Final
Data Summary Report for Chinook Salmon Spawning Escapement and Fry Emergence in Lower Walnut Creek

Contra Costa County, California

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Acronyms and Abbreviations

CIMIS	California Irrigation Management Information System
Corps	U.S. Army Corps of Engineers
GRR	General Reevaluation Report
mm	millimeters
Project	Lower Walnut Creek Flood Control Project
WRCC	Western Regional Climate Center
WY	water year

Final Data Summary Report for Chinook Salmon Spawning Escapement and Fry Emergence in Lower Walnut Creek, Contra Costa County, California

1.0 Introduction

The Lower Walnut Creek Flood Control Project is located along lower Walnut Creek from Suisun Bay to the City of Walnut Creek, California (Figure 1). Construction of the flood control project was initially authorized in 1960. The project originally comprised approximately 22 miles of channel improvements, including channel enlargement, channel stabilization, and levee construction along Walnut Creek and the lower reaches of San Ramon and Las Trampas Creeks. In 1970, the project was extended to include channel improvements on Pine and Galindo Creeks and the construction of backwater levees on Lower Grayson and Pacheco Creeks. The original flood control features were completed in September 1999, and modifications to a channel cover were completed in November 2001 (U.S. Army Corps of Engineers 2003). Past emphasis on flood control objectives in the Walnut Creek watershed has resulted in the loss and modification of riparian, fish, and wildlife habitat in the affected reaches (U.S. Army Corps of Engineers 2003).

The existing floodway is a trapezoidal earth channel that historically has been dredged to maintain design capacity. The floodway capacity is currently reduced as a result of 1 million yards of accumulated sediment clogging the channel (Emigh pers. comm.). Continued maintenance of the floodway has become more costly and there is increasing interest in improving habitat for fish and wildlife; therefore, the U.S. Army Corps of Engineers, Sacramento District (Corps) and the Contra Costa County Public Works Department are initiating a reevaluation phase of the project to reevaluate methods of operating and maintaining the flood control facility. The reevaluation phase includes the preparation of a general reevaluation report, which will describe a new project alternative that incorporates ecosystem restoration as a project purpose. Project alternatives will focus on providing flood capacity while creating additional wetlands, riparian habitat, and the potential for revegetation throughout the floodplain. Project alternatives also will explore the feasibility of providing fish passage beyond the most downstream constructed fish barrier (i.e., Drop Structure Number 1) for anadromous fish species, including steelhead and Chinook salmon. Contra Costa

County Public Works Department is partnering with the Corps as the nonfederal sponsor for the reevaluated project.

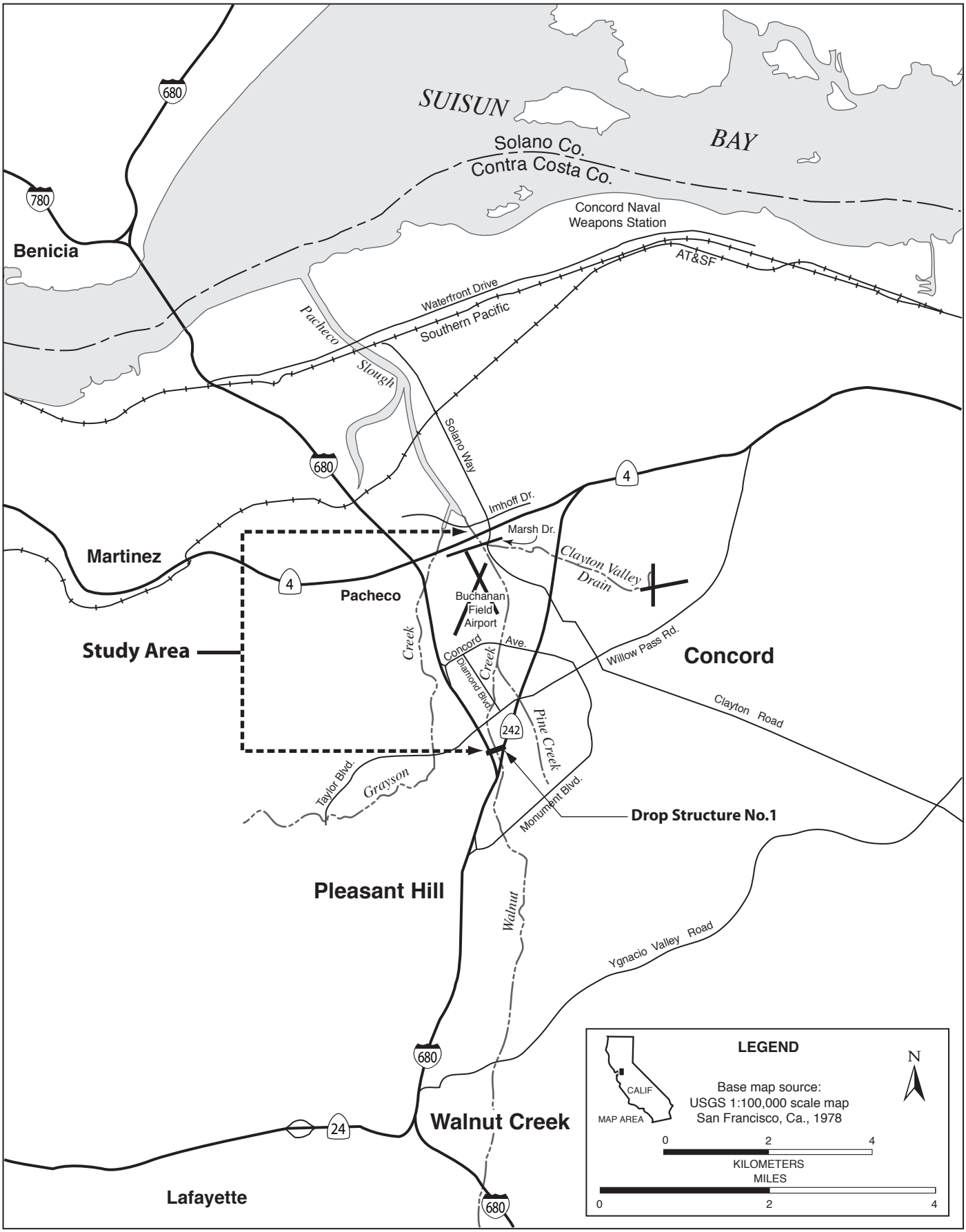
In 2004, Jones & Stokes, under contract to the Corps, prepared a detailed data collection plan to conduct baseline surveys of anadromous fish habitat in lower Walnut Creek (Jones & Stokes 2004a). This plan also proposed studies for monitoring fish use and for assessing existing habitat conditions for anadromous salmonids in the broader study area (i.e., the 6.5 miles of lower Walnut Creek from Suisun Bay to Monument Boulevard in the city of Concord, California (Figure 1). Although monitoring of Chinook salmon fry emergence was a component of the WY 2004 monitoring program, the contract schedule did not provide a full opportunity to study Chinook salmon fry emergence as outlined in the data collection plan. The current monitoring effort was then initiated to fully implement the methods described in the data collection plan to monitor adult migration and spawning and fry emergence for Chinook salmon in lower Walnut Creek.

This report summarizes the results of the monitoring program undertaken in water year (WY) 2006 to evaluate the spawning success of anadromous salmonids in lower Walnut Creek The anadromous salmonids in lower Walnut Creek are the federally threatened steelhead (*Oncorhynchus mykiss*) and Chinook salmon (*O. tshawytscha*). For WY 2006 monitoring, the study area focused on lower Walnut Creek from the upstream limit of tidal influence (i.e., the pipeline crossing immediately downstream of Highway 4) to Drop Structure No. 1, which is located a short distance upstream of Willow Pass Road (Figure 1).

The purpose of this monitoring report is to address data gaps on the use of lower Walnut Creek for spawning by anadromous salmonids. Although adult Chinook salmon and steelhead are known to use lower Walnut Creek for migration and spawning, little, if any, information is available on whether these fish spawn successfully downstream of Drop Structure No. 1. Confounding factors such as water temperature, fines, and scour can all influence spawning success. These factors need to be assessed to determine their relative influence on spawning success. In addition to providing information on spawning success, the WY 2006 monitoring effort provides information on:

- the total number of observed adult Chinook salmon, carcasses, and redds;
- the longitudinal distribution of observed Chinook salmon and redds;
- the ratio of marked (i.e., adipose fin-clipped) to unmarked adult Chinook salmon; and
- a scientific assessment of the correlation between redd success and environmental conditions (e.g., water temperature and gravels) monitored in the survey area.

Finally, the report also provides a recommended strategy for anadromous salmonid spawning habitat restoration and recommendations related to future studies.



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Jones & Stokes

Figure 1
Study Area

2.0 Methods

The methods used to monitor the five indicators are described in *Data Collection Plan for Baseline Surveys of Anadromous Fish Habitat in Lower Walnut Creek* (Jones & Stokes 2004a) and are summarized below in Section 2.3.

2.1 Monitoring Program

From October 7, 2005 through February 13, 2006, Jones & Stokes fish biologists monitored three indicators: Chinook salmon adult migration and spawning, Chinook salmon fry emergence, and spawning gravel quality. These indicators were monitored on Walnut Creek from the upstream limit of tidal influence (a short distance downstream of Highway 4) to Drop Structure No. 1, which is located upstream of the Willow Pass Road bridge (Figure 1). Additionally, hourly water temperature data were collected at three locations in lower Walnut Creek: downstream of Drop Structure No. 1, between Diamond Boulevard and the Pine Creek confluence (next to Water World), and near Marsh Drive (Figure 1).

2.2 Schedule

Monitoring of the adult migration and spawning indicator was conducted every 2 weeks from October 7 through December 15, 2005, for a total of six monitoring activities. Monitoring of the Chinook salmon fry emergence and gravel quality indicators was conducted on selected dates in December 2005 and January and February 2006. Hourly water temperature monitoring was conducted October 7, 2005 through February 13, 2006, when all redd excavations were completed. Table 1 lists the monitoring schedule for each indicator in WY 2006.

Table 1. Schedule for Water Year 2006 Chinook Salmon Adult Migration and Spawning, Chinook Salmon Fry Emergence, and Gravel Quality Monitoring by Date and Location

Monitoring Component	Indicator	Location Monitored	Monitoring Date(s)
Anadromous fish occurrence	Adult migration and spawning	Lower Walnut Creek (between upper limit of tidal influence and Drop Structure No. 1)	October 7 and 20, 2005; November 3, 16, and 30, 2005; December 15, 2005
Anadromous fish occurrence	Chinook salmon fry emergence	Eleven Chinook salmon redds at various locations	November 18, 2005; December 9 and 17, 2005; January 26, 2006; February 13, 2006
Habitat Mapping	Gravel Quality	Eleven Chinook salmon redds at various locations	December 9, 2005; January 26, 2006; February 13, 2006
Water temperature	Hourly water temperature	Lower Walnut Creek (3 locations)	October 7, 2005 to February 13, 2006

2.3 Monitoring Methods

2.3.1 Adult Migration and Spawning

Monitoring for the adult migration and spawning indicator was conducted by fish biologists, who walked in the channel or along the bank and visually surveyed the stream channel for the presence of adult Chinook salmon. Observations for adult Chinook salmon included both live and dead (carcasses) fish. During monitoring activities, special emphasis was placed on viewing stream habitats where spawning fish or redds would be expected to occur, such as the downstream end of pools and the head of riffles. Monitoring data were recorded on data collection forms and included the number and location of live adult fish, carcasses, and redds observed; the stream monitored; the date monitoring was conducted; the name of each monitoring team member; the water temperature and stream flow and time of these measurements; the water clarity (based on Secchi tube readings); and the beginning and ending times of the monitoring activity. In addition, the fork length and sex of each carcass, if they could be determined, were recorded.

The locations of redds, live fish, and carcasses were marked on aerial photographs (printed at a scale of 1 inch = 100 feet) and recorded using GPS (Appendix A). The following alphanumeric naming convention was used to label each fish occurrence or group of decomposed carcasses and fish skeletons: water year, 4-letter abbreviation indicating the type of survey (i.e., FISH), and a consecutive number for each observation for the stream, beginning with 001. For

example, the first fish occurrence observation for WY 2006 was labeled 06-FISH-001. In cases where large numbers of live fish or carcasses were observed, only one occurrence label was mapped on the aerial photographs and one GPS location was recorded to represent the multiple observations of adults.

2.3.2 Redd Selection

In conjunction with monitoring for the adult migration and spawning indicator, the monitoring team selected Chinook salmon redds for fry emergence monitoring. Candidate redds were grouped by timing of construction and location within the study area. Each group contained up to 6 candidate redds. Although the methods for fry emergence monitoring state that as many as 3 monitoring groups can be established in one spawning season (Jones & Stokes 2004), only 2 such groups were established in fall 2005. Too few redds met the selection criteria, precluding the need for establishing more than 2 monitoring groups.

2.3.3 Redd Scour and Sediment Deposition

Redd scour and sediment deposition were monitored between November 2005 and February 2006 using a combination of streambed elevation surveys and scour chains (i.e., short sections of chain link attached to a 9-inch-long bolt; Figure 2). Streambed elevation surveys were conducted and scour chains were installed immediately after candidate redds were selected and before redd features were disturbed by winter storms.

To facilitate the measurement of streambed elevations, permanent cross sections and benchmarks were installed at each selected redd. Cross section monuments were established on opposite streambanks using 3- or 4-foot long sections of rebar. The cross section monuments were positioned so that the measuring tape stretched between the monuments would cross directly over the deepest part of the redd pit. Benchmarks were established by driving similarly sized sections of rebar with metal caps into the streambank until the top of the metal caps were flush with the ground. The benchmarks provided a reference point for which future streambed elevations could be compared. The locations of benchmarks were documented using GPS to assist in re-locating the benchmark. In addition, the distance between the cross section monuments, and between each monument and the benchmark were measured (to the nearest 0.1 foot) with a measuring tape to facilitate re-locating monuments and benchmarks by triangulation. A field sketch diagramming the relative locations and distances between the cross section monuments, and between the monuments and the benchmark was completed for each monitored redd to document relative locations of these features.

The elevations of the streambed were surveyed twice: once immediately after redd selection in November or December (hereinafter referenced as “initial surveys”) and once immediately prior to redd excavation (hereinafter referenced

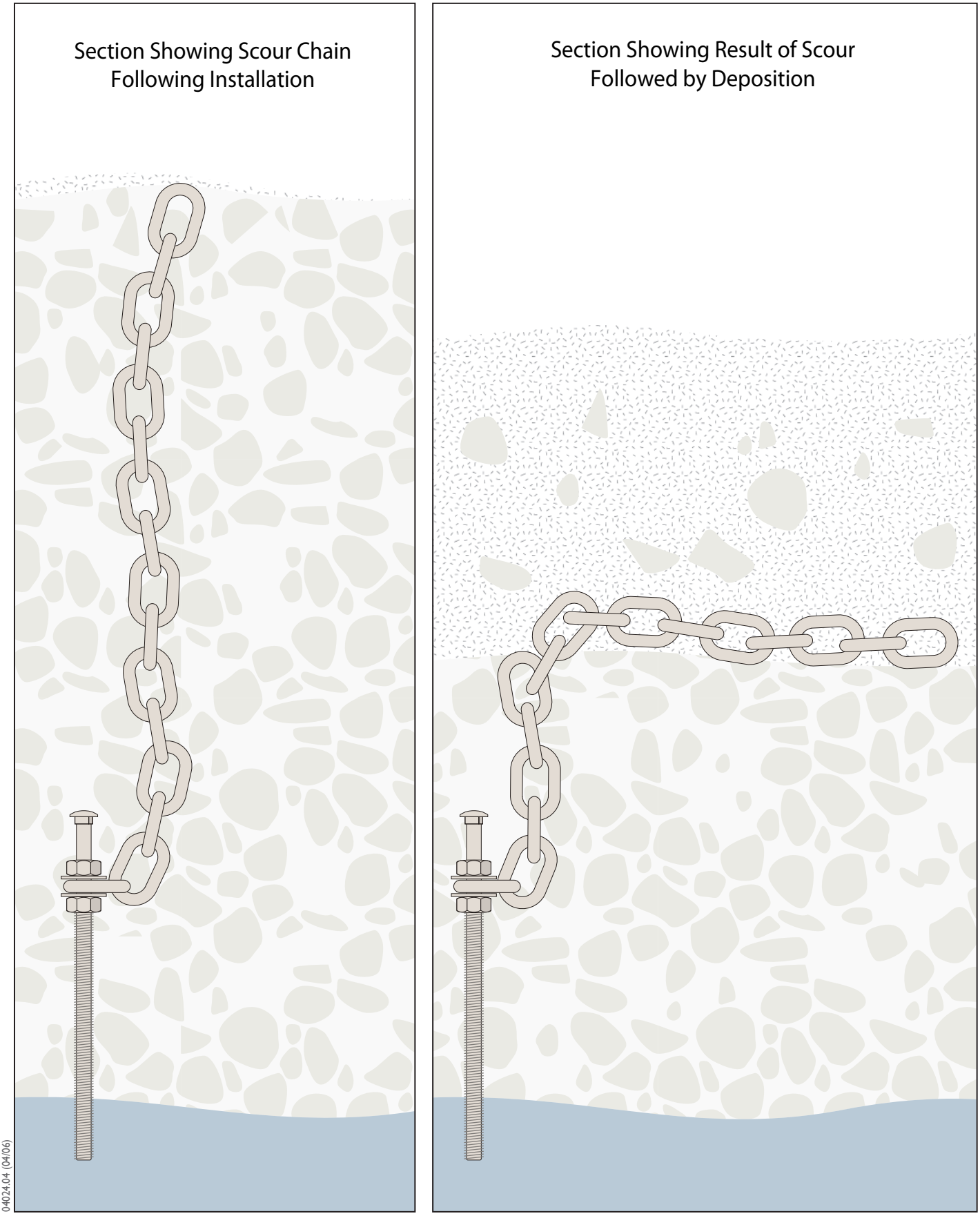
as “final surveys”). After a measuring tape was stretched between the cross section monuments, streambed elevations of redd features were surveyed (to nearest 0.01 foot) relative to the elevation of the benchmark. Redd features surveyed included the lowest elevation (i.e., bottom) of the redd pit and highest elevation (i.e., top) of the redd tail spill. In addition, the elevations of the undisturbed streambed to either side of the redd pit along the cross section also were measured. For surveyed features that were not located along the cross section (e.g., the top of the redd tail spill), the offset distance from the cross section to the redd feature was measured with a measuring tape to ensure that these locations could be resurveyed. Redd dimensions, including the widths and lengths of the redd pit and tail spill, were also measured to the nearest 0.1 foot with a measuring tape. The locations of the left- and right-side edges of the redd pit and tail spill relative to the divisions on the stretched tape were recorded to facilitate re-locating the position of the redds for fry trapping and redd excavation.

Scour chains also were used to document channel bottom scour and sediment deposition at each monitored redd. Scour chains consisted of 18-inch long sections of ¼-inch-thick chain link. Each scour chain was secured by one end to a 7-inch long threaded bolt to anchor the chain to the streambed. Scour chains were placed either alongside or upstream of each redd. Installation of the scour chains was accomplished by driving the bolt with the attached chain link section into the streambed using a section of metal pipe and a sledgehammer. The bolt was driven into the streambed until it could no longer be driven in or until the entire length of chain was vertical within the streambed (i.e., no excess length of chain link was exposed and lying flat on the surface of the streambed). When the bolt and chain link could not be driven completely into the streambed, the excess chain was laid flat and the number of exposed links were counted and the data recorded. A total of 10 scour chains were deployed at 11 redds (in one instance a single scour chain was used for two redds that were in close proximity to one another).

2.3.4 Water Temperature Monitoring and Calculation of Temperature Units and Suitability Indices

Water temperature was monitored using Onset Stowaway® continuous water temperature loggers. Temperature loggers were housed in steel or PVC housings, and tethered using steel cable to stakes driven into the streambank. Anchoring was used to prevent the loss of data loggers from vandalism or from strong currents during high flow events.

Temperature loggers were deployed at three locations in lower Walnut Creek: downstream of Drop Structure No. 1, between Diamond Boulevard and the Pine Creek confluence (next to Water World), and near Marsh Drive (Figure 1; Appendix A). Two data loggers were installed at each of the three locations to provide a backup to guard against data loss resulting from battery failure, vandalism or theft of the data logger, and scour from high flows.



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Jones & Stokes

Figure 2
Scour Chain Position within the Substrate Following Installation and after Scour/Deposition

All temperature loggers were programmed to record water temperature at hourly intervals. The date and time that water temperature loggers were deployed were recorded in the field. In addition, water temperature was measured with a hand-held thermometer at the time of deployment and at any time that temperature data were offloaded in the field. The loggers were retrieved at approximately 2-week intervals to check on their condition and to download new data. After the data were downloaded in the field, the loggers were immediately redeployed. Data were then transferred to a personal computer in the office. Water temperature data were used to predict the timing of fry emergence and to assess water temperature conditions relative to the needs of developing eggs and embryos.

Expected emergence date for fry was estimated by calculating cumulative temperature units, beginning with the estimated date of redd construction. Unless adults were observed actively constructing the redd, the initial date of redd construction for unoccupied redds was assumed to be the median day between the day the redd was first observed and the previous date monitoring for adult migration and spawning had occurred. The predicted date of fry emergence following redd construction was therefore determined to be the date when the cumulative temperature units equaled or exceeded 890 temperature units (method modified from Crisp 1981 and Groot and Margolis 1991). Cumulative temperature units are the cumulative sum of daily average water temperature (°C) beginning with water temperature on the estimated day of redd construction. For example, an average daily water temperature of 10°C equals 10 temperature units. After 2 days, each having an average daily water temperature of 10°C, 20 temperature units have accumulated.

Suitability indices for water temperature effects on Chinook salmon eggs and developing embryos were calculated for each redd based on measured hourly water temperature data. Suitability indices used in the analysis are presented in Table 2. Hourly water temperature data were entered into spreadsheet and converted to suitability indices. The relative frequencies for each suitability category (i.e., 0. 0.25, 0.50, 0.75, and 1.0) were then calculated for each redd.

Table 2. Suitability Indices used to Determine Water Temperature Effects on Chinook Salmon Eggs and Embryos

Suitability Index	Water Temperature (°F)
1.0	less than or equal to 57
0.75	58
0.50	59
0.25	60
0	greater than or equal to 61

2.3.5 Redd Excavations

Redd excavations were conducted to determine the presence of Chinook salmon eggs, alevins, and fry. Redds were excavated on December 9, 2005, and January 26 and February 13, 2006. Redd excavations were conducted by hand using a shovel and dip net. The redd pit and tail spill were located based on measurements taken during the initial survey. Redds were often indistinguishable from the surrounding streambed due to the mobilization of stream substrates during winter storms. The surface layer of the gravel was scraped away while a large dip net was held in the current immediately downstream of the area being excavated. During excavations, the dip net was checked frequently for the presence of dead eggs, live or dead alevins, or fry. Excavations continued until the entire redd was excavated. The number of live and dead eggs, alevins, and fry (if present) in each excavated redd were enumerated. Gravel that was excavated from the redd was saved and set aside for use during gravel quality monitoring (see Section 2.3.6). In addition, scour chains were relocated and removed after recording the number of exposed links and/or depth of burial.

Immediately prior to the excavation of redds, redd features and adjacent streambed locations were re-surveyed using a surveyors level to determine changes in elevation of the stream channel relative to initial measurements.

2.3.6 Spawning Gravel Quality

Gravel removed from each redd during redd excavations was placed in a bucket. Excavated gravel was spread evenly over a tarp, and a sampling grid was placed over the gravel on the tarp to facilitate measurement of particle sizes. The size of each particle that was located under each intersection of the grid of 100 intersecting lines was recorded by size category (Table 3). A tally of the number of particles in each size category was kept, and the total number of particles in each size category was summed. At least 87 particle measurements were recorded. The gravel sample was photographed, and the photograph number was recorded on the data collection form.

Table 3. Numeric Categories of Substrate Particle Size for Steelhead and Chinook Salmon Spawning Habitat

Particle Size		
Inches	Millimeters	Category
<0.08	<2	1
0.08–0.2	2–5	2
0.3–1.0	5–25	3
1.1–4.0	25–102	4
4.1–6.0	102–152	5

Modified from Crouse et al. 1981.

3.0 Monitoring Results

3.1 Local Environmental Conditions

3.1.1 Precipitation and Streamflow

To place the WY 2006 monitoring results in the proper context, it is important to understand the local environmental conditions during the monitoring period that possibly affected the indicators being monitored. Local environmental conditions of most interest are precipitation and streamflow.

Precipitation data are available for the Concord area, including the Walnut Creek watershed, from the California Irrigation Management Information System (CIMIS) station number 170. Total precipitation in Concord in WY 2006 was 23.1 inches for the period July 1, 2005, through June 30, 2006; the average annual precipitation (July 1 through June 30) at the Western Regional Climate Center (WRCC) Martinez Water Plant station for the period 1971 to 2005 is 19.72 inches (Figure 3). During the Chinook salmon spawning escapement and fry emergence study period (i.e., October 7, 2005 to February 13, 2006), 12.3 inches of rainfall was recorded at the WRCC Martinez Water Plant station. Daily precipitation in Concord spanning the study period is shown in Figure 4.

Streamflow in lower Walnut Creek is not currently monitored. However, field-measured streamflow data were collected in lower Walnut Creek during 6 days of monitoring (Table 4).

Table 4. WY 2006 Field-Measured Streamflow for Lower Walnut Creek

Monitoring Activity	Date in 2005	Field-Measured Streamflow for Lower Walnut Creek Immediately Downstream of the Clayton Valley Drain Confluence (cfs)
1	October 7	11.7
2	October 20	13.0
3	November 3	13.3
4	November 16	13.1
5	November 30	26.8
6	December 15	16.1

Note:
cfs = cubic feet per second

3.1.2 Water Clarity and Temperature

In lower Walnut Creek, Secchi tube readings (water clarity) ranged from 610 mm to more than 1,200 mm (i.e., water clarity exceeded the measurement range of the Secchi tube), and measured water temperatures during monitoring activities ranged from 52 to 67ºF (Table 5).

Figure 5 presents hourly water temperature data measured at the three continuous water temperature monitoring station locations. In general, water temperature during the study period (October 7, 2005 through February 13, 2006) ranged from 45.8 to 66.3ºF.

3.2 Adult Migration and Spawning

Over the course of monitoring for the adult migration and spawning indicator , one hundred and seven (107) live adult Chinook salmon and sixty-three (63) carcasses were observed on lower Walnut Creek in the study area (Appendix A; Tables 5 and 6). Although live adult Chinook salmon were first observed on October 20, 2005, the bulk of the run did not occur until late-November and early-December.

In addition to live adult Chinook salmon and carcasses, 31 Chinook salmon redds were also observed in the study area over the course of the monitoring period (Appendix A; Table 6). Of the 63 carcasses observed, 39 were females, 8 were males, 8 were grilse, and 8 were adults of unknown sex (Table 6). Typically, grilse are 2-year-old males that return to spawn early, but occasionally they can also be females. Due to the small size of grilse, sexually dimorphic characteristics may not be as pronounced in grilse carcasses, making it more difficult to determine their gender. The eight unknown carcasses either were in

Table 5. Summary of Monitoring Results for Adult Chinook Salmon Migration and Spawning on Lower Walnut Creek Immediately Downstream of Highway 4 to Drop Structure No. 1 (Water Year 2006)

	Live Adults and Carcasses						Redds					Environmental Data			
Monitoring Activity	Date (2005)	Sex (M, F, U)	Live or Carcass	Fork Length (centimeters)	Number of Live Fish or Carcasses Observed	Channel Type	Location	Habitat Type	Average Gravel Size (inches)	Water Depth (feet)	Water Velocity (feet per second)	Location	Time	Secchi Tube Reading (mm)	Water Temperature (°F)
Lower Walnut Creek															
1	October 7											Hwy 4	9:30	1,000	62
												Drop Structure Number 1	14:30	>1,200	67
2	October 20	U	Live		1	Pool						Hwy 4	9:30	>1,200	60.5
		U	Live		1	Pool						Drop Structure Number 1	14:30	>1,200	64
3	November 3	F	Live		1	Riffle						Near Clayton Valley Drain	12:44	790	56
		U	Live		1	Pool						Marsh Ave.	8:29	>1,200	56
		U	Live		3	Pool						Drop Structure Number 1	13:50	>1,200	59
4	November 16	2M/1F	Live		3	Pool	½ mile below Concord Ave bridge	Riffle	0.59	1.5		50 ft. d/s of Clayton Valley drain	8:50	>1,200	55
		F	Carcass	71	1	Pool	½ mile below Hilton	Riffle	0.31	1.0	1.29	Drop Structure Number 1	14:40	>1,200	58
		U	Live		2	Pool	At d/s end of Hilton	Riffle	0.59	1.0	0.97				
		U	Carcass (head)	ND	1	Pool	At d/s end of Hilton	Riffle	0.28	1.5	0.75				
		U	Live		1	Pool	Above Diamond St bridge	Riffle	0.47	0.9	1.23				
		F	Carcass	63	1	Pool	Above Diamond St bridge	Riffle	0.79	1.3	0.86				
		2M/1F	Live		3	Riffle	100 ft. below Willow Pass bridge (Diamond bridge?)	Riffle	0.59	0.9	1.46				
		F	Live		1	Riffle	300 ft. d/s of Willow Pass bridge	Riffle	0.79	0.6	2.12				
		F	Live		2	Riffle	290 ft. d/s of Willow Pass bridge	Riffle	0.39	0.6	2.63				
		M	Carcass	65	1	Pool	250 ft. d/s of Willow Pass bridge	Riffle	0.59	1.1	1.80				
		U	Live		4	Pool									
		M	Carcass	92	1	Run									
		U	Live		2	Pool									
		F	Carcass	76	1	Pool									
5	November 30	U	Live		4	Pool	Above Pine Creek	Riffle		1.5		Near Clayton Valley Drain	8:00	610	52
		U	Live		1	Run	Downstream of Hilton	Riffle	0.59	1.0	3.53	Drop Structure Number 1	15:00	610	54?
		U	Live		1	Riffle	Below Diamond St bridge	Riffle	0.20	0.8	0.72				
		F	Carcass	73	1	Run	Above Diamond St bridge	Riffle	0.79	1.1	0.65				

Table 5. Continued

	Live Adults and Carcasses						Redds					Environmental Data			
Monitoring Activity	Date (2005)	Sex (M, F, U)	Live or Carcass	Fork Length (centimeters)	Number of Live Fish or Carcasses Observed	Channel Type	Location	Habitat Type	Average Gravel Size (inches)	Water Depth (feet)	Water Velocity (feet per second)	Location	Time	Secchi Tube Reading (mm)	Water Temperature (°F)
5 (cont'd)		U	Live		1	Riffle	200 ft. d/s of Willow Pass Rd bridge	Riffle	0.79	1.5	ND				
		U	Live		4	Run	500 ft.d/s of drop structure	Run	0.39	1.0	2.5				
		F	Carcass	79	1	Bank	450 ft. d/s of drop structure	Riffle	0.59	1.5	ND				
		F	Carcass	79	1	Pool	430 ft. d/s of drop structure	Riffle	ND	1.5	ND				
		U	Live		3	Run/riffle									
		U	Live		2	Run									
		U	Live		2	Riffle									
		F	Carcass	76	1	Pool									
		F	Carcass	71	1	Pool									
		U	Live		2	Run									
		U	Live		3	Riffle									
		U	Live		2	Riffle									
		U	Live		3	Riffle									
		U	Live		1	Run									
		U	Live		1	Run									
		U	Live		2	Pool									
		U	Live		2	Pool									
	December 9[1]						50 ft. d/s Hilton	Run	0.5	1.5	1.50				
							Upstream Diamond Blvd.	Riffle	0.5	1.3	2.77				
							75 ft. d/s Willow Pass Rd.	Run	0.5	1.2	1.65				
							Mid-way between Willow Pass Rd. and Drop Structure No. 1	Run	0.75	1.2	0.48				
							Downstream Drop Structure No. 1	Run	7mm	1.1	1.19				
							Downstream Drop Structure No. 1	Run	7mm	1.1	1.21				

Table 5. Continued

	Live Adults and Carcasses						Redds					Environmental Data			
Monitoring Activity	Date (2005)	Sex (M, F, U)	Live or Carcass	Fork Length (centimeters)	Number of Live Fish or Carcasses Observed	Channel Type	Location	Habitat Type	Average Gravel Size (inches)	Water Depth (feet)	Water Velocity (feet per second)	Location	Time	Secchi Tube Reading (mm)	Water Temperature (°F)
6	December 15	U	Carcass (Head and shriveled body)	ND	1	Left bank	Below Concord Ave bridge at airport	Riffle	0.23	0.9	1.52	Highway 4	10:00	600	62
		U	Live		1	Run	Under first span of Concord Ave bridge	Riffle	0.39	0.6	1.87	Drop Structure Number 1			
		U	Carcass (No head)	ND	1	Run	~ 20' u/s of above redd under Concord Ave bridge	Run	0.39	1.1	1.04				
		U	Carcass	57.5	1	Riffle	At Waterworld	Run	0.70	1.1	1.35				
		U	Live		1	Run	Same as redd 004 at Hilton	Pool (tail)	ND	ND	ND				
		1F/1U	Live		2	Riffle	Between drop structure #1 and Willow Pass Road	Run	ND	ND	ND				
		1F/3U	L/C	66	1L/2C(1 no head)+1 head	Run	Between Willow Pass Road and drop structure #1								
		U	Live		1	Run									
		M	Live		1	Riffle									
		1F/1G	Live		2	Tail of Pool									
		G	Carcass (highly decomposed)	ND	1	Bank									
		U	Live		5	Riffle									
		M	Carcass	65	1	Pool									
		G	Carcass	55	1	Pool									
		U	Live		4	Pool									
		F	Carcass	58	1	Pool									
		G	Carcass	55	1	Pool									
		U	Live		2	Run									
		U	Live		3	Pool									
		G	Live		3	Run									
		U	Live		1	Riffle									

Table 5. Continued

	Live Adults and Carcasses						Redds					Environmental Data			
Monitoring Activity	Date (2005)	Sex (M, F, U)	Live or Carcass	Fork Length (centimeters)	Number of Live Fish or Carcasses Observed	Channel Type	Location	Habitat Type	Average Gravel Size (inches)	Water Depth (feet)	Water Velocity (feet per second)	Location	Time	Secchi Tube Reading (mm)	Water Temperature (°F)
6 (cont.)		F	Carcass	100	1	Pool									
		U	Live		2	Pool									
		U	Live		2	Pool									
		G	Carcass	52	1	Pool									
		G	Carcass	52	1	Pool									
		F	Carcass	72	1	Pool									
		U	Live		1	Pool									
		F	Carcass	85	1	Pool									
		U	Live		1	Run									
		M	Carcass	65	1	Pool									
		F	Carcass	56	1	Pool									
		M	Carcass	57	1	Pool									
		U	Carcass	56	1	Pool									
		U	Live		3	Pool									
		U	Live		2	Run									
		F	Carcass	73	1	Run									
		M	Carcass	54	1	Run									
		F	Carcass	77	1	Pool									
		F	Carcass	84	1	Pool									
		U	Live		1	Pool									
		U	Live		3	Riffle									
		F	Carcass	80	1	Pool									
		U	Carcass	89	1	Pool									
		G	Carcass	64	1	Pool									
		U	Live		2	Run									
		U	Live		3	Run									
		F	Carcass	85	1	Run									
		U	Live		1	Run									
		F	Carcass	85	1	Run									
		U	Live		1	Run									
		F	Carcass	82	1	Run									

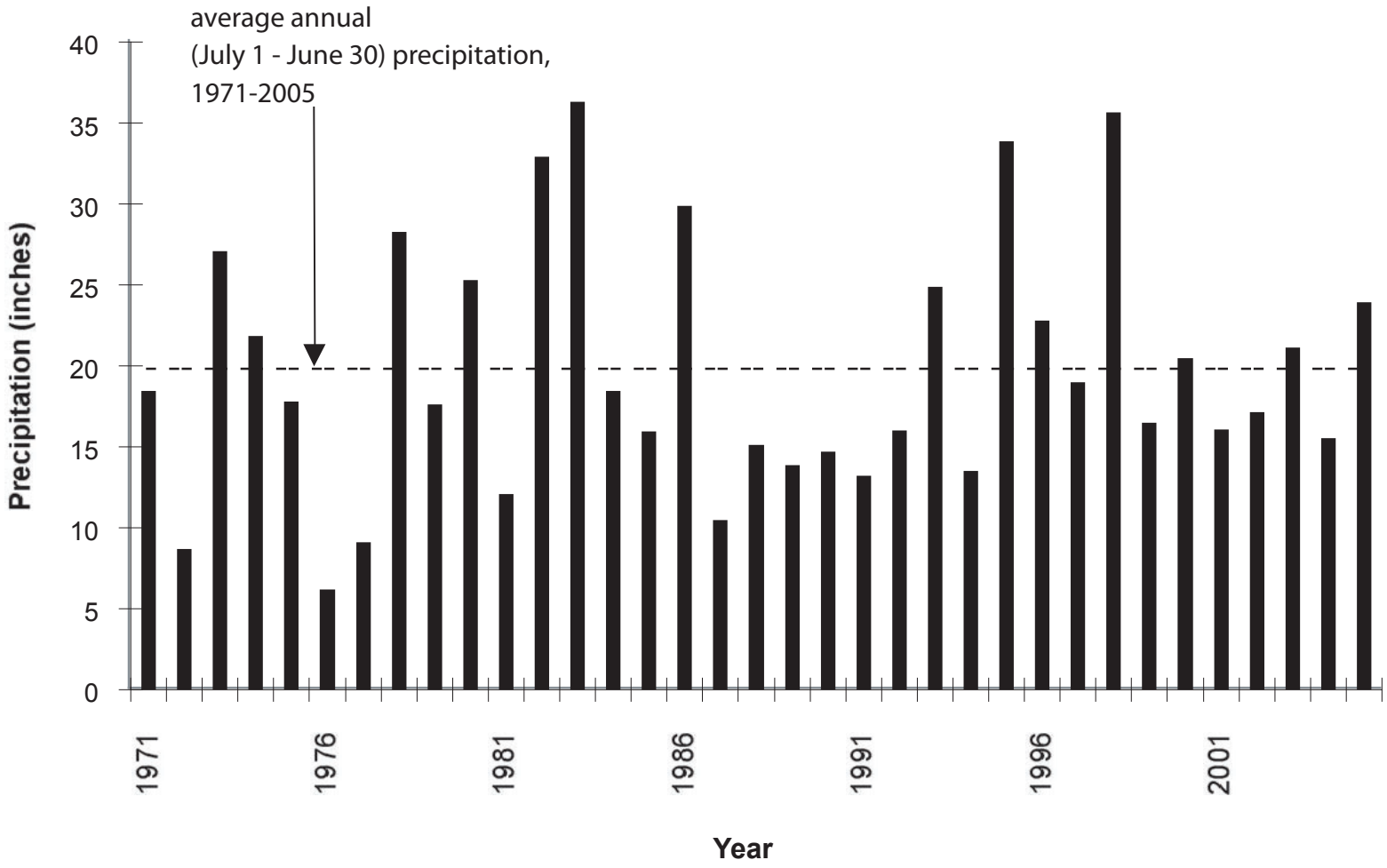
Table 5. Continued

	Live Adults and Carcasses						Redds					Environmental Data			
Monitoring Activity	Date (2005)	Sex (M, F, U)	Live or Carcass	Fork Length (centimeters)	Number of Live Fish or Carcasses Observed	Channel Type	Location	Habitat Type	Average Gravel Size (inches)	Water Depth (feet)	Water Velocity (feet per second)	Location	Time	Secchi Tube Reading (mm)	Water Temperature (°F)
6 (cont.)		U	Live		1	Run									
		G	Carcass	58	1	Run									
		F	Carcass	79	1	Run									
		F	Carcass	86	1	Pool									
		F	Carcass	77	1	Pool									
		F	Carcass	80	1	Pool									
		F	Carcass	80	1	Pool									
		M	Carcass	74	1	Pool									
		M	Carcass	61	1	Pool									
		F	Carcass	80	1	Pool									
		F	Carcass	74	1	Pool									
		F	Carcass (head only)		1	Pool									
		F	Carcass	81	1	Pool									
		F	Carcass	78	1	Pool									
		F	Carcass	78	1	Pool									
		F	Carcass	56	1	Pool									
		G	Carcass	51	1	Pool									
		F	Carcass	59	1	Pool									
		F	Carcass	74	1	Pool									
		F	Carcass	80	1	Pool									
		F	Carcass	84	1	Pool									
		F	Carcass	80	1	Pool									
		F	Carcass	84	1	Pool									
		F	Carcass	75	1	Pool									

Notes:

[1] = Data collected on December 9, 2005, was not part of a regularly scheduled monitoring activity. These additional data were collected to increase the availability of redds to be selected for fry emergence monitoring.

ND = no data



Source: Western Regional Climate Center Martinez Water Plant 045378 (latitude 38.01°/longitude 122.07°)

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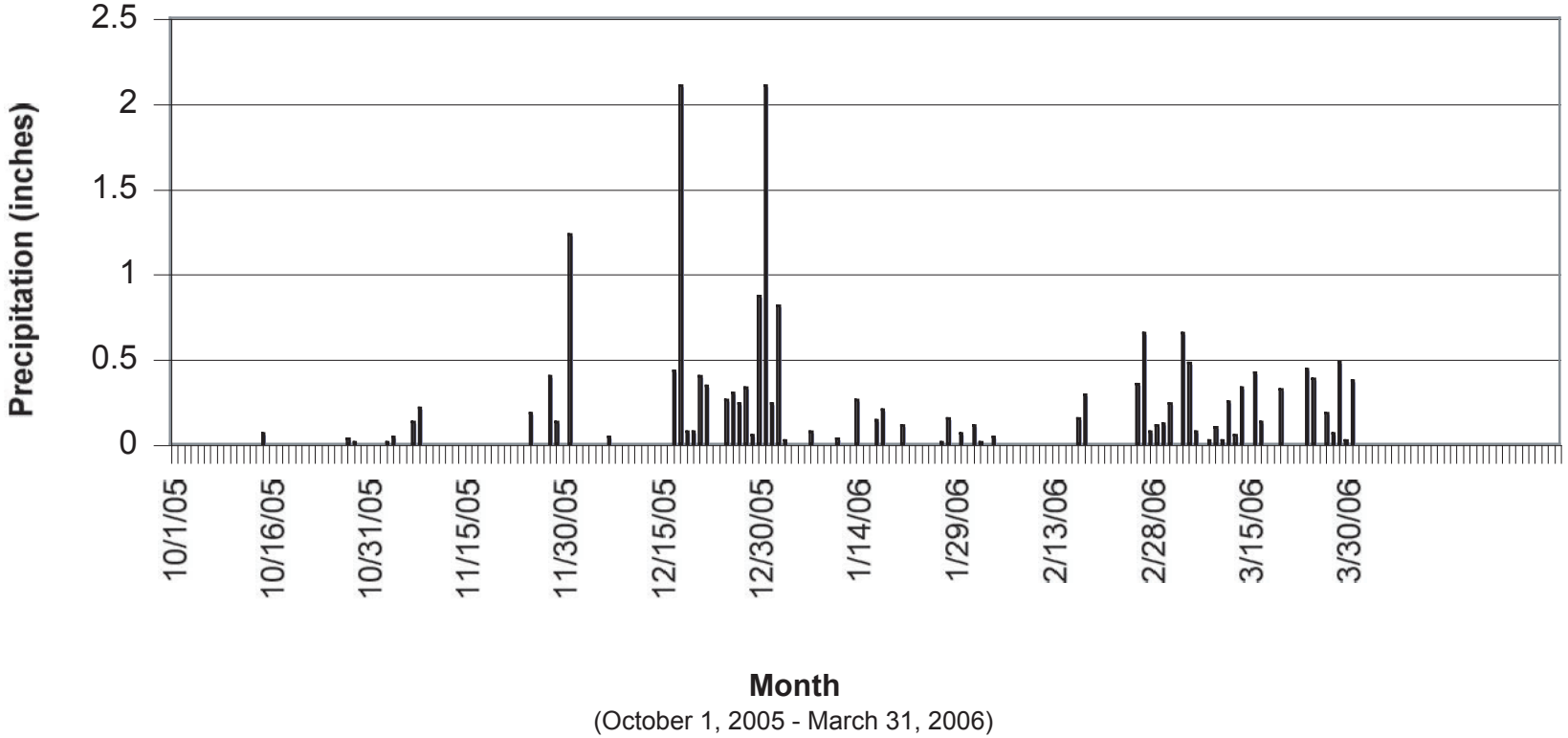
Figure 3
Annual Precipitation (July 1 - June 30)
and Average Annual Precipitation during 1971-2005 in Martinez, California



Source: California Irrigation Management Information System, Station 170

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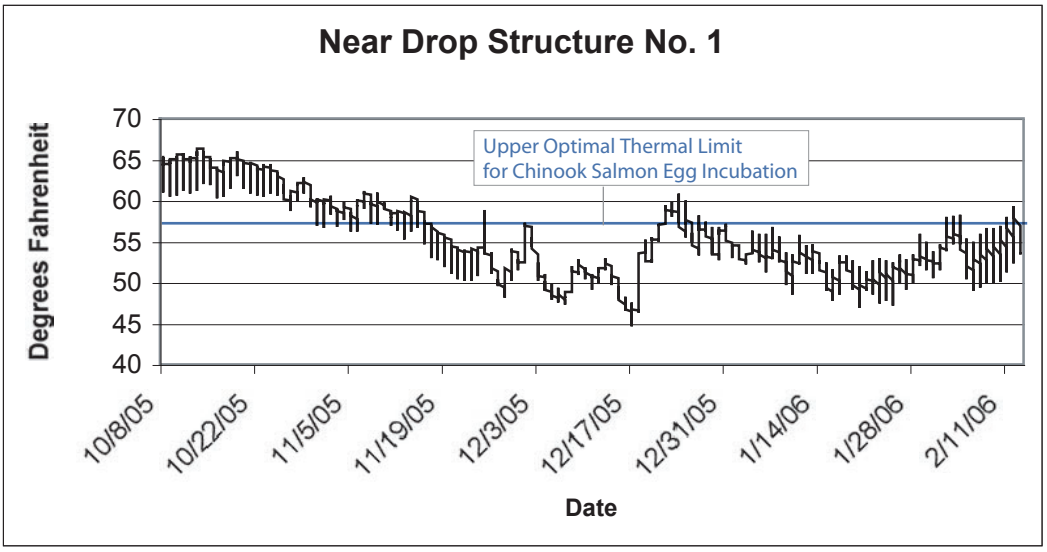
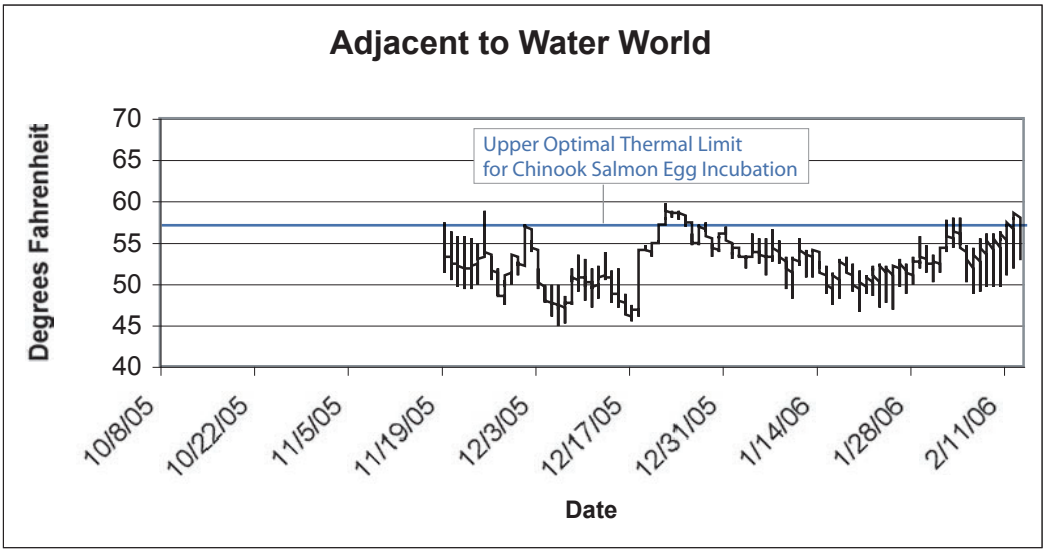
Figure 4
Daily Precipitation in Martinez, California, during Water Year 2006





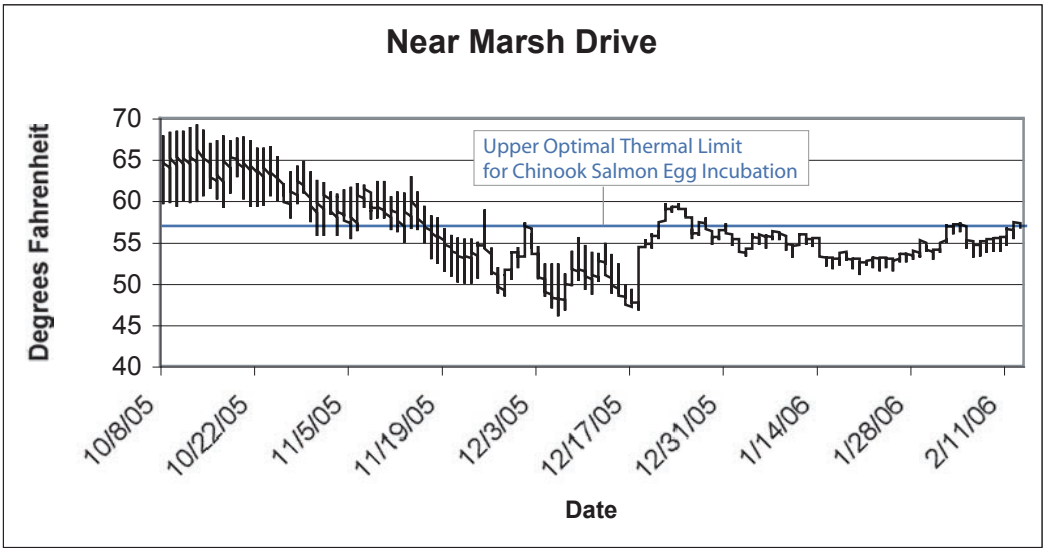


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Figure 5
Measured Hourly Water Temperatures at Three Locations in Lower Walnut Creek (October 8, 2005 to February 13, 2006)

an advanced state of decomposition or the head of the carcass was missing, which made it difficult to accurately determine the sex of the carcass. All of the Chinook salmon carcasses were examined for the presence of their adipose fin, and all carcasses observed were found to have their adipose fin intact. (A portion of hatchery fish is given an adipose fin clip to indicate that they have been marked with a coded-wire tag). Because not all hatchery Chinook salmon receive an adipose fin clip, the presence of an adipose fin does not confirm their origin (i.e., whether they were hatchery fish or naturally spawned).

Numerous female carcasses were found to have unspawned eggs. The presence of unspawned eggs in the carcass indicates that the female died prior to spawning, and may indicate stress from unsuitable conditions prior to spawning. However, only one of the observed female carcasses was believed to have died on its own before spawning. A large number of female (and some male) carcasses near Drop Structure No. 1 were observed to have been cut open; this observation and the bright, silvery appearance of these fish suggested that the fish had been poached (i.e., taken illegally). Anglers were frequently observed fishing for Chinook salmon below Drop Structure No. 1 and Jones & Stokes fish biologists observed poaching on several occasions. Most of the female carcasses found to be cut open had been stripped of their eggs. (Fresh salmon roe is a popular and valuable bait among anglers.). The occurrence of poached female adult Chinook salmon makes it impossible to accurately estimate pre-spawning mortality of females.

Table 6. WY 2006 Chinook Salmon Carcass Survey Data for Lower Walnut Creek

Monitoring Activity	Date in 2005	Redds	Live Adults	Carcasses			
				Males	Females	Grilse	Unknown
1	October 7	0	0	0	0	0	0
2	October 20	0	2	0	0	0	0
3	November 3	0	5	0	0	0	0
4	November 16	10	18	2	3	0	1
5	November 30	8	34	0	5	0	0
*	December 9	6	ND	ND	ND	ND	ND
6	December 15	7	50	6	31	8	7
Total		31	107	8	39	8	8

Notes:

Unknown = adults for which sex determination was not possible.

ND = no data (intermediate survey conducted for redds only).

An intermediate, but abbreviated, survey for redds was conducted during the period when water temperatures were suitable for egg incubation to increase the number of redds available for fry emergence monitoring.

3.3 Redd Scour and Sediment Deposition

Streambed elevations and redd features were initially surveyed in November and December, immediately following the first observation of the redds. Scour chains were installed at each redd at the time of initial streambed elevation surveys. Streambed elevations at 2 redds (06REDD003 and 06REDD006) were re-surveyed on December 9, 2005, to document potential redd scour and sediment deposition following a storm event in late November (Table 7; Figure 4). Streambed elevations were re-surveyed and scour chains were examined on January 26, 2006, at 4 redds (i.e., 06REDD004, 06REDD005, 06REDD008, and 06REDD010), and on February 13, 2006, at 5 redds (i.e., 06REDD019, 06REDD020, 06REDD025, 06REDD028, and 06REDD031).

Initial and final streambed elevations are compared for 11 redds (Table 7). Final streambed elevations adjacent to redd pits ranged from 1.025 feet lower (for 06REDD003) to 1.285 feet higher (for 06REDD010). Of the 22 streambed elevation measurements taken to either side of the redd pits (i.e., 11 taken to the right of the redd pits and 11 taken to the left of the redd pits), 9 indicate that there was a net decrease in streambed elevation (i.e., scoured occurred), 12 indicate that there was a net increase in streambed elevation (i.e., sediment deposition occurred), and one location (i.e., streambed to the right of 06REDD006) showed no change.

Five of the 11 scour chains installed at the time of initial redd surveys were relocated and observed for evidence of scour and sediment deposition. The remaining 6 scour chains were missing and were presumed lost due to scour or other factors (e.g., debris catching on the chains during flow events). All of the 5 scour chains recovered provided information that scoured had occurred. Scour ranged from 0.42 to 0.80 feet (Table 7). All 5 scour chains were useful in determining the amount of sediment deposition that occurred between installation and recovery. Burial of the 5 recovered scour chains ranged from 0.0 to 0.40 feet.

3.4 Spawning Gravel

Spawning gravel quality was measured for 10 of the 11 redds monitored for fry emergence (Appendix A). Gravel quality was not monitored for one redd (i.e., 06REDD020) because the gravel supporting this redd was scoured to clay bedrock as a result of high flows associated with winter storm events.

Gravel quality results include the percentage of substrate in each particle size category and the percentage of fines (i.e., sediment less than 5 mm) for each redd. Most gravel at redds being monitored for fry emergence was round and not angular. The percentage of particles in each size category was identified for the 10 redds (Table 8). Particles in categories 1–3 were observed at all sites. The percentages ranged from 31.9 to 80% for category 1 (less than 2 mm), 9 to 42.3% for category 2 (2–5 mm), 5 to 36.2% for category 3 (5–25 mm), and 0 to 19.3% for category 4 (25–102 mm). No redds had particles in category 5 (102–152

Table 7. Redd Location, Date First Observed, Date Emergence Predicted, Change in Streambed Elevation, Amount of Scour and Burial, and Redd Excavation Results for Ten Chinook Salmon Redds Excavated during WY 2006

					Change in Streambed Elevation		Scour Chain		
Redd Identification Number	Narrative Location	Date Redd First Observed	Predicted Date of Emergence	Date Redd Excavated	Change in Right Streambed Elevation (ft.)	Change in Left Streambed Elevation (ft.)	Amount of Scour (ft.)	Amount of Burial (ft.)	Redd Excavation Results
06REDD003	Opposite Hilton downstream of Diamond Blvd.	November 16, 2005	January 26, 2006	December 9, 2005	-1.025	-0.105	0.60	0.35	One hundred forty eight (148) dead eggs.
06REDD004	Opposite Hilton downstream of Diamond Blvd.	November 16, 2005	January 26, 2006	January 26, 2006	+0.405	-0.185	nd	nd	no eggs (or egg fragments), alevins, or fry observed.
06REDD005	Between Diamond Blvd. and Willow Pass Rd.	November 16, 2005	February 3, 2006	January 26, 2006	-0.105	-0.36	0.70	0.40	Two hundred twenty six (226) dead eggs.
06REDD006	Opposite Hilton downstream of Diamond Blvd.	November 16, 2005	February 3, 2006	December 9, 2005	0	-0.36	nd	nd	One hundred fifty nine (159) dead eggs.

Table 7. Continued

Redd Identification Number	Narrative Location	Date Redd First Observed	Predicted Date of Emergence	Date Redd Excavated	Change in Streambed Elevation		Scour Chain		Redd Excavation Results
					Change in Right Streambed Elevation (ft.)	Change in Left Streambed Elevation (ft.)	Amount of Scour (ft.)	Amount of Burial (ft.)	
06REDD008	Downstream Drop Structure No. 1	November 16, 2005	January 26 2006	January 26, 2006	0.625	+1.01	nd	nd	no eggs (or egg fragments), alevins, or fry observed.
06REDD010	Downstream Drop Structure No. 1	November 16, 2005	January 26, 2006	January 26, 2006	+1.255	+1.285	nd	nd	no eggs (or egg fragments), alevins, or fry observed.
06REDD019	Opposite Hilton downstream of Diamond Blvd.	December 9, 2005	February 18, 2006	February 13, 2006	+0.01	+0.18	0.42	0.40	no eggs (or egg fragments), alevins, or fry observed.
06REDD020	Opposite Hilton downstream of Diamond Blvd.	December 9, 2005	February 23, 2006	February 13, 2006	+0.19	-0.38	0.80	nd	Gravel supporting redd scoured to clay bedrock.
06REDD025	Opposite airport hangers downstream of Concord Ave.	December 15, 2005	February 17, 2006	February 13, 2006	+0.34	+0.37	nd	nd	no eggs (or egg fragments), alevins, or fry observed.

Table 7. Continued

Redd Identification Number	Narrative Location	Date Redd First Observed	Predicted Date of Emergence	Date Redd Excavated	Change in Streambed Elevation		Scour Chain		Redd Excavation Results
					Change in Right Streambed Elevation (ft.)	Change in Left Streambed Elevation (ft.)	Amount of Scour (ft.)	Amount of Burial (ft.)	
06REDD028	Opposite Waterworld	December 15, 2005	February 22, 2006	February 13, 2006	-0.185	-0.305	0.58	0.30	no eggs (or egg fragments), alevins, or fry observed.
06REDD031	Downstream Drop Structure No. 1	December 15, 2005	February 24, 2006	February 13, 2006	+0.59	+0.15	nd	nd	no eggs (or egg fragments), alevins, or fry observed.

mm). The percentage of total fines (i.e., percentage of particles less than 5 mm) for all potential spawning sites varied from 53.4 to 86.6% (Table 8).

Table 8. Percentage of Substrate in Each Particle Size Category for Each Redd Monitored for Fry Emergence in Lower Walnut Creek (Water Year 2006

	Percentage				
Site Number	Category 1 (<2 mm)	Category 2 (2–5 mm)	Category 3 (5–25 mm)	Category 4 (25–102 mm)	Category 5 (102–152 mm)
06REDD003	31.9	24.5	36.2	7.4	0
06REDD004	60.9	19.6	16.3	3.3	0
06REDD005	42.0	11.4	27.3	19.3	0
06REDD006	47.2	9.0	34.8	9.0	0
06REDD008	80.0	15.0	5.0	0	0
06REDD010	48.4	37.6	11.8	2.2	0
06REDD019	59.6	10.1	29.2	1.1	0
06REDD020[1]	ND	ND	ND	ND	ND
06REDD025	71.1	15.5	13.4	0	0
06REDD028	51.0	17.7	20.8	10.4	0
06REDD030	44.3	42.3	13.4	0	0

Notes:

[1] Gravel supporting redd '06REDD020' was scoured completely

ND = no data

3.5 Water Temperature Monitoring and Calculation of Temperature Units and Suitability Indices

Water temperatures were monitored continuously following the initial monitoring activity for adult migration and spawning surveys through the end of the fry emergence monitoring period (i.e., generally from early-October 2005 through February 13, 2006).

Water temperatures at all 3 monitoring locations showed similar patterns in daily and seasonal fluctuations. Generally, daily water temperatures were warmest from early October through early-November and were coolest from late-November through mid-December (Figure 5). A brief rise in water temperatures of 10 to 15 °F occurred in late-December at all 3 monitoring locations, apparently in response to a series of relatively warm storm events (Figure 5). Water temperatures shortly thereafter cooled but remained slightly warmer than those that occurred prior to the storm events. Mean hourly water temperatures at redd locations during the incubation period (i.e., from the time that the redd was observed initially to when redds were excavated) ranged from 45.8 to 60 °F.

Table 9 provides a summary of lower Walnut Creek water temperature conditions and the relationship of these conditions to the needs of incubating Chinook salmon eggs. In general, water temperatures warmer than the suitable range occurred from 5% to approximately 9% of the time for all redds. Overall, there was little difference in the suitability of water temperatures for Chinook salmon eggs and embryos, with the exception of redds 06REDD008 and 06REDD010 (Table 9). These redds were some of the earliest redds constructed in the spawning season and were the most-upstream redds of the 11 monitored for fry emergence.

3.6 Redd Excavations

Fry emergence results are presented in Table 7. Eleven of the 30 redds observed were selected, and monitored, for fry emergence. Of these 11 redds, 10 were excavated to determine the presence of eggs, alevins, or fry. Redd 06REDD020 was not excavated because the gravel supporting this redd was completely scoured due to high flows that occurred during winter storm events in late-December, 2005, and early-January, 2006.

Dead Chinook salmon eggs and fragments of dead eggs were found in three of the 10 redds excavated (Table 7 and Figure 6). One hundred forty eight (148) dead eggs were found in redd 06REDD003, 226 were found in redd 06REDD005, and 159 were found in redd 06REDD006. No Chinook salmon eggs or egg fragments, alevins, or fry were observed at the remaining 7 redds excavated.

4.0 Discussion

Confounding factors such as water temperature, fines, and scour can all influence spawning success. The monitoring conducted during October 7, 2005, through February 13, 2006, allows for the assessment of these factors to determine their relative influence on spawning success.

The results of this monitoring are also evaluated within the context of monitoring results for the Guadalupe River, in San Jose, California, where a monitoring effort similar to that on lower Walnut Creek was undertaken in WY 2006.

4.1 Adult Migration and Spawning

The observation of adult Chinook salmon and redds indicates that lower Walnut Creek supports migration and spawning of Chinook salmon and that adults are able to migrate at least as far upstream as Drop Structure No. 1. In addition, the timing of occurrence of adult Chinook salmon in lower Walnut Creek is generally consistent with the timing of occurrence of fall-run Chinook salmon in

Table 9. Water Temperature Suitability during incubation of Chinook Salmon Eggs and Embryos for 11 Redds in Lower Walnut Creek (Water Year 2006)

Suitability Index Category	Redd Number	06REDD003 06REDD004	06REDD005 06REDD006	06REDD008 06REDD010	06REDD019	06REDD020	06REDD025	06REDD028	06REDD031
	Date of Initial Observation	November 16	November 16	November 16	December 9	December 9	December 15	December 15	December 15
		Percentage of the Incubation Period							
0		0	0	0.11	0	0	0	0	0.13
0.25		0.6	0.05	1.3	0.06	0.06	0.4	0.06	0.7
0.50		2.2	1.8	3.0	2.1	2.3	4.0	2.3	1.8
0.75		2.8	3.2	4.4	3.6	4.0	2.1	3.9	4.1
Total		5.0	5.0	8.9	5.7	6.3	6.5	6.2	6.8

Dead and decaying Chinook Salmon eggs from redd excavated on January 26, 2006

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Figure 6
Fry Emergence—Chinook Salmon Eggs

other Central Valley and coastal streams and rivers in California (Yoshiyama *et al.* 1991).

The numbers of live adult Chinook salmon and carcasses observed in November and December 2005 do not represent an actual count of the total number of the adult Chinook salmon that migrated and spawned in the lower Walnut Creek watershed in WY 2006 because monitoring may not have spanned the entire spawning season. Live fish were still observed in the stream on December 15, 2005. Also, these data do not include fish that migrated up Grayson or Pine Creeks (these stream reaches were not included in WY 2006 monitoring).

Although it is not possible to calculate a precise estimate of the spawning escapement with the above field-collected data, it is possible to make a reasonable estimate of escapement for lower Walnut Creek between Highway 4 and Drop Structure No. 1 based on reasonable, yet conservative, assumptions. For the purposes of making a reasonable estimate of spawning escapement, the following are assumed:

- Carcasses observed during a single monitoring activity represent all carcasses that have been recruited to the stream over the previous 5-day period (which is a reasonable but conservative assumption based on observations of carcass retention times on Central Valley rivers).
- The number of carcasses observed for that 5-day period are representative of the number of carcasses that could be expected to occur during the 5-day period preceding and following the 5-day period that encompasses the day that actual counts of carcasses were made (Table 10).

Table 10 shows the dates of each of the 5-day periods and the assumed number of carcasses within each 5-day period based on the number of carcasses observed on the monitoring days.

Table 10. Actual and Assumed Number of Chinook Salmon Carcasses Observed in Lower Walnut Creek by each Five-Day Period for November 7 through December 20, 2005

Five-day Period	Dates in 2005	Actual (bold) and Assumed Number of Carcasses
1	November 7 – 11	6
2	November 12 – 16	**6**
3	November 17 – 21	6
4	November 22 – 26	5
5	November 27 – 30	**5**
6	December 1 – 5	5
7	December 6 – 10	52
8	December 11 – 15	**52**
9	December 16 – 20	52
Total		189

Note: Values in bold represent the actual number of carcasses observed on November 16 and 30 and December 15, 2005. All other values are assumed.

Based on these assumptions and the results of the monitoring data, 189 adults represents a reasonable estimate of the number of Chinook salmon that returned to lower Walnut Creek from November 7 through December 20, 2005. This value represents 120 more carcasses and 82 more live adult Chinook salmon than was actually observed during the 5 monitoring activities that adults and carcasses were observed. However, it should be noted that the poaching of live adult fish probably reduced the number of carcasses in lower Walnut Creek from the population. The removal of these adults through poaching may have resulted in an underestimation of the spawning escapement estimate.

If the unlikely, but theoretically possible, assumption is made that the respective number of carcasses observed during each monitoring activity was representative of an average daily count of Chinook salmon carcasses between monitoring activities, then the 63 observed carcasses would represent an average daily carcass count of 21 carcasses per day (i.e., 63 carcasses/30 days), or 630 carcasses over the 30-day period that carcasses were observed in lower Walnut Creek (i.e., 21 carcasses/day x 30 days). Based on the observations made by fish biologists over the course of the 6 monitoring activities, the estimate of 630 adults is likely too high.

4.2 Water Temperature

Water temperature during spawning and egg incubation in lower Walnut Creek is suitable to support egg survival to fry emergence, as supported by the data (Table 9). Optimal water temperatures were prevalent at all locations, occurring from approximately 91 to 95% of the time during the incubation period (Table 9). By contrast, the occurrence of unsuitable water temperatures was observed at only 3 redds (i.e., 06REDD008, 06REDD010, and 06REDD031) during the incubation period; however, the frequency of occurrence of unsuitable water temperatures was small (i.e., no more than 2 out of 1,520 hourly measurements, or 0.13% of the time). In addition, egg mortality was not correlated with the occurrence of unsuitable water temperatures. For example, no unsuitable (i.e., lethal) water temperatures occurred at redds 06REDD003, 06REDD005, and 06REDD006, where dead eggs were found (Table 7), suggesting that factors other than water temperature were responsible for egg mortality.

Although it is unclear to what extent egg incubation is supported when water temperatures exceed 60°F, limited exposure of eggs and embryos to unsuitable water temperatures may not preclude successful egg incubation. This hypothesis is supported by a study of fry emergence on the Guadalupe River, in San Jose, California. In that study, Chinook salmon eggs were found to survive and produce fry even though unsuitable water temperatures (i.e., water temperature in excess of 60°F) occurred 0.4% of the time and optimal water temperatures (i.e., 57°F or cooler) occurred 92.4% of the time during the egg incubation period (Jones & Stokes 2003).

Based on the Guadalupe River results, water temperatures in lower Walnut Creek appeared to be sufficiently cool enough to support successful egg incubation after mid- to late-November in WY 2006.

4.3 Fine Sediment

The presence of fines in spawning gravels in lower Walnut Creek may affect survival of eggs and embryos, as supported by the data. Based on gravel quality monitoring, the relative percentage of fine particles less than 2 mm in lower Walnut Creek redds in WY 2006 was relatively high (31.9–80.0%; Table 8). Optimal conditions for spawning of Chinook salmon require less than 10% fines (Raleigh et al. 1986). As discussed above, decomposing eggs were observed in redds at three locations (06REDD008, 06REDD010, and 06REDD031; Table 7; Appendix A).

The percentage of fines is one of the main factors that affects embryo survival, time of emergence, and size of emergent fry (Bjornn and Reiser 1991). Embryo survival is significantly reduced when the percentage of fines exceeds 30–40%. Fines reduce the supply of oxygen to the embryos and impede emergence of fry from redds (Tappel and Bjornn 1983; Waters 1995). Particles between 2 and 5 mm have less effect on flow through a redd and oxygen supply but may impede emergence. Overall, the relative percentage of fine particles less than 2 mm in

diameter at excavated redds in WY 2006 was relatively high (31.9–80.0%) (Table 8). If fines less than 5 mm are also considered, all potential spawning sites have fines in excess of 40% (Table 8). The high percentages of particles in category 1 (i.e., less than 2 mm) and category 2 (i.e., 2–5 mm) in gravels indicates potentially poor spawning habitat and possibly low production of fry.

A second effect that high levels of fine sediment in the spawning gravel may have on survival is impeded emergence of fry from the redd. Impedance of emergence, however, is not well supported because of the lack of data. The presence of dead Chinook salmon alevins or fry in excavated redds would support the hypothesis that fry emergence is impeded by the high levels of fine sediments; however, no alevins or fry (live or dead) were found. The lack of observations of Chinook salmon alevins or fry may reflect undocumented emergence (excavations were conducted well beyond the expected date of fry emergence), scour of eggs and fry, insufficient sampling, or a combination of factors.

Monitoring results for fry emergence in the Guadalupe River in WY 2006 also point to the occurrence of excessive fine sediments as being a likely determinant of poor egg incubation and hatching success in lower Walnut Creek. In the Guadalupe River, successful egg incubation leading to the development of alevins and fry was documented in WY 2006 for a redd where the percentage of substrate in each particle size category was 8% for category 1, 36% for category 2, 29% for category 3, 22% for category 4, and 5% for category 5 (Nishijima pers. comm.). Besides having a greater proportion of particles in categories 4 and 5 (no particles were larger than category 4 in any of the lower Walnut Creek redds), the Guadalupe River redd had substantially fewer particles in the smaller size classes (i.e., categories 1 and 2) than those observed for the excavated redds in lower Walnut Creek. For example, as stated above, the percentage of particles in category 1 ranged from 31.9 to 80.0% for redds excavated in lower Walnut Creek (Table 8), compared to only 7% in the redd excavated in the Guadalupe River for which successful egg incubation was documented. In addition, the median particle size in the Guadalupe River redd fell in category 3, whereas the median particle size for all excavated redds in lower Walnut Creek fell equally in categories 1 and 2 (Table 8). This smaller median particle size for lower Walnut Creek redds translated into 53 to 90% of the particles being 5 mm or smaller, compared to only 44% for the Guadalupe River redd.

4.4 Scour

High peak flows affect survival by scouring eggs and alevins from redds prior to fry emergence, as supported by the data (e.g., 06REDD020; Table 7). However, the observation of eggs in some redds indicates that the effect of scour does not always correlate with complete redd loss (e.g., 06REDD003, 06REDD005, and 06REDD006; Table 7). Measurement of channel topography and observations of scour chains in WY 2006 indicate that streambed scour occurred. The absence of eggs or evidence of eggs in seven excavated redds (Table 7) also indicates that scour may have resulted in the loss of redds; measurement of channel topography

and observations of scour chains indicate that streambed scour occurred at these locations. However, the absence of eggs or evidence of eggs in these redds may also indicate undocumented emergence for redds where the timing of excavations was consistent with the predicted date of emergence, or may indicate insufficient sampling, especially in light of the sediment deposition that occurred.

5.0 Summary and Conclusions

The observations of live and dead Chinook salmon indicate that lower Walnut Creek continues to support the migration and spawning of Chinook salmon. Although these stream sections support migration and spawning of adult Chinook salmon, it is unknown whether the creek below Drop Structure No. 1 supports successful production of Chinook salmon fry.

Several factors may be contributing to the low survival of eggs and fry.

- High percentage of fines less than 5 mm in gravels at spawning sites likely contribute to low survival of eggs and possibly low emergence of fry from the gravel.
- Scour may also play a role in reduced spawning success by removing eggs and alevins.

The observation of Chinook salmon adults and carcasses at the base of Drop Structure No. 1 indicates that lower Walnut Creek continues to support adult migration as far upstream as this constructed feature. Based on a field evaluation of Drop Structure Number 1 in WY 2004 (Jones & Stokes 2004b), it appears that this structure represents the upstream limit of migration for adult steelhead and Chinook salmon. Although adults may pass Drop Structure Number 1 during high-flow conditions, it is likely that passage would be limited to a few adults in any given year.

The timing of entry of adult Chinook salmon into lower Walnut Creek is consistent with the fall-run race of Chinook salmon. The WY 2006 spawning escapement estimate for the creek from the limit of tidal influence to Drop Structure No. 1 probably numbered between 189 and 630 adults, although the actual number is probably closer to the lower estimate. No adipose fin-clipped adults were observed in WY 2006; however, because not all hatchery fish are marked, the origin (i.e., hatchery vs. naturally spawned fish) of the lower Walnut Creek run cannot be conclusively determined.

The observation of high percentages of fines in all redds and dead Chinook salmon eggs at three of the redds suggests that spawning habitat in lower Walnut Creek is poor. The relatively high percentage of fines in spawning gravels is probably the limiting factor with the greatest influence on egg incubation and fry emergence, while water temperature does not appear to be a factor affecting egg and fry survival in lower Walnut Creek for redds that are constructed after mid-November.

Poaching of adult Chinook salmon, especially adult females, appears to be a significant problem during the spawning run, and may be in response to anglers seeking a source of fresh roe, a popular and valuable bait among anglers.

6.0 Recommendations

6.1 Restoration Actions

The WY 2006 fry emergence monitoring results suggest that gravel quality (i.e., percentage of fines) is a primary factor limiting the success of spawning by Chinook salmon in lower Walnut Creek. Augmentation of existing spawning gravels with washed, river-run gravels (to remove fines) could improve survival of Chinook salmon, and possibly steelhead, eggs and embryos in the gravel. It is recommended that gravel augmentation be undertaken as a pilot study by excavating one or more known spawning areas (e.g., pool tailouts and riffles) and replacing the excavated substrate with clean gravel. Alternatively, gravel could be introduced to the channel at key locations upstream of known spawning areas and allowed to distribute downstream in response to seasonal flows. (The precise method for introducing spawning gravels to the channel would need to be determined based on discussions between the Contra Costa Public Works Department, the Corps, and the resource agencies (i.e., DFG, NOAA, and USFWS).

To determine whether future gravel augmentation results in successful egg incubation and fry emergence, it is further recommended that monitoring of fry emergence at gravel augmentation sites be conducted using the methods employed as part of this study. While an additional year of monitoring would yield more data on the success of fry emergence in lower Walnut Creek, it may be possible to scale back the monitoring effort relative to this study by focusing the study to only those areas where gravel augmentation has occurred and to a few nearby spawning areas where gravels are not augmented, thus providing control sites that could be used for comparative purposes.

Because WY 2006 monitoring results documented the occurrence of extensive bedload transport (based on the observations of sedimentation at the monitored redds), the success of any restoration program seeking to improve gravel quality and therefore the success of fry emergence, will rely on addressing erosion and sedimentation issues in the watershed. For this reason, it is also recommended that gravel augmentation sites be monitored for gravel quality (i.e., percent fines) annually for three years following installation to document any changes in gravel quality over time. This information would assist resource managers with determining the feasibility of implementing a larger spawning habitat restoration program using gravel augmentation.

6.2 Future Studies

Monitoring of the adult migration and spawning indicator for WY 2006 provided information that indicated that adult Chinook salmon begin to enter lower Walnut Creek in late-October. Future adult migration and spawning monitoring for Chinook salmon on lower Walnut Creek should focus on more frequent (i.e., weekly) surveys for adults beginning around November 1. More robust estimates of spawning escapement and greater resolution in the timing of redd construction can be achieved by delaying the start of adult migration and spawning monitoring until November 1. Given that few live adults and no carcasses were observed until mid-November, the absence of monitoring in October is not likely to adversely affect spawning escapement estimates or redd counts. Greater resolution in spawning escapement data and timing of redd construction may provide greater utility in guiding management decisions and restoration alternatives in lower Walnut Creek and other streams in the watershed.

In addition, monitoring of water quality within the gravels in conjunction with future fry emergence monitoring would also yield more information on the confounding factors affecting egg and fry survival in gravel.

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7.2 Personal Communications

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Appendix A

Aerial Photographs

FIGURE A - 1

Page 1 of 9
Water Year 2006
Monitoring Locations for
Lower Walnut Creek,
Contra Costa County, California

LEGEND

ANADROMOUS FISH MONITORING

- Fish or carcass
- Redds

06FISH001 (3) Number in parentheses corresponds to number of live adults or carcasses observed at location

STREAM FLOW MONITORING

- Stream flow transect

WATER TEMPERATURE MONITORING

- Temperature probe

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Feet
1 Foot = 2300 Feet

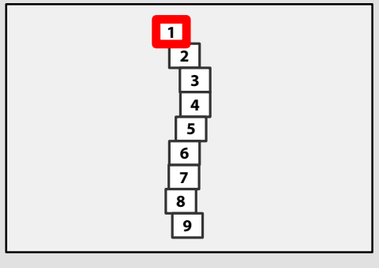

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FIGURE A - 1

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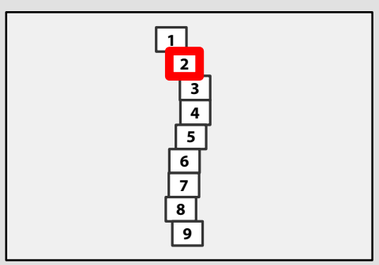

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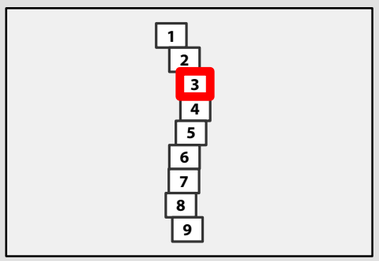

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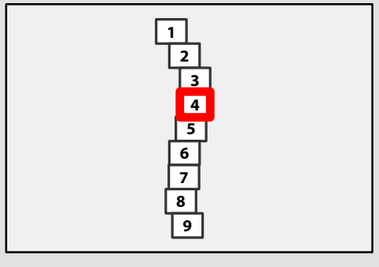

FIGURE A - 1

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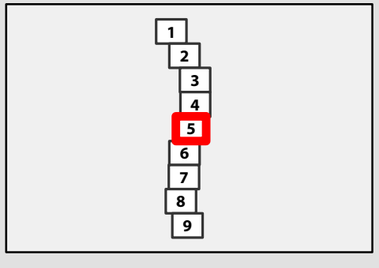

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FIGURE A - 1

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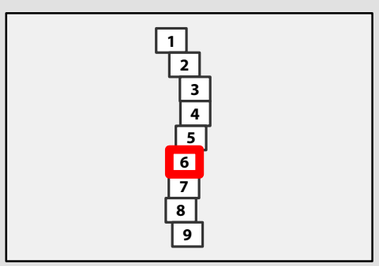

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FIGURE A - 1

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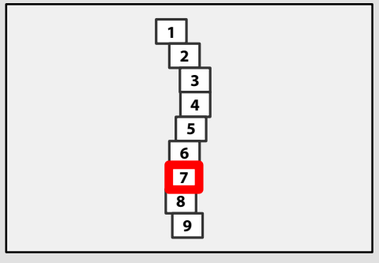

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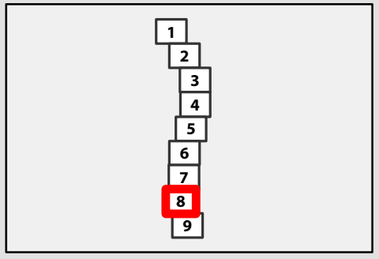

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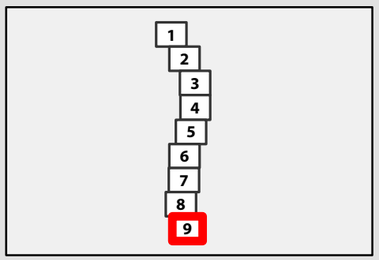

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