1.0 Water Quality and Fish

1.1 Introduction

Water quality results have been reported in previous San Joaquin River Restoration Program (SJRRP) Annual Technical Reports (ATR), but little attention has been given to interpreting these results in terms of possible effects on salmon and other native fish species that live within the San Joaquin River. The purpose of this report is to summarize and assess water quality data collected along the river between Friant Dam and the Merced River for the San Joaquin River Restoration Program during 2009-2010. This summary and assessment considers sampling frequency for adequate characterization of variability, sampling locations for sufficient characterization of the sampling reach, and sampling methods for appropriate media (water, sediment, tissue) and detection levels. A discussion of the water quality data and how it compares to available criteria and thresholds for salmonids, native fishes, and other aquatic organisms is also included.

1.2 Water Quality Methods

As described in Appendix C of the 2009 Annual Technical Report, water and sediment samples were collected by U.S. Bureau of Reclamation (USBR) personnel. All collection was done in accordance with Section 22 of the SWRCB Division of Water Rights Order WR 2009-0058-DWR and corrected WR 2010-0029-DWR.

Samples were collected, preserved, and handled according to USBR quality assurance practices, which included the incorporation of blank, reference, duplicate, and spiked samples to verify laboratory and field measurements. Bacteria, chlorophyll A, dissolved organic carbon, total organic carbon, nitrates, and total suspended solids samples were shipped from the field directly to laboratories. Grab samples were collected from the stream bank in a churn-splitter and then deposited directly into sample bottles. Water

samples were collected from the surface at each location. Sediment samples were collected from the top 5 cm at each location.

In order to summarize and assess the accumulated water quality data for this report, data were first compiled and organized by location and date so that meaningful comparisons could be made. The results were compared to thresholds and criteria obtained from literature sources for effects of water quality on aquatic organisms. This report specifically discusses the results of the Programs' water quality monitoring and how those results might affect the fish community within the Program's restoration reach. Detailed information about each sample's constituent results, location, and collection date is available in Appendix D of the ATR. Constituents that were not detected during SJRRP sampling were not discussed unless recommendations were made to lower current reporting detection limits.

1.3 Results

All available water quality data beginning with interim flows in fall 2009 through October 2010 were used in this summary and analysis. No samples were collected in November 2010, and results are pending for samples collected in December 2010.

Sampling frequency

During fall 2009, 44 water samples (from 11 sites) and 12 sediment samples (from 10 sites) were collected for analysis (Figure 1). Baseline water quality was measured in samples collected prior to the arrival of Interim flows at each site. Water samples were collected approximately once per week through November 2010. Sediment was collected at four sites before the arrival of Interim flow water, and at seven sites in December upon completion of Interim flows.

During 2010, 55 water samples and seven sediment samples were collected from seven sampling sites. Water samples were collected once per week in February and March, twice in April and once per month from June – December. No samples were collected in

May and November 2010 due to staff limitations. Sediment samples were collected once in April from seven monitoring sites.

In total, 99 water samples (from 11 sites) have been collected for the SJRRP water quality monitoring program during 2009-2010 Each water sample was analyzed for 153 different constituents (Table 4). During the same period, nineteen sediment samples were collected (from 10 sites), with each sample being measured for 54 constituents (Table 5).

Sampling locations

In 2009, water samples were taken from three locations in reach 1A, one location in reach 2A, 2B, 3, 4A, and 4B, and two locations in reach 5 (Table 1; Figure 1). Sediment samples were taken from two locations in reach 1A, one location in reach 2A, 3, and 4B, and 4 locations in reach 2B.

In 2010, water samples were taken from two locations each in reach 1A, 2A, and 5, and from one location in reach 3 and 4B. Sediment samples were taken from two locations in reach 1A and one location in reach 2A, 2B, 3, 4B, and 5.

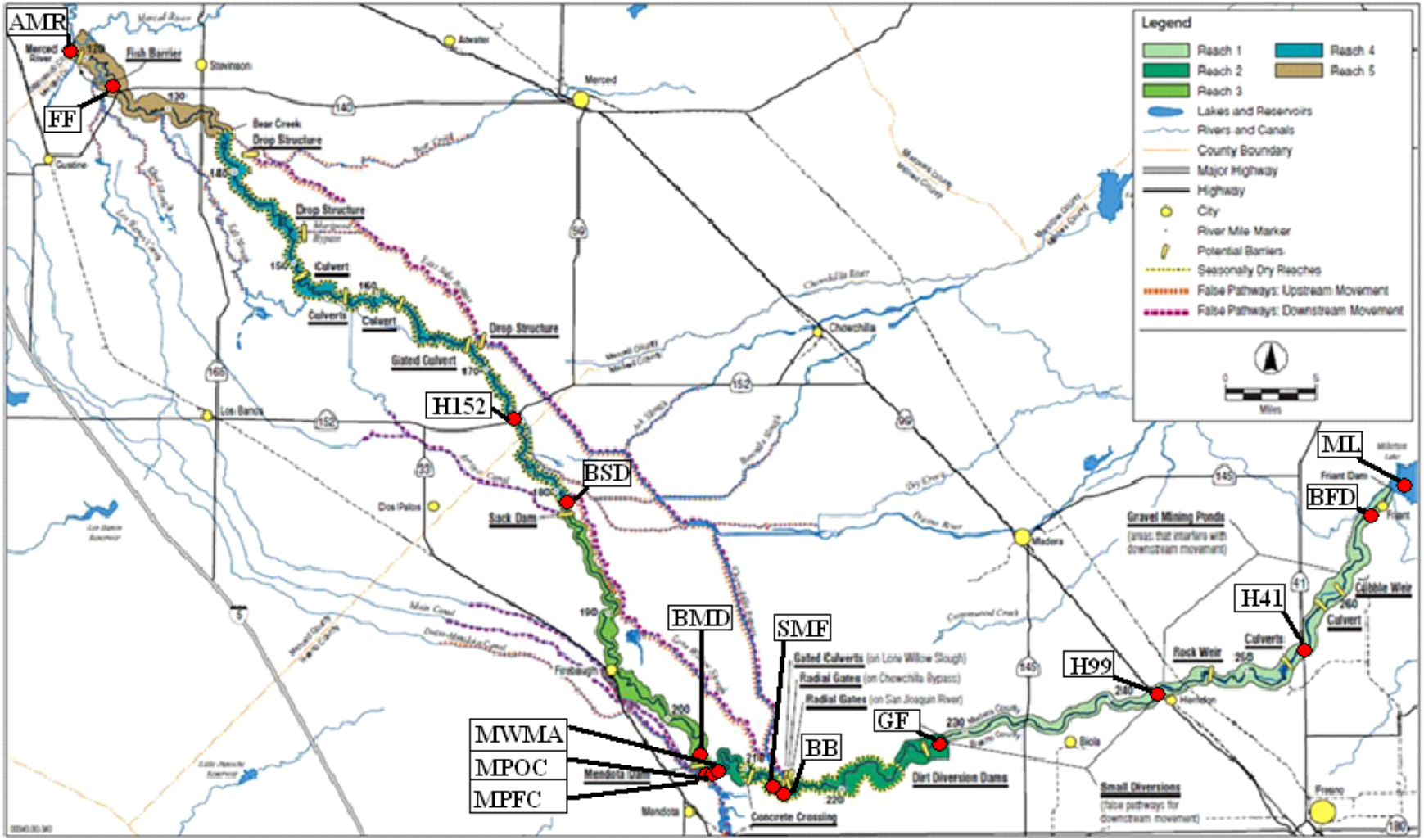

Figure 1: Water quality and sediment sampling site locations. Refer to Table 1 for site codes and descriptions.

Table 1: Water quality and sediment monitoring site locations
Media: wq = water quality sites, s= sediment sites, wq/s= both water quality and sediment sites

River Mile	Site code	Monitoring Site	Reach	Media	Year Collected
268	ML	Millerton Lake		wq	09
266	BFD	SJR below Friant Dam (Lost Lake Park)	1A	wq/s	09/10
255	H41	SJR at HWY 41	1A	wq	09
243	H99	SJR near HWY 99 (Camp Pashayan)	1A	wq/s	09/10
227	GF	SJR at Gravelly Ford	2A	wq/s	09/10
213	BB	SJR below Bifurcation	2B	wq	09
211.9	SMF	SJR at San Mateo Ford	2B	s	09
206	MWMA	Mendota Wildlife Management Area	2B	s	09/10
205.5	MPOC	Mendota Pool (CCID Outside Canal)	2B	s	09
205.2	MPFC	Mendota Pool (Firebaµgh Canal WD Intake Canal)	2B	s	09
205	BMD	SJR below Mendota Dam	3	wq/s	09/10
182	BSD	SJR below Sack Dam	4A	wq	09
174	H152	SJR at HWY 152	4AB	wq/s	09/10
125	FF	SJR at Fremont Ford	5	wq	09/10
118	AMR	SJR above Merced River (Hills Ferry)	5	wq/s	09/10

Sample media

Water and bed sediment are the types of media currently being sampled as part of the Program's water quality monitoring.

Detection limits

Water quality goals for the Program were defined using the water quality objectives for beneficial uses as defined by the Central Valley Regional Water Quality Control Board. Where no goals currently exist, minimum lab detection limits were used (Table 4 and 5). These detection limits may not detect sub-lethal concentrations (discussed further below) and some are above recommendations for detection of biological effects on fishes (Table 6).

Concentrations found and comparisons to criteria

Approximately 75 percent of the lab analyses of water and sediment samples were below minimum lab detection limits. Results for constituent samples above lab detection limits are listed in Table 2 (water) and Table 3 (sediment). A complete list of constituents measured in water and the laboratory reporting limits is provided in Table 4. A complete list of constituents measured in sediment and the laboratory reporting limits is provided in Table 5.

Of results that were above reporting limits, high sediment concentrations of bifenthrin and lambda-cyhalothrin, both pyrethroid pesticides, are of concern. Both of these samples come from the sampling site "San Joaquin River at San Mateo" on October 1, 2009. The collected sediment sample contained a bifenthrin concentration of 23 µg/kg (ppb). A study on the effects of sediment bound bifenthrin on gizzard shad (*Dorosoma cepedianum*) found that an eight day exposure to a bifenthrin concentration of 7.75 ppb induced complete mortality. Partial mortality and stress behaviors occurred at concentrations between 0.185-1.55 ppb. The gizzard shad is of the same family

(Clupeidae) as the threadfin shad, which is a member of the 'deep-bodied' fish assemblage, including Sacramento perch, hitch, and Sacramento blackfish (SJRRP, Background Report, Chapter 7). The gizzard shad is a filter feeder on zooplankton similar to threadfin shad, Sacramento blackfish and hitch. Therefore, although the gizzard shad does not exist on the San Joaquin River, comparable fishes do. This example is meant to illustrate the potential effects of bifenthrin on fishes and as few such studies currently exist, information must be drawn from available sources. In the same study, copepod nauplii experienced significant mortality across concentrations (0.090-7.75 ppb) on day four and seven of exposure (Drenner et al. 1992). Copepods are a group of zooplankton that are likely food for zooplankton-consuming fishes. Also, the larvae of almost all fishes consume zooplankton, including copepods, for at least a short time as they grow. These results highlight the fact that bifenthrin readily binds to sediment and is of particular concern for organisms that feed on organic matter as do some aquatic invertebrates, thus contaminating food sources for organisms that feed on invertebrates, such as salmon. The lambda-cyhalothrin sediment concentration was 21 µg/kg, a sediment-bound concentration harmful to aquatic invertebrates (Amweg et al. 2005; Weston et al. 2004).

Copper levels in water were above laboratory reporting limits (Table 2) in approximately 70 samples. Results for dissolved copper ranged from 7.0 - < 0.5 µg/L. A total of 42 water samples had copper concentrations greater than 1.11 µg/L, which is EPA's Office of Pesticide Programs (OPP) aquatic-life chronic benchmark for invertebrates. Thirty samples were above the acute benchmark for invertebrates (1.8 µg/L) (EPA 2011). Aquatic life benchmarks are extracted from the most current publicly available risk assessment data which is based on the most sensitive toxicity data for each aquatic taxa. Each benchmark is an estimates of the concentration below which pesticides are not expected to harm the organism. The highest copper samples come from the sites; SJ River above Merced River, SJ River below Mendota Dam, and SJ River at Fremont Ford.

Dissolved copper naturally occurs in the environment, but elevated ambient levels can cause negative effects on the food web that salmon and other fish depend on as well as lethal and sub lethal effects to the fish themselves. Sources of copper that can elevate ambient background levels include fertilizers, herbicides, acid mine drainage, and urban runoff. Sub lethal effect of copper have been shown to impair olfaction, interfere with migration, reduce response to predators, depress immune response, and interfere with brain function of salmonids (Lorz and McPherson, 1977; Baker et al. 1983). For example, Baldwin et al. 2003 found that a 2.3-3.0 µg/L increase in copper levels above background levels, for 30- 60 minutes, affected olfactory related behaviors in juvenile coho salmon regardless of water hardness levels. All other constituents sampled in water and sediment were below EPA's available water quality criteria standards for surface water (EPA 2009; EPA 2001; EPA 1986).

Table 2: Results of water quality constituents above lab reporting limits				
Constituent				
General Water Quality	**Max**	**Min**	**Reporting Limit**	**Units**
Alkalinity	200	12	5.0	mg/l
Bicarbonate	190	15	5.0	mg/l
Bicarbonate alkalinity	200	12	5.0	mg/l
E.coli	240	2	1.0	MPN/100mL
Fecal coliform	300	2	2.0	MPN/100mL
Ph	7.8	7.1	0.1	PH
Total coliform	1600	13	2.0	#/100ml
Metals				
Arsenic	6.2	0.5	0.5	µg/l
Boron	790	10	10	µg/l
Chromium	5.3	0.5	0.5	µg/l
Copper	7.0	0.5	0.5	µg/l
Lead	56	0.5	0.5	µg/l
Magnesium	37	1	1.0	mg/l
Mercury	.017	.0022	2.0	µg/l
Nickel	16	1	1.0	µg/l
Selenium	2.3	0.4	0.4	µg/l
Zinc	640	2	2.0	µg/l
Ions				
Calcium	68	2	1.0	mg/l
Carbonate	7	7	5.0	mg/l
Chloride	230	1.1	0.2	mg/l
Potassium	6.6	1	1.0	mg/l
Sodium	170	2	1.0	mg/l
Sulfate	240	0.72	0.4	mg/l
Biological				
Chlorophyll A	6.5	2.4	2.0	µg/l
DOC	8	2	0.3	mg/l
TKN	1.6	0.2	0.2	mg/l
TOC	8.2	2	0.3	mg/l
TSS	85	1.1	1.0	mg/l
Pesticides				
Dacthal	0.014	0.013	0.002	µg/l
Diuron	0.024	0.024	0.005	µg/l
Molybdenum	9.2	0.8	0.5	µg/l
Nutrients				
Ammonia as N	3.5	0.05	0.05	mg/l
Nitrate + Nitrite as N	1.4	0.055	0.05	mg/l
Nitrate as N	1.5	0.05	0.05	mg/l
Nitrite as N	0.04	0.03	0.03	mg/l

Phosphorus, Total as P	0.39	0.05	0.05	mg/l

Table 3: Results of sediment sample constituents above lab detection limits

Constituent	Max	Min	Reporting Limit	Units
Metals				
Chromium	15	1.2	0.5-1.0	µg/g
Copper	23	1.2	0.5-1.0	µg/g
Lead	53	0.98	0.5-1.0	µg/g
Nickel	34	1.3	1.0	µg/g
Zinc	62	5.5	1.5-2.0	µg/g
Pesticides				
Bifenthrin	23	<0.013	1.2-17.0	µg/g
Lambda-cyhalothrin	21	<0.013	2.3-17.0	µg/g

Table 4. Summary of all constituents measured in water with laboratory reporting limits.

Pesticides	Reporting limit
Organochlorine scan	
2,4'-DDD	0.002 µg/L
2,4'-DDE	0.002 µg/L
2,4'-DDT	0.002 µg/L
2,4,5-T	0.1 µg/L
2,4,5-TP	0.2 µg/L
2,4-D	0.1 µg/L
2,4-DB	2.0 µg/L
3,5-Dichlorobenzoic Acid	0.5 µg/L
4,4'-DDD	0.002 µg/L
4,4'-DDE	0.002 µg/L
4,4'-DDMU	0.002 µg/L
4,4'-DDT	0.005 µg/L
Acifluorfen	0.2 µg/L
Aldrin	0.002 µg/L
Bentazon	0.5 µg/L
Chlordane	0.05 µg/L
Chlordane-alpha	0.002 µg/L
Chlordane-gamma	0.002 µg/L
Dachtal	0.002 µg/L
Dalapon	1.0 µg/L
Dicamba	0.1 µg/L
Dichlorprop	0.5 µg/L
Dieldrin	0.002 µg/L
Dinoseb	0.2 µg/L
Endosulfan I	0.002 µg/L
Endosulfan II	0.002 µg/L
Endosulfan sulfate	0.002 µg/L
Endrin	0.002 µg/L
Endrin aldehyde	0.005 µg/L

Carbamates	Reporting limit
3-hydroxycarbofuran	0.5 µg/L
Aldicarb	0.005 µg/L
Aldicarb sulfone	0.5 µg/L
Aldicarb sulfoxide	0.5 µg/L
Baygon	0.5 µg/L
Captan	0.005 µg/L
Carbaryl	0.2 µg/L
Carbofuran	0.001 µg/L
Diuron	0.005 µg/L
Linuron	0.005 µg/L
Methiocarb	0.005 µg/L
Methomyl	0.001 µg/L
Oxamyl	0.5 µg/L
Organophosphates	
Aspon	0.05 µg/L
Azinphosmethyl	0.02 µg/L
Azinphos ethyl	0.05 µg/L
Bolstar	0.05 µg/L
Carbophenthion	0.05 µg/L
Chlorfenvinphos	0.05 µg/L
Chlorpyrifos	0.005 µg/L
Chlorpyrifos, methyl	0.05 µg/L
Ciodrin	0.05 µg/L
Coumaphos	0.05 µg/L
Demeton	3.0 µg/L
Demeton-o	1.0 µg/L
Demeton-s	0.05 µg/L
Diazinon	0.005 µg/L
Dichlorfenthion	0.05 µg/L
Dichlorvos	0.05 µg/L

	Reporting limit
Total Suspended Solids	1.0 mg/L
Total Organic Carbon	0.3 µg/L
Dissolved Organic Carbon	0.3 µg/L
Nutrients	
Ammonia as N	0.05 mg/L
Chlorophyll A	2.0 µg/L
Nitrate and nitrite as N	0.05 µg/L
Nitrate as N	0.05 mg/L
Nitrite as N	0.05 mg/L
Phosphorus, total as P	0.05 mg/L
Bacteria	
E. Coli	1.0 MPN/100mL
Fecal coliform	2.0 MPN/100mL
Total coliform	2.0 #/100ml
Trace elements, cations	
Calcium	1.0 mg/L
Magnesium	1.0 mg/L
Potassium	1.0 mg/L
Sodium	1.0 mg/L
Trace elements, anions	
Alkalinity	5.0 mg/L
Bicarbonate alkalinity	5.0 mg/L
Carbonate alkalinity	5.0 mg/L
Chloride	0.2 mg/L
Hydroxide	5000 µg/L
Sulfate	0.4 mg/L
Trace elements, total	
Arsenic	0.5 µg/L
Boron	10.0 µg/L

Endrin ketone	0.005 µg/L	Dicrotophos	0.05 µg/L	Chromium	0.5 µg/L
Gamma-bhc	0.002 µg/L	Dimethoate	0.03 µg/L	Copper	0.5 µg/L
HCH-Alpha	0.002 µg/L	Dioxathion	0.05 µg/L	Lead	0.5 µg/L
HCH-Beta	0.002 µg/L	Disulfoton	0.02 µg/L	Mercury	2.0 ng/L
HCH-Delta	0.002 µg/L	Epn	1.2 µg/L	Molybdenum	0.5 µg/L
Heptachlor	0.002 µg/L	Ethion	0.05 µg/L	Nickel	1.0 µg/L
Heptachlor epoxide	0.002 µg/L	Ethoprop	0.05 µg/L	Selenium	0.4 µg/L
Hexachlorobenzene	0.001 µg/L	Famphur	0.05 µg/L	Zinc	2.0 µg/L
Methoxychlor	0.002 µg/L	Fenitrothion	0.05 µg/L		
Mirex	0.002 µg/L	Fensulfothion	0.05 µg/L		
Nonachlor, cis	0.002 µg/L	Fenthion	0.05 µg/L		
Nonachlor, trans	0.002 µg/L	Fonophos	0.05 µg/L		
Oxadiazon	0.002 µg/L	Glyphosate	6.0 µg/L		
Oxychlordane	0.002 µg/L	Leptophos	0.05 µg/L		
Pentachlorophenol	0.04 µg/L	Malathion	0.02 µg/L		
Picloram	0.1 µg/L	Merphos	0.05 µg/L		
Tedion	0.002 µg/L	Methidathion	0.02 µg/L		
Total DCPA Mono & Diacid Degradates	0.1 µg/L	Mevinphos	0.05 µg/L		
Toxaphene	0.5 µg/L	Naled	0.05 µg/L		
Trichloronate	0.05 µg/L	O,O,O-Triethylphosphorothioate	0.5 µg/L		
		Parathion, ethyl	1.0 µg/L		
Pyrethroid scan		Parathion, methyl	4.0 µg/L		
Bifenthrin	0.001 µg/L	Phorate	0.02 µg/L		
Cyfluthrin	0.002 µg/L	Phosmet	0.02 µg/L		
Cypermethrin	0.002 µg/L	Phosphamadon	0.05 µg/L		
Deltamethrin	0.5 µg/L	Ronnel	0.05 µg/L		
Esfenvalerate	0.5 µg/L	Sulfotep	0.05 µg/L		
Fenpropathrin	0.002 µg/L	Terbufos	0.05 µg/L		
Lambda-cyhalothrin	0.5 and 0.0005 µg/L	Tetrachlorvinphos	0.05 µg/L		
Permethrin (total)	0.5 µg/L	Thionazin	0.05 µg/L		
Permethrin, cis	0.003 µg/L	Tokuthion	0.05 µg/L		
Permethrin, trans	0.003 µg/L	Trichlorfon	0.05 µg/L		

Table 5. Summary of all constituents measured in sediment with laboratory reporting limits			
Pesticides	**Reporting limit**	**Pyrethroid scan**	**Reporting limit**
Organochlorine scan		Bifenthrin	1.2-17.0 ng/g
2,4'-DDD	1.1-3.3 ng/g	Cyfluthrin	4.7-17.0 ng/g
2,4'-DDE	2.2-3.3 ng/g	Cypermethrin	4.7 ng/g
4,4'-DDD	0.65-1.1 ng/g	Esfenvalerate	13-17 ng/g
4,4'-DDE	2.2-3.3 ng/g	Fenpropathrin	4.7 ng/g
4,4'-DDMU	3.4 ng/g	Lambda-cyhalothrin	2.3-17.0 ng/g
4,4'-DDT	0.65-5.6 ng/g	Permethrin (total)	13-17 ng/g
Aldrin	1.1 ng/g	Permethrin, Cis	5.8 ng/g
Chlordane, technical	3.3 ng/g	Permethrin, Trans	5.8 ng/g
Chlordane-Alpha	1.1 ng/g	**Organophosphates**	
Chlordane-Gamma	1.1 ng/g	Chlorpyrifos	0.46 ng/g
Dachtal	1.1 ng/g	**Trace elements, total**	
Dieldrin	0.56-0.65 ng/g	Arsenic	0.5-1.0 µg/g
Endosulfan I	2.2 ng/g	Chromium	0.5-1.0 µg/g
Endosulfan II	6.8 ng/g	Copper	0.5-1.0 µg/g
Endosulfan sulfate	5.5 ng/g	Lead	0.5-1.0 µg/g
Endrin	0.65-2.2 ng/g	Mercury	0.0117-0.3 µg/g
Gamma-BHC	0.56-13 ng/g	Nickel	1.0 µg/g
HCH-alpha	0.56 ng/g	Selenium	2.5 µg/g
HCH-beta	1.1 ng/g	Zinc	1.5-2.0 µg/g
Heptachlor	1.1 ng/g	Total Organic Carbon	100-2500 µg/g
Heptachlor epoxide	0.65-1.1 ng/g	Dissolved Organic Carbon	2000 µg/g
Hexachlorobenzene	0.77 ng/g	Percent solids	
Methoxychlor	3.4 ng/g	Pecent moisture	
Mirex	1.7 ng/g	H. azteca survival	
Nonachlor, Cis	1.1 ng/g	H. azteca dry weight	
Nonachlor, Trans	1.1 ng/g		
Oxadiazon	1.1 ng/g		
Oxychlordane	1.1 ng/g		

1.4 Discussion and Recommendations

- Sampling frequency

Water quality sampling during 2010 generally occurred once per month for water, and once per year for sediment, in different months. No samples were collected in May and November 2010 due to limited availability of staff. Continuation of monthly water sampling as was done for most of 2010 is recommended so that a thorough understanding of the effects of interim flows can be developed. Routine sediment sampling should be considered, meaning that sediment sampling should be collected at the same time each year, ideally before increases in fall flow releases.

Storm sampling should be considered in order to determine if there are pulses of sampled constituents in the Restoration Area during storm events. In-stream concentrations of constituents that come primarily from surface runoff, such as pesticides, can increase dramatically during a storm event and may have toxic effects on aquatic organisms. A study by Kratzer (1999) found that concentrations of the pesticide diazinon are highly variable during winter storms, with some pulses high enough to be acutely toxic to aquatic invertebrates. Thus, it is important to sample water quality during both base-flow and high-flow events in order to accurately monitor the water quality of the river (Hladik et al. 2009; Weston et al. 2004; Orlando et al. 2003). Storm sampling is labor intensive and requires careful planning. A recommendation and design for a storm sampling study should be developed separately from this report by experts in the field.

- Sampling locations

Sampling is occurring in at least two locations in every reach, with the exception of Reach 3 and 4, where access to the river is restricted. Distribution of sampling locations is fairly even, with the exception of Reach 4. To help remedy this, it is recommended that water and sediment sampling sites be added above and below the confluence of Bear Creek with the San Joaquin River. Even distribution of sampling locations is important

in order to develop an accurate representation of the water quality throughout the restoration reach.

- Sample media

Tissue samples of resident fish species would be a very valuable asset to the Program. Tissue samples can help address questions regarding bioaccumulation and food web transfer of contaminates as such questions are difficult to address with only data from water and sediment. Tissue sampling has been conducted on the San Joaquin River as part of the Graslands Bypass Project for selenium and boron (Reach 5) and for mercury (Davis et al. 2008).

Another method for addressing the bioavailability of hydrophobic organic chemicals to aquatic organisms involves the use of semi-permeable membrane devices (SPMDs). This passive sampling technique can mimic the uptake of contaminates through biological membranes (Kot et al. 2000). They have been used to passively sample organochlorine pesticides in aquatic environments and can be used as a surrogate tissue sample to evaluate bioconcentration from water in aquatic organisms (Esteve-Turrillas et al. 2008). Bioaccumulation of contaminants through the food web cannot be addressed with SPMDs.

Bioassays conducted on aquatic invertebrates can indicate if important food web organisms are affected by the presence of contaminates in the sediment or water column. Previous bioassay studies have identified pesticide related toxicity in invertebrates in the San Joaquin River (Kuivila and Foe 1995; Foe and Connor, 1991). It is recommended that the Program consider conducting bioassays on sediment with benthic invertebrates (e.g., Hyallela sp., Chironomus sp.) and on water with water column oriented invertebrates (e.g., Ceriodaphnia sp.) as food web surrogates to better understand the possible lethal and sub-lethal effects of contaminates on food web organisms in the Restoration Area. Bioassays have been conducted on invertebrates, fish and algae as part of the Grasslands Bypass Project, but none of these tests were conducted at locations

within the San Joaquin River. These bioassays were conducted in Mud Slough and Salt Slough, both inputs to the San Joaquin River in reach 5 of the SJRRP.

- Sample processing

Approximately three percent of constituent analyses from both sampling years exceeded their hold times for lab processing, which can reduce the accuracy of the results. Hold times exceedances ranged from 24 hours to 40 days, with the majority of samples exceeding either their 24 hour (47%) or 14-day hold times (44%). Samples that exceeded 24-hour hold times were primarily bacteria (coliform and E.coli), while those that exceeded 14-day hold times consisted of a variety of constituents including pesticides and general water quality parameters. Seven DOC and one TOC samples were not preserved correctly upon collection. Forty-five chlorophyll A samples were not filtered within the correct amount of time following collection. It is recommended that sample processing protocols, including holding times, be improved upon and applied to the current sampling effort.

- Detection limits

Detection limits are mostly sufficient for detecting concentrations potentially toxic to aquatic biota, with some acceptations. It is recommended that arsenic, boron, chlordane, DDD, DDE, and DDT be tested with lower detection limits than currently utilized (Table 6). It is also important to note that some pesticides such as chlorpyrifos, diazinon, malathion, and bifenthrin can be detected at lower concentrations than possible with laboratory analyses presently being used by the Program. Detection of toxic constituents at low levels can be important for identification and investigation of sub-lethal effects of both salmon and resident native fishes (discussed further below). A review of existing literature indicates that the detection levels currently being used by the Program appear to be sufficient for monitoring biological effects of harmful constituents within the river, with the exception of those present at a sub-lethal concentration.

Table 6: Recommended detection limits for biological effects on fishes from the 2009 SJRRP Water Quality Monitoring Plan		
Constituent	**Current detection limit**	**Recommended detection limit**
Arsenic	0.5 µg/L	0.014 µg/L
Boron	10.0 µg/L	0.8 µg/L
Chlordane	0.05 µg/L	0.0043 µg/L
DDD	0.002 µg/L	0.00031 µg/L
DDE	0.002 µg/L	0.00022 µg/L
DDT	0.005 µg/L	0.001 µg/L

- Thresholds

Review of the water quality data collected to date for the Program shows few constituents present at concentrations that exceed aquatic life thresholds. However, other water quality studies conducted on the San Joaquin River have found elevated levels of constituents, such as selenium and methyl-mercury in the system that may pose threat to aquatic organisms. Thus, it is important to maintain regular and consistent sampling in the Restoration Area to understand possible changes associated with natural factors, such as seasonal differences, storm events, as well as anthropogenic factors, such as changes in restoration flows, restoration of floodplain, and changes in agricultural practices. Monitoring results should be evaluated in the context of current research on the effects of pollutants in surface waters on aquatic biota. Such evaluation can guide refinements in the water quality monitoring program.

The SJRRP manages for Chinook salmon and other native fish that are linked through a food web. The water quality program will not adequately utilize existing results until the translation of water quality effects up the food web is investigated and better understood. This investigation should rely on conclusions from existing studies and address these information gaps. For example, there is little information about toxic effects of pesticides on aquatic invertebrates and how such effects translate up the food web (Macneale et al.

2010). Of the work that has been done in this area, results show that applications of pesticides can have a strong negative effect on the food web. In a study done by Relyea and Diecks (2000) that looked at food web effects of the insecticide malathion, findings showed that all levels of application (10-250 µg/L) over short periods of time (1-4 days) caused a decline in zooplankton, which caused a cascading decline in all other species in the study. They also found that repeated applications of low doses caused a greater negative response than a single application of a high dose. These and other studies highlight the importance of quantifying pesticide exposure in aquatic habitats due to pesticide-use patterns, combined effects of multiple pesticides, and how the fate of various pesticides change in relation to degradation times, uptake rates and binding ability of soils (Laetz et al. 2009; Oros and Werner, 2005; Nowell et al. 1999).

A variety of research has been done on pesticides and their various effects on fish. Organophosphates and carbamates are two classes of pesticides that are of particular concern as both target the nervous system (Fulton and Key 2001). For example, a two hour exposure to the organophosphate insecticide diazinon has been found to decrease olfactory-mediated alarm responses in Chinook salmon at concentrations of 1.0 µg/L. A 24 hour exposure to diazinon at concentrations ranging from 0.1-10.0 µg/L disrupts homing in Chinook salmon males (Scholz et al. 2000). Another currently used pesticide that is commonly applied in the San Joaquin Valley, chlorpyrifos, has been shown to inhibit acetylcholinesterase (AChE), an important chemical in the transmission of nerve impulses, in the nervous system and muscles of juvenile steelhead and coho salmon at concentrations of 510.0 mg/L. Reduction in AChE activity has been linked to decreased swimming behavior and prey consumption by juvenile salmon (Sandahl et al. 2005; Sandahl and Jenkins 2002). The presence of these and other pesticides are well documented on the San Joaquin River and its tributaries (Domagalski et al. 2010; Orlando et al. 2004) and SJRRP monitoring should continue.

Sub-lethal effects of pesticides, such as those discussed above, are of particular concern for aquatic organisms in the San Joaquin River. Sub-lethal effects include reductions in

growth, swimming behavior, reproductive success, and immune system response in aquatic fish and invertebrates, often at much lower than lethal concentrations (Oros and Werner, 2005). The pesticide carbofuran is thought to have sub-lethal effects on reproduction in Atlantic salmon (Waring and Moore, 1997). To date, the results from the Program's water quality sampling show few exceedances, yet it is possible that aquatic organisms within the river are exposed to concentrations of both pesticides and other potentially harmful constituents that are sufficient to cause important sub-lethal effects. It may be valuable to test for some of the most toxic constituents, particularly pesticides, at the lowest available detection limits so that a sub-lethal baseline can be established. If sub-lethal effects occur with exposures in the part per trillion range, then they are not currently being detected since the Program's laboratories detection levels are in the part per million or part per billion range. This type of testing may lead to a better understanding of how present persistent pollutants affect the San Joaquin River fish fauna.

Summary of recommendations

- Continue monthly water quality sampling throughout the year
- Consider sampling sediment at the same time each year, before increases in flow releases (i.e. September).
- Evaluate desirability of storm sampling
- Add sample site above and below Bear Creek confluence
- Evaluate desirability of tissue sampling
- Consider using SPMDs for passive pesticide sampling
- Consider conducting bioassays above Reach 5
- Change detection limits to those listed in Table 6

- Evaluate the likelihood of sub lethal effects based on existing data and literature review

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