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San Joaquin River
Water Quality Improvement Project
Phase 1
2022 Wildlife Monitoring Report

Project #1960-23

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Executive Summary

Monitoring in 2022 represented the 22nd 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 2022 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 15 and June 21, 2022. 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 3 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 2022, 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 2022.

Eggs for three avian species groups were planned for collection: killdeer, red-winged blackbird, and (combined) black-necked stilt and American avocet. Eight killdeer, and 11 red-winged blackbird eggs were collected from the project site. No black-necked stilts or American avocets were detected nesting in 2022. Five 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 2022 were 13.9 parts per million (ppm) for killdeer, and 3.3 ppm for red-winged blackbirds.

The boron analysis of eggs collected from the project site in 2022 revealed that killdeer eggs had boron concentrations right at the 3-ppm dry weight considered to represent "background" levels. Red-winged blackbird eggs were slightly higher at 3.4 ppm dry weight boron.

No San Joaquin kit fox (*Vulpes macrotis mutica*), nor signs of the 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 12 and July 22, 2022. 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 21st year (2022) 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 nearly to 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).

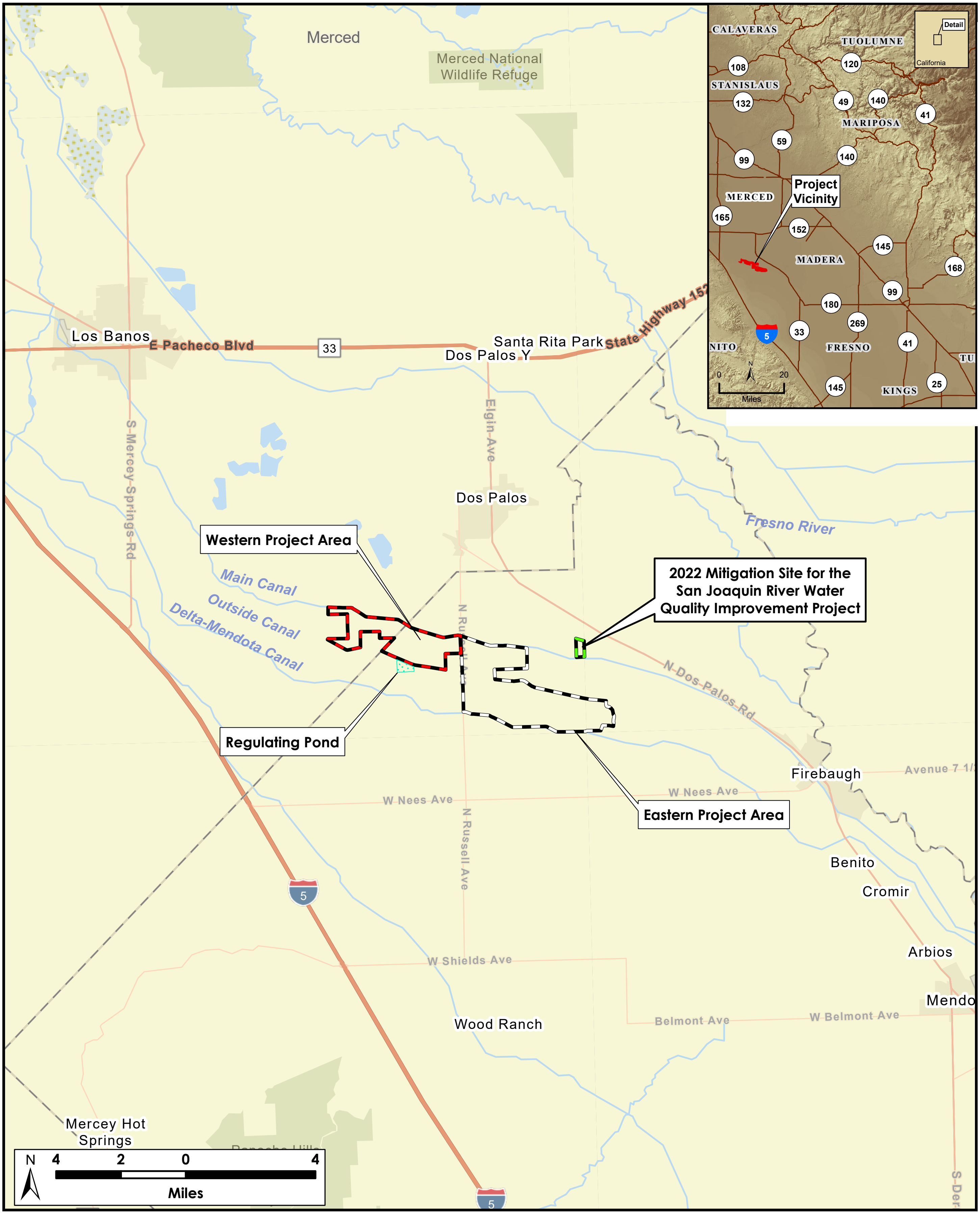

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Figure 1. Vicinity Map of the San Joaquin River Water Quality Improvement Project

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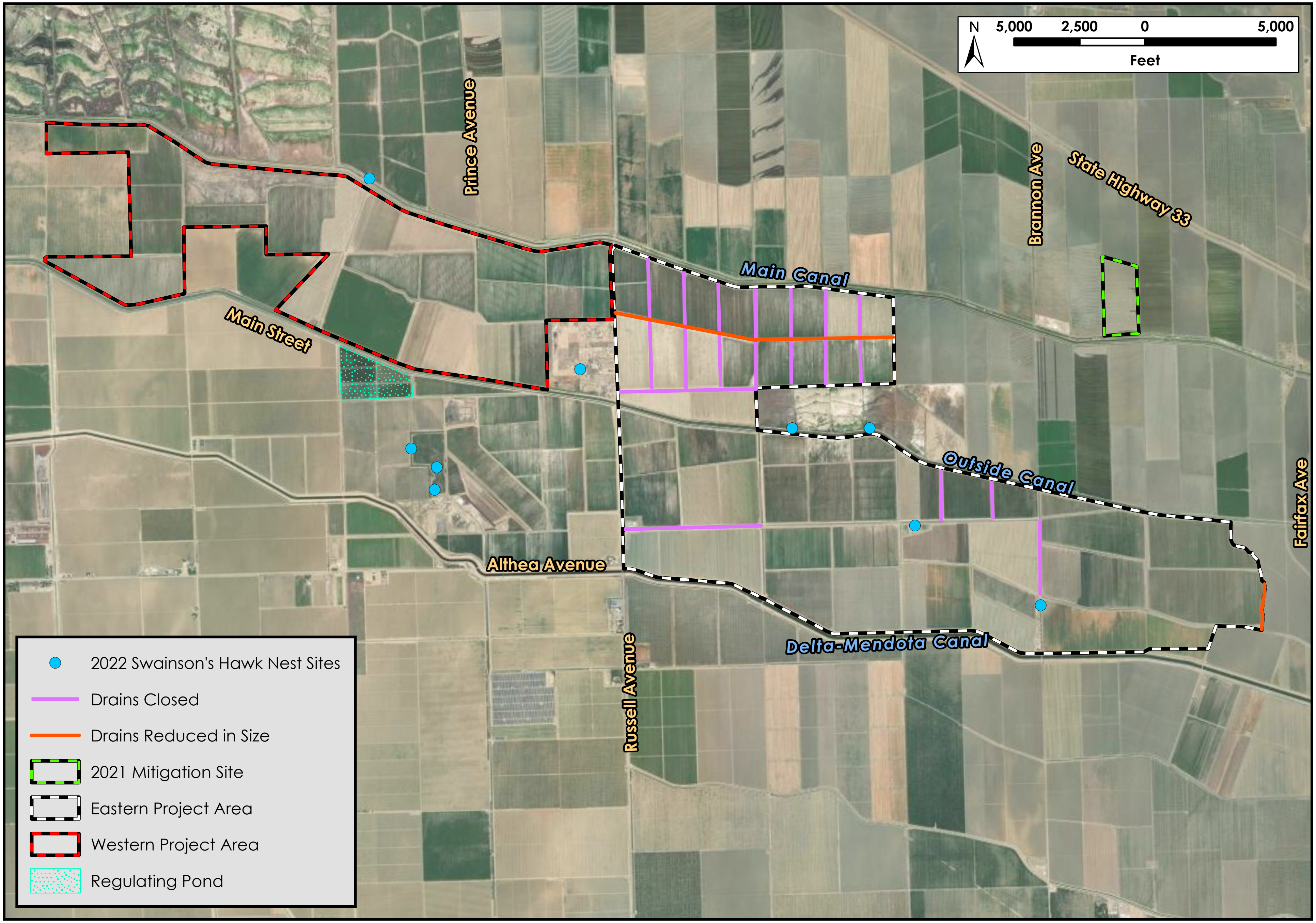

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Figure 2. San Joaquin River Water Quality Improvement Project Site Map

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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 2022, 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, and 2020.

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 2022 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 15 and June 21, 2022. 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 2022, 7 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). Five black-necked stilt eggs were collected from the 2022 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. No eggs were collected from the portion of the western project area that is not irrigated with drainwater. 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.

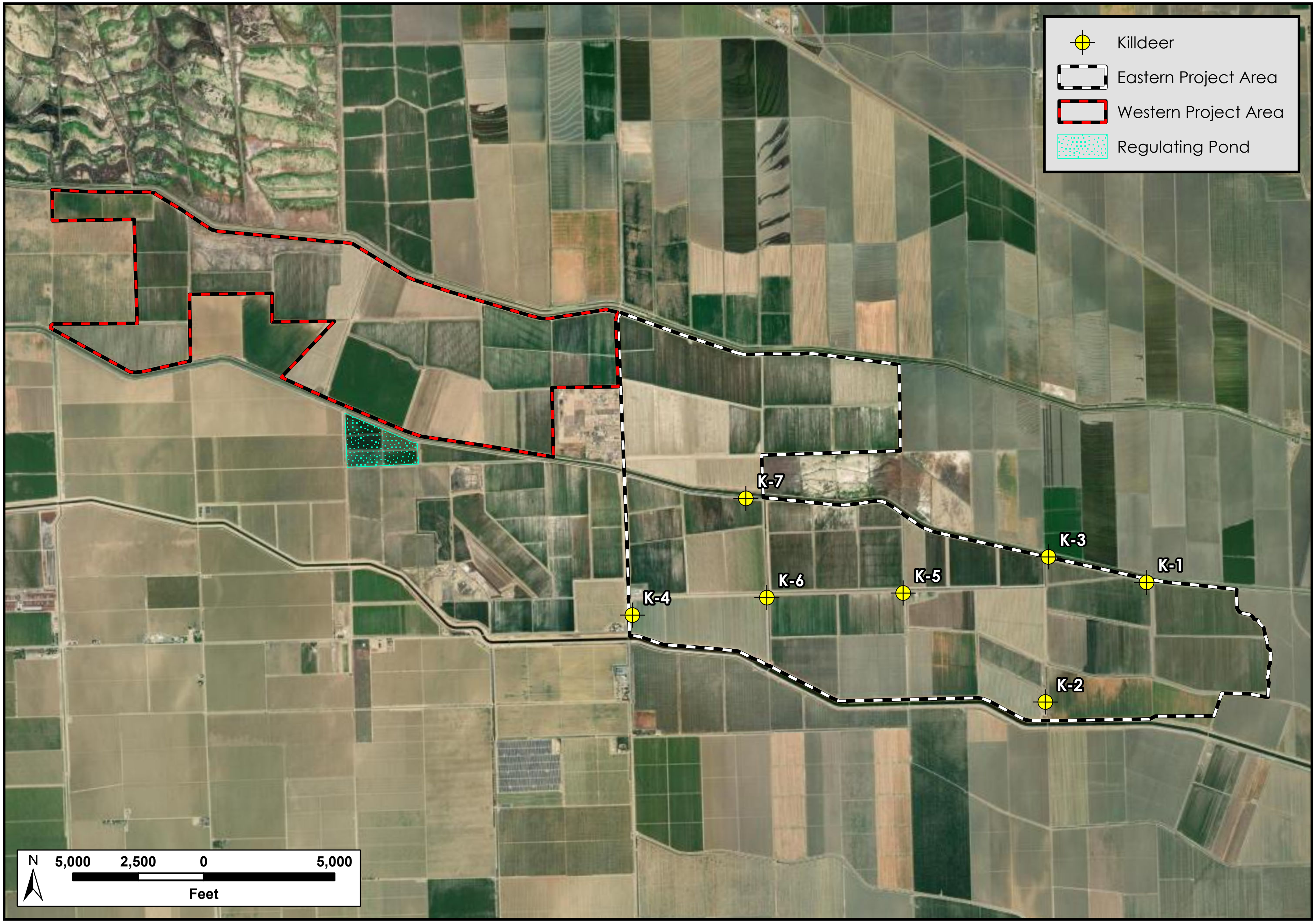

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Figure 4. Location of Killdeer Eggs Collected from the Project Site in 2022

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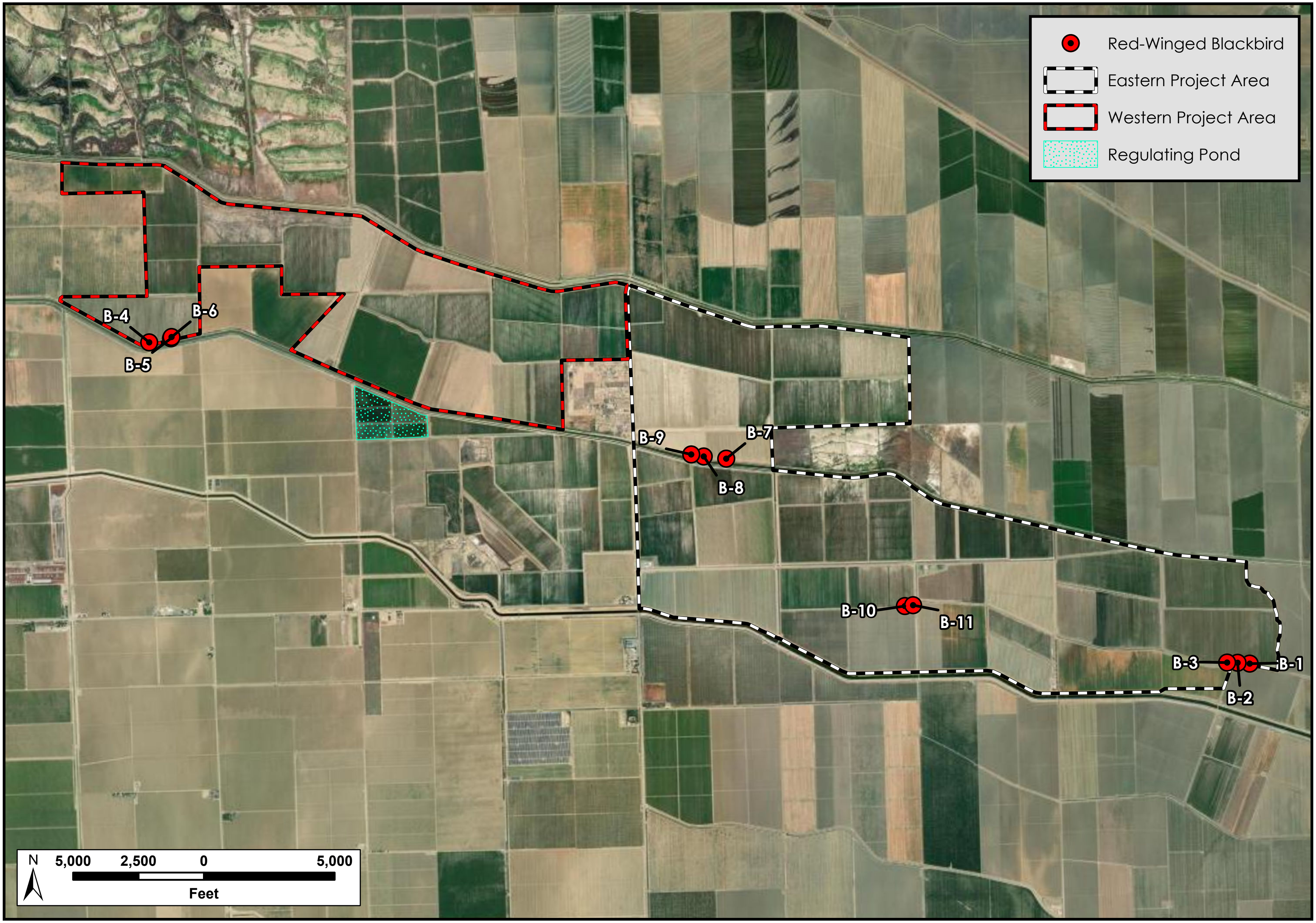

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Figure 5. Location of Red-Winged Blackbird Eggs Collected from the Project Site in 2022
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2.2.1 Egg Chemistry Analysis

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. This laboratory was founded by former personnel of South Dakota State University's Oscar E. Olson Biochemical Laboratory, which closed in 2011. H. T. Harvey & Associates used the Oscar E. Olson Biochemical Laboratory for egg-selenium analyses between 2003 and 2011.

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). 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 2022 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 2022, for red-winged blackbirds based on data from 2003 to 2022, and for recurvirostrids based on data from 2003 through 2021. 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 2022).

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 2022. 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 14, 2022. 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 2022. 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 2022. 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-two avian species were observed within the eastern project area between April 15 and June 21, 2022 (Table 2). Avian numbers were highest on June 8 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. Thirteen of the species observed—spotted sandpiper (*Actitis macularius*), whimbrel (*Numenius phaeopus*), least sandpiper (*Calidris minutilla*), solitary sandpiper (*Tringa solitaria*), western wood-peewee (*Contopus sordidulus*), willow flycatcher (*Empidonax trailii*), Pacific-slope flycatcher (*Empidonax difficilis*), American pipit (*Anthus rubescens*), savannah sparrow (*Passerculus sandwichensis*), Nashville warbler (*Leiothlypis ruficapilla*), yellow warbler (*Setophaga petechia*), Wilson's warbler (*Cardellina pusilla*), and western tanager (*Piranga ludoviciana*)—were present only as spring migrants.

Table 2. Avian Census Results from the Eastern Project Area in 2022

	2022					
Species	**April 15**	**May 3**	**May 13**	**May 24**	**June 8**	**June 21**
* Gadwall	4	2	10	4		
* Mallard	6	4	2	8		2
* Eurasian Collared Dove	8	5	4	4	3	4
* Mourning Dove	15	21	7	5	10	14
Lesser Nighthawk			1			
Anna's Hummingbird	1	1	1		1	1
Black-Necked Stilt	4	5	2			
American Avocet	2	2				
* Killdeer	22	24	27	26	25	18
Spotted Sandpiper	1	1	1			
Long-Billed Curlew					46	92
Least Sandpiper	22	17	21			
Solitary Sandpiper		1	1			
Greater Yellowlegs	5	8	4			2
Great Blue Heron	2	1	3	1	2	1
Great Egret	3	4	2	3	2	2
Snowy Egret	6	3	2	3	1	
Black-crowned Night Heron	5	4	1	2		1

	2022					
Species	**April 15**	**May 3**	**May 13**	**May 24**	**June 8**	**June 21**
White-faced Ibis	25	31	51		43	
Northern Harrier	3	2	2	3	1	2
* Swainson's Hawk	9	14	25	36	9	22
Red-tailed Hawk	2	2	2	1	1	2
Barn Owl	1	1	1		1	
* Great-horned Owl	1	1	1			
Belted Kingfisher		1				
* American Kestrel	2	1	4	5	5	2
Western Wood-pewee		2	1	1		
Willow Flycatcher				1		
Pacific-slope Flycatcher		2		1		
* Western Kingbird	15	22	19	26	24	21
* Loggerhead Shrike	3	3	5	4	3	3
Common Raven	25	16	12	63	51	37
* Horned Lark	7	11	9	6	2	4
Tree Swallow	15	6			145	180
Northern Rough-winged Swallow	16	9	5		5	7
* Barn Swallow	15	18	14	21	23	19
Cliff Swallow	35	51	48	25	29	40
* House Sparrow	14	15	22	17	18	16
American Pipit	6	7				
* House Finch	37	35	40	38	52	47
Savannah Sparrow	27	19	8			
Song Sparrow	4	6	5	4	2	
* Western Meadowlark	12	10	9	14	8	5
Bullock's Oriole	2	3	4	3		1
* Red-winged Blackbird	570	608	685	721	708	510
* Brown-headed Cowbird	14	21	17	15	12	4
* Brewer's Blackbird	8	10	9	8	7	6
* Common Yellowthroat	7	11	10	3	2	1
Nashville Warbler		1	1			
Yellow Warbler		1	3	4		
Wilson's Warbler	1	2	3	1		
Western Tanager		2	1	2		

Species	2022					
	April 15	May 3	May 13	May 24	June 8	June 21
Total	982	1047	1105	1079	1241	1066
Observed density (birds per acre)[1]	0.240	0.256	0.270	0.263	0.303	0.260

* Species for which evidence of nesting was observed in 2022.

[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, and savannah sparrows were absent from the western project area.

Table 3. Avian Census Results from the Western Project Area in 2022

Species	2022					
	April 15	May 3	May 13	May 24	June 8	June 21
Cinnamon Teal	2	3				1
* Gadwall		2	5		6	
* Mallard	6	4	5	4	4	2
Eurasian collared dove	2	2	3	4	2	2
* Mourning Dove	12	10	17	16	15	9
American Coot	5	4	6	3	5	2
Black-Necked Stilt	4	2				2
American Avocet						
* Killdeer	16	15	21	20	14	13
Whimbrel	24	20				
Long-billed Curlew					31	27
Least Sandpiper	31	36	19			
Greater Yellowlegs	2	1	2			
Great Blue Heron	1	2	3	1	1	
Great Egret	4	3	2	1	1	1
Snowy Egret	2	3	4	3	1	
White-faced Ibis	26	17	22		15	9
Northern Harrier	2	1	1	1	2	
* Swainson's Hawk	6	8	9	15	20	16
* Red-tailed Hawk	2	2	3	4	2	2
American Kestrel	1			2	1	
* Western Kingbird	16	14	15	13	12	13

Species	2022					
	April 15	May 3	May 13	May 24	June 8	June 21
* Loggerhead Shrike	6	5	5	6	5	4
* Common Raven	20	12	7	14	31	34
* Horned Lark	4	5	12	6	2	2
Tree Swallow	10				31	26
Northern Rough-winged Swallow	3	4	4	3	2	
* Barn Swallow	8	4	5	5	6	6
Cliff Swallow	17	10	5	4	6	3
* Northern Mockingbird	6	5	6	4	3	4
House Finch	6	7	4	5		7
Savannah Sparrow	16	14	8	6		
* Song Sparrow	5	5	6	3		
* Common Yellowthroat	6	5	3	2		
* Red-winged Blackbird	374	324	298	275	250	229
* Western Meadowlark	6	5	9	7	3	5
* Brewer's Blackbird	10	8	7	3		
* Brown-headed Cowbird	8	7	9	5	4	5
Total	**669**	**569**	**525**	**435**	**475**	**424**
Observed density (birds per acre)[1]	**0.359**	**0.306**	**0.282**	**0.234**	**0.255**	**0.228**

* Species for which evidence of nesting was observed in 2022.

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

3.2 Egg Collection and Processing

Eighteen eggs (7 killdeer eggs and 11 red-winged blackbird eggs) were collected from the project site. Two killdeer eggs contained live, normal embryos 10 days old or older. The five remaining killdeer embryos were too young (fewer than 9 days old) for their condition to be assessed, although they 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 six 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 2022

ID Number	Field Number[1]	Date	Embryo[2]		Embryo Age (days)	Selenium (ppm, dry wt)[3]	Log Base 10	Anti-Log
			Condition	Status				
01	P-K-01	May 24	L	N	10	25.87	1.4128	
02	P-K-02	June 3	L	U	3	13.51	1.1307	
03	P-K-03	June 10	L	N	12	11.87	1.0745	
04	P-K-04	June 14	L	U	3	14.04	1.1474	
05	P-K-08	June 21	L	U	5	8.01	0.9036	
06	P-K-07	June 21	L	U	3	Not analyzed – damaged in transit		
07	P-K-10	June 24	L	U	3	15.70	1.1959	
Arithmetic/***geometric mean***						14.8	1.1441	***13.9***
Standard deviation						6.0	0.1660	***1.5***
Standard error							0.0742	***1.2***
Lower limit of 95% confidence interval							0.9986	***10.0***
Upper limit of 95% confidence interval							1.2896	***19.5***

[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 2022

ID Number	Date	Embryo[1]		Embryo Age (days)	Selenium (ppm, dry wt)[2]	Log Base 10	Anti-Log
		Condition	Status				
01	April 15	U	U	1	Not analyzed - damaged in transit		
02	April 15	U	U	1	Not analyzed - damaged in transit		
03	April 15	L	U	3	Not analyzed - damaged in transit		
04	April 15	U	U	1	2.93	0.4669	
05	April 26	U	U	1	Not analyzed - damaged in transit		

ID Number	Date	Embryo[1] Condition	Embryo[1] Status	Embryo Age (days)	Selenium (ppm, dry wt)[2]	Log Base 10	Anti-Log
06	April 26	U	U	1	Not analyzed - damaged in transit		
07	May 6	L	U	3	Not analyzed - damaged in transit		
08	May 6	L	U	6	3.16	0.4997	
09	May 6	L	U	4	3.34	0.5237	
10	May 11	L	U	5	Not analyzed - damaged in transit		
11	May 11	L	U	6	3.91	0.5922	
Arithmetic/***geometric mean***					3.3	0.5206	***3.3***
Standard deviation					0.4	0.0531	***1.1***
Standard error						0.0237	***1.1***
Lower limit of 95% confidence interval						0.4741	***3.0***
Upper limit of 95% confidence interval						0.5672	***3.7***

[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 2022

ID Number	Date	Embryo[1] Condition	Embryo[1] Status	Embryo Age (days)	Selenium (ppm, dry wt)[2]	Log Base 10	Anti-Log
Black-necked Stilt							
01	June 3	L	N	13	71.95	18.90	
02	June 3	L	U	8	44.27	3.19	
03	June 14	L	N	17+	73.94	7.82	
04	June 14	L	U	5	64.98	4.88	
05	June 14	L	N	14	71.03	4.80	
Arithmetic/***geometric mean***					7.9	0.8086	***6.4***
Standard deviation					6.4	0.2956	***2.0***
Standard error						0.1322	***1.4***
Lower limit of 95% confidence interval						0.5495	***3.5***
Upper limit of 95% confidence interval						1.0678	***11.7***

3.3 Egg-Selenium and Egg-Boron Analysis

3.3.1 Trends in Egg-Selenium and Egg-Boron Concentrations

In 2022, 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 13.9 ppm (dry wt., Table 4) and the geometric mean egg-boron concentration was 3.0 ppm (dry wt., Appendix A). The geometric mean egg-selenium level for red-winged blackbirds collected from the project site was 3.3 ppm (dry wt., Table 5) and the geometric mean egg-boron concentration was 3.4 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 6 and 7). 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 2022), Red-winged Blackbirds (2003 through 2022), 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	0.0054	1.199	19	0.2451
Recurvirostrids	Selenium	-0.0198	-1.671	11	0.1229
Red-winged blackbirds	Selenium	0.0010	0.209	17	0.8371
Killdeer	Boron	0.0050	0.0957	19	0.3504
Recurvirostrids	Boron	0.0073	1.143	11	0.2775
Red-winged blackbirds	Boron	0.0047	0.800	17	0.4347

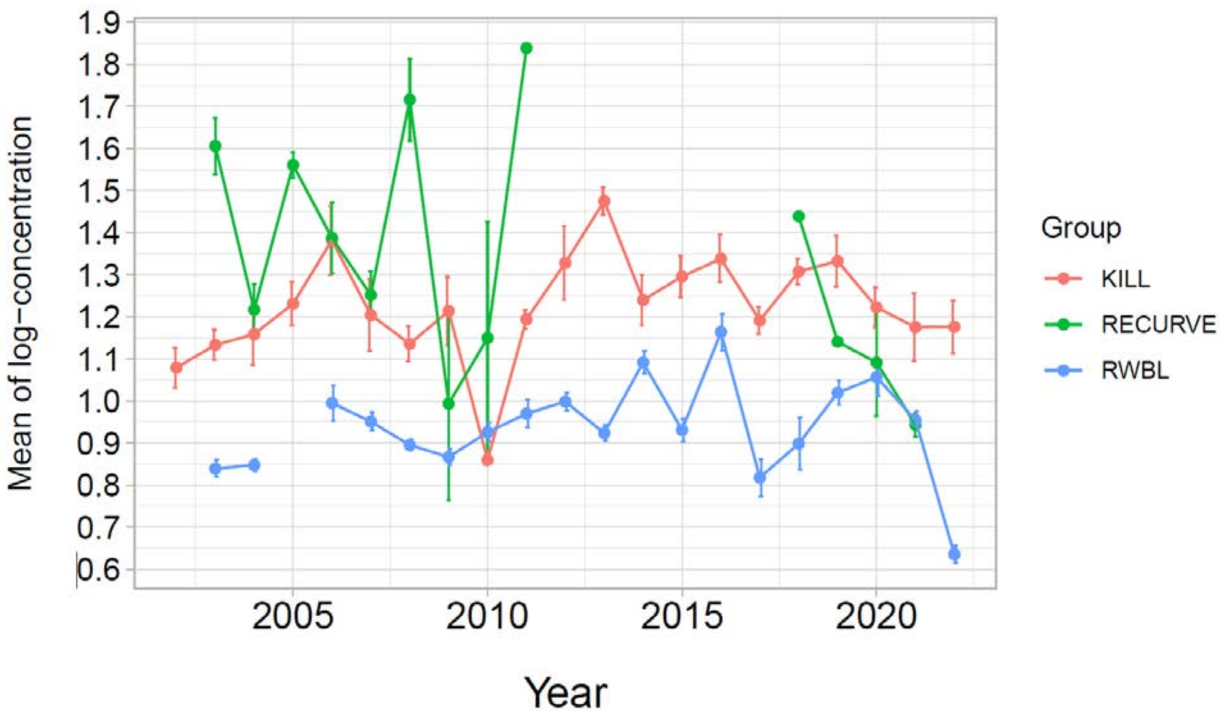


Figure 6. Mean Egg-selenium Concentrations for Killdeer, Red-winged Blackbirds, and Recurvirostrids at the San Joaquin River Water Quality Improvement Project Site (2002 through 2021).
Concentrations are shown in log-concentration, calculated as log10(x+1). Error bars represent ± 1 standard error. Group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

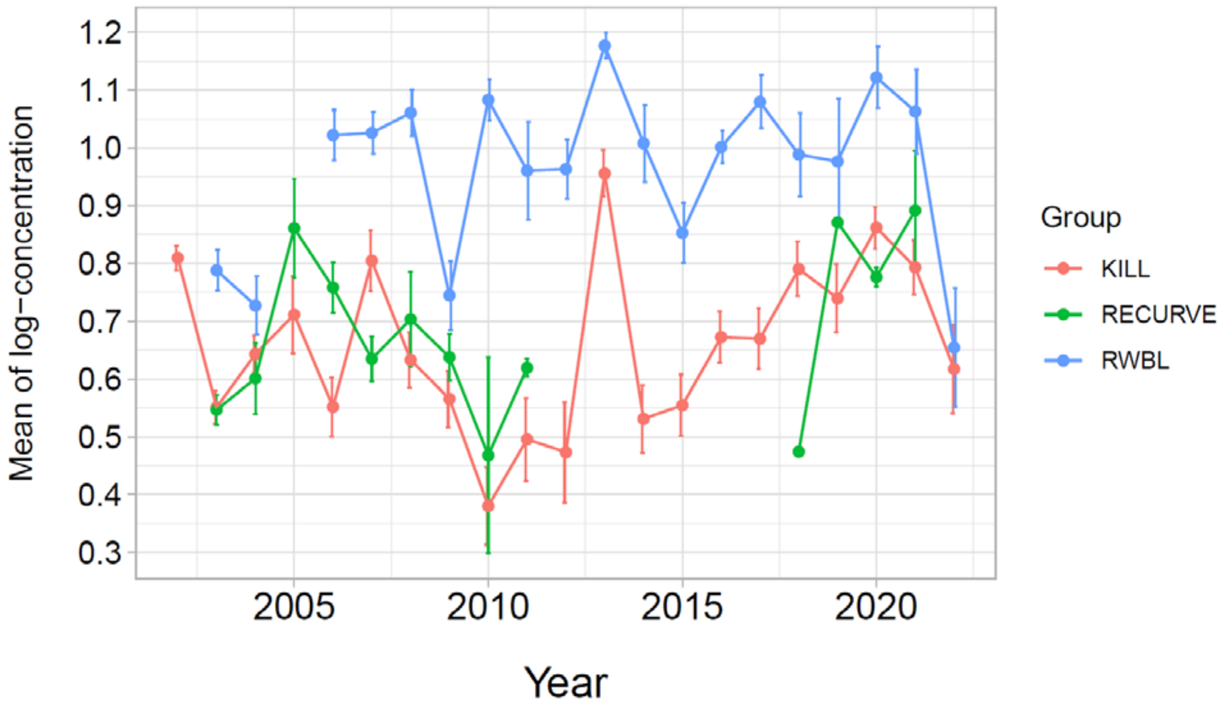


Figure 7. Mean Egg-boron Concentrations for Killdeer, Red-winged Blackbirds, and Recurvirostrids at the San Joaquin River Water Quality Improvement Project Site (2002–2022). Concentrations are shown in log-concentration, calculated as log10(x+1). Error bars represent ± 1 standard error. Group abbreviations: KILL (Killdeer), RECURVE (recurvirostrids), RWBL (red-winged blackbirds). The dashed blue line was fitted to the red-winged blackbird results using a least square regression model, which indicated an increase in log-concentration over time (p = 0.0383).

3.4 Control Eggs

The selenium recovery rate for two egg samples spiked with selenium were 103% and 106% with a mean selenium recovery rate of 104.5% (Appendix C). The instruments used for selenium analysis were calibrated periodically throughout the process. Average values of 0.429 and 0.435 µg/g selenium were obtained from trails 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 D).

The boron-recovery rates for two egg samples spiked with boron were 102% and 105%, with a mean boron recovery rate of 13.5% (Appendix C). The standard deviation of boron results from one duplicate control egg sample was 0.5020 (Appendix E).

3.5 Nest Fate

Eight killdeer nests on the project site were followed to completion in 2022 (Table 8; Appendix F). Six of the killdeer nests monitored within the project site hatched and two were lost to predators (Table 8; Appendix F).

The 2022 mitigation site was first flooded with water on May 10, and black-necked stilts and American avocets were observed courting there soon after. On May 31, five black-necked stilts and one American avocet were observed sitting on islands and nearby levees in incubation posture (Table 8; Appendix F). One American Avocet nest and eight black-necked stilt nests were located within the mitigation site in the 2022 nesting season. Six of the black-necked stilt nests and the American avocet nest were observed to have successfully hatched and the remaining two black-necked stilt nests were taken by predators (Table 8, Appendix F).

Table 8. Nest Fates and Agents That Caused Nest/Clutch Failure on the Project Site and on the Mitigation Sites in 2022

	Hatched		Depredated		Vehicle/Farm Activities		Flooded		
Species	**Nest**	**Percent**	**Nest**	**Percent**	**Nest**	**Percent**	**Nest**	**Percent**	**Total**
Project Site									
Killdeer	6	75	2	25					8
2022 Mitigation Site									
Stilts and Avocets									
Black-necked stilt	(6)		(2)						(8)
American avocet	(1)								(1)
Total	**7**	**78**	**2**	**22**					**9**

3.6 Mitigation Site Water Quality

The results of the water-quality analysis for the 2022 mitigation site are summarized in Table 9. Selenium concentrations in the water samples from the inlet, the middle, and the outlet of the 2022 mitigation site were below the 2.3-ppb selenium thresholds for wildlife safety in fresh water (Eisler 1990, Skorupa and Ohlendorf 1991, Suter 1996).

Table 9. Water Quality in Samples Taken from the 2022 Mitigation Site on June 30, 2022

	Electrical Conductivity (μhmo/cm)	Boron (ppm)	Selenium (ppb)
Freshwater thresholds[1]		5	2.3
Location			
Inlet	166	Not tested	0.198J
Middle	238	Not tested	0.418
Outlet	1250	Not tested	1.07

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.

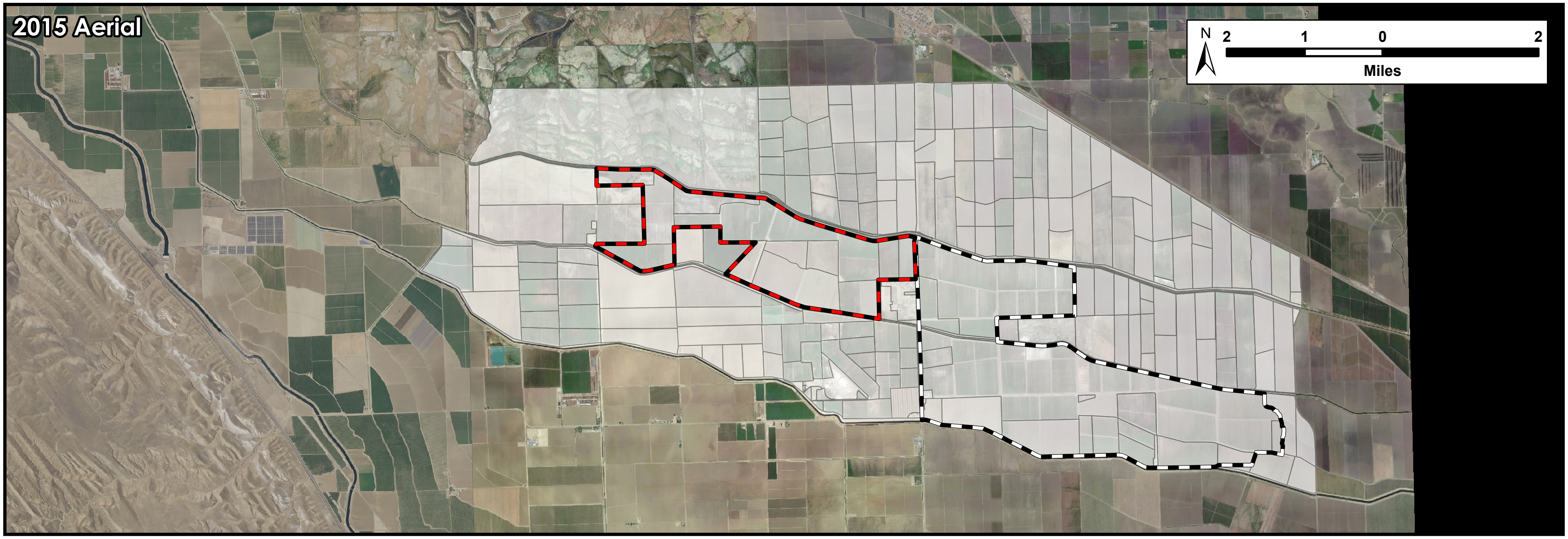
[1] Sources: Eisler 1990, Skorupa and Ohlendorf 1991, Suter 1996.

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.

3.7 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 2022, the suitability of 18,862 acres (55.5%) remained unchanged, the suitability of 4,665 acres (18.0%) increased, and the suitability of 2,343 acres (9.1%) decreased. The habitat suitability value of all the habitat polygons ranged between zero and fifty in 2015 and 2022. The acreage weighted value kit fox habitat suitability was 30.91 in 2015 and was 26.90 in 2022, which equals a 13% decrease (Figure 9). In the seven years between 2015 and 2022 the acreage weighted value has 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.



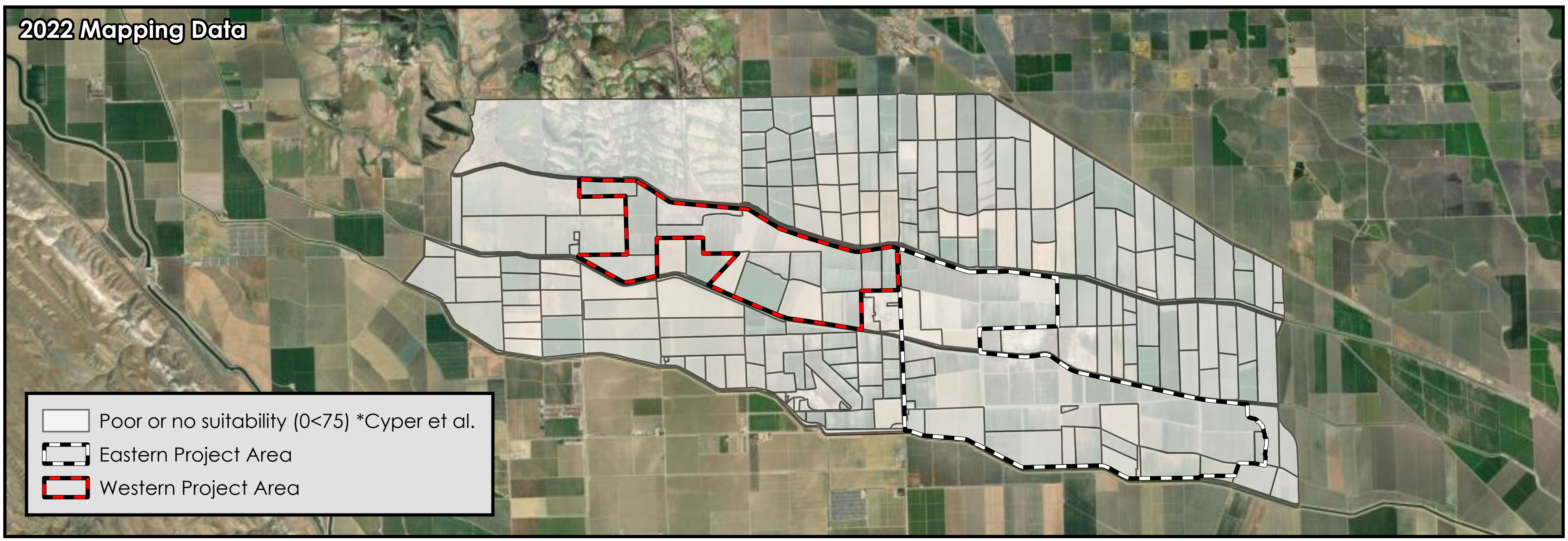


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Figure 8. Habitat Suitability for San Joaquin Kit Fox in the Project Vicinity

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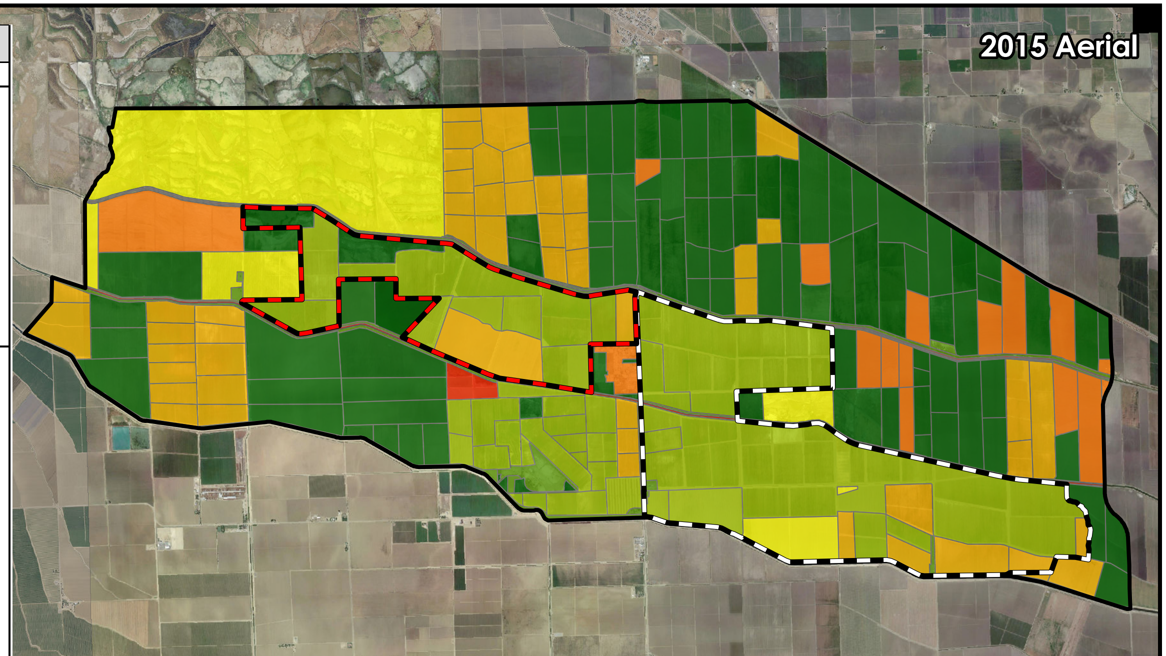
Habitat Suitability Value Change	Habitat Suitability Value Direction	Land Use Type Change (2015-2022)	Acres	Total (ac)
0		Unchanged	16,034.42	16,034.42
5		Rice to Field Crops	376.87	
10		Field Crops to Orchard	225.01	
10		Grain/pasture to Urban Commercial	28.68	
10		Urban Commercial to Idled Farmland	661.15	
15		Rice to Orchard	533.05	
20	Positive	Field Crops to Grain Pasture	831.84	4,308.33
20		Grain/Pasture to Idled Farmland	84.04	
35		Farmstead to Urban Commercial	111.82	
40		Field Crops to Idled Farmland	922.32	
45		Rice to Idled Farmland	441.02	
50		Water to Idled Farmland	92.54	
-5		Field Crops to Rice	99.35	
-10		Idled Farmland to Urban Commercial	2.01	
-10		Lowland Scrub to Urban Commercial	1.28	
-10		Urban Commercial to Grain Pasture	18.39	
-20		Emergent Wetlands to Water	21.52	
-20		Idled Farmland to Grain Pasture	83.95	
-20		Lowland Scrub to Grain Pasture	18.26	
-20	Negative	Urban Commercial to Orchard	15.18	5,527.28
-30		Idled Farmland to Orchard	1,107.84	
-30		Lowland Scrub to Emergent Wetland	47.91	
-30		Urban Commercial to Field Crops	0.03	
-35		Urban Commercial to Farmstead	0.00	
-40		Idled Farmland to Field Crops	2,729.57	
-45		Idled Farmland to Farmstead	3.43	
-45		Idled Farmland to Rice	1,378.58	



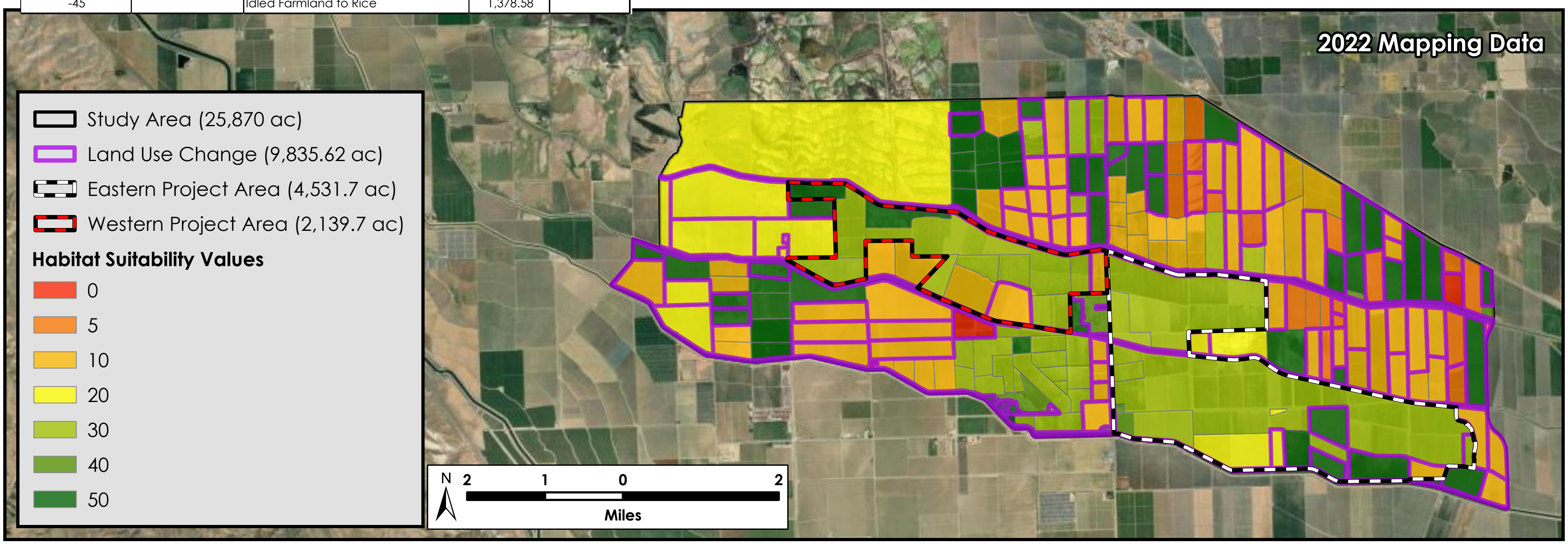


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Figure 9. Habitat Suitability Values Change for San Joaquin Kit Fox in the Project Vicinity
San Joaquin River Water Quality Improvement Project
2022 Wildlife Monitoring Report (1960-23)
February 2024

Section 4.0 Discussion

By 2022, 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. 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 lower than in previous years, likely due to markedly drier conditions on the site this year. As a result of the third year of drought in a row, general conditions in the project area were drier and irrigation allotments were drastically cut, leading to a considerable reduction to drainage water available to irrigate the project site. Because most of the irrigation conveyances were dry, there were only eight killdeer nests located by the monitoring program in 2022 down from 26 killdeer nests in 2021.

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 nine Swainson's hawk nests were located on and adjacent to the eastern and western project areas. Two Swainson's hawk nests were observed within the eastern project area, and three additional nests were situated on the border of the project site, Two 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, and one was in a cottonwood tree next to the Outside Canal near the western project area. Another three nests were observed in the rows of athel pine (*Tamarix aphylla*) trees south of the regulating pond near the Eagle Field airfield (Figure 2). Six of the nine Swainson's hawk nests fledged 2 young and two others fledged one young. The remaining three 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.

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 2022 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 2022 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 in the eggs of killdeer nesting on the site were right at 3.0-ppm, the estimated upper end of background levels for boron. As has been the case since monitoring began, red-winged blackbird eggs in 2022 had higher levels of boron (3.4 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. 2022 Killdeer Egg-Boron Concentrations at the San Joaquin River Water Quality Improvement Project Site

2022 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	7.00	0.8451	
02	2.62	0.4183	
03	1.47	0.1673	
04	2.63	0.4200	
05	2.25	0.3522	
06	Not analyzed – damaged in transit		
07	4.99	0.6981	
Arithmetic/***geometric mean***	3.49	0.4835	***3.0***
Standard deviation	2.1	0.2459	***1.8***
Standard error		0.1100	***1.3***
Lower limit of 95% confidence interval		0.2680	***1.9***
Upper limit of 95% confidence interval		0.6990	***5.0***

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

Appendix B. 2022 Red-Winged Blackbird Egg-Boron Concentrations at the San Joaquin River Water Quality Improvement Project Site

2022 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	Not analyzed – damaged in transit		
02	Not analyzed – damaged in transit		
03	Not analyzed – damaged in transit		
04	2.80	0.4472	
05	Not analyzed – damaged in transit		
06	Not analyzed – damaged in transit		
07	Not analyzed – damaged in transit		
08	2.77	0.4425	
09	2.18	0.3385	
10	Not analyzed – damaged in transit		
11	8.09	0.9079	
Arithmetic/***geometric mean***	3.96	0.5340	***3.4***
Standard deviation	2.77	0.2543	***1.8***
Standard error		0.1137	***1.3***
Lower limit of 95% confidence interval		0.3111	***2.0***
Upper limit of 95% confidence interval		0.7569	***5.7***

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

Appendix C. 2022 Control Eggs Selenium and Boron Spike Results

2022 Control Eggs Spike Results

ID Number	Tissue	Spiked selenate (ng)[1]	Percent Recovery
P-M-04	egg	80	106
W-N-02	egg	80	103
		Mean	**104.5**
		Standard deviation	**2.1**
		Spiked 1000 ppm Boron Standard (µg)[2]	
P-M-01	egg	100	105
P-M-05	egg	100	102
		Mean	**103.5**
		Standard deviation	**2.1**

[1] ng = nanogram, [2]µg = microgram, [3] µl = microliter.

Appendix D. 2022 Control Eggs Selenium Duplicate Results

2022 Control Eggs Selenium Duplicate Results

ID Number	Replication	Selenium (ppm, dry wt)[1]	ID Number	Replication	Selenium (ppm, dry wt)[1]
PK-1	1	25.76	PM-03	1	7.74
	2	25.98		2	7.90
SD		***0.1556***	***SD***		***0.1131***
PK-2	1	14.15	PM-04	1	4.90
	2	12.87		2	4.85
SD		***0.9051***	***SD***		***0.0354***
PK-3	1	12.08	PM-05	1	5.36
	2	11.65		2	5.32
SD		***0.3041***	***SD***		***0.0283***
PK-4	1	14.34	TLDD-M-1	1	4.41
	2	13.75		2	4.56
SD		***0.4172***	***SD***		***0.1061***
PK-7	1	15.77	TLDD-M-2	1	3.50
	2	15.63		2	3.43
SD		***0.0990***	***SD***		***0.0495***
PB-4	1	3.00	TLDD-M-3	1	4.40
	2	2.86		2	4.48
SD		***0.0990***	***SD***		***0.0566***
PB-8	1	3.18	TLDD-M-4	1	2.66
	2	3.13		2	2.91
SD		***0.0354***	***SD***		***0.1768***
PB-9	1	3.35	TLDD-M-5	1	4.11
	2	3.32		2	4.31
SD		***0.0212***	***SD***		***0.1414***
PB-11	1	3.94	WL-N-01	1	1.51
	2	3.88		2	1.60
SD		***0.0424***	***SD***		***0.0636***
PM-01	1	18.79	WL-N-02	1	2.01
	2	19.02		2	2.05
SD		***0.1626***	***SD***		***0.0283***
PM-02	1	3.20	WL-N-03	1	1.58
	2	3.19		2	1.43
SD		***0.0071***	***SD***		***0.1061***

ID Number	Replication	Selenium (ppm, dry wt)[1]	ID Number	Replication	Selenium (ppm, dry wt)[1]
SD					
Mean SD:	**0.1455**				
Low SD:	**0.0071**				
High SD:	**0.9051**				

Note: SD = standard deviation.

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

Appendix E. 2022 Control Eggs Boron Duplicate Results

2022 Control Eggs Boron Duplicate Results

ID Number	Replication	Boron (ppm, dry wt)[1]	ID Number	Replication	Boron (ppm, dry wt)[1]
P-K-02	1	2.96			
	2	2.25			
SD		***0.5020***			

Note: SD = standard deviation.

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

Appendix F. 2022 Black-necked Stilt, American Avocet, and Killdeer Nest Monitoring Results for the Project Area and Mitigation Site

2022 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 Status	Nest Fate	Nest Agent
Killdeer													
18-1	Field edge	5/24	4	5/31	3	6/8	0			P-K-01 collected 5/24. Chicks observed 6/8	1	3	1
10-3	Field edge	5/24	3	5/27	3	5/31	0			5/27 eggs pipping. 5/31 eggs hatched	1	4	1
13-6	Equipment yard	6/3	4	6/17	3	6/24	3	6/28	0	P-K-02 collected 6/3. Nest empty 6/28, no signs of predation.	1	4	1
15-1	Solar collector	6/10	3	6/14	4	6/21	0			P-K-04 collected 6/14. Nest found depredated on 6/21.	5	5	4
18-1	Canal levee	6/10	4	6/17	3	6/24	0			P-K-03 collected 6/3. Nest empty 6/24, no signs of predation.	1	4	1
14-2	Field edge	6/21	4	6/28	0					P-K-05 collected 6/24. Nest found depredated on 6/28.	5	5	4
15-2	Field edge	6/21	4	7/6	3	7/22	0			P-K-06 collected 6/21. Nest empty 7/22, no signs of predation.	1	4	1
10-4	Field edge	6/24	4	7/6	3	7/22	0			P-K-07 collected 6/24. Nest empty 7/22, no signs of predation.	1	4	1

Codes for nest status, nest fate, and nest agent:

Nest Status:
1 Undisturbed/normal
2 Investigator damaged
3 Partially destroyed
4 Some eggs missing
5 Total destroyed
6 Other (e.g. poachers)

Nest Fate:
1 Last (not relocated)
2 Fate uncertain
3 Hatched (certain)
4 Presumed hatched
5 Destroyed
6 Abandoned
7 Past term/unviable
8 Terminated

Nest Agent:
1 None
2 Unknown
3 Observer
4 Predator
5 Livestock
6 Flooding
7 Vehicle
8 Levee maintenance

2022 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 Status	Nest Fate	Nest Agent
Black-Necked Stilt														
001	Row 2, Island 4	Small island	5/24	sit	6/3	4	6/17	sit	6/21	0	P-M-02 collected 6/3. Nest empty with no signs of depredation 6/21.	1	4	1
002	Row 3, Island 5	Small island	5/31	sit	6/3	2	6/14	0			Nest empty with signs of depredation 6/14.	5	5	4
003	Row 3, Island 3	Small island	5/31	sit	6/3	3	6/14	3	6/17	0	Eggs were hatching on 6/14.	1	4	1
004	Row 3, Island 1	Small island	5/31	sit	6/3	3	6/14	3	6/28	0	Nest empty with signs of depredation 6/28.	5	5	4
005	Row 1, Island 5	Small island	5/31	sit	6/3	4	6/14	sit	6/28	0	P-M-01 collected 6/3. Nest empty with no signs of depredation 6/28.	1	4	1
006	Row 5, Island 2	Small island	6/3	sit	6/14	4	6/21	sit	6/28	0	P-M-05 collected 6/14. Nest empty with no signs of depredation 6/28	1	4	1
007	Row 4, Island 3	Small island	6/8	sit	6/14	4	6/21	sit	6/28	sit	P-M-04 collected 6/14. Nest empty with no signs of depredation 7/7.	1	4	1
008	Row 1, Island 2	Small island	6/14	4	6/21	sit	6/28	0			P-M-03 collected 6/14. Nest empty with no signs of depredation 7/7.	1	4	1
American Avocet														
001	Row 1, Island 5	Small island	5/31	sit	6/3	3	6/21	sit	6/28	0	Nest empty with no signs of depredation 7/7	1	4	1

Codes for number of eggs, nest status, nest fate, and nest agent:

Number of eggs:
S Adult sitting on nest in incubation pasture
V Nest is vacant

Nest status:
1 Undisturbed/normal
2 Investigator damage

Nest fate:
1 Lost (not relocated)
2 Fate uncertain

Nest agent:
1 None
2 Unknown

3 Partially destroyed	3 Hatched (certain)	3 Observer
4 Some eggs missing	4 Presumed hatched	4 Predator
5 Totally destroyed	5 Destroyed	
6 Other (e.g. poachers)	6 Abandoned	
7 Past term/unviable	7 Vehicle	
8 Terminated	8 Levee maintenance	