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San Joaquin River
Water Quality Improvement Project
Phase 1
2023 Wildlife Monitoring Report

Project #1960-23

Prepared for:

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Executive Summary

Monitoring in 2023 represented the 23rd year of biological monitoring for Phase I of the San Joaquin River Water Quality Improvement Project (SJRIP). The SJRIP is designed to eliminate discharge of salt and selenium delivered to the San Luis Drain and Mud Slough from the Grassland Bypass Project except for storm related discharges. At this point in the project, approximately 5,341 acres of the project site have been planted with salt-tolerant crops and irrigated with agricultural drainwater. Most of the salt-tolerant crops are located on 4,532 acres, hereafter referred to as the *eastern project area* because they are situated east of Russell Avenue, near the city of Firebaugh, within Fresno County, California. Approximately 82% (1,750 acres) of an additional 2,140 acres acquired since 2008 have also been planted with salt-tolerant crops. These 2,140 acres are hereafter referred to as the *western project area* because they are located west of Russell Avenue.

The ongoing avian monitoring that occurred in 2023 included evaluation of:

- bird use of both the eastern and western project areas;
- numbers and nesting outcomes of killdeer (*Charadrius vociferus*); and
- selenium, boron, and mercury content of eggs of killdeer, black-necked stilts (*Himantopus mexicanus*), American avocets (*Recurvirostra americana*), and red-winged blackbirds (*Agelaius phoeniceus*) nesting within the project areas and within a mitigation site.

The collection of reference-area egg samples that began in 2002 for killdeer and in 2003 for black-necked stilts and American avocets (combined) and red-winged blackbirds was discontinued in 2014 because more than 10 years of data were judged quantitatively sufficient to document background-levels of selenium and boron exposure in the project vicinity.

An ornithologist from H. T. Harvey & Associates monitored bird use of the eastern and western project areas on six occasions between April 18 and July 21, 2023. The diversity of avian species detected was relatively low, and the number of individual birds observed within the eastern and western project areas averaged less than 4 birds per 10 acres per visit.

To avoid project-related impacts to shorebirds, measures to discourage shorebirds from foraging and nesting on the project site have been implemented since 2006. The Grassland Basin Authority (now operator of the SJRIP) has hazed shorebirds from the project site. The Panoche Drainage District previously modified open drains to deter shorebirds from using traditional nest sites and installed a mitigation site to provide alternative clean-water nesting habitat. To further prevent nesting on the project site, 8.5 miles of drains have been filled, and 2.4 miles of drains have been narrowed since 2006. Habitat modifications within the eastern project area in 2023, combined with hazing, kept shorebird nesting attempts within the eastern project area to 8 killdeer nest attempts. No shorebird nest attempts were detected within the western project area in 2023.

Eggs for three avian species groups were planned for collection: killdeer, red-winged blackbird, and (combined) black-necked stilt and American avocet. Fifteen killdeer, and 11 red-winged blackbird eggs were collected from the project site. No black-necked stilts or American avocets were detected nesting in 2023. Two black-necked stilt eggs were collected from the project's mitigation site. The package of embryos collected this year were misplaced by the shipper and arrived at the laboratory late and the package was damaged. As a result, one of the killdeer eggs and seven of the red-winged blackbird eggs could not be analyzed. The remaining collected eggs were analyzed for selenium and boron concentrations.

Nearly all analyzed eggs contained at least partially elevated selenium concentrations. The geometric mean egg-selenium concentrations within the project site in 2023 were 6.9 parts per million (ppm) for killdeer, and 8.0 ppm for red-winged blackbirds.

The boron analysis of eggs collected from the project site in 2023 revealed that killdeer eggs had boron concentrations of 3.1 ppm dry weight which is just above the 3-ppm dry weight considered to represent "background" levels. Red-winged blackbird eggs were higher at 7.9 ppm dry weight boron.

No San Joaquin kit fox (*Vulpes macrotis mutica*), nor signs of presence of this species (e.g., tracks, scat, or burrows showing the characteristics of kit fox dens) were observed within the project site during the 23 monitoring days between April 18 and July 21, 2023. A habitat analysis revealed that habitat suitability in the project vicinity for San Joaquin kit fox has remained poor, like that observed previously when scent detection dog surveys did not detect San Joaquin kit fox in 2015 and 2018.

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Section 1.0 Introduction

To reduce the amount of salt and selenium delivered to the San Luis Drain and Mud Slough through the Grassland Bypass Project, the San Luis & Delta-Mendota Water Authority (SLDMWA) Grassland Basin Drainers implemented Phase I of the San Joaquin River Water Quality Improvement Project (SJRIP). The Panoche Drainage District, acting as the lead agency under the California Environmental Quality Act, prepared a negative declaration for the SJRIP in September 2000. The negative declaration included a provision for the development, in collaboration with the U.S. Fish and Wildlife Service (USFWS), of a biological monitoring program that would detect potential project-related impacts on migratory birds resulting from exposure to elevated levels of selenium. This report presents the results of biological monitoring for the 23rd year (2023) of Phase I of the SJRIP. Since approximately 2015, the SJRIP has been used to eliminate discharge of salt and selenium delivered to the San Luis Drain and Mud Slough from the Grassland Bypass Project except for storm related discharges.

In 2001, the USFWS issued the *Final Biological Opinion for the Grasslands Bypass Project, October 1, 2001–December 31, 2009* (BO) (USFWS 2001), which was updated in 2009 to cover the period ending in 2019. This BO stipulated that a monitoring program and contingency plan be designed, in consultation with USFWS, to address potential San Joaquin kit fox (*Vulpes macrotis mutica*) exposure to selenium at the SJRIP site. Consequently, a Tiered Contaminant Monitoring Program to measure selenium levels in constituents of the San Joaquin kit fox food chain was implemented in 2008. In 2015, surveys for San Joaquin kit fox using scent detection dogs were conducted on the project site (H. T. Harvey & Associates 2016). Based on the negative results of the scent detection dog surveys, USFWS and the U.S. Bureau of Reclamation agreed to allow elements of the Tiered Contaminant Monitoring Program to be put on hold as long as the configuration of habitats in the project vicinity, which represented poor suitability for kit fox in 2015, remain similar and San Joaquin kit fox are not detected on or near the SJRIP site.

1.1 Project Description and Setting

The project site is located west of the city of Firebaugh, within Fresno County, California (Figure 1). The irregularly shaped 6,672-acre site is bordered on the north by the Main Canal and on the south by the Delta-Mendota Canal. The eastern edge extends near Fairfax Avenue (Figure 2). The 4,532 acres of the site, situated east of Russell Avenue, is referred to as the *eastern project area*. An additional 2,140 acres, acquired beginning in 2008, are located west of Russell Avenue and referred to as the *western project area* (Figure 2).

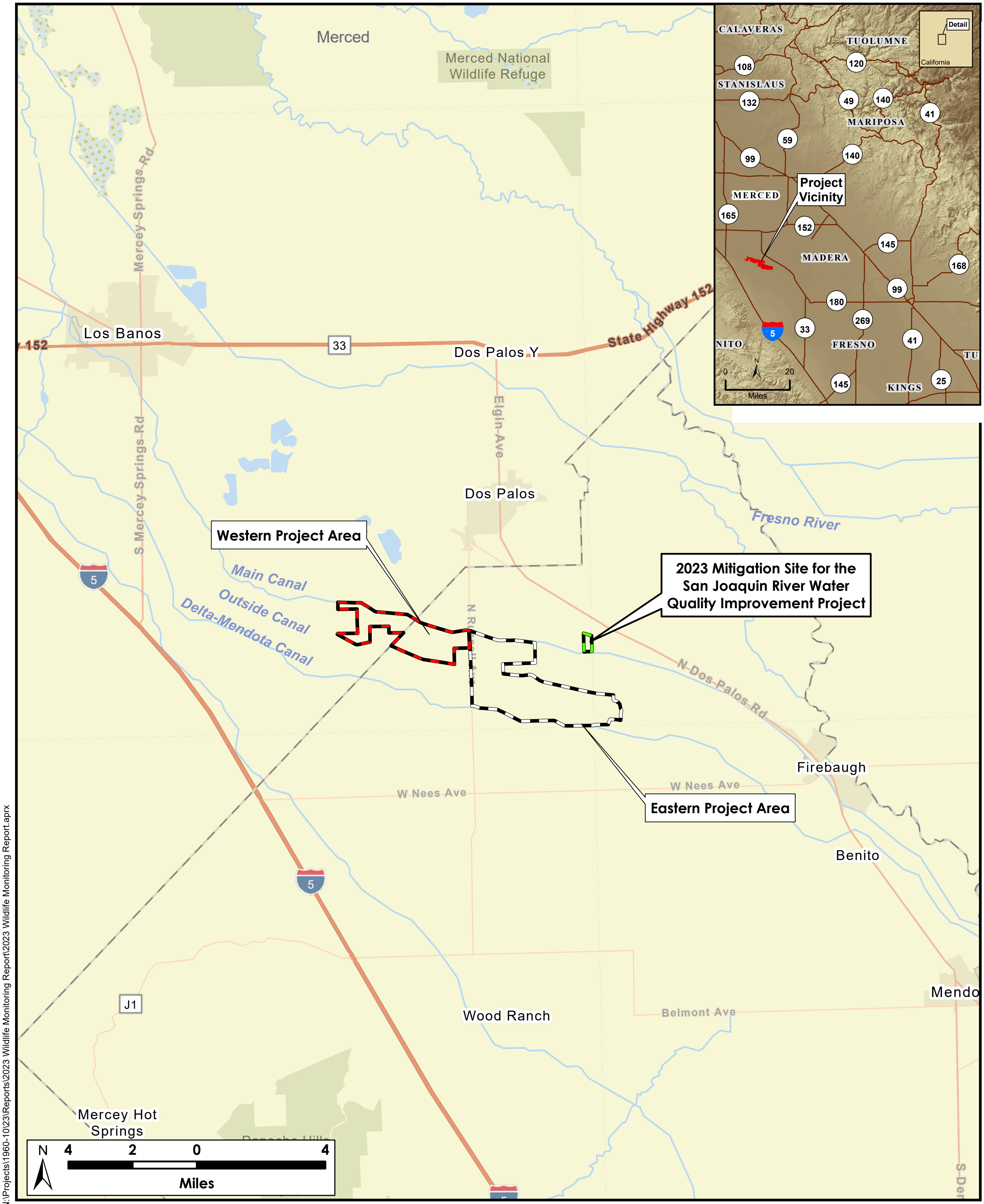

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Figure 1. Vicinity Map of the San Joaquin River Water Quality Improvement Project

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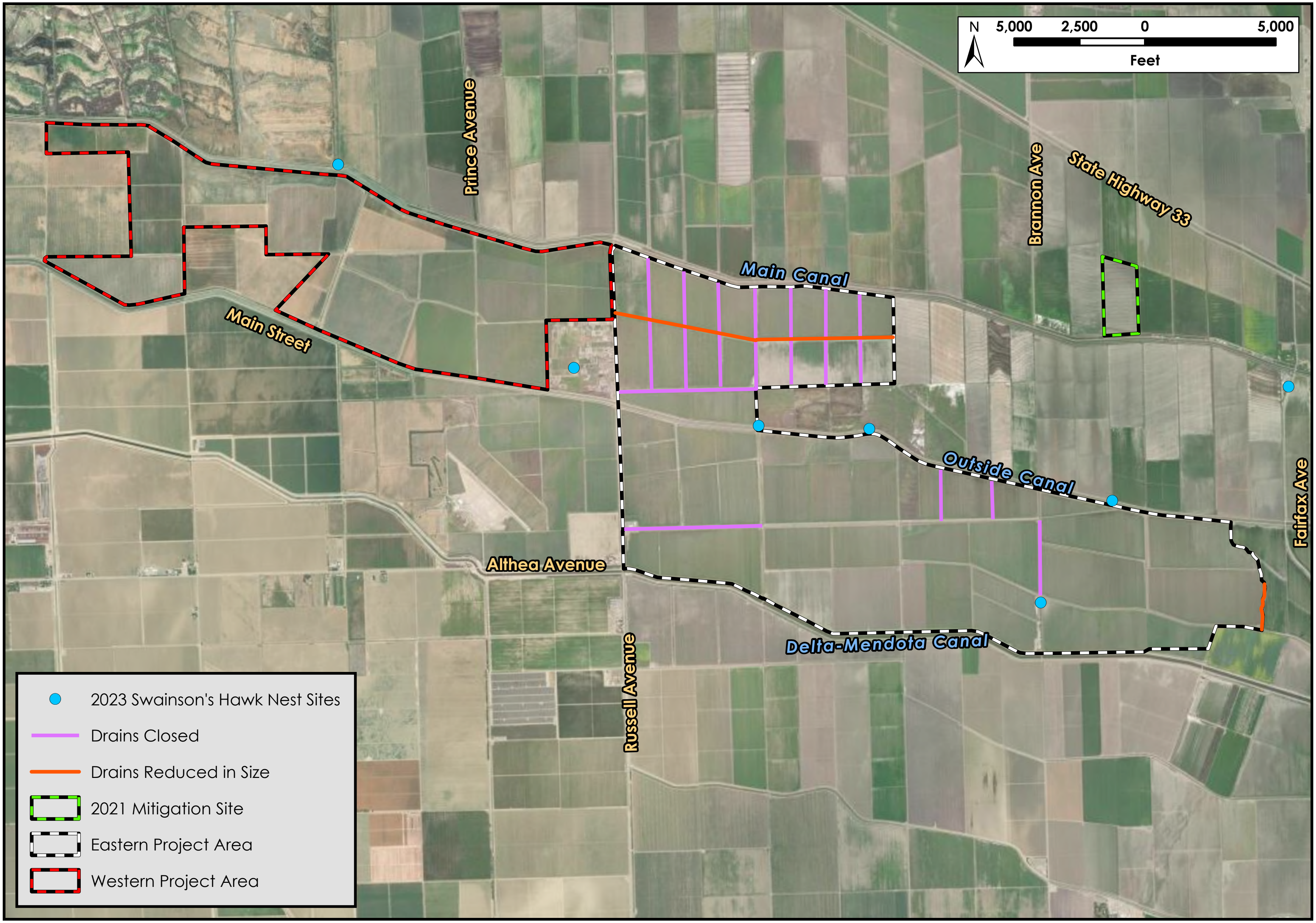

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Figure 2. San Joaquin River Water Quality Improvement Project Site Map

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The SJRIP consists of the initial development of an In-Valley Treatment/Drainage Reuse Facility on land within the Grassland Drainage Area (GDA), which includes irrigated lands within the Panoche Drainage District, Pacheco Water District, Charleston Drainage District, Firebaugh Canal Water District, and Camp 13 Drainage District. These 6,672 acres of GDA land constitute the project site and contain irrigated field crops and related irrigation ditches, drainage ditches, conveyance canals, and farm structures. The topography is nearly level to grade and is flood/furrow irrigated. The highest elevation on the property, 164 feet above mean sea level, is found near the southeastern corner of the property, and the lowest point, 136 feet above mean sea level, occurs in the north-central part of the SJRIP site. Thus, the elevation change on the project site is approximately 28 feet. The shape of the property is influenced by adjacent canals. Russell Avenue provides access to the property via a paved county road. Typical, improved farm roads provide access to the interior of the site. A regulating pond adjacent to the Outside Canal's south levee west of Russell (Figure 2) is now considered part of the project.

The reuse facility dedicates specific lands for the irrigation of salt-tolerant crops with subsurface drainwater to prevent their discharge into the San Joaquin River. Operation of the SJRIP began in 2001. Subsurface drainwater from the GDA has been used to irrigate salt- tolerant crops on land ideally situated on the project site. Channels containing collected drainwater are located adjacent to this location, so water can easily be captured and placed on the land. Also, because this land is at the lowest elevation within the GDA, collected water can be applied without excessive pumping costs.

As of 2023, approximately 6,672 acres had been purchased for the project. Since 2001, approximately 5,341 acres have been planted in crops and irrigated with water that otherwise would have been discharged into the San Joaquin River. Soil and water constituents on the project site are monitored to prevent irreversible soil changes and to protect groundwater from contamination.

1.2 Monitoring History and Mitigation Measures

The negative declaration prepared for the SJRIP included provisions for wildlife monitoring that would assess project-related impacts on wildlife. It stated that mitigation measures could be applied if the monitoring program detected negative impacts.

The SJRIP biological monitoring program began in 2001, the first year in which drainwater was applied to the project site, and it consisted of collecting killdeer (*Charadrius vociferus*) eggs on the site for selenium and boron analysis. Since then, the monitoring program has evolved in response to monitoring results and to comply with monitoring requirements in the BO. The collection of black-necked stilt (*Himantopus mexicanus*) and American avocet (*Recurvirostra americana*) eggs from the project site, the collection of reference sample killdeer eggs for selenium and boron analysis, and six censuses of bird use of the project site during nesting season were added in 2002. The red-winged blackbird (*Agelaius phoeniceus*) was added to the species groups for egg-selenium and boron analysis in 2003. The sample size of eggs collected from the three species groups: 1) killdeer, 2) black-necked stilts and American avocets (hereafter, stilts, and avocets), and 3) red-winged blackbirds for selenium and boron analysis was increased to 20 eggs from each group for both project site and reference samples in

2003. In 2004, the sample size of eggs collected from each species group was adjusted based on power analyses of the 2003 egg-selenium results. The resulting sample sizes—15 for killdeer, 17 for stilts and avocets, and 11 for red-winged blackbirds—were applied to both project-site and reference samples. A mitigation site was added to the project in 2006, and additional monitoring included collection of stilt and avocet eggs from the mitigation site for selenium and boron analysis. Monitoring of nest success for both killdeer and stilts and avocets at the project site and for stilts and avocets at the mitigation site was also added in 2006.

In 2009, USFWS requested that mercury be added to the list of metals being analyzed in bird eggs. Panoche Drainage District requested dropping mercury analysis after including it in 2009. The USFWS agreed (Winkel pers. comm. 2010) to reduce mercury analysis to every third year if the results of 3 years of egg-mercury analysis indicated that toxicity levels were low. Mercury was analyzed through 2012. Because toxicity levels remained low during that period, mercury was not analyzed in 2013. It was analyzed in 2014, 2017, 2020 and again this year.

The collection of reference eggs from the project vicinity on lands similar in character to the eastern project area began in 2002 for killdeer and in 2003 for stilts and avocets, and red-winged blackbirds. These eggs were collected to provide reference data on regional selenium and boron concentrations outside of the site. The SLDMWA requested cessation of reference area sampling before the 2014 nesting season, based on the adequacy of more than 10 years of data to document the three avian species groups' exposure to selenium and boron within the project area. The USFWS approved the request (Winkel pers. comm. 2014).

Waterbirds breeding on the project site potentially experience sublethal and lethal effects associated with substantially elevated selenium levels documented in drainwater and in eggs. Selenium levels have decreased significantly over time. From 2013 to 2023 water samples from the sources of drainwater used to irrigate the existing SJRIP reuse site averaged 41 parts per billion (ppb) selenium (range from 18 to 78 ppb selenium) (Panoche Drainage District data). Thus, some of the levels are above the level of waterborne selenium (32 ppb) associated with a high probability of reduced hatchability and increased probability of embryonic defects, or teratogenesis (CH2M HILL et al. 1993). Consistent with water-test results, elevated egg-selenium levels have been found in killdeer, stilts and avocets, and red-winged blackbird eggs from the project site. Egg-selenium levels in all three avian groups have been higher within the project area than in similar sets of reference eggs collected from the project vicinity. From 2003 through 2011, annual geometric mean egg-selenium levels from stilt and avocet eggs in the project area varied from 8.7 to 68 parts per million (ppm) (dry weight). Approximately 24% of the black-necked stilt eggs sampled during this 8-year period had selenium levels between 40 and 60 ppm (dry weight), a level of selenium concentrations described in Janz et al. (2010) as being associated with observable selenium-induced deformities in stilt embryos.

Beginning in 2006, three mitigation measures were implemented to reduce impacts on nesting waterbirds. First, the bottoms of open drains consistently used by shorebirds were dredged to eliminate potential feeding and nesting substrates and thereby deter avian use. Second, Panoche Drainage District personnel discharged cracker shells to discourage shorebird use where shorebird nesting had been concentrated in the past. These hazers patrolled the project site throughout the day to discourage birds from establishing nests. The third measure, implemented in 2006, consisted of enhancing habitat for nesting shorebirds outside the project site at a mitigation location with clean (nonseleniferous) water.

These measures were continued and enhanced in 2007. Several drains were filled within the northern portion of the eastern project area (Sections 2 and 3), where killdeer and stilt and avocet nesting had been concentrated in previous years and drains that could not be filled were covered with netting to prevent avian use. Drain closure and netting measures were expanded into the southern portion of the eastern project area in 2008. To date, a total of 8.5 miles of drains have been closed, and 2.4 miles of drains have been narrowed through re-contouring (Figure 2). The use of netting was discontinued in 2011 because of the difficulty of maintaining netting in a bird-safe manner.

Mitigation habitat for nesting shorebirds was again provided within a cultivated rice field 0.5 miles east of Brannon Avenue just north of the Main Canal (Figures 2 and 3). This rice field was improved by the addition of 20 small nesting islands approximately 3 feet around in four rows of five islands near the center of the field. Shorebird nests were monitored in approximately 11 acres around the small islands.

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Figure 3. San Joaquin River Water Quality Improvement Project Mitigation Site Map

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Section 2.0 Materials and Methods

2.1 Bird Censuses

An ornithologist from H. T. Harvey & Associates monitored bird use at the project site on six occasions between April 18 and June 20, 2023. The ornithologist conducted censuses on these occasions to determine species composition and relative abundance of bird species within the eastern and western project areas during the breeding season. Censuses were completed by driving perimeter roads of each agricultural field within the project area and stopping at frequent intervals to observe birds. Birds were identified and counted using 10x binoculars and a 20–60x spotting scope mounted on a tripod.

2.2 Egg Collection and Processing

Scientific collecting permits were obtained from the California Department of Fish and Wildlife and USFWS for the collection of bird eggs. In 2023, 15 killdeer eggs, and 11 red-winged blackbird eggs were collected from the combined eastern and western project areas for selenium, boron, and mercury analysis. Single eggs were randomly collected from separate, full-clutch nests (those with at least four eggs). Two black-necked stilt eggs were collected from the 2023 mitigation site.

Because the western project area is now almost completely (approximately 82%) planted with salt-tolerant crops irrigated with drainwater, egg-contaminant data have been combined for the eastern and western project areas. The locations of killdeer and red-winged blackbird eggs collected from the project areas are illustrated in Figures 4 and 5, respectively.

Collected eggs were labeled with a permanent marker, and all the egg contents, including membranes, were removed from the shell, and transferred to 1-ounce Dynalon® jars. Each embryo was examined for morphological abnormalities, and the stage of incubation was established using photographs of known-age embryos. The embryo was also examined to determine whether it was alive or dead, and it was photographed. The egg contents were then frozen for storage. Eight of the embryos collected this year were damaged during shipping. The package was misplaced by the shipper and arrived late and severely damaged at the lab. One of the killdeer embryos and seven of the red-winged blackbird embryos had leaked out of the Dynalon jars contaminating the samples. These samples were therefore not analyzed for selenium or boron content. The remaining samples were intact enough to be analyzed.

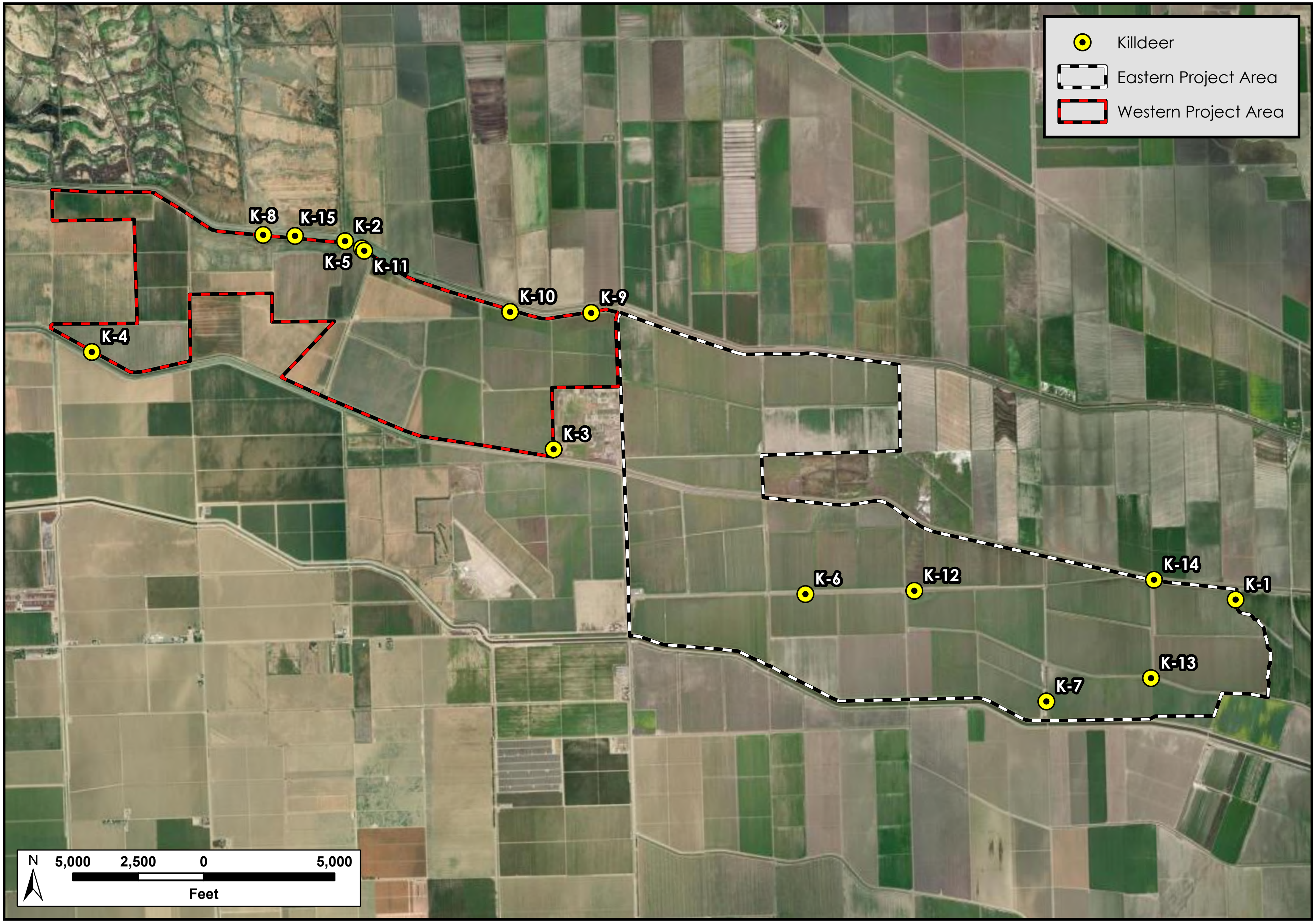

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Figure 4. Location of Killdeer Eggs Collected from the Project Site in 2023

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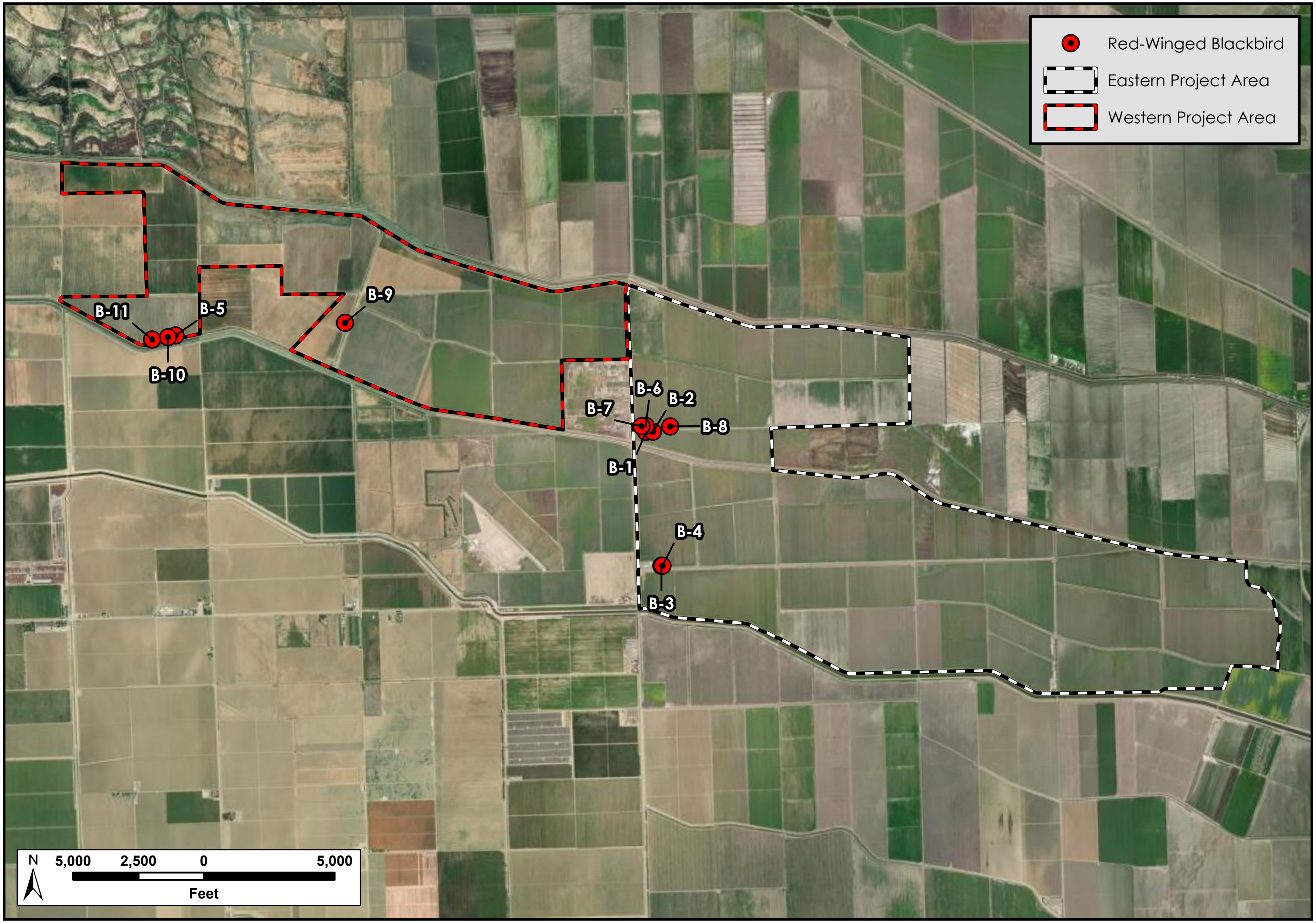

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Figure 5. Location of Red-Winged Blackbird Eggs Collected from the Project Site in 2023

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2.2.1 Egg Chemistry Analysis

All egg contents collected by H. T. Harvey & Associates were shipped overnight on dry ice to South Dakota Agricultural Laboratories, a private enterprise headed by Dr. Regina Wixon.

At the laboratory, selenium concentrations were determined using the Association of Official Analytical Chemists Method 996.16. Boron levels were quantitated using a nitric acid/peroxide digest in a microwave oven and an inductively coupled plasma optical emission spectrometer. All egg-selenium and egg-boron concentrations were presented in ppm based on dry tissue weight (dry weight). Whole mercury concentrations were determined using Cold Vapor Atomic Fluorescence Spectroscopy. Egg-mercury results were analyzed based on wet-weight values in parts per million (ppm) because wet weight is the format in which most published toxicity thresholds for eggs are presented. Egg-mercury results are also presented in parts per billion (ppb) dry weight. For quality control, selected subsamples were divided into two aliquots. The duplicate was spiked with known amounts of selenium and boron, and the samples were tested to determine the accuracy of the analysis.

2.2.2 Analyses of 2023 Data

We used generalized least squares regression in a time series analysis to evaluate egg-selenium and egg-boron concentrations over time for killdeer based on data from 2002 through 2023, for red-winged blackbirds based on data from 2003 through 2023, and for recurvirostrids based on data from 2003 through 2021. The time scope of recurvirostrid analyses were limited to 2003-2021 because no results for this group were obtained in 2022 or 2023. To homogenize variance as much as possible, each measurement of egg-selenium and egg-boron concentration was log-transformed ($\log_{10}[x+1]$, where x is the concentration), producing a "log-concentration". To conduct a time-series analysis, we calculated the mean of the log-concentration for every species for each site per year. We evaluated temporal autocorrelation using autocorrelation and partial autocorrelation plots, checking for significant problematic autocorrelation of values between years, which must be considered in time-series analysis when present. We found no evidence of autocorrelation or partial autocorrelation. Thus, for each species-metal (i.e., boron and selenium) combination, we tested for change over time using a regression of log-concentration on year, with year as a continuous variable. The presence or absence of a significant correlation between log-concentration and time was evaluated using a t-test on the regression coefficient for time. All statistical analyses were conducted in R version 4.2.1 (R Core Team 2025).

2.3 Nest Fate

In addition to conducting egg-selenium monitoring, the ornithologist monitored killdeer and stilt and avocet nests within the project site and mitigation site to determine nest fate. Red-winged blackbird nests were not monitored after egg collection because revisiting their nests multiple times can negatively affect fledging success. Active nests were located on the project site by conducting vehicle surveys for adult killdeer (there were no active stilt and avocet nests on the project site in 2023. After they were located, adults were monitored with a spotting scope or binoculars until a nest location could be determined. Nest locations were marked using a handheld Global Positioning System unit. Nest location, stratum, date, number of eggs present, nest status, nest/clutch fate, and, if appropriate, nest agent (cause of nest failure) were recorded for each nest encountered.

The nests were monitored to completion. A completed nest was one that was empty (chicks presumed to have hatched or eggs presumed to have been eaten by a predator), abandoned, destroyed, or one in which chicks were present. Monitoring at the mitigation sites was conducted by scoping the sites from exterior roads and mapping locations where birds were observed incubating. Nests were visually inspected only when they were observed to have finished, to reduce the amount of human disturbance that may attract predators to the nests.

2.4 Mitigation Site Water Quality

Water samples were collected from the inlet, center, and outlet of the mitigation site on June 23, 2023. The samples were sent to the South Dakota Agricultural Laboratories to be analyzed for total dissolved solids and selenium content. The request to have the water analyzed for boron content was inadvertently omitted from the request to the laboratory when the samples were submitted.

2.5 Tiered Contaminant Monitoring Program

2.5.1 Habitat Suitability for San Joaquin Kit Fox

H. T. Harvey & Associates' GIS staff used crop-maps to assess the change in distribution of suitable habitat for San Joaquin kit fox in the study area between 2015 and 2023. The boundaries of the area analyzed were the Delta Mendota Canal on the south, Fairfax Avenue on the east, the Spillway and Hamburg Intake Canals on the west, and the San Luis Drain (and its alignment) on the north. The project site was originally mapped based upon the annual crop report and the remainder of the study area was mapped using Google Earth aerial images dated July 15, 2015. Beginning in 2018, GIS Collector was used to map the study area. Mapped habitats were assigned suitability values (Table 1) as described in Cypher et al. (2013).

The Union Tool from the Analysis Toolbox in ArcGIS (ESRI 2017) was used to create a composite map for the years being compared, in this case the baseline years of 2015 and 2023. This enabled topology errors to be removed and the two years to be compared without overestimating changes that could have been the result of slightly different geometries. The attributes of each unique land-cover polygon were exported to excel and analyzed to determine if there was a biologically meaningful change in the habitat suitability value across years. To further illustrate the change between years, the Dissolve Tool from the Data Management Toolbox in ArcGIS was used to summarize acreage of land-use type in each year.

Table 1. San Joaquin Kit Fox Habitat Suitability Values from Cypher et al. 2013

Habitat	Habitat Suitability Value
Emergent Wetlands	20
Farmstead	5
Field Crops	10
Grain/Pasture	30
Idled Farmland	50
Lowland Scrub	50
Orchard	20
Rice	5
Urban Commercial	40
Water	0

Section 3.0 Results

3.1 Bird Censuses

Fifty-one avian species were observed within the eastern project area between April 15 and June 21, 2023 (Table 2). Avian numbers were highest on June 7 when large flocks of post-nesting tree swallows (*Tachycineta bicolor*) perched on project fences near the Delta-Mendota and Outside canals (Table 2) and the numbers of red-winged blackbirds were augmented by the recently fledged young-of-the-year. Nineteen species were either observed nesting, or were suspected of nesting, based on observations of courtship behavior or young. Eleven of the species observed—spotted sandpiper (*Actitis macularius*), whimbrel (*Numenius phaeopus*), least sandpiper (*Calidris minutilla*), western wood-peewee (*Contopus sordidulus*), willow flycatcher (*Empidonax trailii*), American pipit (*Anthus rubescens*), savannah sparrow (*Passerculus sandwichensis*), yellow warbler (*Setophaga petechia*), Wilson's warbler (*Cardellina pusilla*), western tanager (*Piranga ludoviciana*), and black-headed grosbeak (*Pheucticus melanocephalus*) —were present only as spring migrants.

Table 2. Avian Census Results from the Eastern Project Area in 2023

	2023					
Species	**April 18**	**May 2**	**May 14**	**May 20**	**June 7**	**June 20**
Cinnamon Teal	2	6		2		
* Gadwall		2	4	13	10	
* Mallard	8	12	10	7	4	5
* Eurasian Collared Dove	7	6	10	7	5	7
* Mourning Dove	14	23	14	12	17	8
Lesser Nighthawk		1	2			
Anna's Hummingbird	1		1		1	
Black-Necked Stilt	2	2	3			
American Avocet	5	3				
* Killdeer	19	23	25	28	21	22
Spotted Sandpiper	1	2	3			
Whimbrel	56	37				
Long-Billed Curlew					74	58
Least Sandpiper	27	51	18			
Greater Yellowlegs	6	11	5			2
Great Blue Heron	3	4	2		2	
Great Egret	4	6	3	2	1	1
Snowy Egret	8	11	5	4	3	5
Black-crowned Night Heron	7	8	6	7	3	4

	2023					
Species	**April 18**	**May 2**	**May 14**	**May 20**	**June 7**	**June 20**
White-faced Ibis	31	40	9		11	
Northern Harrier	2	2	2	1	1	1
* Swainson's Hawk	10	9	8	51	23	31
Red-tailed Hawk	4	4	2	2	3	4
Barn Owl	1	1		1	1	
* Great-horned Owl	2	3	2		1	
* American Kestrel	2	2	6	4	6	4
Western Wood-pewee		1	1	1		
Willow Flycatcher				1		
* Western Kingbird	17	20	18	22	27	26
* Loggerhead Shrike	4	2	4	5	4	2
Common Raven	16	11	9	32	63	51
* Horned Lark	5	8	7	5	5	2
Tree Swallow	16				133	210
Northern Rough-winged Swallow	8	10	9	7	8	6
* Barn Swallow	14	16	17	19	26	22
Cliff Swallow	41	38	44	52	33	29
* House Sparrow	14	15	22	17	18	16
American Pipit	15	5				
* House Finch	40	45	52	41	55	44
Savannah Sparrow	33	17	6			
Song Sparrow	5	5	6	3	2	1
* Western Meadowlark	7	8	15	9	7	6
Bullock's Oriole	3	4	4	2		1
* Red-winged Blackbird	610	636	650	715	690	480
* Brown-headed Cowbird	20	17	15	12	9	6
* Brewer's Blackbird	6	5	7	9	5	4
* Common Yellowthroat	8	12	7	4	2	2
Yellow Warbler		2	2	1		
Wilson's Warbler		1	2	2		
Western Tanager		3	2	1		
Black-headed grosbeak		1	2	0		
Total	**1104**	**1151**	**1041**	**1101**	**1274**	**1060**
Observed density (birds per acre)[1]	**0.270**	**0.281**	**0.254**	**0.269**	**0.311**	**0.259**

* Species for which evidence of nesting was observed in 2023.
[1] The eastern project area encompasses 4,095 acres.

The avian-species composition observed within the western project area was like that reported for the eastern project area, with a few notable exceptions (Table 3). For instance, the spring migrants observed within the eastern project area apart from whimbrels, least sandpipers, American pipits, and savannah sparrows were absent from the western project area.

Table 3. Avian Census Results from the Western Project Area in 2023

	2023					
Species	**April 18**	**May 2**	**May 14**	**May 20**	**June 7**	**June 20**
* Gadwall	6	5		4		
* Mallard	4	5	2	2	3	1
Eurasian collared dove	3	4	2	1	5	3
* Mourning Dove	10	9	11	10	8	7
American Coot	2		3	1		
Black-Necked Stilt	5	3				2
* Killdeer	17	18	22	24	26	21
Whimbrel	24	20				
Long-billed Curlew					63	48
Least Sandpiper	16	10	23			
Greater Yellowlegs	3	1	1			
Great Blue Heron	1	1	2	2	2	1
Great Egret	5	6	3	1	2	1
Snowy Egret	3	2	3	7	1	2
White-faced Ibis	17	21	19	4	8	15
Northern Harrier	2	1	1	1	2	
* Swainson's Hawk	7	6	8	11	26	32
* Red-tailed Hawk	3	1	2	3	3	5
American Kestrel	2	1	1		2	
* Western Kingbird	13	12	14	16	18	20
* Loggerhead Shrike	5	7	6	5	4	6
* Common Raven	7	14	21	26	47	43
* Horned Lark	7	4	5	4	6	4
Tree Swallow					63	41
Northern Rough-winged Swallow	4	5	4	6	2	3
* Barn Swallow	6	5	4	4	7	5

Species	2023					
	April 18	May 2	May 14	May 20	June 7	June 20
Cliff Swallow	32	8	7	5		6
Marsh Wren	2	1		1		
* Northern Mockingbird	4	7	5	5	4	3
House Finch	16	22	7	9	6	4
Savannah Sparrow	7	10	12			
* Song Sparrow	6	7	7	5	2	
* Common Yellowthroat	4	8	6	4	3	1
* Red-winged Blackbird	410	385	326	309	316	278
* Western Meadowlark	5	8	6	5	2	3
* Brewer's Blackbird	8	7	10	5		
* Brown-headed Cowbird	11	16	10	3	6	4
Blue Grosbeak				1	1	
Total	**677**	**640**	**553**	**484**	**638**	**559**
Observed density (birds per acre)[1]	**0.364**	**0.344**	**0.297**	**0.260**	**0.343**	**0.300**

* Species for which evidence of nesting was observed in 2023.

[1] The western project area encompasses 1,861 acres.

3.2 Egg Collection and Processing

Twenty-six eggs (15 killdeer eggs and 11 red-winged blackbird eggs) were collected from the project site. Five killdeer eggs contained live, normal embryos 10 days old or older. The 10 remaining killdeer embryos were too young (fewer than 9 days old) for their condition to be assessed, although five were old enough (3 days old or older) to determine that they were alive at the time of collection (Table 4). All eleven red-winged blackbird embryos were too young (fewer than 7 days old) for their condition to be assessed, although five of those embryos were old enough (2 days old or older) to determine that they were alive at the time of collection (Table 5).

Table 4. Selenium Concentrations in Killdeer Eggs from the Project Site in 2023

ID Number	Field Number[1]	Date	Embryo[2] Condition	Embryo[2] Status	Embryo Age (days)	Selenium (ppm, dry wt)[3]	Log Base 10	Anti-Log
01	P-K-01	April 28	U	U	1	21.88		
02	P-K-02	May 12	L	U	6	6.81		
03	P-K-03	May 22	L	U	6	10.15		
04	P-K-04	May 22	U	U	1	11.07		
05	P-K-05	May 22	L	N	10	5.32		
06	P-K-06	May 26	L	N	15	10.30		
07	P-K-07	May 30	U	U	1	33.49		
08	P-K-08	June 9	L	U	7-8	3.91		
09	P-K-09	June 14	U	U	1	11.28		
10	P-K-10	June 14	L	U	3	4.50		
11	P-K-11	July 7	L	N	18	3.58		
12	P-K-12	July 20	U	U	2	4.28		
13	P-K-13	July 20	L	N	12	4.05		
14	P-K-14	July 20	U	U	1	3.20		
15	P-K-15	July 20	L	N	20+	3.11		
Arithmetic/***geometric mean***						9.1	0.8384	***6.9***
Standard deviation						8.4	0.3145	***2.1***
Standard error							0.1407	***1.4***
Lower limit of 95% confidence interval							0.5627	***3.7***
Upper limit of 95% confidence interval							1.1141	***13.0***

[1] See Appendix F; [2] L = live; N = normal; U = unknown; [3] ppm, dry wt = parts per million dry weight.

Table 5. Selenium Concentrations in Red-Winged Blackbird Eggs from the Project Site in 2023

ID Number	Date	Embryo[1] Condition	Embryo[1] Status	Embryo Age (days)	Selenium (ppm, dry wt)[2]	Log Base 10	Anti-Log
01	April 21	L	U	3	4.77	0.6785	
02	April 21	L	U	4	5.82	0.7649	
03	April 28	U	U	1	7.64	0.8831	
04	April 28	L	U	6	7.94	0.8998	
05	May 12	L	U	2	3.12	0.4942	
06	May 16	U	U	1	11.53	1.0618	
07	May 16	L	U	3	9.15	0.9614	
08	May 16	U	U	1	10.86	1.0358	
09	May 19	U	U	1	12.49	1.0966	
10	May 19	U	U	1	10.11	1.0048	
11	May 19	U	U	1	10.91	1.0378	
Arithmetic/***geometric mean***					8.6	0.9017	***8.0***
Standard deviation					3.0	0.1869	***1.5***
Standard error						0.0836	***1.2***
Lower limit of 95% confidence interval						0.7379	***5.5***
Upper limit of 95% confidence interval						1.0655	***11.6***

[1] L = live; N = normal; U = unknown; [2] ppm, dry wt = parts per million dry weight.

Five black-necked stilt eggs were collected from the mitigation site. Two black-necked stilt eggs contained live, normal embryos 13 days old or older. The remaining three black-necked stilt embryos were too young (fewer than 9 days old) for their embryo status to be determined, though they were old enough to determine that they were alive at the time of collection (Table 6).

Table 6. Selenium Concentrations in Recurvirostrid Eggs from the Mitigation Site in 2023

ID Number	Date	Embryo[1]		Embryo Age (days)	Selenium (ppm, dry wt)[2]	Log Base 10	Anti-Log
		Condition	Status				
Black-necked Stilt							
01	June 20	L	U	17	3.67	0.5647	
02	June 20	L	N	6	7.35	0.8663	
Arithmetic/***geometric mean***					5.5	0.7155	***5.2***
Standard deviation					2.6	0.2133	***1.6***
Standard error						0.0954	***1.2***
Lower limit of 95% confidence interval						0.5285	***3.4***
Upper limit of 95% confidence interval						0.9024	***8.0***

[1] L = live; N = normal; U = unknown; [2] ppm, dry wt = parts per million dry weight.

3.3 Egg-Selenium and Egg-Boron Analysis

3.3.1 Trends in Egg-Selenium and Egg-Boron Concentrations

In 2023, both species groups sampled for which results were obtained (killdeer and red-winged blackbirds) had egg-selenium and egg-boron levels that were elevated above background levels, typically considered 3 ppm (dry wt.). The geometric mean egg-selenium levels for killdeer collected from the project site was 6.9 ppm (dry wt., Table 4) and the geometric mean egg-boron concentration was 3.1 ppm (dry wt., Appendix A). The geometric mean egg-selenium level for red-winged blackbirds collected from the project site was 8.0 ppm (dry wt., Table 5) and the geometric mean egg-boron concentration was 7.9 ppm (dry wt., Appendix B).

None of the species groups showed a significant increase in mean egg-boron or mean egg-selenium concentration over time (all $p > 0.12$; Figures 7, 8). The results of regression models of log-concentration versus year for each contaminant in each species group are depicted in Table 7. None of the correlation coefficients are significantly different than zero (i.e., the correlation coefficients for each chemical within each species group are all greater than 0.05), indicating a lack of evidence for long-term directional change in contaminant concentrations.

Table 7. Results of Regression Models of Selenium and Boron Content Versus Year for Eggs of Killdeer (2002 through 2023), Red-winged Blackbirds (2003 through 2023), and Recurvirostrids (2003-2021) at the San Joaquin River Water Quality Improvement Project Site

Avian Species Group	Element	Correlation coefficient	*t*	df	p
Killdeer	Selenium	0.0010	0.198	20	0.8453
Recurvirostrids	Selenium	-0.0198	-1.671	11	0.1229
Red-winged blackbirds	Selenium	0.0012	0.267	18	0.7927
Killdeer	Boron	0.0039	0.812	20	0.4264
Recurvirostrids	Boron	0.0073	1.143	11	0.2775
Red-winged blackbirds	Boron	0.0040	0.75	18	0.463

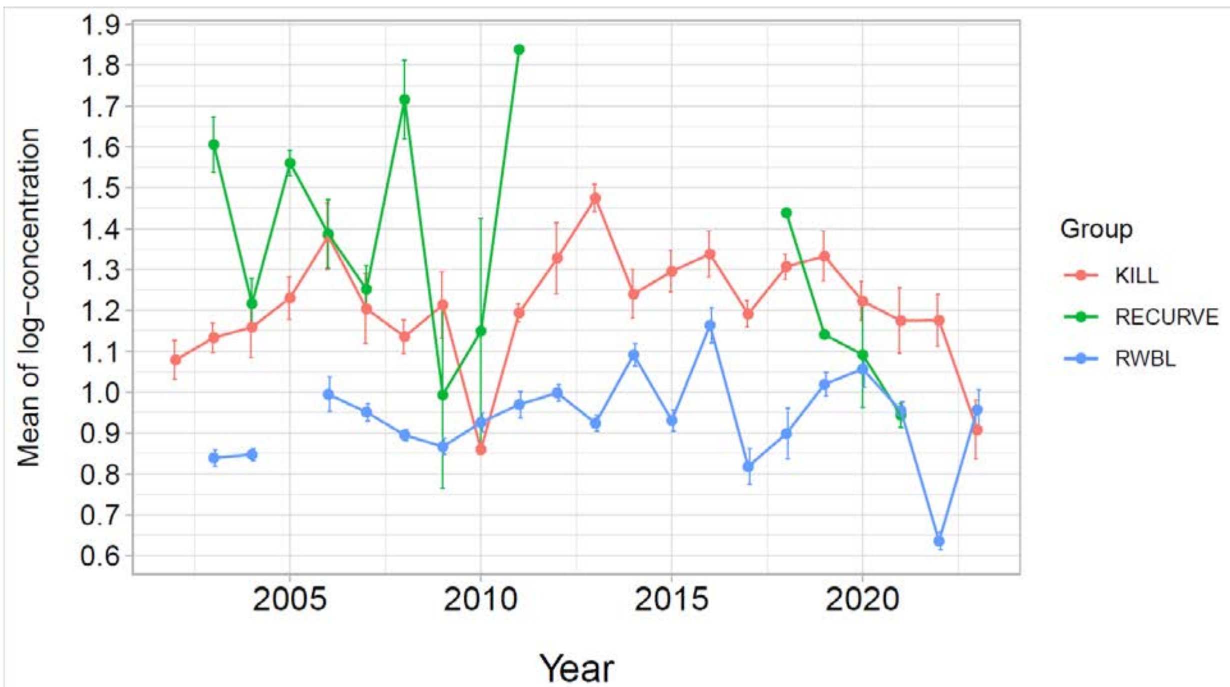

Figure 6. Mean Egg-selenium Concentrations for Killdeer, Red-winged Blackbirds, and Recurvirostrids at the San Joaquin River Water Quality Improvement Project Site (2002 through 2021). Concentrations are shown in log-concentration, calculated as log10(x+1). Error bars represent ± 1 standard error. Group abbreviations: KILL (Killdeer), RECURVE (recurvirostrids), RWBL (red-winged blackbirds).

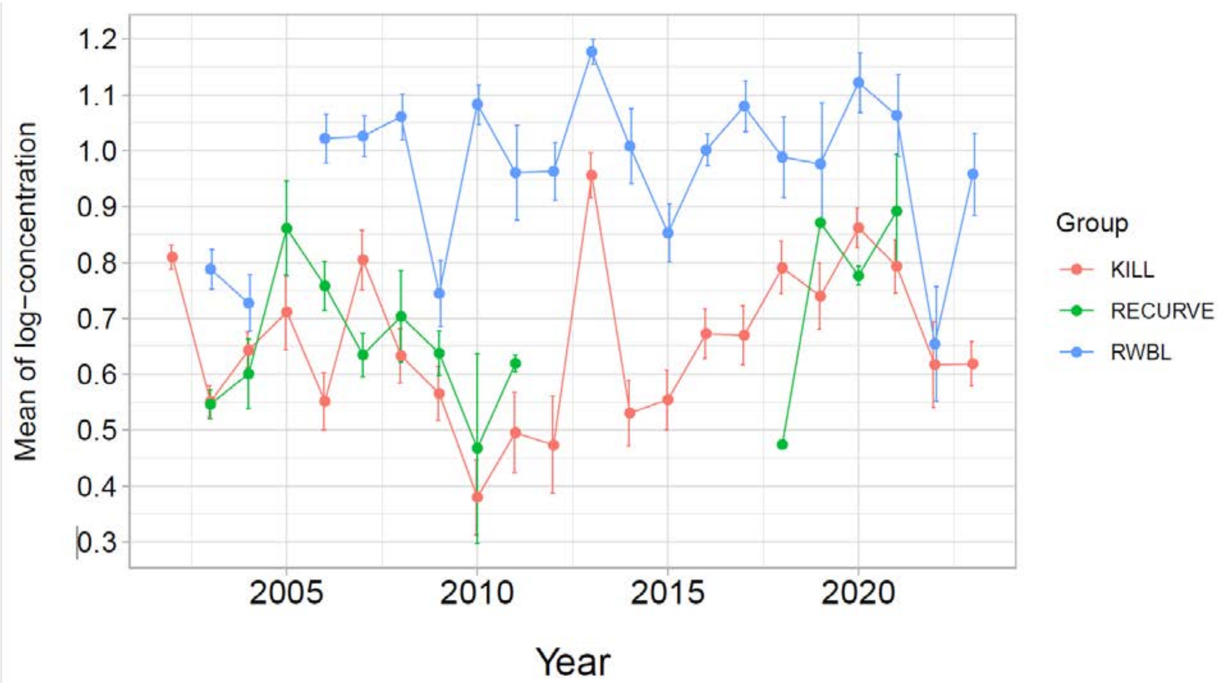

Figure 7. Mean Egg-boron Concentrations for Killdeer, Red-winged Blackbirds, and Recurvirostrids at the San Joaquin River Water Quality Improvement Project Site (2002–2023). Concentrations are shown in log-concentration, calculated as log10(x+1). Error bars represent ± 1 standard error. Group abbreviations: KILL (Killdeer), RECURVE (recurvirostrids), RWBL (red-winged blackbirds).

3.4 Egg-Mercury Analysis

The eggs collected from the project site in 2023 had similar mean mercury concentrations to eggs collected at the mitigation site. Project site killdeer had mean egg-mercury concentrations of 0.13 ppm (all mercury values are reported as wet weight) (Appendix D). The red-winged blackbird mean wet weight egg-mercury concentration was 0.0.66 ppm (Appendix E). The recurvirostrid eggs collected at the mitigation site had a mean mercury concentration of 0.22 ppm (wet wt.) (Appendix F).

3.5 Control Eggs

The selenium recovery rate for five egg samples spiked with 80 ng selenium were between 87% and 103% with a mean selenium recovery rate of 98%. The boron recover rate for (Appendix G). The instruments used for selenium analysis were calibrated periodically throughout the process. A value of 0.395 µg/g selenium was obtained from a trail using an in-house selenate Standard (value = 0.400 µg/g). The standard deviation of selenium results from 21 duplicate egg samples were between 0.0071 and 0.9051, with a mean standard deviation of 0.1455 (Appendix H).

The boron-recovery rate for an egg sample spiked with100 ng boron was 91% (Appendix G). The standard deviation of boron results from one duplicate control egg sample was 0.7071 (Appendix I).

The mercury recovery rate for five egg samples spiked with 100 ng mercury ranged between 88% and 107% with a mean mercury recovery rate of 94.8% (Appendix G). The standard deviation of mercury results from 11 duplicate egg samples ranged between 1.782 and 45.9619, with a mean standard deviation of 14.6123 (Appendix I).

3.6 Nest Fate

Seventeen of the 21 killdeer nests located on the project site in 2023 were followed to completion (Table 8; Appendix F). Five of the killdeer nests monitored within the project site hatched, six were lost to predators, and another six were destroyed by road and levee maintenance. Four of the nests were discovered on the last day of monitoring so the outcomes of those nests remained unknown (Table 8; Appendix J).

The 2023 mitigation site was first flooded with water in the third week of May, and black-necked stilts and American avocets were observed courting there soon after. On May 30, a black-necked stilt was observed sitting on a levee between the cells with islands in incubation posture, though a coyote was seen walking the levees nearby that day. (Table 8; Appendix J). Fewer stilts and avocets were observed at the mitigation site after that day. Four black necked stilt nests were located at the mitigation site in 2023. The two nests located on the small island appeared to hatch successfully though the two nests located on the nearby levees were both depredated (Table 8, Appendix J).

Table 8. Nest Fates and Agents That Caused Nest/Clutch Failure on the Project Site and on the Mitigation Sites in 2023

	Hatched		Depredated		Vehicle/Farm Activities		Unknown		
Species	**Nest**	**Percent**	**Nest**	**Percent**	**Nest**	**Percent**	**Nest**	**Percent**	**Total**
Project Site									
Killdeer	5	24	6	28.5	6	28.5	4	19	21
2023 Mitigation Site									
Black-necked stilt	2	50	2	50					4

3.7 Mitigation Site Water Quality

The results of the water-quality analysis for the 2023 mitigation site are summarized in Table 9. Selenium concentrations in the water samples from the inlet and the outlet of the 2023 mitigation site were slightly above the 2.3-ppb selenium thresholds for wildlife safety in fresh water (Eisler 1990, Skorupa and Ohlendorf 1991, Suter 1996) while the sample from the middle of the mitigation site was below that threshold.

Table 9. Water Quality in Samples Taken from the 2023 Mitigation Site on June 30, 2023

	Electrical Conductivity (µhmo/cm)	Boron (ppm)	Selenium (ppb)
Freshwater thresholds[1]		5	2.3
Location			
Inlet	174	0.324	3.63
Middle	816	1.44	1.40
Outlet	1790	3.13	2.34

Notes: µhmo/cm = micromhos per centimeter; ppb = parts per billion; ppm = parts per million, J = results fall between the level of detection and the level of quantification.

[1] Sources: Eisler 1990, Skorupa and Ohlendorf 1991, Suter 1996.

J Sample is above the detection limit of 0.1 ppb selenium, but below the limit of 0.4 ppb selenium at which it can confidently be measured.

3.8 Habitat Suitability for San Joaquin Kit Fox in the Project Vicinity

Cypher et al. (2013) used three suitability classes: High (value > 90), Medium (90 >= value > 75), and Low or Unsuitable (value <= 75) to classify habitat suitability for San Joaquin kit fox. All the land use types within, and in the vicinity of the SJRIP currently represent habitats that correspond with the Low or Unsuitable classes (i.e., scores <= 75) (Figure 8).

The habitat suitability analysis encompassed 25,870 acres, which includes the eastern and western areas of the SJRIP and an additional 19,538 acres in the vicinity of the SJRIP (Figure 7). Between 2015 and 2023, the suitability of 14,284 acres (55.2%) remained unchanged, the suitability of 4,660 acres (18.0%) increased, and the suitability of 6,795 acres (26.3%) decreased. The habitat suitability value of all the habitat polygons ranged between zero and fifty in 2015 and 2023. The acreage weighted value kit fox habitat suitability was 30.91 in 2015 and was 25.95 in 2023, which equals a 16% decrease in suitability (Figure 9). In the seven years between 2015 and 2023 the acreage weighted value ranged between 23.44 and 32.56. In summary, the suitability of the analysis area for San Joaquin kit fox has declined since the original assessment in 2015, remaining well within the Low or Unsuitable class (value <= 75) over the last eight years.

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Figure 8. Habitat Suitability for San Joaquin Kit Fox in the Project Vicinity
San Joaquin River Water Quality Improvement Project
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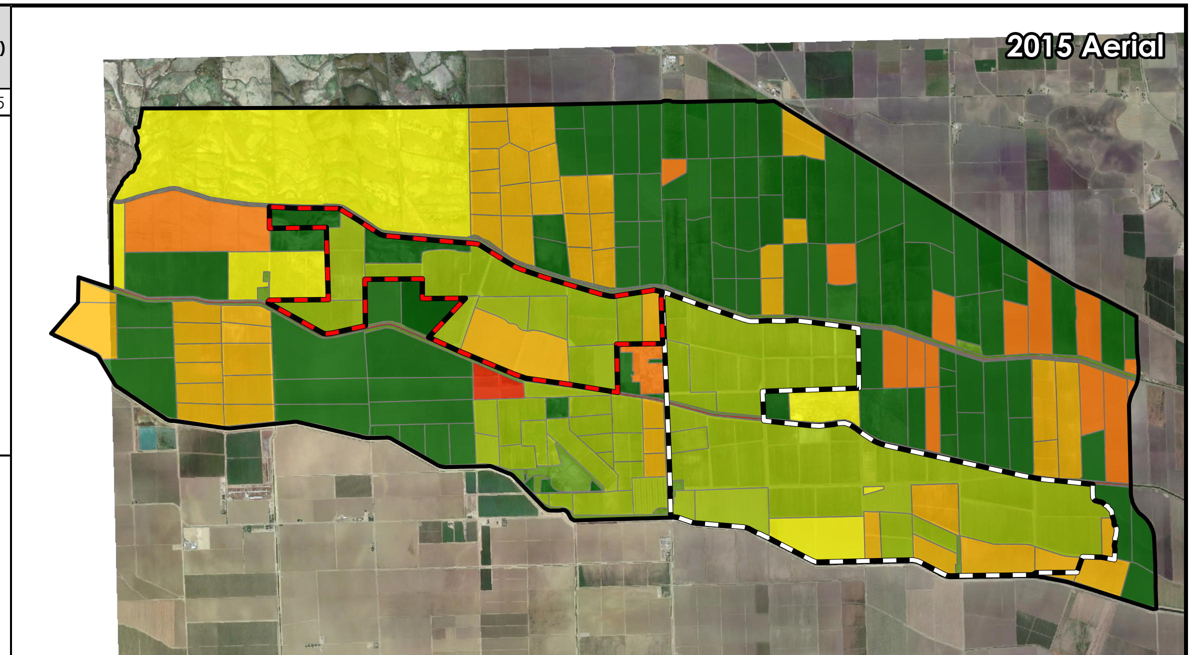
Habitat Suitability Value Change	Habitat Suitability Value Direction	Land Use Type Change (2015-2022)	Acres	Total (ac)
0	Unchanged		14,284.25	14,284.25
5	Positive	Rice to Field Crops	0.00	4,659.76
10		Field Crops to Orchard	225.01	
10		Grain/pasture to Urban Commercial	28.68	
10		Urban Commercial to Idled Farmland	678.95	
15		Rice to Orchard	533.05	
20		Field Crops to Grain/Pasture	1,427.85	
20		Grain/Pasture to Idled Farmland	7.46	
25		Rice to Grain/Pasture	73.48	
30		Orchard to Idled Farmland	8.10	
35		Farmstead to Urban Commercial	125.90	
40		Field Crops to Idled Farmland	1,177.92	
45		Rice to Idled Farmland	280.84	
50		Water to Idled Farmland	92.54	
-5	Negative	Field Crops to Rice	174.64	6,795.15
-10		Idled Farmland to Urban Commercial	2.01	
-10		Lowland Scrub to Urban Commercial	0.00	
-10		Urban Commercial to Grain Pasture	0.00	
-20		Emergent Wetlands to Water	21.52	
-20		Grain/Pasture to Field Crops	84.04	
-20		Idled Farmland to Grain/Pasture	464.14	
-20		Urban Commercial to Orchard	15.18	
-30		Idled Farmland to Orchard	1,221.94	
-30		Lowland Scrub to Emergent Wetland	47.91	
-30		Urban Commercial to Field Crops	0.00	
-35		Urban Commercial to Farmstead	0.00	
-40		Idled Farmland to Field Crops	2,953.35	
-45		Idled Farmland to Farmstead	3.43	
-45		Idled Farmland to Rice	1,806.17	
-50		Idled Farmland to Water	0.84	



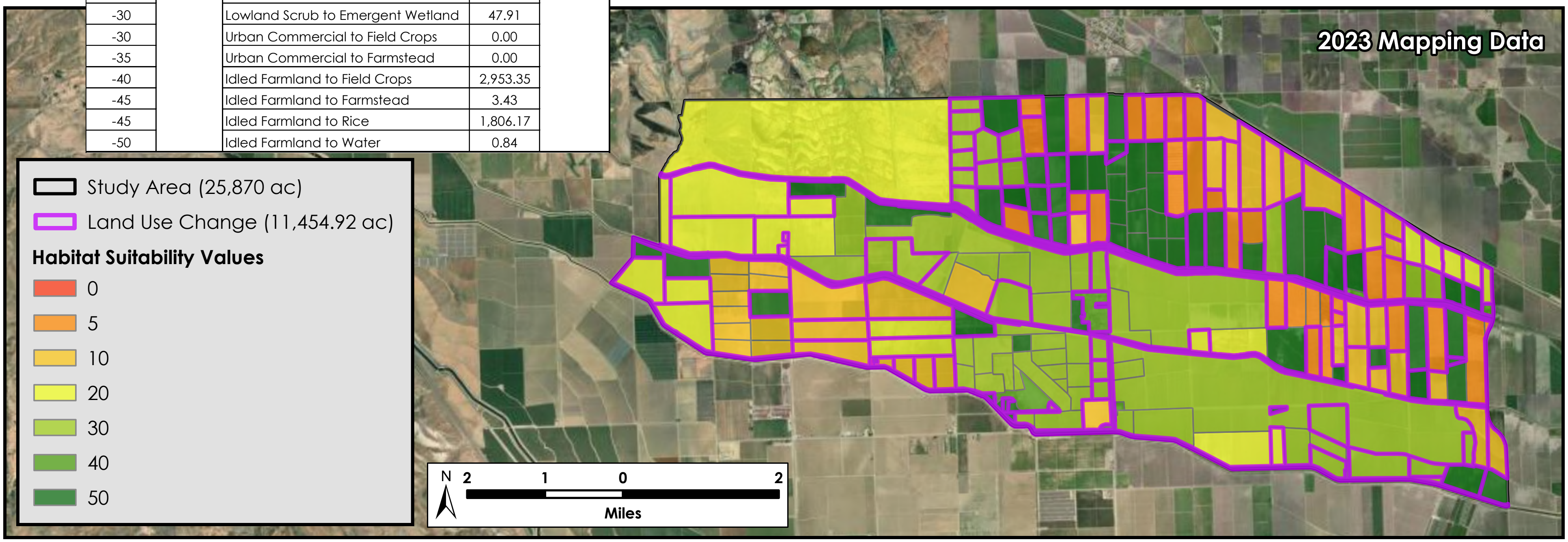


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Figure 9. Habitat Suitability Values Change for San Joaquin Kit Fox in the Project Vicinity

San Joaquin River Water Quality Improvement Project
2023 Wildlife Monitoring Report (1960-24)
December 2025

Section 4.0 Discussion

By 2023, approximately 5,341 acres of the SJRIP site had been planted with salt-tolerant crops and irrigated with agricultural drainwater. To date, 8.5 miles of drains have been filled, and another 2.4 miles of open drains have been narrowed through re-contouring to reduce habitat quality and deter birds from using the SJRIP site. The hazing of birds during the nesting season, diligent water management, and modification of drains to discourage avian use of the project site continued during this reporting period. Hazing and drain management will continue as part of the operation of the project in future years.

The avian census data indicate that the eastern and western project areas are used by bird species common within San Joaquin Valley agricultural habitats. The tall vegetation within some pastures provided nesting habitat for red-winged blackbirds, western meadowlarks (*Sturnella neglecta*), and song sparrows (*Melospiza melodia*) and wet, irrigated pastures provided temporary foraging opportunities for birds such as the long-billed curlew (*Numenius americanus*), white-faced ibis, common raven (*Corvus corax*), red-winged blackbird, and western meadowlark. The number and densities of birds observed in both the eastern and western project areas were similar to previous years. Even though 2023 was a considerable wet rainfall year, fewer crops were planted, leading to a considerable reduction to drainage water available to irrigate the project site.

Loggerhead shrikes (*Lanius ludovicianus*), a species listed by the State of California as a species of special concern, were observed nesting within the project. Shrike nests were observed within the eastern and western project areas. Swainson's hawks, which are listed as threatened by the State of California, also were observed on the project site and seven Swainson's hawk nests were located on and adjacent to the eastern and western project areas. One Swainson's hawk nest continued within the eastern project area in a row of eucalyptus trees adjacent to the equipment yard, and five additional nests were situated on the border of the project site. There were three immediately north of the Outside Canal adjacent to the eastern project area, one in an eucalyptus tree in the residential area west of Russell Avenue between and adjacent to both the eastern and western project areas, one was in a cottonwood tree next to the Main Canal near the western project area and one more was on a utility pole along Fairfax Avenue near the Main Canal (Figure 2). Five of the nine Swainson's hawk nests fledged at least one young. The remaining two nests were abandoned before hatching.

The hazing of waterbirds during the nesting season, diligent water management, and modification of drains to discourage avian use continued to result in preventing recurvirostrid nesting on the project site during this reporting period. The number of recurvirostrid nests within the eastern project area decreased from more than 30 in 2003, to two in each year from 2009 through 2011, zero from 2012 to 2017, one in both 2018 and 2019, two in 2020, three in 2021, and zero in 2022 and 2023.

Avian species are known to have differing sensitivities to selenium exposure, showing differing rates of both teratogenesis and rates of egg hatchability impairment (Ohlendorf 2003). The hatchability of eggs when incubated to full term is thought to be a better benchmark for setting selenium exposure thresholds because it is a more sensitive measure than teratogenesis (Janz et al 2010). Rates of hatchability impairment have been published for several species including black-necked stilts, American Avocets, and red-winged blackbirds, but not for killdeer (Table 10). The rates of hatchability impairment in Table 10 are not directly comparable because the studies referenced used different methodologies and measured different endpoints.

Table 10. Hatchability of Bird eggs in Relation to Se Concentrations in Eggs

Species	Egg Selenium Concentration (ppm dry wt.)	Effect	Notes	References
Black-necked Stilt	6-7	Threshold point for hatchability effects (EC 3)	Field study – Se measured in randomly selected egg from each clutch – hatch success of each clutch compared to that of group with lower range of Se concentrations	USDOI 1998
Black-necked stilt	21-31	Hatchability EC 10	Same data as above but different data analysis approach	Adams et al. 2003
American Avocet	60	Low bound of a concentration range associated with reproductive impairment of 20% of clutches	Field study – measured viability of clutches from which sampled egg Se ranging from 0 to 100 ppm analyzed by grouped by intervals of 20 (0-20, 20-40, etc.)	USDOI 1998
Red-winged Blackbird	22	Threshold for adverse effects	Field study examined hatchability of eggs incubated to full term	Harding 2008

Note: Table adapted from Janz et al. 2010.

Though selenium induced hatchability impairment has not been published for killdeer, some inference can be drawn from other studies. Killdeer sensitivity to selenium, measured by rates of teratogenesis, has been shown to occur between the sensitivities of black-necked stilts and American avocets (Janz et al. 2010). It follows, then, that the rate of hatchability impairment in killdeer would likely occur between that of stilts and avocets. For black-necked stilts, reported rates of hatchability impairment range from a clutch-wise EC 3 (concentration at which at least one egg in 3% of the clutches would not hatch) of between 6 and 7 ppm selenium (USDOI 1998) to an EC10 of between 21- and 31-ppm selenium (Adams et al. 2003, using the same data as USDOI 1998 but analyzed differently). American avocets have been shown to be far less sensitive to selenium than most other bird species. The lower boundary of a concentration range associated with reproductive impairment in 20% of clutches (with 13.5% impairment being the background level) is 60 ppm selenium (USDOI 1998). Groups of avocet clutches with egg-selenium values of between 20 and 40 ppm and 40 and 60 ppm did not differ in hatchability rates from the control group (zero to 20 ppm). The mean egg-selenium content of killdeer (13.9 ppm) eggs collected in 2023 fall between the values reported by USDOI (1998) and Adams et al. (2003) to cause hatchability impairment in black-necked stilts.

One of the most detailed avian selenium response studies looked at red-winged blackbird nesting over three years (2003-2005) in Canadian lakes that have elevated selenium resulting from coal mining (Harding 2008). This study found that egg-selenium uptake in red-winged blackbirds was not linear, with rates of uptake decreasing as environmental selenium increased. The study also found that both red-winged blackbird egg hatchability and nestling survival were not impacted until egg-selenium levels reached 22 ppm. The geometric mean red-winged blackbird project site egg selenium concentration in 2023 of 3.3 (Range 2.93 to 3.91) ppm was well below the threshold of 22 ppm selenium that this study estimated for reproductive impairment for the species.

Boron levels, measured as the geometric mean, in the eggs of killdeer nesting on the site were 3.1-ppm, above the estimated upper end of background levels for boron. As has been the case since monitoring began, red-winged blackbird eggs in 2023 had higher levels of boron (7.9 ppm boron dry wt.) than the shorebird eggs. The likely explanation is that boron, unlike selenium, is readily absorbed by most vascular plants, and red-winged blackbirds consume a higher portion of plant material than do shorebirds.

Conditions related to the potential for San Joaquin kit fox to occur on the project site remained poor, like those observed in 2015 (H. T. Harvey & Associates 2016) and 2018 (H. T. Harvey & Associates 2018) when extensive scent-detection dog surveys detected no San Joaquin kit fox within and in the vicinity of the project. Both the project site and its surrounding area continue to be dominated by intensely manipulated agricultural habitats. The project site is unsuitable for residency by San Joaquin kit fox based on annual field inspections, a conclusion consistent with published habitat classifications (Cypher et al. 2013). Cypher et al. (2013) describe that persistent populations of kit foxes have not been reported to occur in medium-suitability habitat, which represent conditions more favorable than those occurring within the SJRIP.

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Appendix A. 2023 Killdeer Egg-Boron Concentrations at the San Joaquin River Water Quality Improvement Project Site

2023 Killdeer Egg-Boron Concentrations at the San Joaquin River Water Quality Improvement Project Site

ID Number	Boron (ppm, dry wt)[1]	Log Base 10	Anti-Log
01	3.95	0.5966	
02	1.50	0.1761	
03	2.66	0.4249	
04	6.94	0.8414	
05	1.64	0.2148	
06	2.64	0.4216	
07	5.80	0.7634	
08	4.60	0.6628	
09	2.75	0.4393	
10	4.85	0.6857	
11	4.92	0.6920	
12	2.25	0.3522	
13	2.53	0.4031	
14	1.90	0.2788	
15	2.35	0.3711	
Arithmetic/***geometric mean***	3.42	0.4882	***3.1***
Standard deviation	1.7	0.2052	***1.6***
Standard error		0.0918	***1.2***
Lower limit of 95% confidence interval		0.3084	***2.0***
Upper limit of 95% confidence interval		0.6681	***4.7***

[1] ppm, dry wt = parts per million, dry weight.

Appendix B. 2023 Red-Winged Blackbird Egg-Boron Concentrations at the San Joaquin River Water Quality Improvement Project Site

2023 Red-Winged Blackbird Egg-Boron Concentrations at the San Joaquin River Water Quality Improvement Project Site

ID Number	Boron (ppm, dry wt)[1]	Log Base 10	Anti-Log
01	9.20	0.9638	
02	8.80	0.9445	
03	5.31	0.7251	
04	4.81	0.6821	
05	1.70	0.2304	
06	8.43	0.9258	
07	6.86	0.8363	
08	8.30	0.9191	
09	13.30	1.1239	
10	20.14	1.3041	
11	15.87	1.2006	
Arithmetic/***geometric mean***	9.34	0.8960	***7.9***
Standard deviation	5.28	0.2900	***1.9***
Standard error		0.1297	***1.3***
Lower limit of 95% confidence interval		0.6418	***4.4***
Upper limit of 95% confidence interval		1.1502	***14.1***

[1] ppm, dry wt = parts per million, dry weight.

Appendix C. 2023 Stilt and Avocet Egg-Boron Concentrations at the San Joaquin River Water Quality Improvement Project Mitigation Site

2023 Black-necked Stilt Egg-Boron Concentrations at the San Joaquin River Water Quality Improvement Project Mitigation Site

ID Number	Boron (ppm, dry wt)[1]	Log Base 10	Anti-Log
01	4.18	0.6212	
02	3.52	0.5465	
Arithmetic/***geometric mean***	3.9	0.5839	***3.84***
Standard deviation	0.5	0.0528	***1.1***
Standard error		0.0236	***1.1***
Lower limit of 95% confidence interval		0.5376	***3.4***
Upper limit of 95% confidence interval		0.6301	***4.3***

[1] ppm, dry wt = parts per million, dry weight.

Appendix D. 2023 Killdeer Egg-Mercury Concentrations at the San Joaquin River Water Quality Improvement Project Site

2023 Killdeer Egg-Mercury Concentrations at the San Joaquin River Water Quality Improvement Project

64B**ID Number**	**Wet Weight Egg-Mercury Concentrations**			**Dry Weight Egg-Mercury Concentrations**		
	Mercury (ppm, wet wt)[a]	**Log Base 10**	**Anti-Log**	**Mercury (ppb, dry wt)[b]**	**Log Base 10**	**Anti-Log**
01	0.067814	-1.1687		261.73	2.4179	
02	0.2331	-0.6325		831.91	2.9201	
03	0.2985	-0.5251		1087.83	3.0366	
04	1.1725	0.0691		4436.3	3.6470	
05	0.2356	-0.6278		866.81	2.9379	
06	0.0685	-1.1643		230.25	2.3622	
07	0.0608	-1.2161		245.06	2.3893	
08	0.114	-0.9431		466.07	2.6685	
09	0.0977	-1.0101		376.93	2.5763	
10	0.1791	-0.7469		705.12	2.8483	
11	0.0606	-1.2175		249.38	2.3969	
12	0.06113	-1.2137		232.53	2.3665	
13	0.0564	-1.2487		203.83	2.3093	
14	0.093006	-1.0315		357.72	2.5535	
15	0.154435	-0.8113		608.73	2.7844	
Arithmetic/***Geometric Mean***	0.197	-0.8992	***0.13***	744.01	2.6810	***479.69***
Standard deviation	0.281	0.3636	***2.31***	1058.92	0.3608	***2.3***
Standard error		0.1626	***1.45***		0.1614	***1.4***
Lower limit of 95% confidence interval		-1.2179	***0.06***		2.3647	***231.6***
Upper limit of 95% confidence interval		-0.5805	***0.26***		2.9972	***993.6***

Notes: CI = confidence interval; SD = standard deviation; SE = standard error.
[a] ppm, wet wt = parts per million, wet weight.
[b] ppb, dry wt = parts per billion, dry weight.
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Appendix E. 2023 Red-Winged Blackbird Egg-Mercury Concentrations at the San Joaquin River Water Quality Improvement Project Site

2023 Red-Winged Blackbird Egg-Mercury Concentrations at the San Joaquin River Water Quality Improvement Project

	Wet Weight Egg-Mercury Concentrations			Dry Weight Egg-Mercury Concentrations		
ID Number	**Mercury (ppm, wet wt)[a]**	**Log Base 10**	**Anti-Log**	**Mercury (ppb, dry wt)[b]**	**Log Base 10**	**Anti-Log**
01	0.042235	-1.3743		245.25	2.3896	
02	0.033993	-1.4686		216.85	2.3362	
03	0.060678	-1.2170		382.85	2.5830	
04	0.013176	-1.8802		91.04	1.9592	
05	0.12082	-0.9179		738.01	2.8681	
06	0.125053	-0.9029		679.71	2.8323	
07	0.080968	-1.0917		435.45	2.6389	
08	0.052235	-1.2820		286.91	2.4577	
09	0.120337	-0.9196		744.25	2.8717	
10	0.140419	-0.8526		916.75	2.7901	
11	0.084807	-1.0716		614.10	2.7882	
Arithmetic/***Geometric***	0.080	-1.1799	***0.066***	486.470	2.6079	***405.45***
Standard deviation	0.043	0.3104	***2.0***	266.253	0.3020	***2.0***
Standard error		0.1388	***1.4***		0.1351	***1.4***
Lower limit of 95% confidence interval		-1.4519	***0.0***		2.3432	***220.4***
Upper limit of 95% confidence interval		-0.9078	***0.1***		2.8727	***745.9***

Notes: CI = confidence interval; SD = standard deviation; SE = standard error.
[a] ppm, wet wt = parts per million, wet weight.
[b] ppb, dry wt = parts per billion, dry weight.

Appendix F. 2023 Recurvirostrid Egg-Mercury Concentrations at the San Joaquin River Water Quality Improvement Project Mitigation Site

2017 Recurvirostrid Egg-Mercury Concentrations at the San Joaquin River Water Quality Improvement Project Mitigation Site

	Wet Weight Egg-Mercury Concentrations			Dry Weight Egg-Mercury Concentrations		
ID Number	Mercury (ppm, wet wt)[a]	Log Base 10	Anti-Log	Mercury (ppb, dry wt)[b]	Log Base 10	Anti-Log
01	0.249911	-0.6022		1010.56	3.0046	
02	0.192852	-0.7148		761.06	2.8814	
Arithmetic/***Geometric Mean***	0	-0.6585	***0.22***	885.8	2.9430	***877***
Standard deviation	0	0.0796	***1.2***	176.4	0.0871	***1.2***
Standard error		0.0356	***1.1***		0.0389	***1.1***
Lower limit of 95% confidence interval		-0.7283	***0.2***		2.8667	***735.6***
Upper limit of 95% confidence interval		-0.5887	***0.3***		3.0193	***1045.5***

Notes: CI = confidence interval; SD = standard deviation; SE = standard error.
[a] ppm, wet wt = parts per million, wet weight.
[b] ppb, dry wt = parts per billion, dry weight.

Appendix G. 2023 Control Eggs Selenium, Boron, and Mercury Spike Results

2023 Control Eggs Spike Results

ID Number	Tissue	Spiked selenate (ng)[1]	Percent Recovery
23S006879	egg	80	87
23S006882	egg	80	103
23S006885	egg	80	96
23S006899	egg	80	102
23S006922	egg	80	102
		Mean	**98.0**
		Standard deviation	**6.7**
		Spiked mercury (ng)	
23S006876	egg	100	88
23S006877	egg	100	103
23S006880	egg	100	86
23S006890	egg	100	107
23S006903	egg	100	90
		Mean	**94.8**
		Standard deviation	**9.5**

[1] ng = nanogram.

Appendix H. 2023 Control Eggs Selenium Duplicate Results

2023 Control Eggs Selenium Duplicate Results

ID Number	Replication	Selenium (ppm, dry wt)[1]	ID Number	Replication	Selenium (ppm, dry wt)[1]
23S006876	1	22.22	23S006886	1	3.63
	2	21.55		2	3.53
SD		***0.4721***	***SD***		***0.0710***
23S006877	1	6.83	23S006887	1	4.26
	2	6.78		2	4.29
SD		***0.0404***	***SD***		***0.0215***
23S006878	1	10.39	23S006888	1	4.03
	2	9.90		2	4.08
SD		***0.3479***	***SD***		***0.0383***
23S006879	1	10.93	23S006889	1	3.20
	2	11.22		2	3.20
SD		***0.2033***	***SD***		***0.0057***
23S006880	1	5.38	23S006890	1	3.08
	2	5.25		2	3.14
SD		***0.0911***	***SD***		***0.0376***
23S006881	1	10.20	23S006891	1	4.26
	2	10.41		2	5.29
SD		***0.1450***	***SD***		***0.7301***
23S006882	1	33.43	23S006892	1	5.81
	2	33.05		2	5.84
	3	33.50	***SD***		***0.0271***
	4	33.97	23S006893	1	7.60
SD		***0.3806***		2	7.67
23S006883	1	3.37	***SD***		***0.0491***
	2	4.45	23S006894	1	7.87
SD		***0.7649***		2	8.01
23S006884	1	11.72	***SD***		***0.0977***
	2	12.03	23S006895	1	3.22
SD		***0.2155***		2	3.02
23S006885	1	4.48	***SD***		***0.1434***
	2	4.52	23S006896	1	11.43
SD		***0.0278***		2	11.63
			SD		***0.1384***

ID Number	Replication	Selenium (ppm, dry wt)[1]	ID Number	Replication	Selenium (ppm, dry wt)[1]
23S006897	1	9.24	23S006908	1	6.39
	2	9.06		2	6.50
SD		***0.1246***	***SD***		***0.0789***
23S006898	1	10.90	23S006909	1	2.55
	2	10.83		2	2.61
SD		***0.0505***	***SD***		***0.0429***
23S006899	1	12.44	23S006910	1	2.64
	2	12.54		2	2.70
SD		***0.0700***	***SD***		***0.0432***
23S006900	1	10.03	23S006911	1	2.493
	2	10.18		2	2.494
SD		***0.1108***	***SD***		***0.0012***
23S006901	1	10.87	23S006912	1	2.75
	2	10.96		2	2.76
SD		***0.0614***	***SD***		***0.0030***
23S006902	1	3.69	23S00693	1	1.14
	2	3.65		2	1.15
SD		***0.0297***	***SD***		***0.0038***
23S006903	1	7.42	23S006914	1	8.70
	2	7.27		2	8.49
SD		***0.1088***	***SD***		***0.1482***
23S006904	1	9.13	23S006915	1	6.10
	2	9.00		2	6.17
SD		***0.0926***	***SD***		***0.0488***
23S006905	1	12.36	23S006916	1	5.93
	2	12.47		2	6.20
SD		***0.0748***	***SD***		***0.1911***
23S006906	1	4.79	23S006917	1	8.23
	2	4.53		2	8.27
SD		***0.1795***	***SD***		***0.0241***
23S006907	1	8.34	23S006918	1	4.80
	2	8.40		2	4.91
SD		***0.0417***	***SD***		***0.0773***

ID Number	Replication	Selenium (ppm, dry wt)[1]	ID Number	Replication	Selenium (ppm, dry wt)[1]
23S006919	1	4.91	23S006921	1	5.62
	2	4.40		2	4.06
SD		***0.3657***	***SD***		***1.1017***
23S006920	1	3.53	23S006922	1	5.20
	2	3.51		2	5.24
SD		***0.0149***		3	5.23
			SD		***0.0204***
			23S006923	1	3.87
				2	5.12
			SD		***0.8892***
Mean SD:	**0.1677**				
Low SD:	**0.0012**				
High SD:	**1.1017**				

Note: SD = standard deviation.

[1] ppm, dry wt = parts per million, dry weight.

Appendix I. 2023 Control Eggs Boron and Mercury Duplicate Results

2023 Control Eggs Boron Duplicate Results

ID Number	Replication	Boron (ppm, dry wt)[1]	ID Number	Replication	Boron (ppm, dry wt)[1]
23S006883	1	5.10			
	2	4.10			
SD		***0.7071***			

Note: SD = standard deviation.

[1] ppm, dry wt = parts per million, dry weight.

2023 Control Eggs Mercury Duplicate Results

ID Number	Replication	Selenium (ppm, dry wt)[1]	ID Number	Replication	Selenium (ppm, dry wt)[1]
23S006876	1	69.04	23S006885	1	172.50
	2	66.59		2	185.70
SD		***1.7282***	***SD***		***9.3338***
23S006877	1	237.40	23S006887	1	64.30
	2	241.40		2	56.90
	3	220.50		3	62.20
SD		***11.0937***	***SD***		***3.8136***
23S006878	1	311.70	23S006889	1	95.10
	2	285.30		2	90.91
SD		***18.6676***	***SD***		***2.9649***
23S006879	1	1205.00	23S006890	1	156.86
	2	1140.00		2	152.02
SD		***45.9619***	***SD***		***3.4224***
23S006880	1	254.30	23S006903	1	176.81
	2	216.90		2	208.90
SD		***26.4458***	***SD***		***22.6911***
Mean SD:	**0.1677**				
Low SD:	**0.0012**				
High SD:	**1.1017**				

Appendix J. 2023 Black-necked Stilt, American Avocet, and Killdeer Nest Monitoring Results for the Project Area and Mitigation Site

2023 Killdeer Nest Monitoring Results for the San Joaquin River Improvement Project Site

Field Number	Strata	Date	No. of Eggs	Date	No. of Eggs	Date	No. of Eggs	Date	No. of Eggs	Field Notes	Nest Fate
Killdeer											
17-1	Field edge	4/28	4							P-K-01 collected 4/28	Depredated
32-1	Canal levee	5/12	4	5/19	3	5/30	0			P-K-02 collected 5/12	Hatched/Presumed hatched
4-7	Field edge	5/12	3	5/16	0					5/22 P-K-04 collected	Hatched/Presumed hatched
1-1	Field edge	5/16	1	5/22	4	6/6	3	6/14	0	5/22 P-K-04 collected	Hatched/Presumed hatched
14-1	Field edge	5/22	4	5/26	4	6/2	3	6/9	0	5/26 P-K-06 collected	Hatched/Presumed hatched
4-7	Field edge	5/22	4	6/2	3	6-6	0			5/22 P-K-03 collected	Depredated
32-1	Canal levee	5/22	4	5/30	3	6/6	0			5/22 P-K-05 collected	Depredated
13-6	Equipment yard	5/26	3	5/30	4	6/6	0			5/22 P-K-07 collected	Depredated
4-1	Field edge	6/9	2	6/14	4	6/30				6/14 P-K-09 collected	Depredated
31-1	Canal levee	6/9	1	6/14	0					Lost to levee maintenance	Depredated
31-1	Canal levee	6/9	4	6/14	0					6/9 P-K-08 collected	Lost to levee maintenance
32-1	Canal levee	6/9	0	6/30	3	7/7	3	7/13	0	6/9 pair at cup, 7/7 P-K-11 collected	Hatched/Presumed hatched
4-4	Field edge	6/14	4	6/20	3	6/30	0			6/14 P-K-10 collected	Lost to road maintenance
32-1	Canal levee	7/13	3	7/21	0						Lost to levee maintenance

Field Number	Strata	Date	No. of Eggs	Date	No. of Eggs	Date	No. of Eggs	Date	No. of Eggs	Field Notes	Nest Fate
32-1	Canal levee	7/13	3	7/21	0						Lost to levee maintenance
13-1	Field edge	7/13	3	7/21	4					7/21 P-K-12 collected	Unknown
12-3	Canal levee	7/13	3	7/21	0						Lost to levee maintenance
18-3	Drain edge	7/13	2	7/21	4					7/21 P-K-13 collected	Unknown
10/1	Field edge	7/13	3	7/21	0						Lost to road maintenance
17-1	Canal levee	7/21	4							7/21 P-K-14 collected	Unknown
31-1	Canal levee	7/21	4							7/21 P-K-15 collected	Unknown
17-1	Field edge	4/28	4							P-K-01 collected 4/28	Depredated

2023 Killdeer, Stilt, and Avocet Nest Survey Results for the Mitigation Site

Nest ID	Cell	Strata	Date	No. of Eggs[1]	Date	No. of Eggs	Date	No. of Eggs	Date	No. of Eggs	Field Notes	Nest Fate
Black-Necked Stilt												
001	Row 3/4	Levee	5/30	S	6/9	S	6/20	V			Nest disturbed	Depredated
002	Row 2, Island 1	Small Island	6/2	S	6/9	S	6/20	4	6/30	0	P-M-01 collected 6-20	Hatched/Presumed hatched
003	Row 3/4	Levee	6/16	S	6/20	0					Nest disturbed	Depredated
004	Row 4, Island 5	Small Island	6/16	S	6/20	4	6/30	S	7/7	S	P-M-02 collected 6-20, 7/13 Vacant	Hatched/Presumed hatched