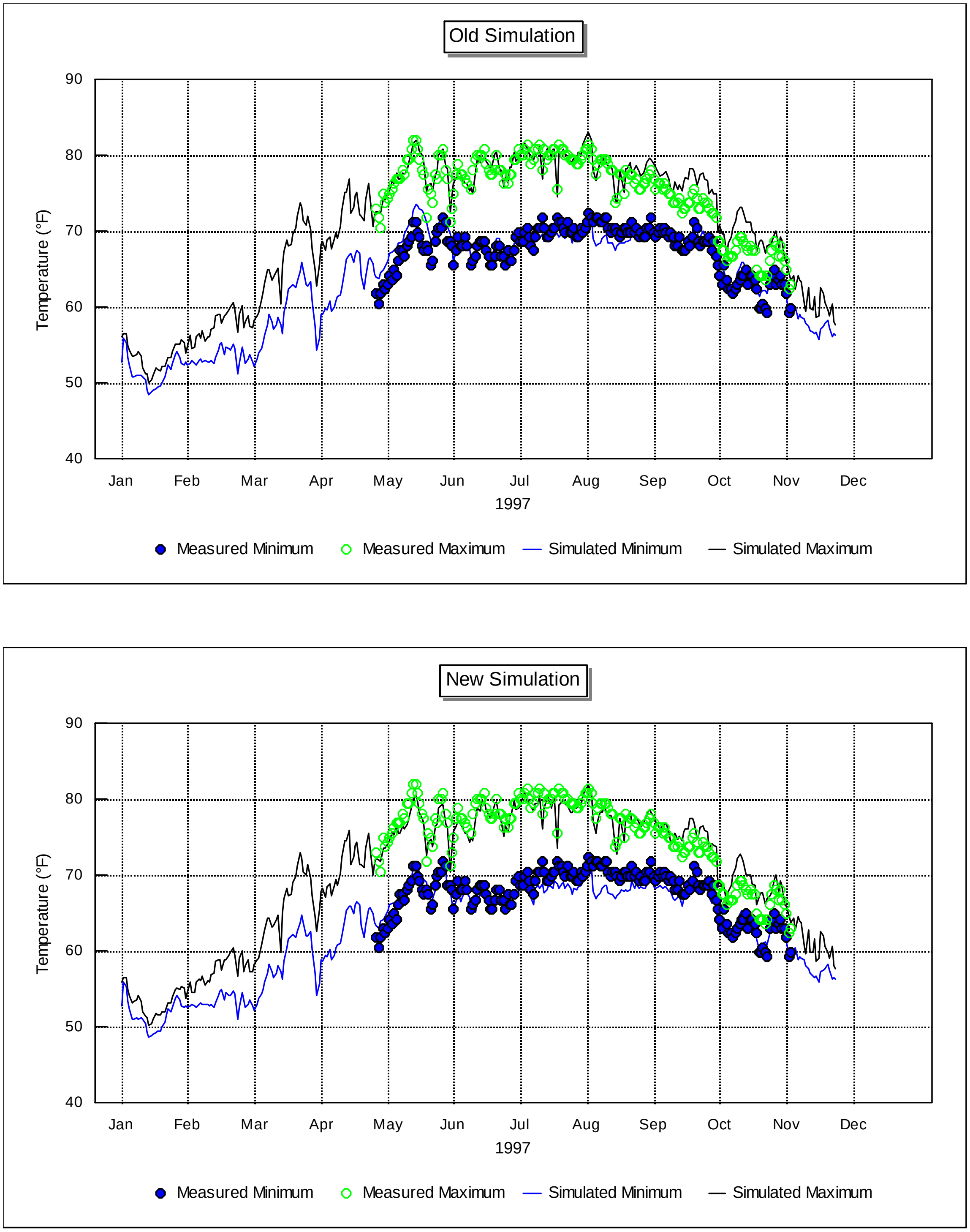


Figure 10. Water Temperature at Branham Lane during 1997, Comparison of Measured Temperatures to Old and New Simulated Temperatures

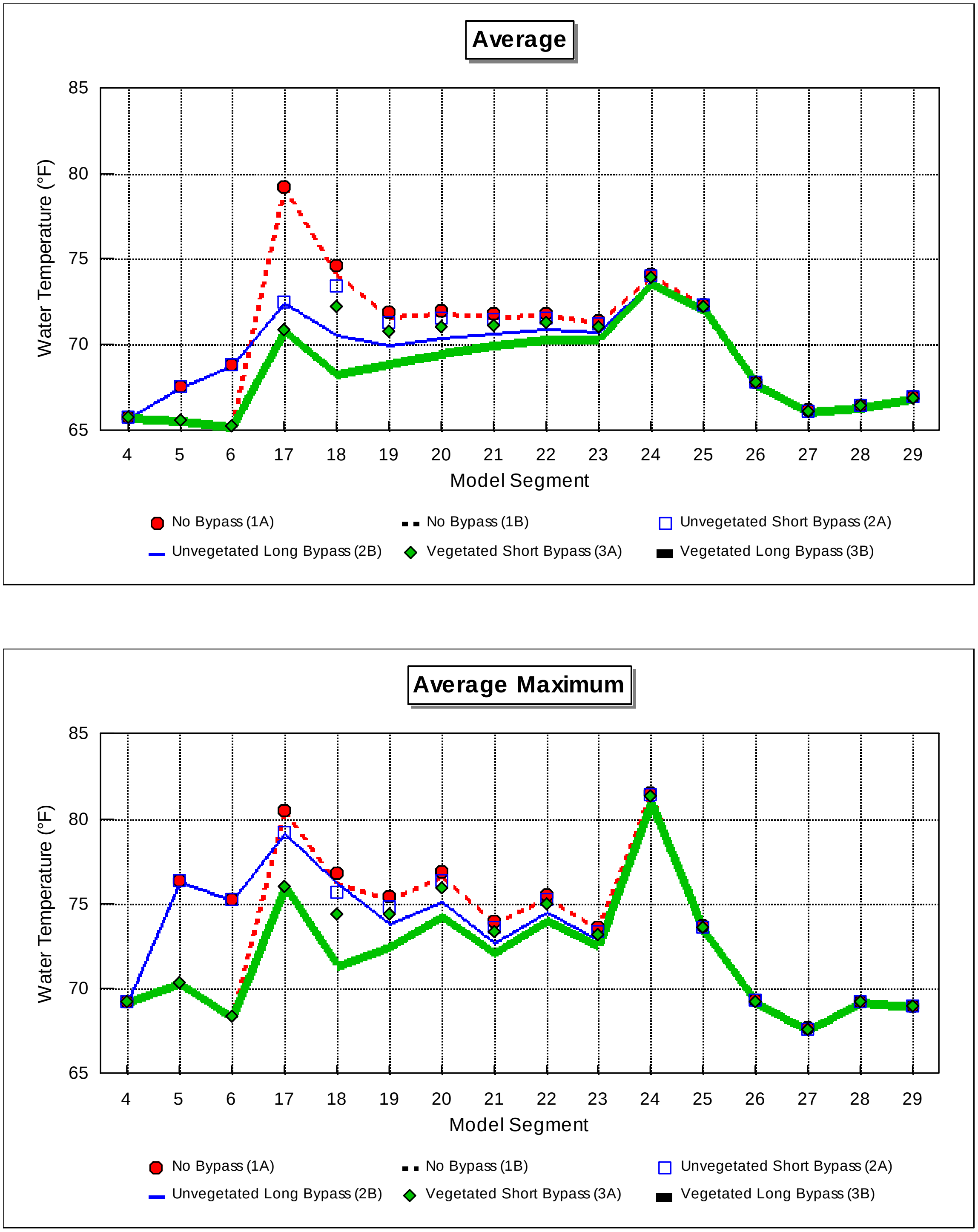


Figure 11. August Temperatures in Guadalupe Creek through the Upper Project Area during the Dry/Median Year

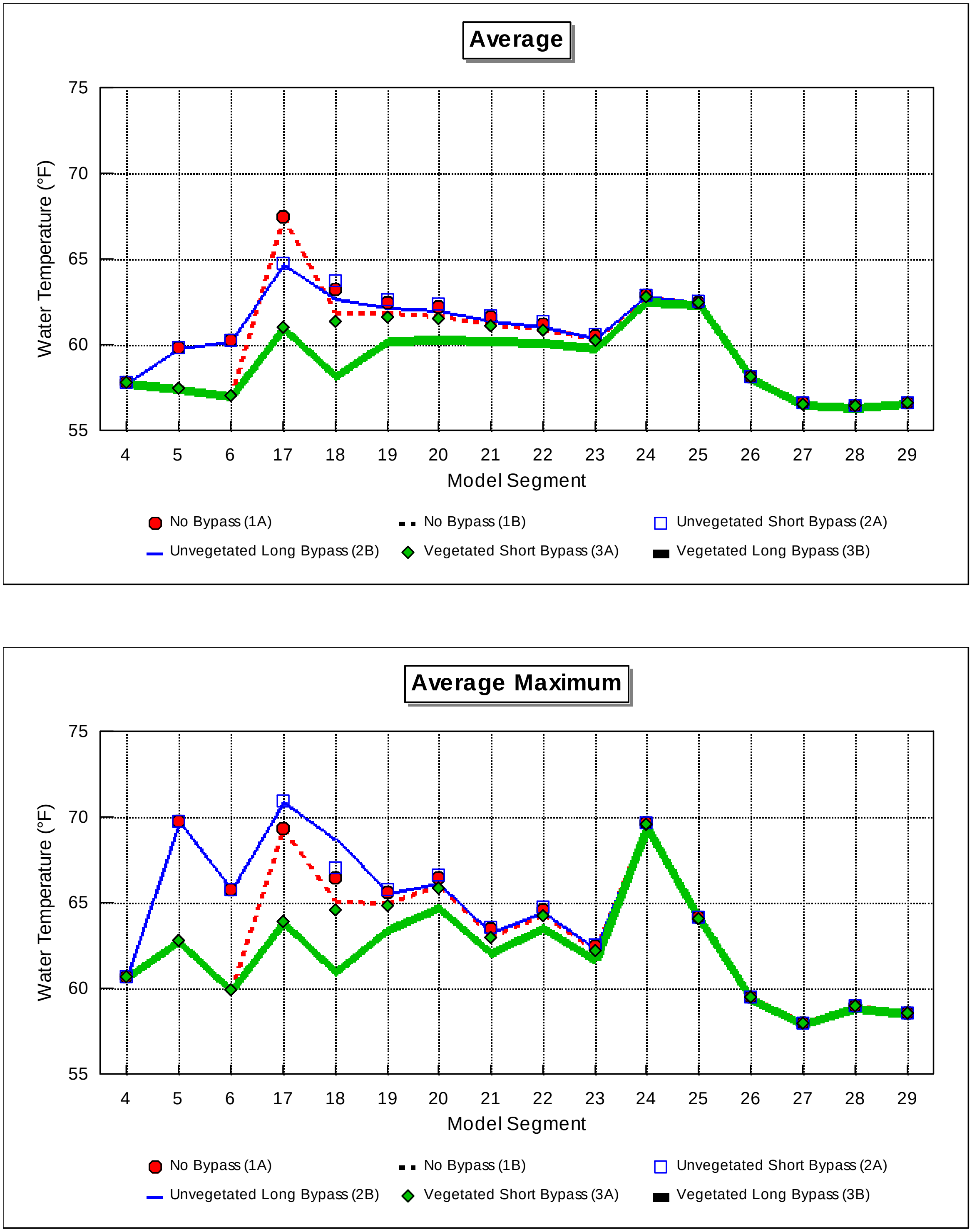


Figure 12. April Temperatures in Guadalupe Creek through the Upper Project Area during the Dry/Median Year

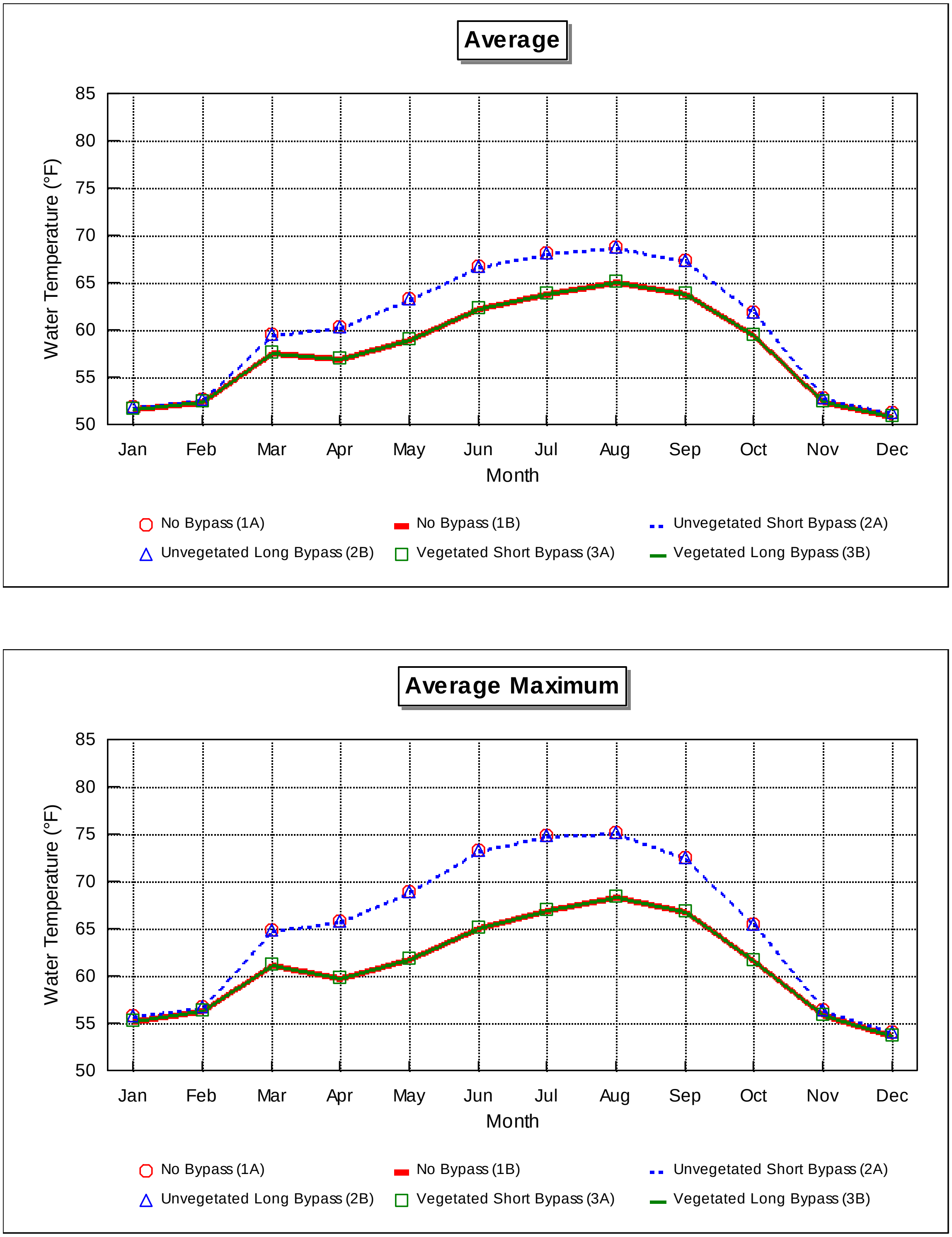
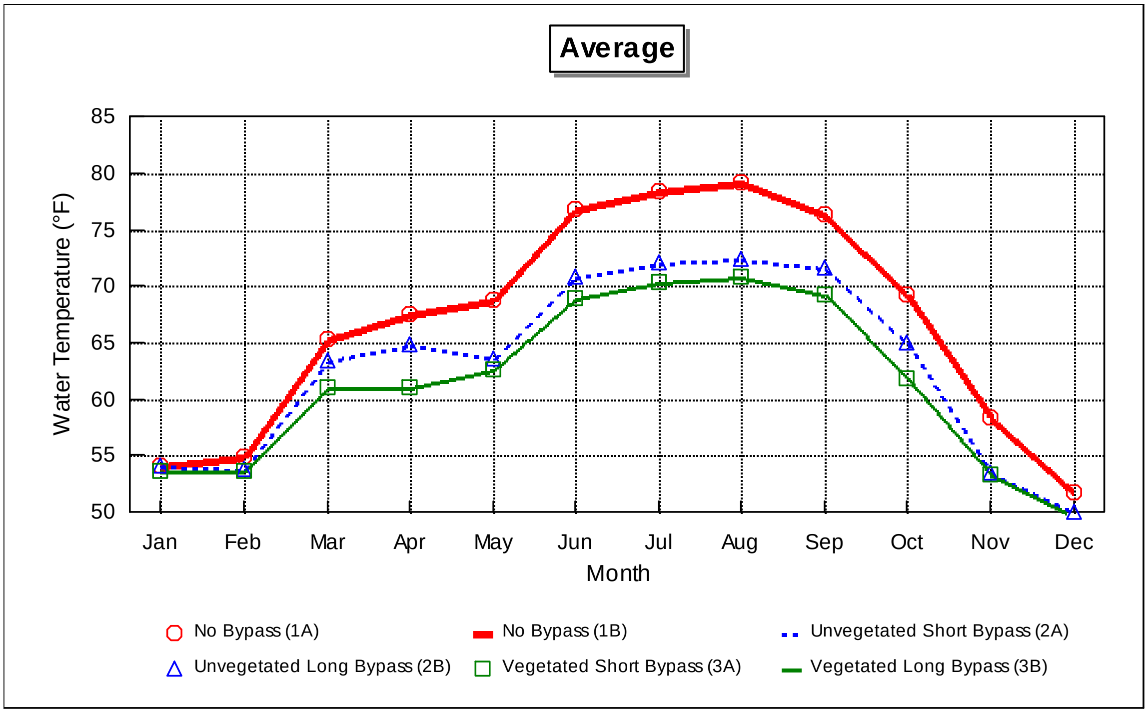


Figure 13. Monthly Temperatures in Model Segment 6, Lower Guadalupe Creek, during the Dry/Median Year



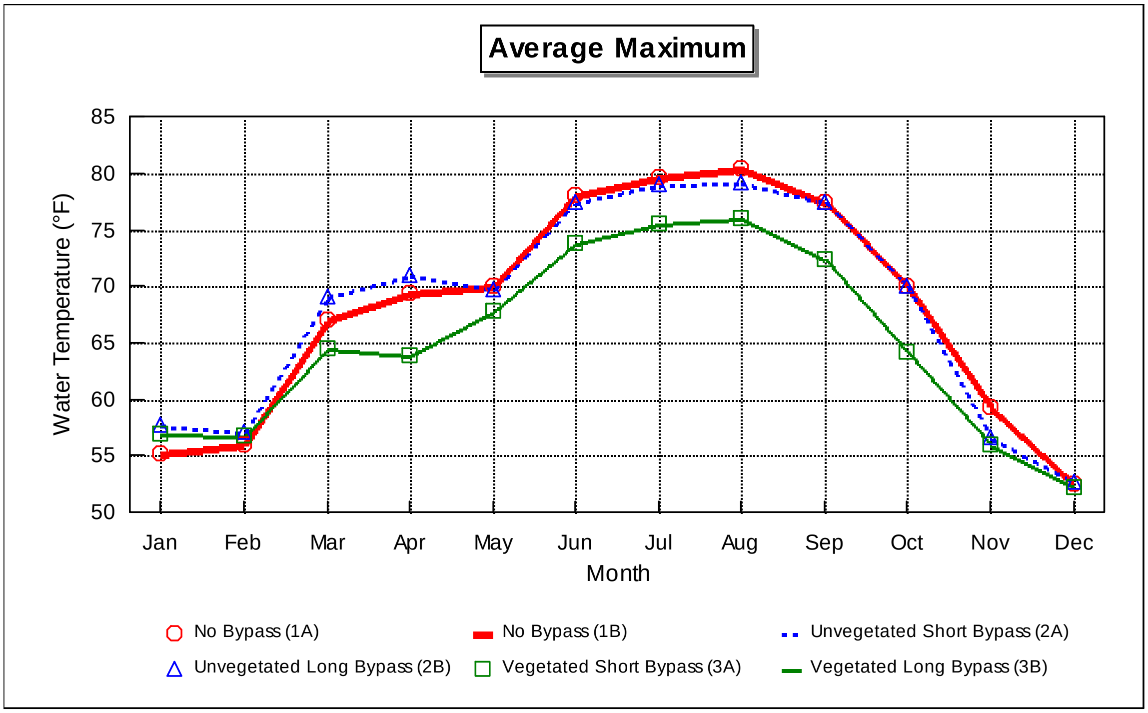
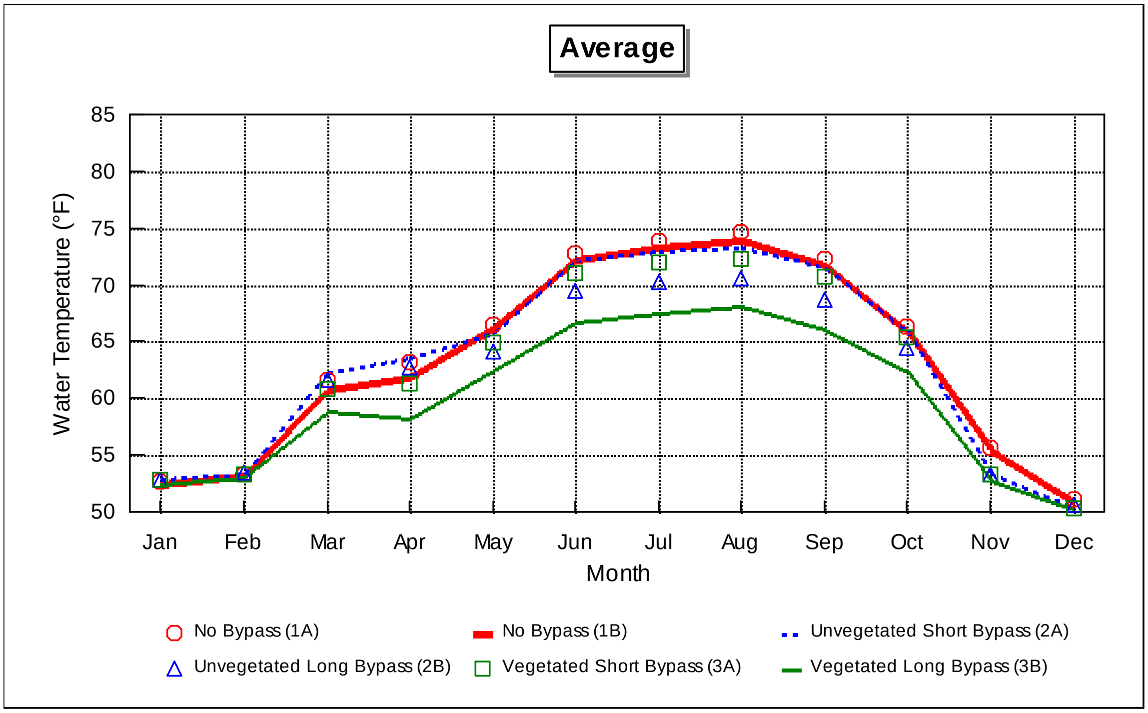


Figure 14. Monthly Temperatures in Model Segment 17, Lake Almaden Area, during the Dry/Median Year



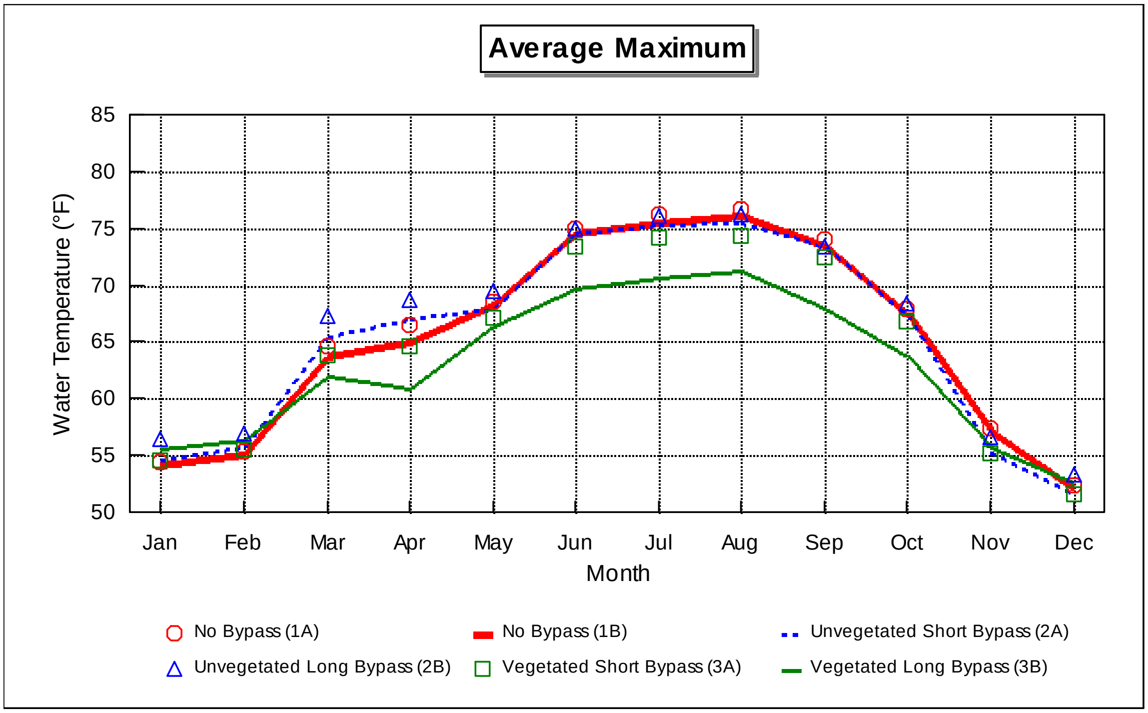
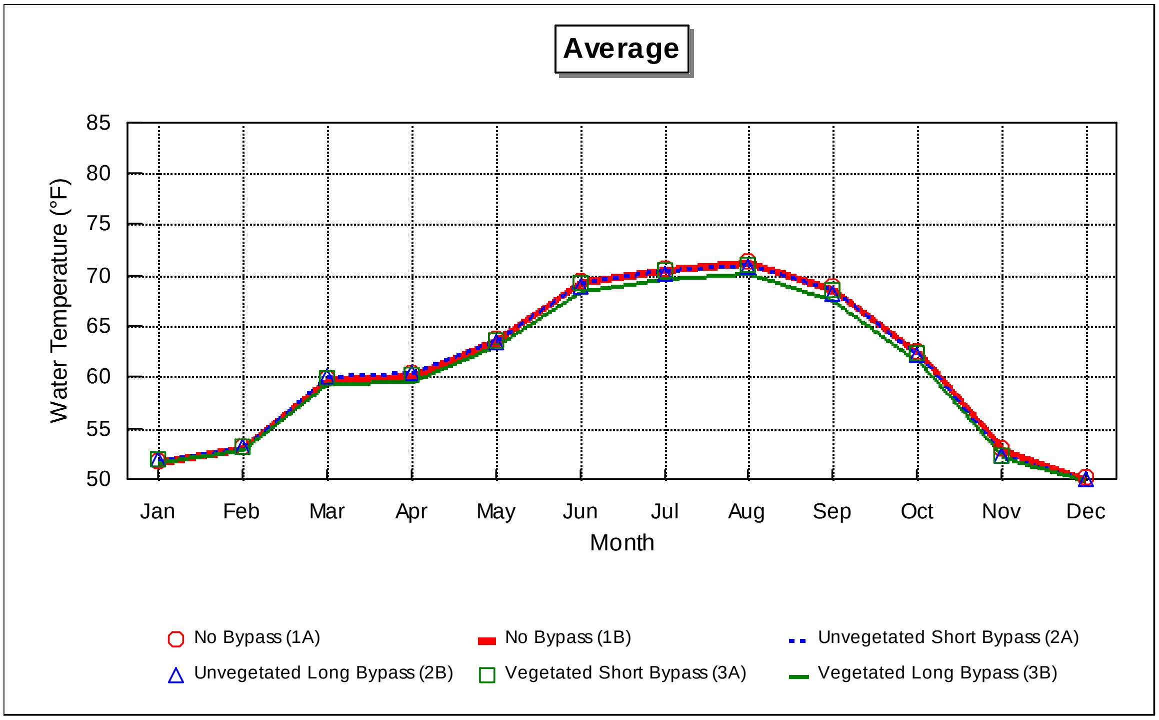


Figure 15. Monthly Temperatures in Model Segment 18, upstream of Alamitos Drop Structure, during the Dry/Median Year



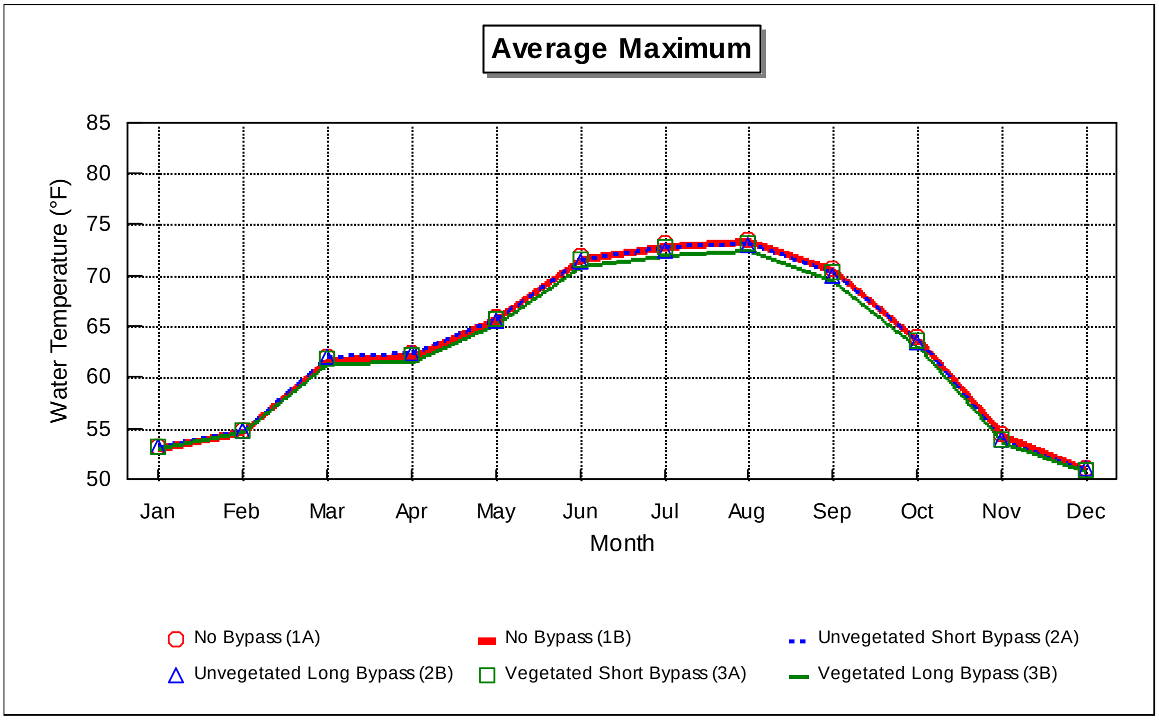


Figure 16. Monthly Temperatures in Model Segment 23, near Gage 23B, during the Dry/Median Year