November 2009

City of Elk Grove

New Development Stormwater Monitoring Program

~ Final Report ~

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List of Acronyms and Abbreviations

City	City of Elk Grove
BMP	Best Management Practices
BOD	Biological Oxygen Demand
DO	Dissolved Oxygen
DOC	Dissolved Organic Carbon
NPDES	National Pollutant Discharge Elimination System
PAH	Polycyclic Aromatic Hydrocarbons
Regional Board	Central Valley Regional Water Quality Control Board
RPD	Relative Percent Difference
Stone Lakes NWR	Stone Lakes National Wildlife Refuge
SWPPP	Storm Water Pollution Prevention Plan
TIE	Toxicity Identification Evaluation
TOC	Total Organic Carbon
USEPA	U.S. Environmental Protection Agency
USFWS	U.S. Fish and Wildlife Service

1. Introduction

The City of Elk Grove (City) is currently subject to the requirements of the Sacramento area-wide Phase I National Pollutant Discharge Elimination System's (NPDES) Municipal Stormwater Permit[1]. Pursuant to the NPDES permit, the City has led local efforts over the past several years to construct water quality treatment basins/wetlands and to monitor stormwater runoff from newer developments within the City's jurisdiction.

In a 26 July 2007 letter, the Central Valley Regional Water Quality Control Board (Regional Board) detailed its concerns with a development project, Promenade Mall, within the City's jurisdiction and the effects of urban runoff to the Stone Lakes National Wildlife Refuge (Stone Lakes NWR). Among other requirements, the Regional Board required the City to implement "a monitoring program…needed to measure the cumulative impacts from developments which discharge to waters that flow into Stone Lakes NWR". The Board went on to clarify that "a City implemented monitoring program is needed to evaluate water runoff quality from the Promenade Mall and downstream developments which discharge to waters that flow into Stone Lakes NWR and is in addition to the City's current storm water monitoring activities." In response to this requirement, the City developed a monitoring program work plan, which was submitted to stakeholders—including Regional Board staff—for review in December 2007 and approved by the Elk Grove City Council in February 2008.

Key questions associated with urban development's impact on downstream environments include the following:

- Does the development degrade water quality?
- Does the development modify the local hydrology?
- Do the development and associated runoff stress plant and animal habitats?

The monitoring program focused on responding to the first question by sampling tributary waters within the City and downstream refuge, and sediment deposited in the refuge. Also, citizens were recruited to initiate a community-based monitoring effort of monitoring water quality and riparian habitats. The second question was investigated by deploying continuous water depth sensors at two sites and by field crew observations. The third question was addressed by comparing measurements to water quality objectives, by testing for toxicity of sediment and water column samples, and by photographing and observing site conditions during sampling events.

1.1. STUDY AREA

The City of Elk Grove, located approximately 12 miles south of downtown Sacramento (**Figure 1**), was incorporated on 1 July 2000. The southern boundary of the City has been extended southwards into farmland, now largely bordering Kammerer Road. The farmland is primarily seasonal row crops, with some dairy operations and farmhouses. The City and other municipalities within Sacramento County collaborate as co-permittees under the same NPDES permit. The collaborative group is called the Sacramento Stormwater Quality Partnership. Co-permittees are also identified in Figure 1.

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[1] Permit No. CAS082597, Order R5-2002-0206

The study area (**Figure 2**) encompasses the southwest region of the City and is largely farmland at this time. The area slated for urban development now includes Promenade Mall, which covers approximately 525 acres at the upstream end of the undeveloped area. Promenade Mall is the first urban development project along the southern boundary of the City. In Figure 2**,** the red-hashed area east of station C-Promenade and west of Highway 99 encompasses the Mall. The City refers to the planned development's drainage area as "Shed C". Mall runoff drains towards the west approximately four miles via agricultural drains to Stone Lakes NWR. The study area also included "Central Drainage Channel", which drains recently developed "Shed B" adjacent to the north and enters North Stone Lake.

Stone Lakes NWR, established in 1994, encompasses three large lakes within an 18,000-acre project boundary: Beach Lake, North Stone Lake and South Stone Lake (**Figure 3)**. The U.S. Fish and Wildlife Service (USFWS) manages over 6000 acres in Stone Lakes NWR. Stone Lakes NWR is within the Cosumnes and Mokelumne Rivers' watershed and is considered part of the Delta. Floodwaters from these rivers to the south and Morrison Creek to the north also flow into the refuge. A photo of the typical grasslands view is included in **Appendix A**. Stone Lakes NWR lies within the Pacific Flyway, and provides valuable habitat to migrating, wintering and breeding migratory birds as well as resident wildlife. The migration/wintering season generally runs from October through March.

1.2. MONITORING STATIONS

Monitoring stations for this program are shown in Figure 2 along with historical monitoring stations in Stone Lakes NWR watershed. Photos taken at each monitoring station are provided in **Attachment A**. These stations were selected for several reasons:

- C-Promenade represents site runoff. The drainage area for C-Promenade is now almost entirely commercial development. The Mall property had been graded and was under construction during the study period.
- B-Franklin represents conditions from a recently developed urban residential area draining into Stone Lakes NWR. However, Shed B was planned, designed and mostly constructed before the Stormwater Quality Design Manual[2] was issued. Nonetheless, while there are no detention basins in the Shed B watershed, the trapezoidal-shaped, grass-lined channel used to convey the 100-year storm flows is the first known in the area to incorporate multi-functional elements that serve to: improve stormwater treatment, reduce channel maintenance costs, increase environmental and aesthetic values, replace lost riparian and wetland habitat and preserve useful space.
- C-Franklin and C-Bruceville represent pre-development runoff from the planned development area. The remaining drainage area in Shed C between these stations and Stone Lakes NWR is almost entirely agricultural.
- C-SLNWR represents conditions in Stone Lakes NWR at the downstream end of Shed C.

The Franklin Blvd ("C-Franklin") monitoring station was replaced with a new site at Bruceville Road ("C-Bruceville") after Event #2. The main reasons for changing locations included:

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[2] See http://www.sacramentostormwater.org/SSQP/development.asp.

- C-Franklin was stagnant during Events #1 and #2. The water appeared to be characteristic of dairy runoff (no oxygen, high ammonia) and was quite toxic to test organisms. There was little value in sampling it again under those conditions.
- C-Franklin is outside of the City's jurisdictional boundary. The land between Franklin Blvd and Bruceville Road is not in the City and is not slated for urban development.
- Bruceville is at the downstream edge of the City's jurisdictional boundary. While groundwater pumping may influence runoff from the agricultural drain, this station is closer to current and planned urban development and thus better for characterizing baseline (pre-development) conditions.

Basic monitoring components used to characterize site runoff and receiving water quality are included in **Table 1**. Pollutants and toxicity were analyzed from grab samples, and field measures were taken while collecting those grab samples.

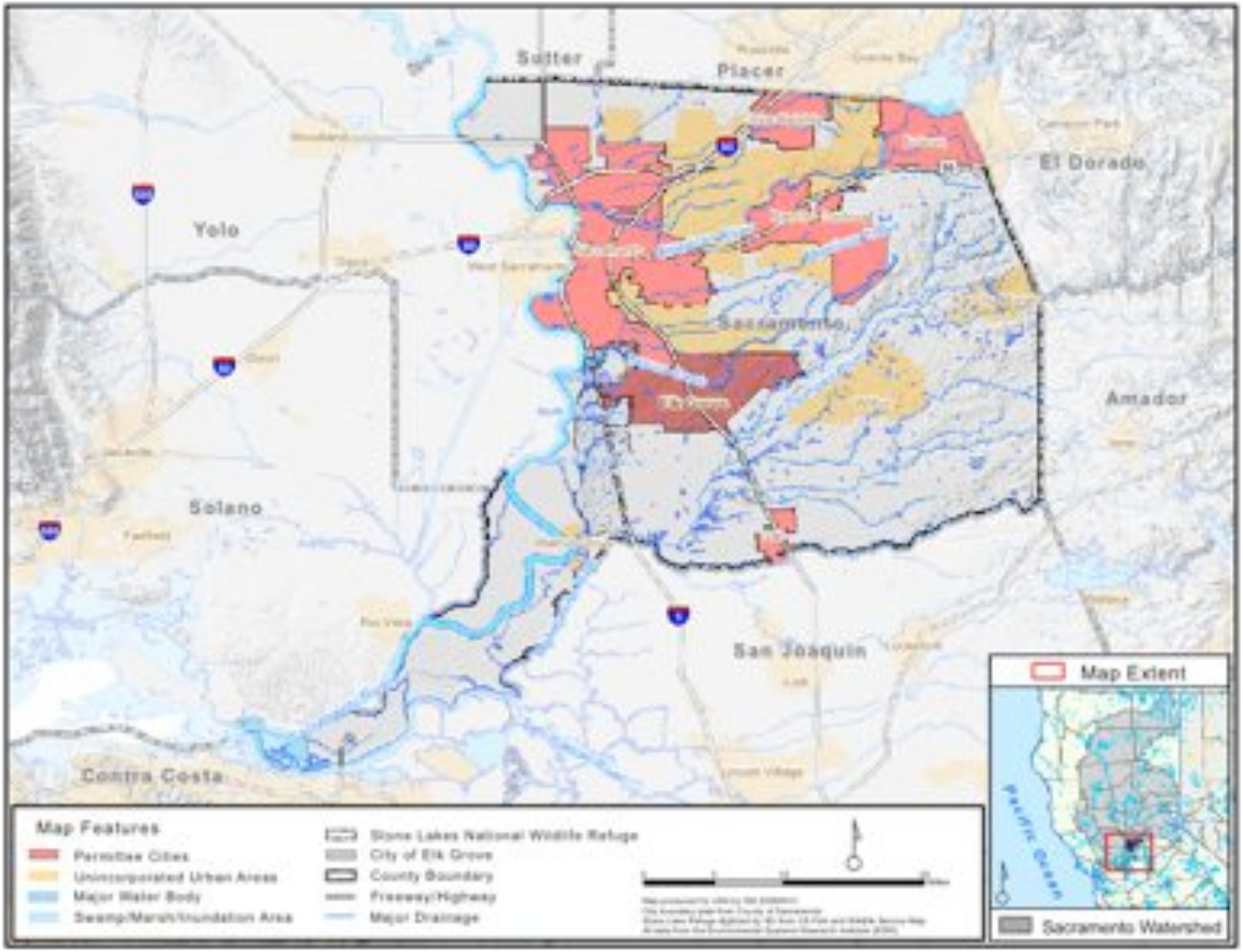

Figure 1. City of Elk Grove in relationship to Sacramento County co-permittees and Stone Lakes NWR

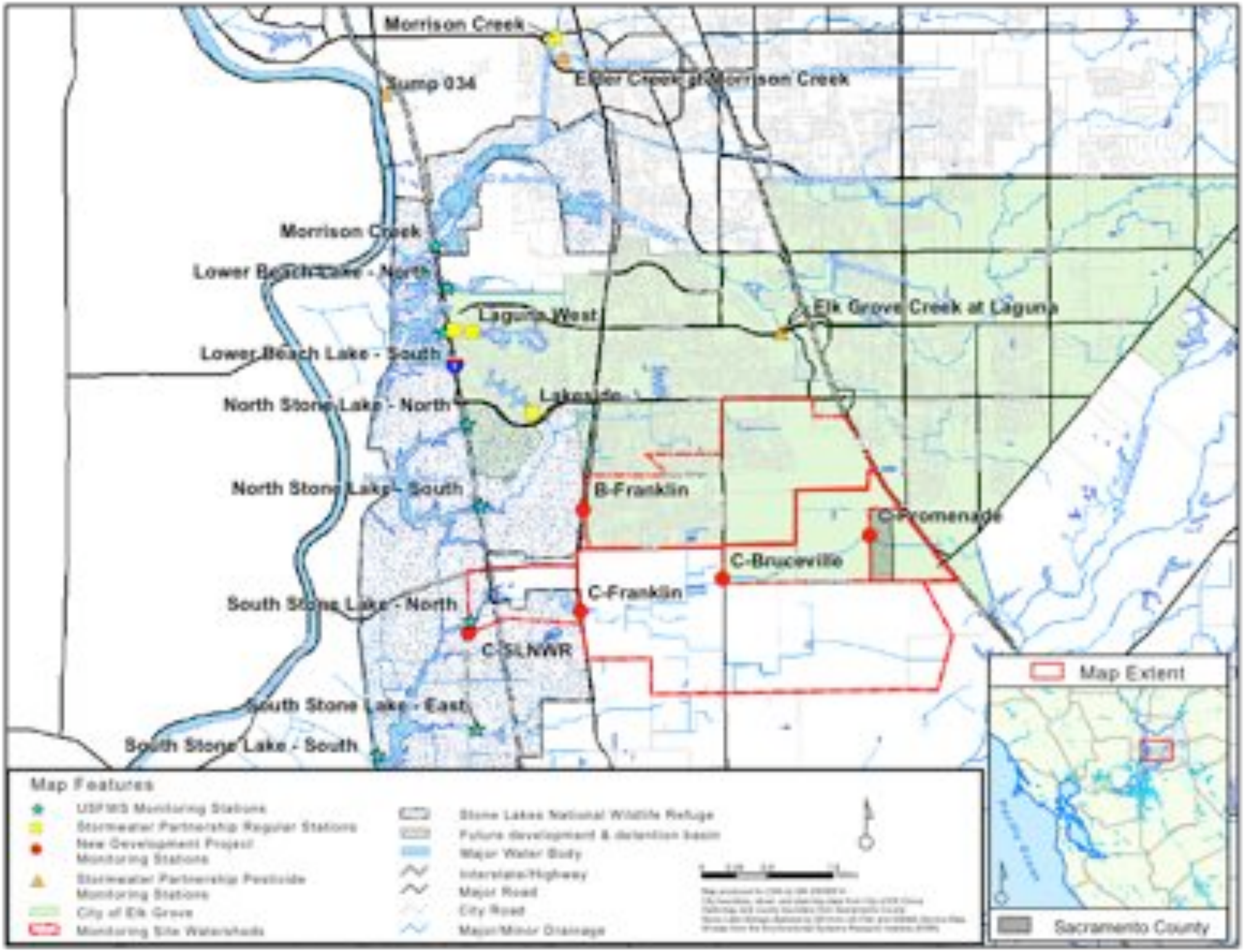

Figure 2. City of Elk Grove stormwater monitoring study area. Program monitoring stations are shown as red circles and their approximate drainage areas outlined by red lines; stations historically monitored by other programs are identified with unique markers.

Table 1. City of Elk Grove Stormwater Monitoring Stations

Name	Purpose	Location	Monitoring Components			
			Pollu-tants	Cont. Sensor	Field Measures	Toxicity
Site Runoff:						
C-Promenade	Represent local runoff from the newly developed Promenade Mall after treatment in a detention basin	Eastern end of agricultural drain. Sampled agricultural drain if no discharge from basin	See Table 3		√	
Receiving Water:						
B-Franklin	Represents conditions from a recently developed urban area of the City draining into Stone Lakes NWR	East side of Franklin Blvd bridge over Central Drainage Channel (Shed B), ¼ mile north of Bilby Rd near the town of Franklin	See Table 3	√	√	√ (Water Column)
C-Franklin (Events #1&2)	Represent pre-development runoff from the planned development area	Franklin Creek channel on East side of Franklin Blvd culvert		√	√	√ (Water Column)
C-Bruceville (Event #3)		Franklin Creek channel on East side of Bruceville Rd., 200 feet north of Kammerer Rd.			√	√ (Water Column)
C-SLNWR	Represents conditions in Stone Lakes NWR	West of I-5 within Stone Lakes NWR, East side of Stone Lakes Road culvert			√ [1]	√ (Water Column & Sediment)

[1] Many additional sites within Stone Lakes NWR were monitored for basic water quality conditions during two citizen-monitoring events.

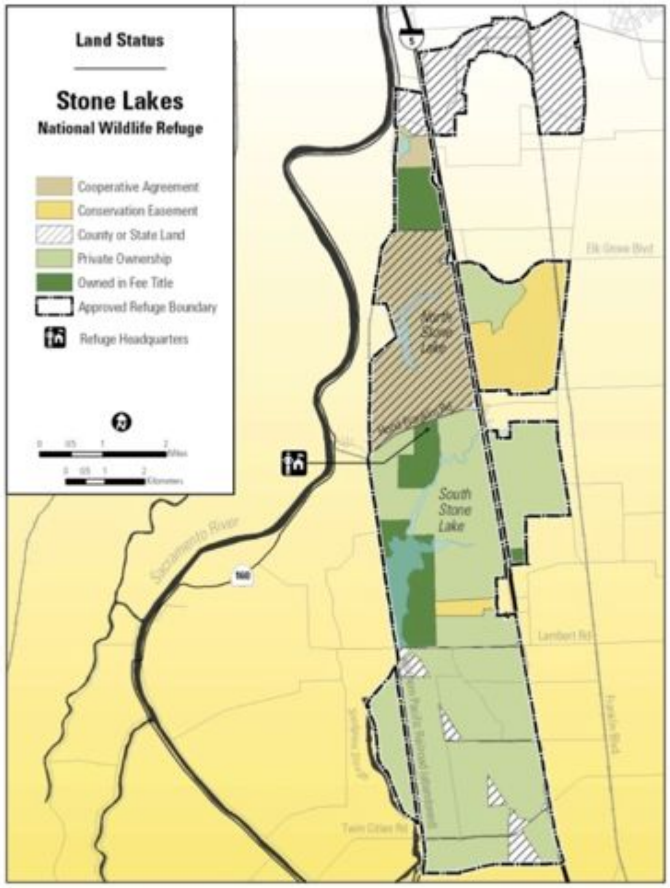

Figure 3. General map outlining Stone Lakes NWR and major lakes.

1.3. SCHEDULE

The schedule followed for training, sampling events, and reporting is summarized in **Figure 4**. The initial schedule was modified when no rainfall fell after February 2008.

Activity Description	2008											2009		
	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar
DSMP Workshop presentations		●									●			
CA Coastwide Snapshot Day				●										
Sediment Toxicity Monitoring Event						●								
World Water Monitoring Day Event								●						
Wet-weather monitoring crew training									●					
First-flush Storm, Event #1										●				
DSMP Workshop presentation												●		
Mid-winter Storm, Event #2													●	
Late-season Storm, Event #3														●

Figure 4. City of Elk Grove Stormwater Monitoring Program Schedule.

2. Citizen Involvement

Citizen involvement was an important component of this monitoring program. Local citizens reviewed the work plan, shared local knowledge with storm conditions, participated in two citizen-based monitoring events in Stone Lakes NWR, and assisted during the three storm sampling events. The City, in hopes of continuing their involvement, registered all interested participants, provided necessary field materials (e.g., monitoring kits, log sheets, site maps), provided necessary training, and passed out a fact sheet describing potential future monitoring activities. The City also provided volunteers and the local newspaper with summaries of the monitoring results. All monitoring data have been included in the study database and were submitted into each event's central database.

Measurements for the two citizen-based events were taken during dry weather (several months after the last rainfall) and in essentially stagnant water. Consequently, data from these events should be used with caution and not be used to characterize runoff from surrounding land use activities. Instead, these data may be used to identify trends in surface water conditions over time. The field kits provided for such volunteer events were reasonably accurate for this purpose, when compared to professional-quality sensors' accuracy.

2.1. RECRUITMENT EFFORTS

The following tools were used to recruit volunteers for the two citizen-based events:

- City of Elk Grove newsletter
- Volunteer Match web site[3]
- World Water Monitoring Day website
- Notices and invitations sent to Laguna Creek Watershed Council and Stone Lake Refuge Association staff and volunteers

2.2. CALIFORNIA COASTWIDE SNAPSHOT DAY, 3 MAY 2008

The first citizen-based monitoring event was held on May 3, in association with three related events: Creek Week[4], California Coastwide Snapshot Day[5], and Earth Day. Eight volunteers in two groups measured water conditions at eight sites throughout Stone Lakes NWR to develop a picture of water quality and watershed health at a single point in time. Working in teams, the volunteers measured temperature, dissolved oxygen (DO), pH, turbidity, and electrical conductivity using World Water Monitoring Day Test Kits provided by the Laguna Creek Watershed Council. Photos taken during this event are provided in **Appendix A**. Calibrated, electronic field meters were used to verify pH and temperature measurements. Results from this event, summarized in **Figure 5**, indicate generally good quality**.**

[3] See www.volunteermatch.com

[4] See http://www.creekweek.net/.

[5] See http://www.epa.gov/region09/features/coast_snapshot/index.html.

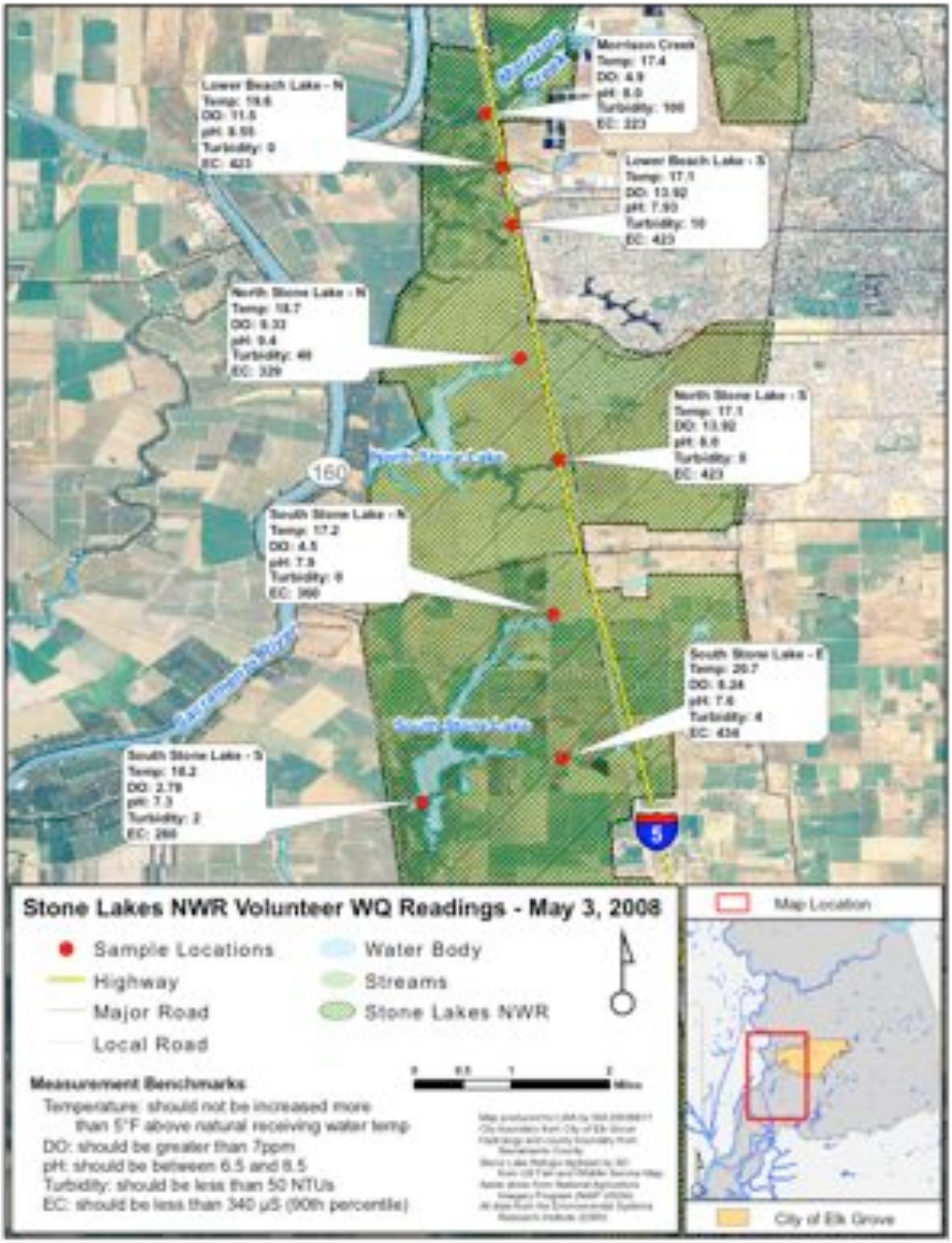

Figure 5. Spring Snapshot Day citizen-based monitoring results, 3 May 2008. DO = dissolved oxygen; EC = electrical conductivity.

2.3. WORLD WATER MONITORING DAY, 27 SEPTEMBER 2008

The second citizen-based monitoring event was held on 19 September 2008 in association with World Water Monitoring Day[6], an international outreach program that builds public awareness and involvement in protecting water resources around the world. Held annually between September 18 and October 18, the program engages communities in monitoring the condition of local rivers, streams, estuaries and other water bodies. Nine volunteers measured water quality conditions at eight sites located throughout Stone Lakes NWR. Volunteers used World Water Monitoring Day Kits provided by the Laguna Creek Watershed Council to measure water temperature, DO concentration, pH, turbidity and electrical conductivity. Photos taken during this event are provided in **Appendix A**. Field meters were used to verify the pH and temperature measurements. Results from this event are summarized in **Figure 6**. Dissolved oxygen was low, which is typical of wetland environments yet likely lower than average because measurements were done in the morning.

[6] See http://www.worldwatermonitoringday.org/.

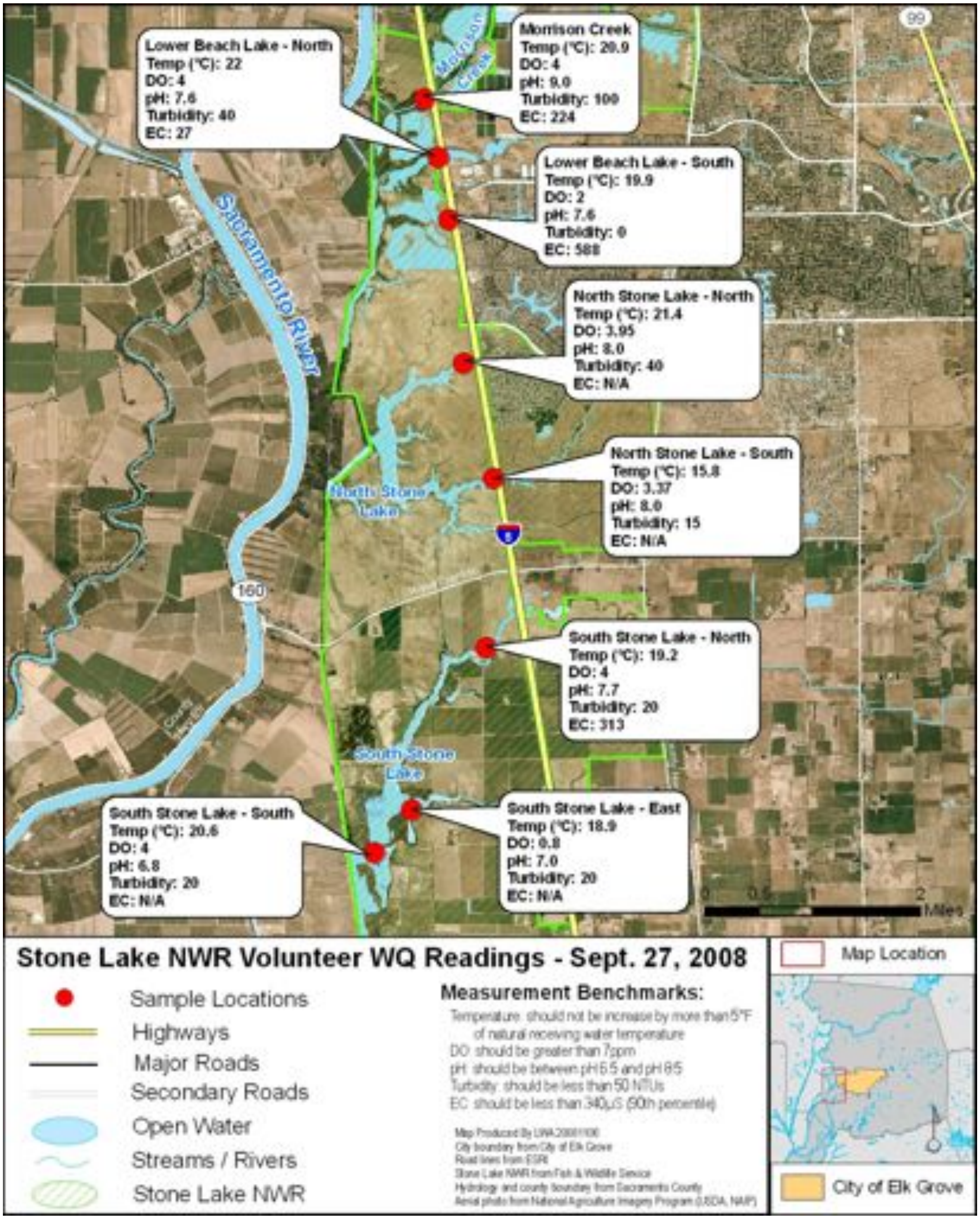

Figure 6. World Water Monitoring Day citizen-based monitoring results, 27 September 2008. DO = dissolved oxygen; EC = electrical conductivity.

3. Sampling and Analyses Protocols

The monitoring program included sediment toxicity, water column toxicity, water column chemistry and field measures for selected parameters. In addition, continuous sensors for several field measures were deployed at two stations during a five-week period overlapping two storm-sampling events. Each program element is described in this section first, followed by a narrative summary of each storm-sampling event.

3.1. SEDIMENT TOXICITY TESTING

A representative sediment sample was collected at station C-SLNWR on 14 July 2008. The sample was collecting using an appropriately cleaned stainless steel scoop, and deposited into a 2-liter amber glass bottle. Individual surface "scoops" were composited and homogenized, and a subsample delivered to a separate lab for physical (grain size distribution) and chemical (total organic carbon) analyses.

The sediment sample was tested for toxicity using the U.S. Environmental Protection Agency's (USEPA) 10-day survival test with the amphipod *Hyalella azteca* (**Figure 7**), following established guidelines[7] except that the growth endpoint was excluded consistent with other local regulatory programs.

Figure 7. Photograph of *Hyalella azteca*. Copied from http://www.aquatax.ca/images/gammarus.jpg.

The *Hyalella* were tested in 8 replicates of sample and in 8 replicates of control treatment. Samples were tested at 100% concentration only. Each day the overlying water was measured for condition (temperature, dissolved oxygen, pH, etc.) and flushed with fresh control water. Test conditions were all within acceptable limits for this test. After 10 days exposure, sediments in each replicate were sorted and sieved and the number of surviving individuals counted.

3.2. WATER COLUMN TOXICITY TESTING

Chronic toxicity evaluations were performed on ambient water samples collected during the three storm sampling events at the three receiving water stations (see stations in Table 1 and Figure 2 presented previously). The field crew submitted water samples within 36 hours in five one-gallon amber bottles per station per event.

Chronic toxicity evaluations consisted of performing two USEPA short-term chronic toxicity tests:

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[7] USEPA (2000). "Methods for Measuring the Toxicity and Bioaccumulation of Sediment-associated Contaminants with Freshwater Invertebrates, 2nd Ed." EPA 600/R-99/064.

- 3-brood (6- to 8-day) survival and reproduction test with the crustacean water flea (*Ceriodaphnia dubia*)
- 7-day survival and growth test with larval fathead minnows (*Pimephales promelas*) using the Geis method to reduce the frequency of observing pathogen-related morality. The Geis method typically provides comparable results to the 20-replicate exposure[8]

If 100% mortality to fathead minnows or water fleas were detected within 24 hours of test initiation, then a dilution series was to be initiated (0.5x steps) ranging from the undiluted sample (or the highest concentration that can be tested within the limitations of the test methods or sample type) to less than or equal to 6.25% of the sample.

Further, if greater than or equal to 50% increase in fathead minnow or water flea mortality[9], or reduction in water flea reproduction compared to the laboratory control were observed, then targeted Toxicity Identification Evaluations (TIEs) were to be conducted within 24 hours on the initial sample that caused toxicity. Dilution series were to be run on the fathead minnows to characterize the magnitude of toxicity.

3.3. WATER COLUMN CHEMISTRY

Water samples were collected during three storm events. The methods followed to collect those samples are described in this section.

3.3.1. Sample Timing

Grab samples were collected as close to peak flow as possible. In the study area, the general estimate of delay between the time of rainfall initiation and peak runoff was 6-12 hours. The more upstream stations were expected to peak sooner while the more downstream stations to peak later, as shown in **Table 2**. However, grab sampling during peak flows were problematic due to the difficulty in predicting the time of peak flow. Therefore, to the greatest extent possible, grab samples were collected when flow rates were increasing (measured as water levels rising) and the local precipitation rate was decreasing.

Table 2. Estimated Peak Runoff Lag Time for Monitoring Stations

Name	Timing After Onset of Rain
C – Promenade	2-4 hours
B – Franklin	4-8 hours
C – Bruceville	8-12 hours
C – SLNWR	8-12 hours

The monitoring manager determined sampling times based on rainfall forecasts and reports. Real-time precipitation was measured and reported from these nearby stations:

- http://www.sacflood.org/sensdata/raingrp.htm; Laguna Cr/Waterman Rd (# 270)

[8] This statement is based on several years of comparing the 10-replicate Geis method and the 20-replicate USEPA method for the Sacramento River Watershed Program Proposition 50-funded work. This approach was approved by the Regional Water Board.

[9] Comparable to 2 toxic units as noted in the USEPA TIE manual

- http://cdec.water.ca.gov/cgi-progs/queryF?s=elg; Elk Grove Fish Hatchery (ELG)

3.3.2. Target Pollutants

Target pollutants monitored in site runoff and downstream receiving water stations are indicated in **Table 3**. Target pollutants for monitoring were reduced in number at the site runoff station (C-Promenade) versus the three receiving water stations. Field blanks and duplicates were run only on those target pollutants noted in the tables. Analytical methods, contracted laboratories, and reporting limits for each of these pollutants are tabulated in **Appendix B, Table B-1**.

Table 3. Target Pollutants for Site Runoff Station (C-Promenade) and Receiving Water Stations (B-Franklin, C-Franklin, C-Bruceville, C-SLNWR)

Analysis	Method	Site Runoff Monitoring	Preservation	Blanks	Dupli-cates
Trace Metals, dissolved (Cu, Ni, Pb & Zn)	EPA 1638 ICP/MS		Field filter, 4˚C, preserve ASAP in lab	√	
Trace Metals, total (Cu, Ni, Pb & Zn)	EPA 1638 ICP/MS		4˚C, preserve ASAP in lab		√
Total Hardness (Ca & Mg)					√
Mercury, total	EPA 1631		HCl , 4˚C	√	√
Mercury, filtered	EPA 1631		Lab filter w/in 48 hrs, then HCl		
Mercury, methyl	EPA 1630		HCl, 4˚C, store in dark	√	√
Polynuclear Aromatic Hydrocarbons	EPA 625		4˚C	√	√
Organophosphate Pesticides		√			√
Pyrethroids	EPA 625m	√	None		√
Total Organic Carbon (TOC)	EPA 415.1	√	4˚C, HCl	√	
Dissolved Organic Carbon (DOC)	EPA 415.1	√	4˚C, lab filter and preserve ASAP	√	
Nitrate + Nitrite	EPA 353.2	√	H_2SO_4, 4˚C		
Total Kjeldahl Nitrogen	EPA 351.3	√			
Total Ammonia-N	EPA 350.2	√			
Escherichia coli	SM 9223		$Na_2S_2O_3$, 4˚C		
Total Suspended Solids (TSS)	SM2540D	√	4˚C		
Total Phosphorus	EPA 365.4	√			
Five-day Biochemical Oxygen Demand (BOD_5)	SM 5210B				
Water Column Toxicity	USEPA (2002)		Ice ASAP		

3.3.3. Clean Sample Handling

"Clean sampling" techniques were used to collect and handle water samples, pump tubing and strainers. Such techniques minimize contamination, loss, or change in the chemical form of the analytes of interest. For this program, clean techniques[10] were employed whenever handling the flexible suction tubing, strainers, the double-bagged aliquot bottles, or mercury and bacteriological grab sample bottles.

3.3.4. Quality Control Samples

Field-generated quality control samples (field duplicates and field blanks) were submitted "blind" to the laboratory. Quality control samples were collected according to the schedule shown in **Table 4**. Quality control samples were not scheduled at C-Promenade because fewer pollutants were monitored at that station.

Table 4. Quality Control Sample Collection Schedule

Station	Storm Event #1 (First-flush)	Storm Event #2 (Mid-winter)	Storm Event #3 (Late-season)
C – Promenade			
B – Franklin	Field Blank		Field Duplicate
C – Franklin		Lab Duplicate	
C – Bruceville			Field Blank
C – SLNWR	Field Duplicate	Field Blank	

Blanks consisted of laboratory-prepared blank water (certified to be contaminant-free by the laboratory) processed through clean sampling equipment using the same procedures used for environmental samples. Field blanks were submitted "blind" to the laboratory using the "Better Creek" station name pseudonym.

Field duplicates were collected immediately following—and in the same manner as—the environmental grab samples. A pair of field duplicates is two samples taken at the same time, in the same manner into two unique containers. Field duplicates were submitted to the laboratory with letters "FD" added to the station name. Laboratory duplicates are samples that are split by the laboratory from a single field sample. Each half of the split sample was then analyzed and reported by the laboratory.

3.3.5. Grab Samples

Grab samples were collected with a peristaltic pump and flexible tubing. Samples for total organic carbon (TOC) and dissolved organic carbon (DOC) were collected directly into volatile organic analysis vials to avoid plastic contamination. The integrity of bottles with preservative was maintained (i.e., no preservative was lost).

Dissolved metals samples were filtered during collection. The field crew installed a 0.45-um in-line capsule filter on the end of the tubing. For field blanks, the filter was installed first on the tubing and then removed for subsequent total metals field samples.

[10] Based on USEPA Method 1669.

3.4. FIELD MEASUREMENTS

Field measurements were taken at each station during each storm sampling event and recorded in field logs after all samples were collected. Measurements included:

- Temperature
- pH
- Dissolved oxygen
- Water depth
- Electrical conductivity
- Turbidity

All field measurements and observations were recorded on log sheets. One log sheet was completed for each station during each event. The program manager retained all log sheets.

3.5. CONTINUOUS SENSOR DEPLOYMENTS

Water quality conditions in creeks vary over the course of the day, during storm events, seasonally, and annually. Instantaneous measurements and "grab" samples cannot characterize such short-term variability and may misrepresent water quality for longer averaging periods. Recent advances in remote sensing technology enable real-time continuous measurement and reporting of water quality conditions surrounding stormwater sampling events. These high temporal-resolution data support the timing and interpreting of grab samples.

3.5.1. Sensor Measurements

Continuous sensors were deployed at stations B-Franklin and C-Franklin (see Figure 2 presented previously) for several weeks in January-March 2009, coinciding with storm sampling Events #2 and #3. Both sensors measured temperature, pH, depth, dissolved oxygen (DO), turbidity and electrical conductivity. The sensors were also equipped with real-time remote data acquisition to assist with timing sample collection, and to enable remote monitoring of both water quality and equipment status. The sensor units are shown in **Figure 8**.

a)  b) 

Figure 8. Continuous sensor units deployed for this study, including a) data loggers, cellular modems and batteries [casing removed], and b) individual probes for measuring pH, DO, temperature, electrical conductivity and turbidity.

3.5.2. Sensor Calibration

Each sensor was calibrated to manufacturer specifications prior to deployment. However, some uncertainty may still exist in absolute concentrations and peak/trough heights caused by (for example) offset drift, slope uncertainty, water velocity, water temperature, background ions, and electronic "noise". To address this uncertainty, post-deployment calibration is conducted and compared to pre-deployment calibration.

Post-deployment calibration results are shown in **Table 5.** All sensors at both stations exhibited excellent correlations with standards (within 3%) except the turbidity sensor at C-Franklin, which measured significantly lower. The sensor likely fouled in the highly turbid conditions found at that station. Consequently, the turbidity data are not regarded as accurate values even though changes over time are still considered actual signals of change in the water.

Table 5. Post-calibration Results for Continuous Sensor Probes.

		Location:	C-Franklin	B-Franklin	C-Franklin	B-Franklin	C-Franklin	B-Franklin
Probe	**Units**	**Calibrated**	**Post-deployment**		**Magnitude of Change**		**% Change**	
pH	pH	7	6.92	7.04	-0.08	0.04	-1.1%	0.6%
pH	pH	10.01	9.94	10.06	-0.07	0.05	-0.7%	0.5%
Specific Conductivity[1]	uS/cm	500	515	508	15	8	3.0%	1.6%
Specific Conductivity	uS/cm	1412	1419	1418	7	6	0.5%	0.4%
Depth	m	0	-0.03	-0.01	-0.03	-0.01		
Turbidity	NTU	0	0	0	0	0	0	0
Turbidity	NTU	100	55	100.2	-45	0.2	-45.0%	0.2%
DO	% Sat.	100	100.2	100	0.2	0	0.2%	0.0%
Barometric Pressure	mmHg		765	765	765	765		

[1] Specific conductivity is electrical conductivity normalized to a standard temperature of 25 °C.

The sensor readings can also be compared to concurrent field readings using a similar instrument calibrated prior to each event (**Figure 9**). Such field data are available for Events #2 and #3 at B-Franklin and for Event #2 at C-Franklin. All points in the graphs aligned on the 1:1 slope would demonstrate perfect correspondence.

The anomalous pH pair is likely a field crew error, such as reading or transcribing 6.38 instead of 8.38. The consistent slope difference in DO readings may be a calibration slope offset error, likely in the field probe. Temperature and conductivity exhibited good correlation. Conductivity and turbidity data cover a wide range of conditions—there are two data points near the origins for B-Franklin data. The difference in turbidity is consistent with the post-calibration error for the C-Franklin sensor, in which the sensor read 45% lower than the standard.

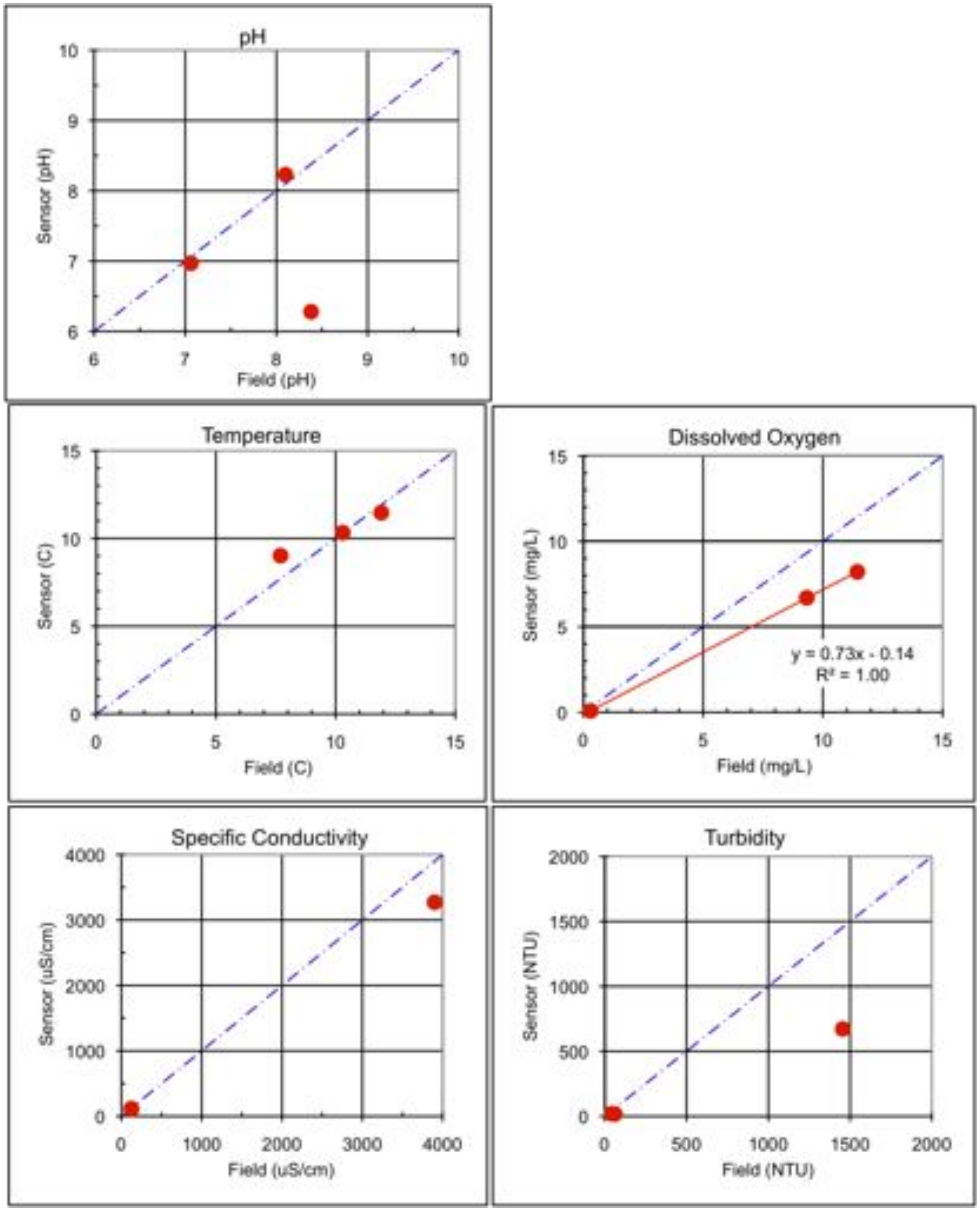

Figure 9. Comparison between concurrent field probe readings and continuous sensor readings. All points in the graphs aligned on the 1:1 slope would demonstrate perfect correspondence.

3.6. STORM SAMPLING EVENT SUMMARIES

The three storm-sampling events were conducted as described previously. Conditions experienced and adjustments made to address specific issues are summarized in this section.

3.6.1. Event #1: First Flush, 1 November 2008

Event #1 occurred on 11/1/08. The weak front defied the forecast model estimates of a trace to 0.1" on 10/30/08-10/31/08 and delivered between 0.25" to 0.46" of rainfall around the Sacramento area between 5 PM (Thursday, 10/30/08) and 3 AM (Friday, 10/31/08) with some additional minor accumulations afterwards (**Figure 10**). The same storm system brought a second front through on Saturday, 11/1/08. The sampling crew was mobilized on Saturday morning, began sampling at station C-Promenade at 11:30 AM, and finished sampling at C-SLNWR at 3:45 PM. Samples were collected primarily during dry periods, although rain began during the latter part of the sampling period. This event proved to be the season's first significant rainfall event over 0.25" since 3/1/08 (243 days).

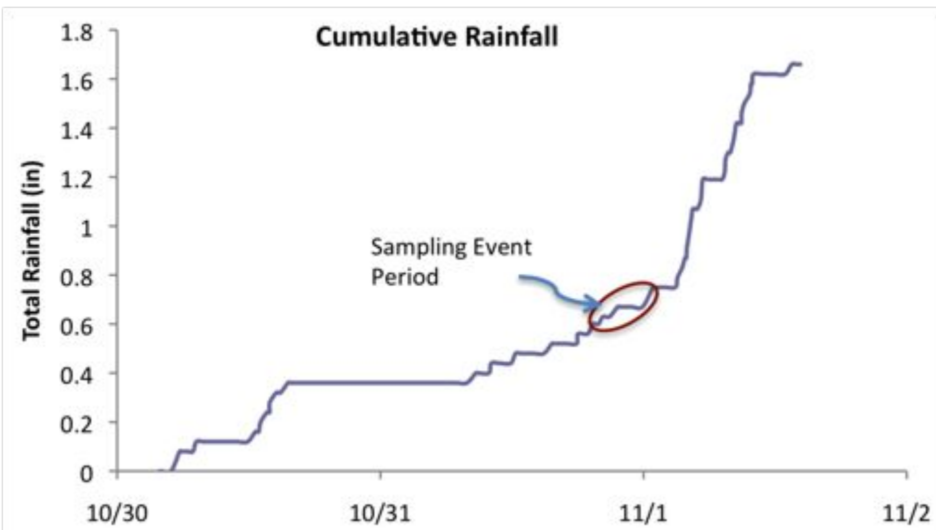

Figure 10. Cumulative rainfall and sampling time period for Event #1.

The field crew delivered time-critical *E. coli* samples to the Sacramento Regional Wastewater Treatment Plant and subsequently processed other samples for delivery to designated labs. All samples were received on time and in good condition (none broken, all on ice).

Issues and how they were addressed are summarized here:

- In spite of the rainfall, the Promenade basin was not full and did not discharge. Samples were collected from the ditch and noted as representative of the receiving water, not of basin discharges.
- In spite of the rainfall, water at the C-Franklin site was also stagnant. Dissolved oxygen was measured to be zero. A targeted TIE was run on aerated samples to characterize ammonia toxicity levels.

- The high level of sediment in water at C-Franklin clogged the in-line filter and caused it to blow off. Although a sufficient volume was collected, a larger filter was recommended (and used) for subsequent sampling events.
- Collecting samples at B-Franklin's center channel was time-consuming. Extending the peristaltic pump tubing from the bridge was recommended (and used) for subsequent sampling events.
- Water at C-SLNWR was flowing upstream. This effect was the result of less inflow from Shed C's channel (if any) than from other waterways draining to the downstream wetlands and flowing up towards the sampling site.
- One bottle of blank water spilled, not allowing the crew to obtain a "blank" sample for dissolved metals at B-Franklin.
- Two mercury bottles were mis-labeled prior to the event, with preservative in a dissolved mercury bottle and none in a total mercury bottle at a different site (so they could not simply be switched for analysis). Consequently, dissolved mercury at B-Franklin was not analyzed.
- One methylmercury bottle was collected in a clear bottle rather than an amber bottle. This difference was noted but the sample was still analyzed, because while amber protects from photodegradation, the effect of sunlight during the stormy weather would have been minimal. The bottles were checked more closely in subsequent sampling events.
- The field meter ran out of battery power before reaching two sites. More spares were kept on hand during subsequent sampling events.

3.6.2. Event #2: Mid-Winter Storm, 22 January 2009

Contrary to forecasts, over an inch of rainfall fell on the Elk Grove area during the evening of 1/21/09-1/22/09. Another 0.2-0.4 inches was predicted for the morning of 1/22/09. Based on the latter forecast, the field crew was mobilized at 10:47 AM on 1/22/09 (**Figure 11**). The field crew sampled through late afternoon, finishing fieldwork just after dark. The field crew delivered time-critical *E. coli* samples to the Sacramento Regional Wastewater Treatment Plant and processed the others there for delivery to appropriate labs. All samples were delivered within holding times and processed as necessary.

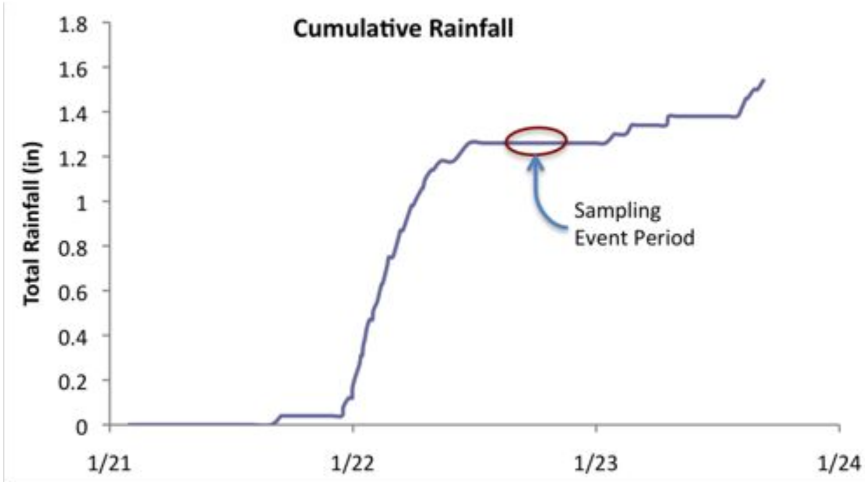

Figure 11. Cumulative rainfall and sampling time period for Event #2.

Issues and how they were addressed are summarized here:

- The field crew arrived at Promenade Mall around 2 PM and found the gate surrounding the detention basin locked. City staff responded quickly to locate a key and open the gate. Nonetheless, sampling did not begin until approximately 2:45 PM.
- The field probe was inadvertently missing, so one crew member returned to the office for it. To minimize delays, the crew moved on to the next site without measuring field parameters at C-Promenade. Some field parameters (electrical conductivity, turbidity) were measured instead by Caltest from the sample bottles.
- In spite of the heavy rain, the detention basin was not full and thus still not discharging. It was noted that the drainage channel appeared to be much more turbid than during Event #1.
- Likewise, the channel flow at C-Franklin was again essentially stagnant. The water was found to be so turbid that the field filter was unable to process a filtered sample, as the water immediately clogged the filter media. Instead, Caltest filtered the “dissolved trace metals” sample in the lab.
- Conditions at C-Franklin appeared similar to conditions observed during Event #1. For this station the toxicity test protocol was adjusted to aerate immediately and measure ammonia/temperature/pH. The lab assumed the same high ammonia levels were the cause of toxicity and referred to Event #1’s test results.
- Water at C-SLNWR was also stagnant. However, the floating aquatic vegetation kept this water much less turbid. To have a better chance of capturing flowing water in Shed C, the project manager prioritized a larger storm for the final sampling event.
- Sampling occurred close to the runoff peak (see later section 4.4), indicating that the expected timing was accurate.

3.6.3. Event #3: Late-Season Storm, 4 March 2009

The 10-day forecast on 2/27/09 indicated three storm systems passing through the Sacramento area between Saturday (2/28/09) and the following Friday (3/6/09). The first system contributed

0.75" between 9 AM on 3/1/09 and noon on 3/2/09. The second system arrived earlier than forecast, contributing another 0.75". Following the heavy rains on Tuesday (3/3/09), flows passing Franklin Blvd during sampling were elevated but had already started decreasing from peaks Tuesday evening.

The field crew collected all samples successfully on Wednesday afternoon (**Figure 12**) and shipped to the various labs within allowable holding times.

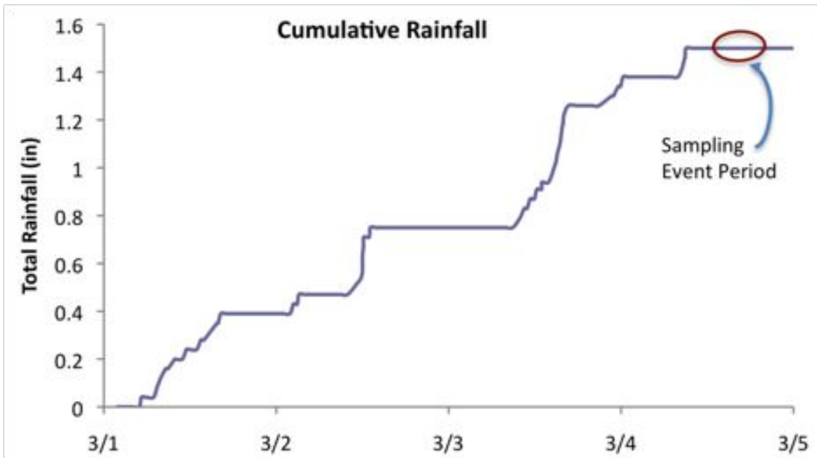

Figure 12. Cumulative rainfall and sampling time period for Event #3.

Issues and how they were addressed are summarized here:

- The Promenade Mall detention basin was not full and, therefore, not discharging over the outlet weir into the drainage channel. Furthermore, the downstream channel's water level was higher than the basin weir. The City stacked sandbags across the outlet weir to prevent backflow eastward from the channel into the basin. Samples collected at C-Promenade are thus representative of the drainage channel, not Promenade Mall runoff (of which there was none).
- Water from the drainage channel was discharging westward through the culvert under Bruceville Rd. Samples at C-Bruceville were collected from the downstream side of the culvert. Sampling was hazardous because of the narrow shoulder and auto traffic.
- The C-SLNWR toxicity test sample arrived with a temperature of 7.2˚C and the C-Bruceville sample had a temperature of 6.6˚C. USEPA protocol requires that any samples that were stored or transported overnight prior to the use of the sample be received at the testing lab between 0˚ and 6.0˚C. With permission, lab staff proceeded with the testing as scheduled.
- All samples delivered to Caltest were received and logged. However, lab staff erroneously preserved the dissolved total mercury samples before filtering. To obtain sufficient volume for analyses, a portion of the unpreserved volume received for DOC was filtered for dissolved mercury. These samples will be flagged as biased high due to field contamination because clean sampling protocols were no longer being followed for DOC samples. The lab analyzed filter and bottle blanks to quantify potential contamination from those sources.

4. Results and Data Analyses

This section describes the data analyses and associated reporting that were used to interpret the monitoring data. The monitoring results are evaluated along with relevant historical data to describe the current and potential effects of stormwater runoff associated with development in the City of Elk Grove to Stone Lakes NWR. All chemical and physical results are presented in **Appendix B**.

4.1. QUALITY CONTROL SAMPLES

Field blanks and field duplicates were used to identify potential contamination from the sampling equipment and procedures. Quality control samples prepared in the laboratory consisted of method blanks, laboratory duplicates, matrix spikes/duplicates, and laboratory control samples. Analytical results were compared to acceptable limits shown in **Appendix B**, **Table B-2**.

The overall assessment from the quality control samples' results is that the data are generally high quality. Specific issues are noted here and then used to qualify messages in section 4.3.

4.1.1. Field Blanks

Field blanks were collected according to the schedule outlined previously in Table 4. Field blank "hits" are shown in **Table 6** for each pollutant type (conventional, metals, or organics), along with the concentration of pollutant detected. Most pollutants that were detected in field blanks were near or below the reporting limit and below the levels in environmental samples; however, some pesticides and polycyclic aromatic hydrocarbons (PAHs) were detected at levels above the reporting limit.

Table 6. Detected Pollutants in Field Blanks

Storm Sampling Event	Conventional (Nutrients, TSS, Biological)	Metals	Organics (TOC, DOC, Pesticides, PAHs)
Event #1 (B-Franklin)	Total coliform (1 MPN/100 mL)	Methylmercury (0.0195 ng/L)	Bifenthrin (6.8 ng/L) 1-Methylnaphthalene (4.9 ng/L) 2-Methylnaphthalene (12.8 ng/L) Biphenyl (7 ng/L) Fluoranthene, (5.3 ng/L) Fluorene (4.8 ng/L) Naphthalene (1.8 ng/L) Phenanthrene (7.1 ng/L) Pyrene (6.7 ng/L)
Event #2 (C-SLNWR)	Not analyzed	Mercury (J0.0003 ug/L)[1] Copper (0.2 ug/L) Zinc (J0.7 ug/L)	DOC (1.9 mg/L) TOC (2.3 mg/L) 1-Methylnaphthalene (1.8 ng/L) 2-Methylnaphthalene (1 ng/L) Naphthalene (26.9 ng/L)
Event #3 (C-Bruceville)	Not analyzed	Mercury (0.0005 ug/L) Copper (J0.07 ug/L) Nickel (J0.03 ug/L) Zinc (J1.9 ug/L)	DOC (0.9 mg/L) TOC (0.99 mg/L) Naphthalene (13.8 ng/L)

J = value is above the detection limit but less than the reporting limit

For each event, pollutants detected in field blanks were qualified in the dataset for all stations. While field blanks were collected from only one station per sampling event, the results are applied to all stations' data for that event. In instances where the field blank result is with 10% of the regular field sample's value, the field sample value is qualified as less than ("<").

4.1.2. Field Duplicates

Relative percent difference (RPD) of a duplicate sample is calculated as the difference in concentration from the primary sample divided by the concentration of the primary sample. Typical levels of acceptability, depending on the analytical method, are 10-25% RPD. Generally, RPDs fell within the acceptance limits specified in **Appendix B**, **Table B-2**, indicating that field duplicate variability was likely due to either sampling technique or concentration gradients of analytes in the water body sampled.

Field duplicates that exceeded acceptable RPDs are listed in **Table 7**. In addition, a few organic pollutants were detected in either the field duplicate sample or the environmental sample, but not in both, during Event #3. The detected organic pollutants were cyfluthrin, cypermethrin, and 2,6-dimethylnaphthalene.

Table 7. Field Duplicate RPD Exceedances

Storm Sampling Event	Conventional (Nutrients, TSS, Biological)	Metals	Organics (TOC, DOC, Pesticides, PAHs)
Event #1	Ammonia RPD 70%	--	--
Event #3	Ammonia RPD 81%	Total mercury RPD 22%	Diazinon RPD 65% Fluoranthene RPD 28% Naphthalene RPD 43% Phenanthrene RPD 31%

4.1.3. Laboratory Quality Control Samples

Two laboratory quality control sample types (duplicates and spikes) were included in Event #2 for C-Franklin. Results indicating quality control concerns are described here.

4.1.3.1. Laboratory Duplicates

Laboratory duplicate RPDs fell within acceptance limits for most pollutants. Exceptions are listed below:

- *E. coli* RPD of 144%
- Dissolved lead RPD of 45%
- Total mercury RPD of 168%

4.1.3.2. Matrix Spikes and Matrix Spike Duplicates

During Event #2, 14 organic pollutant analyses were outside of the acceptance range for matrix spikes. Those pollutants and their corresponding recovery percentages were: fenitrothion (0%), malathion (0%), 2,6-dimethylnaphthalene (138% recovery), allethrin (227%), bifenthrin (183%), cyfluthrin (174%), cypermethrin (190%), danitol (170%), esfenvalerate (162%), fenvalerate (195%), fluvalinate (151%), l-cyhalothrin (149%), permethrin (231%), and prallethrin (135%). None of these compounds were measured in storm samples at levels exceeding objectives. However, 0% recovery in a spiked sample indicates considerable matrix interference, which could also have interfered with analyses of the regular field samples.

4.1.4. Dissolved Fractions

Dissolved concentrations are a fraction of the total concentration in a sample. In samples where the pollutant is almost completely dissolved, the reported dissolved concentration may exceed the reported total concentration. Total and dissolved organic carbon (TOC and DOC, respectively) were at expected levels at all stations. However, DOC equaled or exceeded TOC in eight of 12 samples. The magnitude of error in these reported TOC and DOC data is likely ~25% based on the range of those differences. The dissolved fractions of trace metals were typically half of the reported total concentrations.

4.2. PHYSICAL CONDITIONS

Physical conditions observed and measured at each site are important for interpreting the chemistry and toxicity data at any site, but particularly in this study. Each site had unique characteristics that may have had a significant influence on the observed water quality:

- **B-Franklin**: The channel was typically thick with cattails, but sometimes mechanically cleared near the bridge. While a relatively new development, Shed B was planned, designed and mostly constructed before the Stormwater Quality Design Manual was issued.
- **C-Promenade**: The detention basin was not full and the water level in the drainage channel was higher than the basin outlet. Consequently, City staff had placed sandbags over the basin outlet to prevent back drainage *into* the basin. Thus, samples were representative of the agricultural drainage water (a combination of groundwater pumping, irrigation return flow, groundwater seepage, and rainfall runoff).
- **C-Franklin (Events #1 and #2 only)**: Water was stagnant and chocked with algae and had exceptionally high ammonia and no dissolved oxygen. The stagnant water appeared to be runoff from the adjacent dairy operation.
- **C-Bruceville (Event #3 only)**: Water from the drainage channel was discharging westward through the culvert under Bruceville Rd. Samples at C-Bruceville were collected from the downstream side of the culvert. Sampling was hazardous because of the narrow shoulder and auto traffic.
- **C-SLNWR**: Water was stagnant or flowing upstream. The surface of the pool was at times covered with a thick layer of duckweed, but other times clear (likely removed by a combination of tractor and herbicide).

4.3. WATER COLUMN CONCENTRATIONS

Pollutant concentrations in grab samples at each station for each event are provided in **Tables 8-11**. The data are compared and contrasted in this section in terms of spatial variability among stations, and against established objectives and other regional stormwater data. Values exceeding their lowest applicable objectives are bolded.

Table 8. Summary of Storm Event Sampling Data for C-Promenade

Parameter	Unit	Event 1 11/1/2008	Event 2 11/22/2008	Event 3 3/4/2009	Lowest Objective
Field					
pH	--	8.23	-	8.06	6.5-8.5
Water Temperature	˚C	15.6	-	12.14	-
Dissolved oxygen	mg/L	10.1	-	12.57	>5
Electrical Conductivity	µS/cm	359	-	146	700
Turbidity	NTU	-	-	118	-
Conventional					
Nitrate + Nitrite (as N)	mg/L	0.068	0.47	0.29	10
Total Kjeldahl Nitrogen	mg/L	1.5	0.96	17	-
Ammonia (as N)	mg/L	ND	0.14	1.8	5.4/-/7.5[1]
Total Phosphorus (as P)	mg/L	0.69	0.38	0.18	-
Total Suspended Solids	mg/L	8	53	21	-
Organics					
TOC	mg/L	13	<6.5	13	-
DOC	mg/L	12	<7.5	16	-
Organophosphate Pesticides					
Chlorpyrifos	ng/L	ND	ND	ND	25/15[2]
Diazinon	ng/L	ND	15.2	14.7	160/100[2]
Pyrethroids[3]					
Cypermethrin	ng/L	0.8	ND	ND	-

[1] Based on the pH-corrected acute (salmonid fish not present) National Recommended Water Quality Criteria (NRWQC); see http://www.epa.gov/waterscience/criteria/wqctable/nrwqc-2006.pdf.

[2] Recalculated CDFG Aquatic Life Criteria for freshwater – Acute/Chronic criteria.

[3] Data only shown for detected pyrethroids.

Table 9. Summary of Storm Event Sampling Data for B-Franklin

Parameter	Unit	Event 1 11/1/2008	Event 2 11/22/2008	Event 3 3/4/2009	Lowest Objective
Field					
pH	--	-	7.06	8.38	6.5-8.5
Water Temperature	˚C	-	10.3	11.91	-
Dissolved oxygen	mg/L	-	11.44	9.33	>5
Electrical Conductivity	µS/cm	-	123	127	700
Turbidity	NTU	-	62.1	42.4	-
Conventional					
BOD_5	mg/L	2	4	2	-
Hardness as $CaCO_3$	mg/L	46	43	50	-
Nitrate + Nitrite (as N)	mg/L	0.79	0.9	0.31	10
Total Kjeldahl Nitrogen	mg/L	1.3	0.96	0.67	-
Ammonia (as N)	mg/L	0.31	0.15	0.13	-/34.2/4.0[1]
Total Phosphorus (as P)	mg/L	0.14	0.59	0.15	-
Total Suspended Solids	mg/L	3	6	6	-
E. coli	MPN/100 mL	**16,000**	**8000**	**1100**	235
Metals (Total Recoverable and Dissolved)					
Copper (total)	µg/L	4.4	**4.9**	4.6	4.8/4.5/5.2 [2]
Copper (dissolved)	µg/L	3.9	3.4	3.2	4.6/4.4/5.0 [2]
Lead (total)	µg/L	0.3	0.44	0.54	1.2/1.1/1.3 [2]
Lead (dissolved)	µg/L	0.18	0.08	0.09	1.1/1.0/1.2 [2]
Nickel (total)	µg/L	2.2	2.2	3	27/26/29 [2]
Nickel (dissolved)	µg/L	2.1	1.3	1.7	27/25/29 [2]
Zinc (total)	µg/L	12	16	18	62/59/67 [2]
Zinc (dissolved)	µg/L	8	12	12	61/58/66 [2]
Mercury (total)	µg/L	0.0096	0.0074	0.0074	0.050
Mercury (dissolved)	µg/L	-	0.0051	0.0029	-
Mercury, methyl	ng/L	**0.0783**	**0.0936**	**0.156**	0.06 [3]
Organics					
TOC	mg/L	13	<7.9	<6.6	-
DOC	mg/L	13	<7.6	<7.4	-
Organophosphate Pesticides					
Chlorpyrifos	ng/L	ND	9	ND	25/15 [4]
Diazinon	ng/L	ND	22.9	6.5	160/100 [4]
Pyrethroids[5]					
Bifenthrin	ng/L	ND	23.8	8.8	-
Cyfluthrin	ng/L	ND	2.8	ND	-
Cypermethrin	ng/L	ND	2.6	ND	-
PAHs[6]					
1-Methylnaphthalene	ng/L	<1.3	<3.3	1.5	-
2-Methylnaphthalene	ng/L	<1.7	<9.4	2.4	-
Acenaphthene	ng/L	ND	2.9	ND	-
Acenaphthylene	ng/L	ND	1.3	ND	-
Benzo[e]pyrene	ng/L	ND	1.8	1	-
Biphenyl	ng/L	ND	3.6	ND	-
Chrysene	ng/L	ND	3.1	1.8	-
Fluoranthene	ng/L	ND	3.9	2.8	-
Fluorene	ng/L	ND	2.9	ND	-
Naphthalene	ng/L	<12.8	<10.1	<5	-
Phenanthrene	ng/L	ND	6.9	2.6	-

[1] Based on the pH-corrected acute (salmonid fish not present) National Recommended Water Quality Criteria (NRWQC); see http://www.epa.gov/waterscience/criteria/wqctable/nrwqc-2006.pdf.
[2] Adjusted for sample hardness as specified in the CTR. Chronic freshwater criteria are given for event 1/event 2/event 3.
[3] Proposed water column target in draft the Delta Methylmercury TMDL.
[4] Recalculated CDFG Aquatic Life Criteria for freshwater – Acute/Chronic criteria.
[5] Data only shown for detected pyrethroids.
[6] Data only shown for detected PAHs.

Table 10. Summary of Storm Event Sampling Data for C-Franklin (Events #1 and #2) and C-Bruce (Event #3)

Parameter	Unit	Event 1 11/1/2008 C-Franklin	Event 2 11/22/2008 C-Franklin	Event 3 3/4/2009 C-Bruce	Lowest Objective
Field					
pH	--	7.8	8.1	8.23	6.5-8.5
Water Temperature	˚C	14.35	7.7	-	-
Dissolved oxygen	mg/L	**1.1**	**0.3**	9.13	>5
Electrical Conductivity	μS/cm	**1400**	**3900**	198	700
Turbidity	NTU	-	1455	132	-
Conventional					
BOD_5	mg/L	65	150	3	-
Hardness as $CaCO_3$	mg/L	540	840	86	-
Nitrate + Nitrite (as N)	mg/L	0.73	1.7	0.16	10
Total Kjeldahl Nitrogen	mg/L	37	88	1.3	-
Ammonia (as N)	mg/L	**19**	**54**	0.13	12.1/6.9/5.4[1]
Total Phosphorus (as P)	mg/L	5.3	14	0.59	-
Total Suspended Solids	mg/L	920	140	17	-
E. coli	MPN/100 mL	**1600**	**8000**	**1000**	235
Metals (Total Recoverable and Dissolved)					
Copper (total)	μg/L	**160**	**85**	7.1	39.4/57.5/8.2 [2]
Copper (dissolved)	μg/L	2.2	2.7	3.8	37.8/55.2/7.9 [2]
Lead (total)	μg/L	26	4.4	1.9	27.2/47.8/2.6 [2]
Lead (dissolved)	μg/L	0.13	0.29	0.26	14.8/23.0/2.1 [2]
Nickel (total)	μg/L	74	26	9.1	217/316/46 [2]
Nickel (dissolved)	μg/L	12	21	4.4	217/315/46 [2]
Zinc (total)	μg/L	320	180	14	500/727/105 [2]
Zinc (dissolved)	μg/L	9	6	5.9	493/717/104 [2]
Mercury (total)	μg/L	**0.052**	**0.33**	0.012	0.050
Mercury (dissolved)	μg/L	ND	0.0025	0.0042	-
Mercury, methyl	ng/L	**0.906**	**3.11**	**0.149**	0.06 [3]
Organics					
TOC	mg/L	61	190	12	-
DOC	mg/L	58	110	14	-
Organophosphate Pesticides					
Chlorpyrifos	ng/L	ND	ND	ND	25/15 [3]
Diazinon	ng/L	ND	ND	21	160/100 [3]
Pyrethroids[4]					
Danitol	ng/L	ND	1.2	ND	-
PAHs[5]					
1-Methylnaphthalene	ng/L	<7.2	<7	1.1	-
2,6-Dimethylnaphthalene	ng/L	86.2	215.8	1.2	-
2-Methylnaphthalene	ng/L	<8.5	<8.7	1.2	-
Acenaphthylene	ng/L	6.7	5.8	ND	-
Anthracene	ng/L	9.3	5.6	ND	-
Benz[a]anthracene	ng/L	12.6	5.2	ND	-
Benzo[b]fluoranthene	ng/L	18.6	5.2	ND	-
Benzo[e]pyrene	ng/L	18.2	2.1	ND	-
Benzo[g,h,i]perylene	ng/L	55.9	ND	ND	-
Biphenyl	ng/L	<11.1	11.2	ND	-
Chrysene	ng/L	31.7	9.3	ND	-
Fluoranthene	ng/L	<57.2	25.4	1.1	-
Fluorene	ng/L	<19.7	16	ND	-
Naphthalene	ng/L	ND	<20.5	<10.3	-
Phenanthrene	ng/L	<47.2	37.3	1.5	-

[1] Based on the pH-corrected acute (salmonid fish not present) National Recommended Water Quality Criteria (NRWQC); see http://www.epa.gov/waterscience/criteria/wqctable/nrwqc-2006.pdf.

[2] Adjusted for sample hardness as specified in the CTR. Chronic freshwater criteria are given for event 1/event 2/event 3.

[3] Recalculated CDFG Aquatic Life Criteria for freshwater – Acute/Chronic criteria.

[4] Data only shown for detected pyrethroids.

[5] Data only shown for detected PAHs.

Table 11. Summary of Storm Event Sampling Data for C-SLNWR

Parameter	Unit	Event 1 11/1/2008	Event 2 11/22/2008	Event 3 3/4/2009	Lowest Objective
Field					
pH	--	-	7.7	8.0	6.5-8.5
Water Temperature	˚C	-	7.13	11.04	-
Dissolved oxygen	mg/L	-	**0.57**	**4.58**	>5
Electrical Conductivity	µS/cm	-	621	281	700
Turbidity	NTU	-	335	116	-
Conventional					
BOD_5	mg/L	3	7	5	-
Hardness as $CaCO_3$	mg/L	130	170	120	-
Nitrate + Nitrite	mg/L	ND	0.035	0.12	10
Total Kjeldahl Nitrogen	mg/L	1.4	3.3	3.9	-
Ammonia (as N)	mg/L	0.16	1.7	1.9	-/14.4/8.4[1]
Total Phosphorus (as P)	mg/L	0.59	2.8	2.6	-
Total Suspended Solids	mg/L	13	58	11	-
E. coli	MPN/100 mL	62	17	**270**	235
Metals (Total Recoverable and Dissolved)					
Copper (total)	µg/L	1.4	4.9	6.1	11.7/14.7/10.9 2]
Copper (dissolved)	µg/L	0.8	2.6	4.1	11.2/14.1/10.5 [2]
Lead (total)	µg/L	0.26	0.99	0.66	4.4/6.3/4.0 [2]
Lead (dissolved)	µg/L	0.03	0.62	0.19	3.3/4.5/61 [2]
Nickel (total)	µg/L	2.8	6.1	6.3	65/82/61 [2]
Nickel (dissolved)	µg/L	2.4	3.2	4.7	65/81/61 [2]
Zinc (total)	µg/L	3	8	10	150/188/140 [2]
Zinc (dissolved)	µg/L	3	4	6.7	148/185/138 [2]
Mercury (total)	µg/L	0.0027	ND	0.011	0.050
Mercury (dissolved)	µg/L	0.0019	0.0008	0.005	-
Mercury, methyl	ng/L	**0.399**	**0.611**	**0.282**	0.06 [3]
Organics					
TOC	mg/L	12	<11	21	-
DOC	mg/L	12	<11	22	-
Organophosphate Pesticides					
Chlorpyrifos	ng/L	ND	ND	ND	25/15 [4]
Diazinon	ng/L	ND	6.2	8.1	160/100 [4]
Pyrethroids	ng/L	ND	ND	ND	-
PAHs[5]					
2,6-Dimethylnaphthalene	ng/L	11.4	2.8	1.7	-
2-Methylnaphthalene	ng/L	<3.9	<1.9	2.1	-
Biphenyl	ng/L	<3.9	2.9	1.2	-
Fluoranthene	ng/L	ND	ND	1.2	-
Fluorene	ng/L	ND	1.5	ND	-
Naphthalene	ng/L	ND	<9.1	<6.4	-
Phenanthrene	ng/L	<4	2.3	2.8	-

[1] Based on the pH-corrected acute (salmonid fish not present) National Recommended Water Quality Criteria (NRWQC); see http://www.epa.gov/waterscience/criteria/wqctable/nrwqc-2006.pdf.
[2] Adjusted for sample hardness as specified in the CTR. Chronic freshwater criteria are given for event 1/event 2/event 3.
[3] Proposed water column target in draft the Delta Methylmercury TMDL.
[4] Recalculated CDFG Aquatic Life Criteria for freshwater – Acute/Chronic criteria.
[5] Data only shown for detected PAHs.

4.3.1. Spatial Patterns

Differences were observed in water column concentrations of monitored pollutants among the four monitoring stations. The differences are most likely attributable to the obvious differences in conditions among the stations. Each station's chemistry data is characterized individually as a means to compare and contrast them:

- **C-Promenade**: Because the detention basin was not discharging, samples collected from the drainage channel were representative of local agricultural irrigation and drainage rather than of new development runoff from Promenade Mall. The water in the drainage channel was a combination of groundwater pumping, irrigation return flow, groundwater seepage, and rainfall runoff. Field readings were generally within expected ranges. TSS levels were lower than C-Franklin downstream. Nutrient levels were similar to B-Franklin during Events #1 and #2, but were higher during Event #3. Diazinon was detected in two samples. The pyrethroid cypermethrin was detected in one sample. None of the monitored pollutants exceeded their lowest applicable objectives.
- **B-Franklin**: This channel's discharge was representative of urban runoff (albeit not applying the Stormwater Quality Design Manual), and it responded with a rainfall-runoff pattern characteristic of traditional urbanized areas. *E. coli* was highest at this station, which may be attributable to the wetland-type environment in this channel. Many PAHs—more than at any other station—were detected, including: naphthalene, 1-methylnapthalene, and 2-methylnapthalene in all samples; phenanthrene, biphenyl, chrysene, and pyrene in two samples; and anenapthene, acenaphthylene, fluorene, and benzo[e]pyrene in one sample. Organophosphate pesticides diazinon (in two samples) and malathion (in one sample) were also detected. The numbers and concentrations of pyrethroids detected were highest at this station—bifenthrin was detected in two samples, and cypermethrin and cyfluthrin were detected in one sample.
- **C-Franklin**: This station was monitored for Events #1 and #2 only. Water was stagnant and chocked with algae at this station, even following the season's largest storms. Exceptionally high ammonia concentrations and BOD, most likely caused by runoff from the adjacent dairy operation, resulted in low dissolved oxygen concentrations. Most other measurements (especially metals and organic carbon) were also much higher here than at other stations. Several PAHs were detected here as well, likely coming from vehicle traffic on Franklin Blvd. No organophosphate pesticides were detected, but two pyrethroids were detected (L-cyhalothrin in both samples; danitol in one sample).
- **C-Bruceville**: This station was monitored for Event #3 only. Most basic measures (DOC, TOC, turbidity, pH, TSS, metals) were similar to C-Promenade, which is upstream in the same agricultural drain. Nitrogen was higher at the upstream C-Promenade. PAHs were detected at this station (1-methylnaphthalene, 2,6-dimethylnaphthalene, 2-methylnaphthalene, and fluoranthene), which likely came from farm equipment, irrigation pumps, and construction vehicles at the Promenade Mall. Diazinon was detected at a higher concentration than C-Promenade. No pyrethroids were detected. Almost all analytes were at lower concentrations at this station than at C-Franklin 1.5 miles downstream, some by an order of magnitude.
- **C-SLNWR**: Water was stagnant or flowing upstream during each storm sampling event. Water quality was much better than at the upstream C-Franklin station, although

dissolved oxygen was typically still low. Methylmercury levels were higher than at B-Franklin, attributable to the productive wetland environment. PAHs (2,6-dimethylnapthalene, 2-methylnaphthalene, biphenyl, and phenanthrene) were detected in all three events, with naphthalene detected in two samples, and fluorene and fluoranthene were detected in one sample. The sources of PAHs at this station are most likely Interstate-5 traffic and the nearby diesel-engine irrigation pump. No pyrethroids were detected.

4.3.2. Exceedances of Applicable Objectives

Levels of monitored pollutants were compared to the lowest applicable objectives in **Tables 8-11** presented previously. Results that exceeded applicable objectives (bolded in the tables) are discussed below by constituent class.

Indicator bacteria *E. coli* were considerably greater in number than the single sample maximum of 235 MPN/100 mL during all three events at B-Franklin and C-Franklin/C-Bruceville. However, *E. coli* laboratory duplicates exceeded acceptable limits in Event #2, so the reported values (some of which exceed objectives) are considered approximate. Dissolved oxygen levels at C-Franklin and C-SLNWR were below the minimum objective of 5 mg/L. Consistent with the toxicity testing results discussed below, ammonia levels greatly exceeded toxicity thresholds based on measured pH.

Trace metals total copper and total mercury were above the objective for Events #1 and #2 at C-Franklin. Total copper at B-Franklin also exceeded the objective in Event #2. However, total mercury laboratory duplicates exceeded acceptable limits in Event #2, so the reported values (some of which exceed objectives) are considered approximate. No other metals at any of the four stations exceeded applicable objectives. However, methylmercury, the toxic and bioaccumulative form of mercury, exceeded the proposed water column target in the draft Delta Methylmercury TMDL of 0.06 ng/L in all events at all three stations.

Pyrethoids, as a newer type of pesticide, do not have applicable objectives. However, University of California at Berkeley toxicologist Don Weston reported[11] recently that for many of the pyrethroids, 2 ng/L would impair or kill 50% of *Hyalella*. Only one sample (for bifenthrin at B-Franklin in Event #2) exceeded that level and chronic toxicity was not observed. Weston also noted that bifenthrin and cyfluthrin (both were detected at B-Franklin) are the pyrethroids of greatest toxicological concern in urban runoff. While toxic effects may be additive, such that low concentrations (i.e., below potential thresholds of concern for individual compounds) of multiple pyrethroids could also produce toxic effects, water column toxicity was not observed to have any association with higher or lower pyrethroid concentrations (see section 4.5 below).

While several PAHs were detected and sources attributed, blank samples also had detectable levels of many PAHs. Consequently, while the PAHs detected were likely present in the water samples, the measured concentrations appear biased high by sampling contamination.

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[11] Presentation to the Urban Pesticide Committee. PowerPoint slides for this presentation are available at http://www.up3project.org/up3_upc.shtml.

4.3.3. Comparisons to Other Local Monitoring Data

US Fish and Wildlife Service (USFWS), Upper Laguna Creek Collaborative, Laguna Creek Watershed Council, Sacramento County stormwater partnership, and local development projects have monitored water quality in the study area. These monitoring stations are identified in Figure 2 presented previously. These studies are summarized and compared to the study dataset in this section.

4.3.3.1. Stone Lakes NWR Tributaries Monitoring

The USFWS[12] monitored eight major inputs to Stone Lakes NWR during four storms from December 1998 to January 2000. The purpose of the study was two-fold: to measure the concentrations of trace elements and organophosphate pesticides in winter and spring stormwater collected from inputs to Stone Lakes NWR, and to determine the biological impact of stormwater runoff on biota through TIEs. Results from water samples and field measures (temperature, dissolved oxygen, electrical conductivity, and pH) were reported. Methylmercury, pyrethroids and PAHs were not monitored by USFWS.

Overall, conventional water quality indicators and trace metals concentrations were lower than selected threshold values (generally based on Basin Plan water quality objectives). Diazinon levels were generally high, but did not consistently exhibit toxicity. The USFWS report mentions a 1997 contaminant survey of Stone Lakes NWR, which found that organic and inorganic contaminants in water and biota were relatively low.

The storm monitoring results at station C-SLNWR for this study (one of the stations also monitored by the USFWS tributaries monitoring project) found similar conditions. Chlorpyrifos was not detected by USFWS or in the present study. Diazinon was detected during the present study in two samples at much lower levels (6 and 8 ng/L) than were detected by USFWS (up to 1488 ng/L).

The citizen-based monitoring events measured conditions at many of the same stations as USFWS. Because the field measurements depend greatly on the time of day and season, a longer-term dataset would be needed for clearer comparison to the USFWS dataset. Nonetheless, banning the use of chlorpyrifos and diazinon appears to have reduced diazinon levels significantly, DO was lower and salinity higher, likely attributable to the different monitoring schedule (dry season for the present study)

4.3.3.2. Laguna Creek Receiving Water Characterization Monitoring

Laguna Creek is a major tributary to Morrison Creek and receives approximately half of its flow from the City's storm water runoff. The Upper Laguna Creek Collaborative and the Laguna Creek Watershed Council both focus their efforts on this watershed. The Laguna Creek hydromodification study[13] initiated by the Collaborative evaluated the existing hydrologic and geomorphic character of the Laguna Creek watershed and stream system. The study also summarized water quality data collected and reported by the Sacramento Stormwater Quality

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[12] Thomas, C.M., and T.C. Maurer (2003). "Toxicity of Stormwater Runoff at Stone Lakes National Wildlife Refuge, 1999-2000." Final Report, Investigation No.: 199910003. Prepared for U. S. Dept. of the Interior, Fish and Wildlife Service, Region 1, Portland, Oregon. 28 pp.

[13] Available on-line at http://www.lagunacreek.org/.

Partnership for Elk Grove Creek at Laguna Blvd. and Laguna Creek upstream of confluence with Morrison Creek and by the Sacramento Regional County Sanitation District for Laguna Creek at Franklin Blvd., Laguna Creek at the Western Pacific Railroad Tracks, and Morrison Creek upstream and downstream of its confluence with Laguna Creek.

Target values (which were not all associated with established criteria) were observed in some samples for the following pollutants: chlorpyrifos, diazinon, fecal coliform, dissolved oxygen, arsenic, copper, lead, zinc, and nutrients (nitrogen and phosphorus). Aside from these spurious exceedances, concentrations of these and other pollutants were generally similar to levels measured by the present study in Sheds B and C.

4.3.3.3. Laguna West Lake and Lakeside Treatment Control BMPs Monitoring

The Laguna West development implemented a Laguna West Lakes Water Quality Monitoring and Evaluation Program[14] (ERA and Jones & Stokes, 2007). The goal of the program was to determine whether the Laguna West Lake's runoff treatment system was operating effectively and complying with established criteria. Results from recent and earlier monitoring efforts were in compliance with federal and state water and sediment quality objectives, indicating that the treatment system was operating as designed. These results included: (1) lack of ecologically significant toxicity in test results for three sensitive species; (2) compliance with water quality objectives; and (3) compliance with sediment quality guideline numeric criteria.

A similar stormwater runoff monitoring effort is currently being implemented for the Lakeside development project. The monitoring program, developed in cooperation with the County of Sacramento, aims to (1) quantify levels of pollutants in water discharged from Lakeside Lake, (2) quantify trace metals levels in aquatic plants and sediments in Lakeside Lake, and (3) test discharge waters for toxicity to sensitive test organisms. Previous annual reports submitted to the City[15] indicate that the project meets these established criteria.

The results of these studies would be most directly comparable to station C-Promenade *were the detention basin discharging*. Because of the greater ability to detain runoff, discharge quality from the Promenade basin, when it does occur, would likely be similar to or better than discharges from the West Lake and Lakeside projects'.

4.3.3.4. Sacramento Stormwater Quality Partnership Runoff and Receiving Water Monitoring

The Sacramento Stormwater Quality Partnership implements a monitoring program on a scale sufficiently broad to characterize stormwater discharges associated with urbanization / land development and the Partnership's stormwater management program. Historical monitoring data are available for several long-term stations within Sacramento County that represent urban runoff. Pesticides have been monitored at additional stations. A summary of historical data at major monitoring stations is presented in **Appendix B**, **Table B-3.** These data generally indicate

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[14] Ecological Research Associates and Jones & Stokes (2007). "Laguna West Lakes Water Quality Monitoring and Evaluation Program" Final Report. Prepared for City of Elk Grove. 48 pp.

[15] See for example: Perry, S., and M. Sytsma (2007). "Lakeside Water Quality Compliance Monitoring Report for February 2007." Prepared for City of Elk Grove. 12 pp.

similar water quality conditions as observed in the present study, although concentrations of metals were generally lower in the Elk Grove samples.

4.4. CONTINUOUS SENSORS

Continuous sensor data for B-Franklin are shown in **Figure 13**. The electrical conductivity sensor was dry (i.e., the water level was too low to submerge the probe) until Event #2. Sampling Events #2 and #3 were timed well, within a few hours of the peaks in water level and turbidity. Specific conductivity tended to increase steadily between storms, and then return to lower levels by stormwater. Dissolved oxygen decreased following storms, but tended to be 50-100% of saturation. The daily cycling of oxygen would be related to both the temperature fluctuations (daily highs in temperature lower the saturation concentration) and algal photosynthesis (peaking mid-day with maximum sunlight).

Continuous sensor data for C-Franklin are shown in **Figure 14**. Event #2 sampled a stagnant pool dominated by dairy drainage—not a flowing creek with rainfall runoff. This assessment is based on observations around the time of sampling that the water level increased only ~2 cm and specific conductivity only decreased from 3900 to 3700 uS/cm. Water at this station likely only flows towards Stone Lakes NWR during larger storms than what had occurred during this wet season. Event #3 portrays a more recognizable rainfall-runoff pattern: the water level increased ~10 cm, and the specific conductivity spike on 3/5/09 dissipated. Grab samples were collected ~1.5 miles upstream at C-Bruceville for this event, but the pattern was likely similar.

The most significant changes in basic water properties at C-Franklin during the monitoring period do not appear to be directly linked with storms. Aside from the two monitored storms, there were also signs of discrete discharges not directly related to rainfall runoff. In particular:

- Conductivity spiked high at 10 PM on 2/26/09 and again on 3/5/09. The simultaneous increase in depth suggests a nearby source.
- Conductivity spiked low at 4 PM and 10 PM on 1/30/09 and 2/1/09. The 3-hour delay in depth increase suggests an upstream source.
- Dissolved oxygen was essentially zero except during these spikes (except 3/5/09).

Compared to Basin Plan water quality objective, these data indicated the following:

- pH was with the range 6.5-8.5 88% of the time at B-Franklin and 100% of the time at C-Franklin.
- Dissolved oxygen was above 5 mg/L at B-Franklin 89% of the time (average=8.1 mg/L) but essentially zero at C-Franklin except during apparent flushing flows.
- Specific conductivity was below 700 uS/cm all of the time at B-Franklin (average = 133 uS/cm) but only 31% of the time at C-Franklin (average = 1670 uS/cm), and each station exhibited different patterns.
- Temperatures varied daily at both stations in response to the same weather patterns.

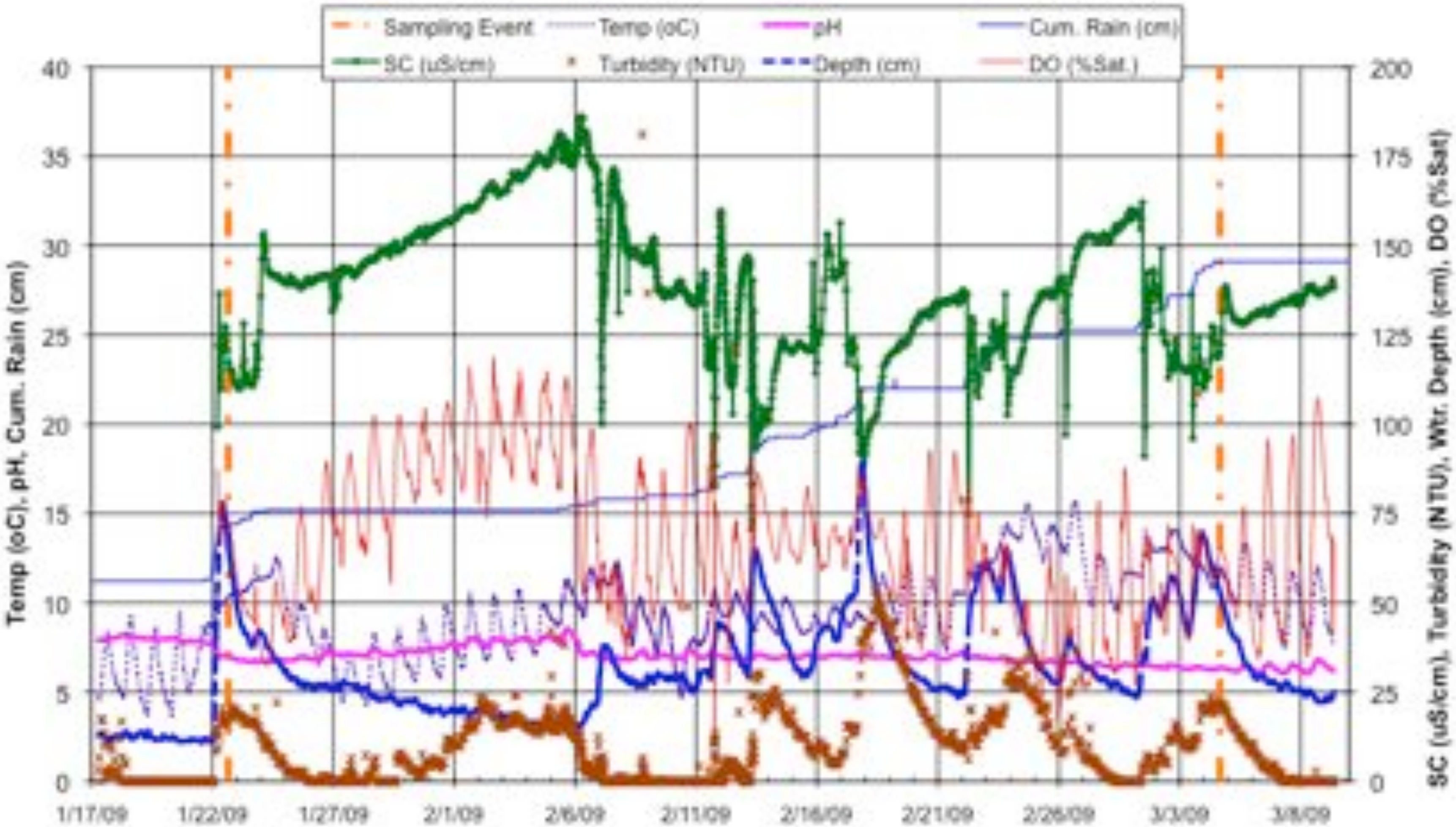

Figure 13. Continuous sensor data at B-Franklin, 1/17/09-3/10/09.

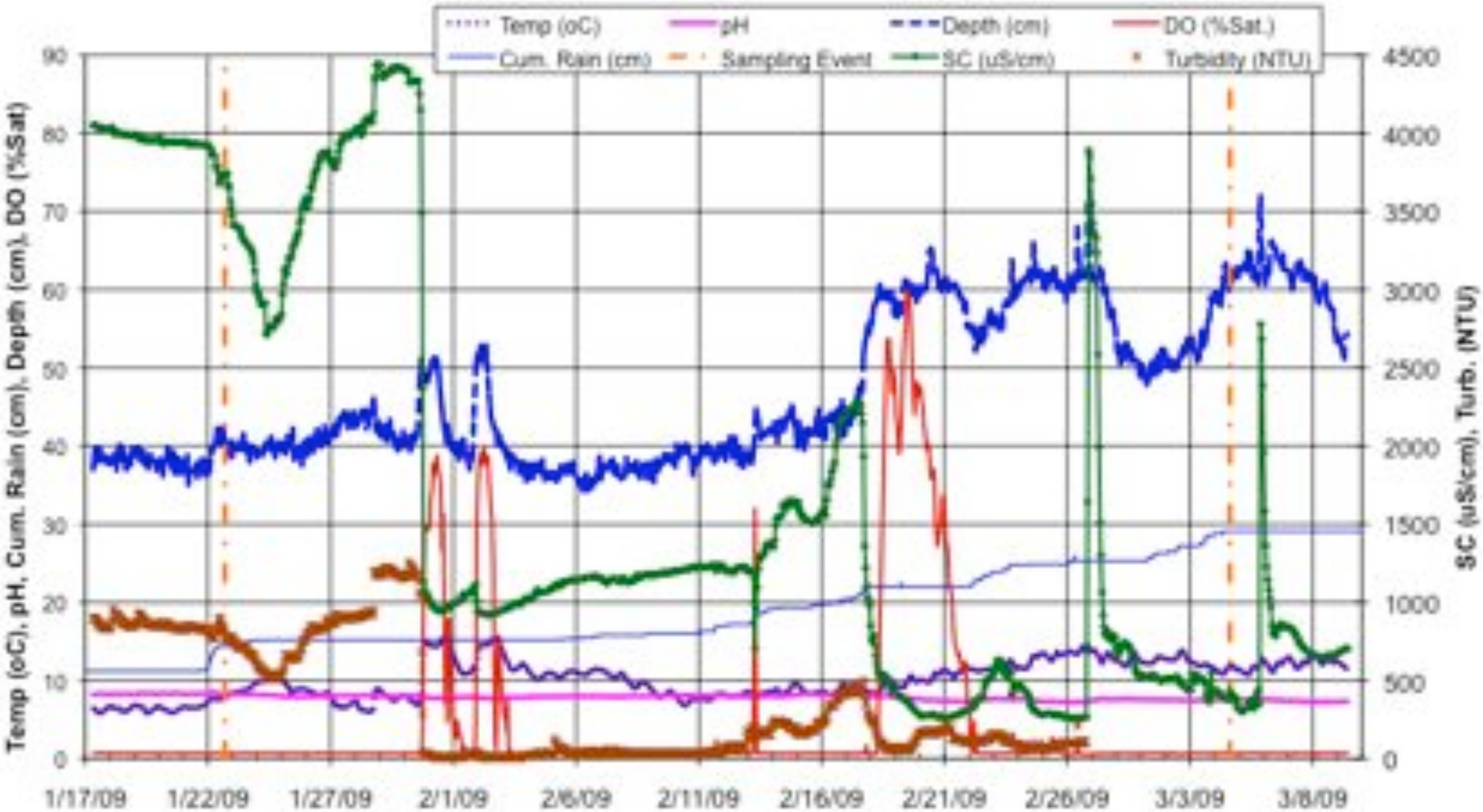

Figure 14. Continuous sensor data at C-Franklin, 1/17/09-3/10/09.

4.5. WATER COLUMN TOXICITY

The results of water column toxicity tests are summarized in **Table 12**. Specific test results for each storm sampling event are presented below.

Table 12. Water Column Toxicity Test Results Summary, Counts of Toxicity / # Samples

Station	Water Flea (*Ceriodaphnia Dubia*)		Fathead Minnow (*Pimephales promelas*)	
	Survival	**Reproduction**	**Survival**	**Growth**
B-Franklin	1/3	0/3	0/3	0/3
C-Franklin	2/2	N/A	2/2	N/A
C-Bruceville	0/1	0/1	0/1	0/1
C-SLNWR	0/3	0/3	0/3	0/3

4.5.1. Toxicity Test Results for Event #1: 1 November 2008

Chronic toxicity was observed in fathead minnows exposed to C-Franklin samples. To characterize the cause(s) of toxicity, an acute fathead minnow TIE was performed on the C-Franklin sample. The TIE was targeted toward ammonia because there was ~17 mg/L total ammonia in the sample. Zeolite neutralizes ammonia toxicity; lower pH decreases the fraction of unionized ammonia (the toxic form). The toxicity test results for the field sample were as follows:

- 100% baseline sample - 0% survival
- 100% zeolite-treated sample - 100% survival
- 100% zeolite-treated sample + ammonia spiked in at ~17 mg/L - 0% survival
- 100% pH 6.0 adjusted sample - 90% survival
- 100% pH 7.0 adjusted sample - 20% survival
- 100% pH 8.0 adjusted sample - 0% survival

For comparison, the control sample results were as follows:

- Lab Control - 100% survival
- Zeolite Blank - 90% survival
- pH 6.0 Blank - 100% survival
- pH 7.0 Blank - 90% survival
- pH 8.0 Blank - 100% survival

The test water also had to be aerated due to hypoxic conditions that developed with the sample. Although buffers were used to control pH drift in the pH-adjusted samples, the aeration caused the pH to increase each day. Even with pH-adjustments (i.e., dilute acid additions), the pH of the "pH 7.0 treatment" sample drifted to >8.0, resulting in a greater-than-normal reduction in survival at this treatment (higher pH results in greater ammonia toxicity). With this exception, the above results are characteristic of toxicity related to ammonia (i.e., baseline is toxic, Zeolite treatment removes toxicity, ammonia add-back recovers toxicity, and toxicity decreases with decreasing pH). These results also confirm the ammonia toxicity threshold exceedances in water column samples at C-Franklin (see Table 10 presented previously).

There was also complete mortality to water fleas exposed to the C-Franklin sample. The unionized ammonia concentration ranged from 1.3 - 2.0 mg/L during the test, which is well above the chronic toxicity values published in the literature (e.g., 0.53 - 1.2). Although coming to any definitive conclusion as to the cause of the water flea toxicity is impossible without also performing a TIE, it is most likely that the toxicity was due to ammonia based on the concentrations of unionized ammonia that occurred during the test. Reproduction (for water fleas) and growth (for fathead minnow) were not assessed because a survival end point was already reached.

Water fleas survival in the B-Franklin sample averaged 50%, which was statistically significantly lower than control samples. Survival and growth of fathead minnows in the same sample were normal (i.e., not significantly different than control samples).

4.5.2. Toxicity Test Results for Event #2: 22 January 2009

There were again significant reductions in water fleas and fathead minnow survival in the C-Franklin sample. Consistent with Event #1's sample at C-Franklin, the measured unionized ammonia concentrations (2.9-6.5 mg/L) were well above chronic toxicity thresholds. Because of the clear findings from Event #1 regarding ammonia toxicity at this station and even higher ammonia concentrations in this event's sample, a TIE was not performed. Reproduction (for *Ceriodaphnia*) and growth (for fathead minnow) were not assessed because a survival end point was already reached.

There were no significant reductions in *Ceriodaphnia* or fathead minnow survival or reproduction/growth in the B-Franklin or C-SLNWR samples.

4.5.3. Toxicity Test Results for Event #3: 4 March 2009

There were no significant reductions in *Ceriodaphnia* or fathead minnow survival or reproduction/growth in any of the samples. Ammonia concentrations at C-Bruceville were well below levels measured previously at C-Franklin.

Sample waters for stations C-Bruceville and C-SLNWR were measured upon arrival at the testing lab at 6.5 ^{o}C and 7.2 ^{o}C, which exceeds the maximum threshold of 6 ^{o}C. Temperature effects on toxicity are variable—for example, pyrethroids are inherently less toxic at higher temperatures[16], but the organisms experience faster metabolic processes. Given that toxicity was not observed in any of the samples, the slightly higher temperatures are not considered problematic. Nonetheless, the results are considered "estimated" because of the temperature exceedances.

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[16] Weston D.P., J. You, A.D, Harwood, and M.J. Lydy (2009). "Whole sediment toxicity identification evaluation tools for pyrethroid insecticides: III. Temperature manipulation." *Environ Toxicol Chem.*, 28(1):173-80.

4.6. SEDIMENT TOXICITY

There was 100% survival by *Hyalella azteca* of the lab control sediments. The C-SLNWR samples had 90% survival, which was not a significant reduction compared to the control samples. Physical analysis indicated that the sample consisted primarily of sand, silts and clays. Chemical analysis indicated 14,400 mg/kg total organic carbon. The sampled sediment is presumed to be representative of agricultural runoff at other points in Stone Lakes NWR.

During the growing season, USFWS controls water hyacinth growth in Stone Lakes NWR waterways. Control methods include a combination of mechanical removal and herbicide applications. Additional pesticide use in the drainage area is unknown, although both organophosphate- and pyrethroid-based pesticides are likely applied. Such applications may affect local biota, but no such effects were observed in this summertime sample.

5. Conclusions and Next Steps

The City of Elk Grove's New Development Stormwater Monitoring Program described in this report monitored runoff from relatively new residential development (Shed B), from a new commercial development (the Promenade Mall), and from agricultural areas (remainder and majority of Shed C). The program measured physical conditions, concentrations of dissolved and particulate compounds, and whole-water toxicity during three storm events during the 2008-2009 wet season. Results were compared to water quality objectives, as well as other local monitoring project reports. Continuous sensors provided high frequency field measurements to put storm event grab samples into a broader temporal context. Sediment toxicity was also tested at the first depositional zone for sediments draining into Stone Lakes NWR from Shed C to provide cumulative effects data in the area of interest (Stone Lakes NWR). At the downstream end of the study area, volunteers measured physical conditions at eight locations in Stone Lakes NWR in spring and fall of 2008.

The project team successfully developed and implemented a stormwater monitoring program for the first time in the Shed B and Shed C drainage areas of the City of Elk Grove. The team overcame logistical constraints associated with identifying and accessing appropriate monitoring locations, timing rainfall-runoff sampling, and sampling several matrices under a wide range of environmental conditions. Success was due in part to the team's coordination with City staff, regulators (regional, state and federal), and analytical labs. The program also involved local citizens in the development and implementation of the monitoring program during both storm events and dry-weather events within Stone Lakes NWR.

Conclusions are drawn from the monitoring results and field experience. But in broad terms, it must be recognized that results from one year are insufficient for drawing sweeping conclusions or recommending significant programmatic changes. Nonetheless, suggested next steps are guided by and built upon this recent experience.

5.1. CONCLUSIONS

Conclusions are presented as responses to the three key questions raised in section 1.

5.1.1. Does the development degrade water quality?

Chemical concentrations at all monitoring stations predominantly met water quality objectives. *E. coli* bacteria were typically measured at levels exceeding the single-sample maximum objective. The most common chemical exceedance was for methylmercury, for which all samples exceeded the water column target in the draft Delta Methylmercury TMDL of 0.06 ng/L. Other metals were almost always below objectives. Organophosphate pesticides were detected at least once at most stations, but were below objectives.

Many monitored compounds do not have criteria for comparison. Only four pyrethroid pesticides were ever detected. Although individual pyrethroid concentrations were low or non-detected, additive effects are a potential toxic stressor. At least seven PAHs were detected at each of the three receiving water monitoring stations; however, there are significant concerns with sample contamination. Nutrients (nitrogen species and total phosphorus) were typical of surface waters in the Central Valley.

Spatial patterns were difficult to ascertain in light of the few monitoring events and essentially stagnant conditions at all of the Shed C stations. Water quality at station C-Franklin—measured by grab samples, toxicity testing and continuous sensors—was poorest. Results for the other stations indicate similar conditions as measured previously in Stone Lakes NWR and in the Sacramento urbanized area.

If Shed B is considered representative of the effects of traditional urban residential development on water quality, the monitoring results indicate the presence of more trace constituents, but not more toxic conditions. Water quality changes associated with development in Shed C is unpredictable owing to the lack of rainfall runoff during the monitoring period (for characterizing baseline conditions), the myriad effects of landscape changes, and the overall benefits of designing development according to the Stormwater Quality Design Manual.

5.1.2. Does the development modify the local hydrology?

There was essentially no surface runoff in Shed C during the study period.As recorded by the National Weather Service, precipitation for the Sacramento area totaled 16.47 inches from 1 July 2008 to 30 June 2009. The basin was designed[17] with a water quality volume capacity of 38 acre-feet and a flood control capacity of approximately 64 acre-feet. Although the required water quality volume portion of the basin was not intended to capture and retain storm runoff above the required "first-flush" volume, precipitation runoff from the Promenade Mall buildings and parking lot were never released into the downstream channel even with 83% of the annual normal precipitation[18].

C-SLNWR, at the downstream end of Shed C, also had negligible flow. The sampled water was likely a mixture of local rangeland runoff and backflow from other canals in Stone Lakes NWR.

Continuous sensor data at B-Franklin and C-Franklin portrayed situations in which some conditions varied over daily cycles (e.g. temperature, dissolved oxygen), but flushing events (associated with rainfall runoff at B-Franklin but not C-Franklin) generally had a greater affect.

Impervious areas and non-stormwater runoff conveyed through engineered storm drain channels in Shed B likely resulted in both dry-weather flows and some measurable runoff response to smaller rainfall events. The multi-functional elements of the Shed B channel may have improved water quality at the urban boundary, but may not have retained large volumes of water. New develop anticipated in Shed C, which would follow the area's Stormwater Quality Design Manual, would likely respond differently to rainfall events.

5.1.3. Do the development and associated runoff stress plant and animal habitats?

Water column toxicity was monitored at the three receiving water monitoring stations for three storms. Results found significant toxicity at the C-Franklin station during both monitoring events. Toxicity was attributed to very high levels of un-ionized ammonia, although organisms could not have survived the lack of dissolved oxygen either. No other sites exhibited acute or chronic toxicity to test organisms (except some effect to *Ceriodaphnia* at B-Franklin during Event #1).

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[17] Master Drainage Plan for Elk Grove Promenade Local Drainage Area Shed C, Wood Rodgers, November 2005.

[18] 19.87 inches is considered average annual precipitation total for the Sacramento area.

Sediment toxicity was performed at one station (C-SLNWR) at one time (mid-summer). Toxicity of that sample was not observed. Weed control and removal in Stone Lakes NWR's waterways may have a greater short-term impact on local biota than did sediment chemistry conditions. These results confirm the field observations of no stress to plant or animal habitats.

5.2. NEXT STEPS

The monitoring results described in this document initiate a baseline database of urban runoff from Shed B (new residential development) and Shed C (agricultural lands slated for future urban development) into Stone Lakes NWR. Subsequent monitoring by the City should be implemented based on the experience gained from this initial effort. Monitoring activities already required and additional ones proposed for the City to continue monitoring local waterways are outlined here.

5.2.1. Required Monitoring

Some stormwater monitoring activities supported by the City are required by either the Sacramento Area's NPDES Stormwater Permit (conducted by the Sacramento Stormwater Quality Partnership) or by the Statewide General Permit for Construction Activities. These requirements and the monitoring performed to comply with them are described here.

5.2.1.1. Sacramento Stormwater Quality Partnership Monitoring

The City, as a co-permittee of the Sacramento Stormwater Quality Partnership, funds and participates in Partnership-led monitoring. Activities and monitoring results are documented annually. The monitoring program address the following interests:

- Baseline monitoring of urban runoff and discharge characterization monitoring (3 sites each) plus receiving water in the American and Sacramento Rivers (2 sites each) for water chemistry and toxicity, approximately 6 events annually
- Sediment chemistry analysis and assessment of sediment-associated biometrics at four urban tributary sites, 2 of every 3 years
- Additional monitoring and analyses of pesticides and mercury to address specific impairments and regulations
- Special studies to evaluate the effectiveness of detention basins[19], new development BMPs, and proprietary treatment BMPs

Analyses particularly relevant to the City's interests include:

- Effectiveness assessment for each program element
- Data summaries and identification of water quality trends, including improvements in (or degradation of) urban storm water

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[19] The Partnership is monitoring influent into and effluent from a wet detention basin in Natomas to characterize stormwater runoff from new developments. The Partnership expects that the study will be finished by July 2010 and the results will be incorporated within the 2010-2011 Annual Report. The detention basin at Promenade Mall is similar in function to the wet detention basins studied by the Partnership. The City, as a member of the Partnership, should use these study results to guide future development designs (including detention basins) within its jurisdiction.

- Estimates of discharge volumes and pollutant loads
- Evaluation of significant correlations of target pollutants with other constituents, such as total suspended solids.

5.2.1.2. Construction Site Permit Compliance Monitoring

New development projects generally follow BMPs recognized statewide[20]. Construction-phase projects disturbing one acre or more must comply with the statewide construction general permit, which requires a Storm Water Pollution Prevention Plan (SWPPP). Effective July 1, 2010, the general permit includes the following significant changes:

- Establishes three levels of risk possible for a construction site based on (1) Project Sediment Risk, and (2) Receiving Water Risk
- Includes Numeric Effluent Limits for Risk Level 3 sites and Numeric Action Levels for pH and turbidity (and discharge monitoring requirements) for Risk Level 2 and 3 sites
- Imposes minimum BMPs and requirements
- Requires some Risk Level 3 dischargers to monitor receiving waters and conduct bioassessments
- Requires that key personnel (e.g., SWPPP preparers, inspectors, etc.) have specific training or certifications

Typically the City reviews SWPPPs for proposed development projects and inspects sites to ensure compliance with those SWPPPs. Projects disturbing less than an acre must comply with City's stormwater ordinance and include pollution controls, which the City also monitors visually.

5.2.2. Additional Monitoring

The following monitoring activities should be considered by the City to continue its monitoring of the effects of new development runoff to Stone Lakes NWR. These additional monitoring efforts are generally prioritized with the more relevant and useful efforts listed first; the actual monitoring program would depend on available budget and ongoing discussions with stakeholders. Whatever monitoring is implemented should continue until the Partnership's NPDES permit is renewed or for five years, whichever is sooner.

5.2.2.1. Monitor Hydromodification Effects

In October 2008, the National Research Council (NRC) published the report "Urban Stormwater Management in the United States"[21]. This report was the product of a two-year study of the federal stormwater regulatory program. The NRC was commissioned by USEPA to clarify the links between stormwater discharge pollutants and ambient water quality, to assess the state of science of current stormwater management, and to make policy recommendations.

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[20] California Stormwater Quality Association (CASQA) (2004). *California Stormwater Best Management Practices Handbook for Construction*. Available on-line at http://www.cabmphandbooks.com/Construction.asp.

[21] Available at http://www.epa.gov/npdes/pubs/nrc_stormwaterreport.pdf.

The NRC report addressed a number of substantive issues within in the stormwater and water quality regulatory arena. In particular, NRC recommended that flow and related parameters like impervious cover should be considered for use as proxies for stormwater pollutant loading. Based on this recommendation and as a way to enhance the value of the Partnership's regional efforts described above, long-term monitoring of hydromodification is suggested for the City. The monitoring effort is outlined briefly here:

- Install depth sensors (self-contained pressure transducers) to measure discharges at stations B-Franklin and C-Bruceville. These two stations are located at the downstream limits of the City's jurisdictional boundary in Sheds B and C, respectively. Shed B data will be used to represent recent urban residential development. Shed C data will be used as a baseline for trend analysis as that watershed is developed following low-impact development guidelines. Hydraulic analyses can be used to estimate discharges based on water level data, channel geometry measurements and surface roughness estimates.
- Collect regional data for precipitation and atmospheric pressure (to subtract from pressure transducer data). The precipitation data can be paired with discharge estimates to characterize local hydrology.
- Collect single grab samples at each station during three storm events per wet season (early, peak, and late). Analyze each sample for suspended sediment concentration and particle size distribution. Particle concentrations and loads can be used as surrogates for pollutant concentrations and loads.

Trend analyses and comparisons between Sheds B and C for these data could characterize the effects of urban residential development under both older and newer development design criteria. Additional effort would be required for managing the project, communicating with stakeholders, and analyzing and reporting the results at the end of the monitoring period.

5.2.2.2. Deploy Continuous Sensors

Continuous sensors could be deployed similar to the Year 1 monitoring effort. The scope could include:

- Monitoring at stations B-Franklin and C-Bruceville
- Deploying sensor units for ~2 months annually coinciding with storm sampling events
- Measuring temperature, pH, depth, dissolved oxygen, turbidity and electrical conductivity
- Tracking and downloading sensor data remotely in real-time

This effort would provide a continuous record of multiple parameters and real-time tracking of the sensor units and their measurements. The benefit would be to identify daily, weekly, seasonal and episodic patterns in basic water quality conditions, putting the discharge and suspended sediment concentration data in context and relating suspended sediment concentrations to turbidity measurements.

5.2.2.3. Measure Sediment Toxicity

Representative bed sediment samples could be collected and analyzed annually. The scope could include:

- Monitoring at station C-SLNWR and in a similar deposition zone for Shed B (North Stone Lake, Southern arm)
- Collecting, compositing and homogenizing individual surface "scoops"
- Sampling annually in spring
- Performing physical (grain size distribution) and chemical (total organic carbon) analyses
- Testing each composite sediment sample for toxicity using the USEPA 10-day survival test with the amphipod *Hyalella azteca*, following established guidelines
- If toxicity is observed, testing sediment samples for the most common pyrethroid-based pesticides.

The benefits of this effort would be to provide a measure of cumulative effects in the area of interest—Stone Lakes NWR. The State Water Resources Control Board has recently developed sediment quality objectives for enclosed bays and estuaries[22], but no similar objective is available for conditions in the Refuge, so there would remain some uncertainty regarding the actual implications of the sediment toxicity findings.

5.2.3. Citizen-based Monitoring Options

Depending on the interest level indicated by volunteers, other citizen involvement opportunities could include those described in this section. A multi-tiered volunteer monitoring strategy[23] also could be developed and implemented to encompass several such activities. Because these activities would be led by volunteers, they are simply suggested here as useful ancillary efforts.

Needs for the City to support these events would be minimal, for example: providing staff time to publicize events, contributing funding for a volunteer coordinator, purchasing surveying or monitoring equipment, transporting collected trash, and contributing funds to support a volunteer coordinator. In addition, there are several resources available to organize and fund citizen-based efforts such as those described below. Two web sites in particular may be most useful:

- CaliforniaVolunteers (http://www.californiavolunteers.org)—This new state office is charged with managing programs and initiatives to increase the number and impact of Californians involved with service and volunteering. Through the Web site, individuals can find volunteer opportunities throughout the state by area of interest.
- Volunteer Center of Sacramento (www.volunteersac.org)—Connects community volunteers to important causes in the area. Through the Web site, individuals can find volunteer opportunities by geographic area of the greater Sacramento area (including Elk Grove) and by category (including Environment).

5.2.3.1. Bioassessments

Aquatic community habitat is a major determinant of aquatic community potential. Both the quality and quantity of available habitat affect the structure and composition of resident biological communities. Several options are available for assessing the habitat value and impacts

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[22] See http://www.swrcb.ca.gov/water_issues/programs/bptcp/sediment.shtml.

[23] See, for example, this Stream Watch Program description:
http://www.cwp.org/Resource_Library/Restoration_and_Watershed_Stewardship/residential.htm

of urban stormwater runoff. The Rapid Bioassessment Protocol[24], developed by USEPA, is the most common and widely accepted. The protocol is appropriate for volunteers because it is user-friendly and can be performed rapidly (less than one hour) at most sites with less than a half-day of training. A Stream Waders Program could train volunteers to sample macroinvertebrates twice annually (http://www.dnr.state.md.us/streams/mbss/mbss_volun.html).

Additional considerations regarding the use of the Protocol include:

- Originally designed as a screening tool for determining if a stream is or is not supporting a designated aquatic life use
- Can be integrated with macroinvertebrates and water quality monitoring
- Should be two people to a field team; at least one field team member should be trained
- May not be appropriate for every station depending on the nature of the stream channels
- Should be conducted annually over several years

5.2.3.2. Water Monitoring and Cleanup Events

World Water Monitoring Day and Coastal Snapshot Day provide occasions and centralized logistical support for conducting citizen-based water monitoring. Citizens can collect chemical data about water quality in local streams to characterize stream quality and track changes over time. The stormwater database for this project includes the data reported by the two citizen-based events described previously in this report.

Similarly, stream cleanup (trash removal) events can be conduct periodically in local streams to provide a visible improvement to local environment while increasing public awareness of water quality issues. Creek Week, held regionally each spring, is a logical time to organize local volunteers.

5.2.3.3. Riparian Wildlife and Habitat Assessments

Volunteers can score streams on a variety of characteristics such as bank stability. The higher the score, the better the habitat is for fish or wildlife. Citizens could also survey wildlife and/or plant populations within Stone Lakes NWR. This effort could build upon bird counts and other surveying that USFWS staff and Stone Lakes Association volunteers currently conduct.

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[24] Barbour, M.T., Gerritsen, J., Snyder, B.D. and Stribling, J.B. (1999). *Rapid Bioassessment protocols for in streams and wadeable Rivers: Periphyton, Benthic Macroinvertebrates and Fish*. Second Edition. EPA 841-B-99-002. U.S. Environmental Protection Agency; Office of water: Washington, D.C.

Appendix A. Site Photos

B-Franklin from Franklin Blvd bridge looking upstream

C-Promenade looking downstream

C-Franklin looking upstream from Franklin Blvd

C-Franklin at Franklin Blvd culvert sampling point

C-SLNWR during field reconnaissance, October 2007

C-SLNWR during First-flush Sampling Event November 1, 2008

Typical view in the eastern side of the Stone Lakes NWR


Spring Snapshot Day, May 2008


World Water Monitoring Day, October 2008

Appendix B. Water Quality Data Support

Table B-1. Constituents, Analytical Methods and Reporting Limits

Constituent	Method	Lab[1]	Reporting Limits	Units
Metals (Total Recoverable and Dissolved[1])				
Copper	ICP-MS	Caltest	0.5	µg/L
Lead	ICP-MS	Caltest	0.5	µg/L
Nickel	ICP-MS	Caltest	1	µg/L
Zinc	ICP-MS	Caltest	5	µg/L
Mercury	EPA 1631	Caltest	0.0005	µg/L
Mercury, methyl	EPA 1630	Caltest	5e-5	ng/L
Conventional Inorganics				
BOD_5	SM 5210B	SRWTP	1	mg/L
Hardness	EPA 130.2 Titration	Caltest	1	mg/L
Nitrate + Nitrite (as N)	EPA 353.2	Caltest	0.1	mg/L
Total Kjeldahl Nitrogen	EPA 351.3	Caltest	0.1	mg/L
Ammonia (as N)	EPA 350.2	Caltest	0.1	mg/L
Phosphorus, total (as P)	EPA 365.4	SRWTP	0.02	mg/L
Solids, Total Suspended	SM 2540D	SRWTP	3	mg/L
E. coli	SM9223	SRWTP	2 to 2 x 10^6	MPN/100 mL
Total coliform	SM9223	SRWTP	2 to 2 x 10^6	MPN/100 mL
Organics				
Organophosphate Pesticides	EPA 625(m)	CRG	2-100	ng/L
Pyrethroids	EPA 625(m)NCI	CRG	2-25	ng/L
PAHs	EPA 625(m)	CRG	5	ng/L
TOC	EPA 415.1	Caltest	1	µg/L
DOC	EPA 415.1	Caltest	1	µg/L
Toxicity				
Water Column Toxicity	USEPA (2002)	PER	N/A	N/A
Sediment Toxicity	USEPA (2000)	PER	N/A	N/A

[1] SRWTP = Sacramento Regional Wastewater Treatment Plant; PER = Pacific EcoRisk.
[2]: Dissolved constituents were filtered using an in-line filter at the time of sample collection.

Table B-2. Data Quality Evaluation – Field and Laboratory

Quality Control Sample Type	QA Parameter	Frequency[1]	Acceptance Limits	Corrective Action
Quality Control Requirements – Field				
Field Blank	Contamination	5% of all samples	< MDL	Examine field log. Identify contamination source. Qualify data as needed.
Field Duplicate	Precision	5% of all samples	Suspended solids, total – RPD ≤ 20 Nutrients – RPD ≤ 20 Hardness – RPD ≤ 10 Metals – RPD ≤ 20 Pesticides – RPD ≤ 20 TOC/DOC – RPD ≤ 25	If laboratory duplicate is within acceptance limits, no corrective action needed. Otherwise, reanalyze both samples if possible. Identify variability source. Qualify data as needed.
Quality Control Requirements – Chemistry Laboratory				
Method Blank	Contamination	1 per analytical batch	< MDL	Identify contamination source. Reanalyze method blank and all samples in batch. Qualify data as needed.
Lab Duplicate	Precision	1 per analytical batch	Suspended solids, total – RPD ≤ 20 Nutrients – RPD ≤ 20 Hardness – RPD ≤ 10 Metals – RPD ≤ 20 Pesticides – RPD ≤ 20 TOC/DOC – RPD ≤ 25	Recalibrate and reanalyze.
Matrix Spike	Accuracy	1 per analytical batch	80-120% Recovery	Check LCS/SRM recovery. Attempt to correct matrix problem and reanalyze samples. Qualify data as needed.
Matrix Spike Duplicate	Precision	1 per analytical batch	RPD ≤ 25% if |Difference| ≥ RL	Check lab duplicate RPD. Attempt to correct matrix problem and reanalyze samples. Qualify data as needed.
Laboratory Control Sample (or SRM)	Accuracy	1 per analytical batch	80-120% Recovery	Recalibrate and reanalyze LCS/ SRM and samples.

MDL = Method Detection Limit   RL = Reporting Limit   RPD = Relative Percent Difference

LCS = Laboratory Control Sample/Standard   SRM = Standard/Certified Reference Material

[1] "Analytical batch" refers to a number of samples (not to exceed 20 environmental samples plus the associated quality control samples) that are similar in matrix type and processed/prepared together under the same conditions and using the same reagents (equivalent to preparation batch).

Table B-3. Sacramento Stormwater NPDES Monitoring - Summary Statistics for Urban Runoff, December 2002 – February 2007

Parameter	Units	Strong Ranch Slough (a)				Sump 111 (b)				Sump 104 (c)			
		n det (d)	Mean (e)	Min det (f)	Max det (g)	n det (d)	Mean (e)	Min det (f)	Max det (g)	n det (d)	mean (e)	Min det. (f)	Max det. (g)
Metals													
Copper, Dissolved	µg/L	18	5.20036	2.91	14.1	18	5.5155	1.98	10.9	18	3.6136	1.01	7.76
Copper, Total	µg/L	18	15.036	3.53	65	18	19.338	4.46	118	18	12.829	1.58	68.6
Lead, Dissolved	µg/L	18	0.63843	0.161	1.81	18	0.7343	0.095	1.94	17	0.4832	0.032	1.33
Lead, Total	µg/L	18	10.5596	0.495	33.5	18	16.289	0.506	90.4	18	8.1457	0.281	30.4
Mercury, Dissolved	µg/L	17	0.00432	0.0017	0.0102	19	0.0038	0.0011	0.009	19	0.003	6e-04	0.007
Mercury, Total	µg/L	18	0.05882	0.0035	0.609	19	0.0227	0.0029	0.071	19	0.0145	0.002	0.041
Mercury, methyl	µg/L	18	0.00048	7e-05	0.002	18	0.0003	9e-05	9e-4	18	0.0002	5e-05	6e-04
Nickel, Dissolved	µg/L	18	1.35433	0.36	3.78	18	1.7295	0.54	4.41	18	1.8755	1.16	6.35
Nickel, Total	µg/L	18	4.07793	0.62	12.5	18	6.2725	2.02	28.2	18	4.9005	1.4	18.3
Zinc, Dissolved	µg/L	18	20.4953	3.96	47.6	18	52.856	13.5	133	18	23.419	2.44	55.2
Zinc, Total	µg/L	18	82.169	6.85	298	18	149.66	27.3	829	18	75.095	6.13	334
Conventional Inorganics													
BOD	mg/L	14	109.692	3	730	17	53.9214	4	390	14	60.396	3	630
Hardness	mg/L	17	55.0529	16.5	140	17	45.2588	8	160	17	93.247	12	260
Nitrate + Nitrite	mg/L	13	0.41055	0.1	1.4	17	0.58588	0.2	1.8	16	1.0546	0.2	5.2
Total Kjeldahl Nitrogen	mg/L	17	2.09235	0.7	8.2	17	1.40941	0.6	4.6	17	1.9594	0.25	8.2
Ammonia	mg/L	5	0.38	0.2	0.5	5	0.32	0.2	0.5	5	0.56	0.3	1.2
Phosphorus, Total	mg/L	17	0.47949	0.1	1.4	18	0.42778	0.14	2.6	18	0.5039	0.2	1.9
Solids, Total Suspended	mg/L	17	83.2414	3	440	16	55.3313	4	270	11	26.313	4	60
E. Coli	MPN/ 100mL	19	15235.3	140	80000	18	2270.56	20	8000	18	79900	500	1E+0 6
Organics													
TOC	mg/L	15	73.267	7	310	15	28	3	160	15	39.4	6	240
DOC	mg/L	15	70.9133	5	300	15	28	3	160	15	34.913	5	230
PAH, Total Detectable	µg/L	17	0.7811	0.0041	2.915	17	1.3122	0.008	12.18	18	0.592	0.023	3.139
OP Pesticides													
Chlorpyrifos	µg/L	ND	ID	ND	ND	1	ID	0.04	0.04	1	ID	0.03	0.03
Diazinon	µg/L	12	0.10209	0.0186	0.28	6	0.0885	0.0338	0.56	11	0.086	0.008	0.36

(a) Strong Ranch Slough - drains a 5,162 acre mixed-use area of the County of Sacramento.
(b) Sump 111 – drains an industrialized 420 acre area of the City of Sacramento.
(c) Sump 104 - drains a 2,220 acre area of mixed residential/commercial land use in the City of Sacramento.
(d) Number of samples in which analyte was detected.
(e) Arithmetic mean value; "ID" indicates insufficient data detected to calculate value.
(f) Minimum value reported; "ND" if no detected values.
(g) Maximum value reported; "ND" if no detected values.