# Thermal conditions in riverine pools from the Eastside Bypass/Reach 4 to Reach 5

## Introduction / Background

A survey of thermal refugia in 53 riverine pools and detailed two-week measurements of surface and subsurface thermal conditions in six pool-riffle-pool sites were conducted in the San Joaquin River and the Eastside Bypass from July to November 2012. Thermal refuge is created when upwelling groundwater, hyporheic exchange, or a combination of both forms vertical temperature gradients in the surface water column. It provides cold water habitat needed by salmonids when ambient water temperatures exceed their temperature tolerances. Data collected from this study quantified the amount and quality of thermal refugia in 53 pools and how thermal refugia varied over time in six pool-riffle-pool sites along Reach 4B2 and Reach 5 of the San Joaquin River and the Eastside Bypass from the Merced National Wildlife Refuge to its confluence with the San Joaquin River.

## Methods

**1.2.1 Summer Thermal Refugia Survey**

Water temperature and conductivity profiles were measured at 75 locations in 53 riverine pools during July 2012 to assess the abundance and degree of thermal refugia in the Eastside Bypass, Reach 4B2, and Reach 5. Using San Joaquin River and Eastside Bypass LIDAR and bathymetric data, 46 pools with thermal refugia potential were identified based on their depth, change in streambed elevation, and potential for hyporheic exchange. Measurements of water temperature and conductivity with depth were made at locations by an In-Situ Troll 9000 lowered from a canoe or boat. Locations were added or subtracted to the initial list of pools based on field observations. Collected data were analyzed to identify six pool-riffle-pool sites with thermal refugia for instrumentation with piezometers and water temperature sensor arrays.

**1.2.2 Piezometer and Water Temperature Array Instrumentation**
Between September and November, six pool-riffle-pool sites distributed along the Eastside Bypass, Reach 4B2, and Reach 5 were instrumented with piezometers equipped with temperature and pressure sensors. Each site’s piezometers and temperature sensor arrays were installed in the pools for a minimum of two weeks. Surface water temperature and water surface elevation were measured by temperature and pressure sensors fixed to the exterior of piezometers and positioned vertically in the water column. Subsurface water temperature and hydraulic head gradients were measured by temperature and pressure sensors installed inside piezometers screened between 1 to 7 feet below the streambed. At one Eastside Bypass site, conductivity sensors were also installed in piezometers and in sensor pods positioned at the streambed to evaluate variations in surface and subsurface water conductivity. All sensors recorded every 15 minutes for a minimum of two weeks to quantify hourly to weekly variations in pool thermal refugia conditions.

## Results

### Summer Thermal Refugia Survey

 Thermal stratification was measured in numerous pools in the Eastside Bypass, Reach 4B2, and Reach 5. Differences between surface and bottom temperatures (dT) in the 53 pools surveyed ranged from less than 1 °F to greater than 20 °F with an average dT of 7.6 °F across all 75 locations measured. Surface water temperatures ranged from 92 °F to 76 °F and averaged 83 °F, while the water temperature at the bottom of pools ranged from 87 °F to 66 °F with an average of 76 °F. Eight-seven percent of the locations measured had dT between 1 °F and 12 °F. The shape of the surface water dT curve with depth varied from location to location resulting in a wide range of pool water volume that could serve as thermal refugia. Linear and exponential decreases in surface water temperature with depth were the most common with exponential curves providing a greater volume of water below ambient surface water temperatures. Data from several sites had thermoclines in the middle of linear decreases in surface water temperature with depth. The increased water temperature gradient of the thermocline formed a multi-step “staircase” decrease of water temperature with depth

Conductivity measurements in the Eastside Bypass, Reach 4B2, and Reach 5 indicated that vertical conductivity gradients existed in many pools and frequently correlated with vertical water temperature gradients. Variations in vertical conductivity gradients suggest upwelling groundwater or hyporheic exchange because groundwater generally has higher conductivity than surface water. Caution must be exercised assuming this though since groundwater conductivity below the pools is not known and may be lower than surface water conductivity. Differences between surface and bottom conductivity (dC) in the 53 pools surveyed ranged from 1 μS/cm to 1682 μS/cm with an average dC of 254 μS/cm across all 75 locations measured. Increases in dC strongly correlated with increases in maximum dT indicating an influence of upwelling subsurface flow on surface water thermal conditions

**1.3.2 Piezometer and Water Temperature Array Instrumentation**

Daily formation and breakdown of thermal stratification was measured in pools at all six pool-riffle-pool sites instrumented in the Eastside Bypass, Reach 4B2, and Reach 5. In general, over the course of a day, pools started out with a near uniform temperature with depth at 6 AM, increasingly became more stratified during the day as air temperature rises, and finally began to cool off and return to a uniform water temperature as air temperature decreased in the evening. The degree of thermal stratification in the surface water was observed to correlate with daily variation in air temperature. Larger daily variation in air temperature resulted in greater differences between pool surface and bottom water temperature with the maximum water temperature difference observed between 9 °F and 16 °F. Patterns in subsurface water temperature varied with some sites having subsurface water temperatures decreasing with depth while other sites had it increasing with depth. Cooling of the daily mean subsurface water temperature signals between sensor locations indicated that hyporheic exchange did not occur at any sites and all surface-subsurface water exchange was groundwater. Hydraulic head calculations from the piezometer pressure data indicated that most of the six sites had at least one location that was gaining with hydraulic head greater in the subsurface than at the streambed.

## Discussion

Analysis of the data from both the summer survey and the piezometer instrumentation is ongoing and a full report detailing the temperature, hydraulic head, and conductivity data is expected by the next annual technical report.

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