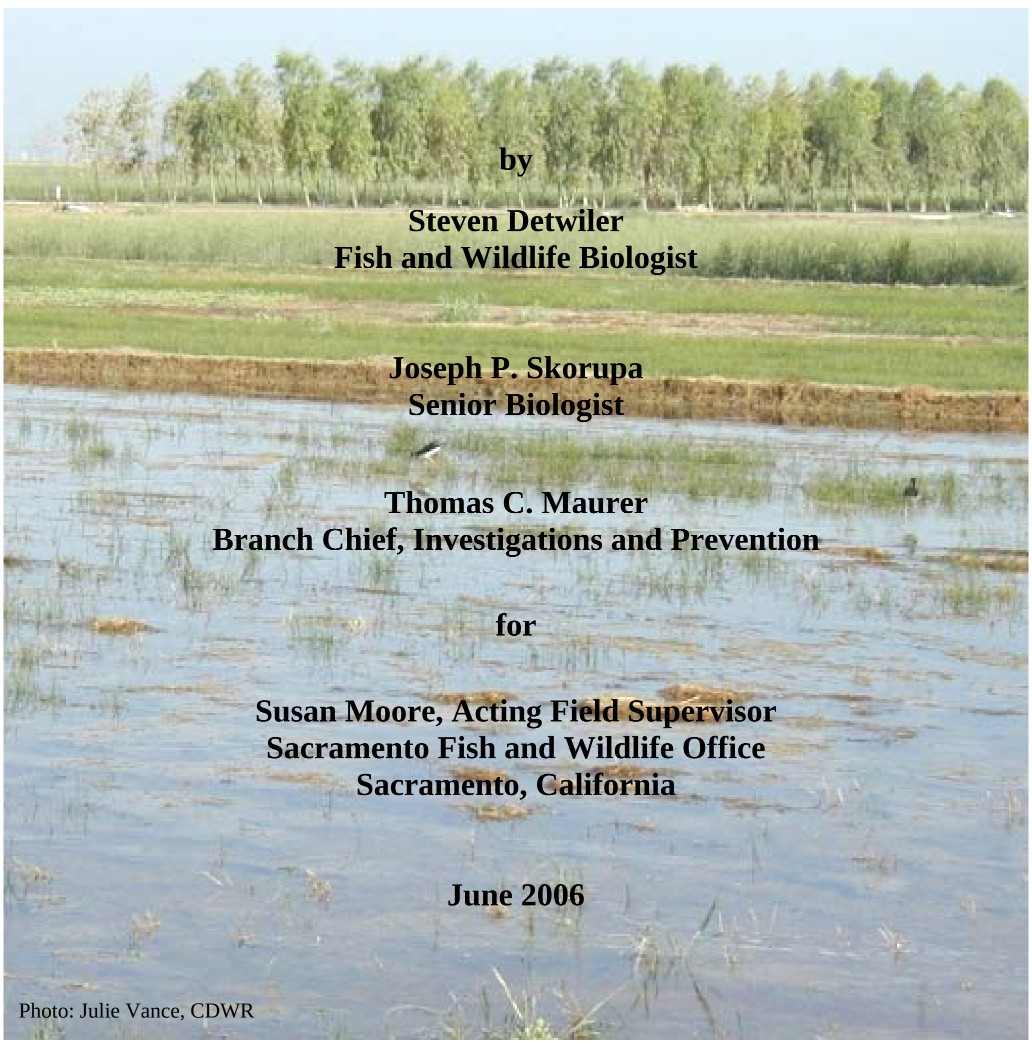
United States Department of the Interior
Fish and Wildlife Service
Sacramento Fish and Wildlife Office
2800 Cottage Way, Room W-2605
Sacramento, California 95825-1846

Assessment of Avian Selenium Exposure at Agroforestry Sites in California

FINAL REPORT

Project ID: 10003.1



by

Steven Detwiler
Fish and Wildlife Biologist

Joseph P. Skorupa
Senior Biologist

Thomas C. Maurer
Branch Chief, Investigations and Prevention

for

Susan Moore, Acting Field Supervisor
Sacramento Fish and Wildlife Office
Sacramento, California

June 2006

Photo: Julie Vance, CDWR

Cover Photo: Shorebirds like black-necked stilts quickly utilize ponded reuse drainwater in the semi-arid San Joaquin Valley. Invertebrates can populate ponded water in furrows, fields, sumps, and ditches within three weeks thus providing a food source for many species of birds. Photo by Julie Vance, California Department of Water Resources.

United States Department of the Interior
Fish and Wildlife Service
Sacramento Fish and Wildlife Office
2800 Cottage Way, Room W-2605
Sacramento, California 95825-1846

Assessment of Avian Selenium Exposure at Agroforestry Sites in California

Final Report
Project ID: 10003.1
June 2006

Steven Detwiler[1], Joseph P. Skorupa[2], and Thomas C. Maurer[1]

[1] U. S. Fish and Wildlife Service. Sacramento Fish and Wildlife Office. 2800 Cottage Way, Room W-2605. Sacramento, California 95825-1846

[2] U. S. Fish and Wildlife Service. Division of Environmental Quality. 4401 North Fairfax Drive, Suite 322. Arlington, Virginia 22203

Abstract

The west-side and southern end of the San Joaquin Valley in California is often poorly drained and infiltration of saline water into the root zone of crops affects a significant portion of the area. One option available to growers is installing subsurface tile drains to remove the saline groundwater and discharging it into large evaporation basins; however, this water often contains high concentrations of elements along with the salts. A chief element of concern, shown to have ecotoxicological significance, is selenium (Se). Alternatives to evaporation basins reused subsurface drainwater to grow salt tolerant crops leading to smaller evaporation basins. In early systems eucalyptus trees were commonly utilized and thus the practice was termed “agroforestry”. More elaborate management configurations incorporate salt tolerant traditional crops (cotton), non-traditional halophyte crops (pickleweed), eucalyptus trees, and small terminal solar evaporators with sequential recovery and re-use of drainage waste water. These systems are referred to as Integrated On-Farm Drainage Management (IFDM) or drainage “reuse facilities.” In 1996, U.S. Fish and Wildlife Service staff collected a small set of waterbird eggs from two agroforestry sites. These samples yielded the highest rates of selenium-induced teratogenesis (embryo deformities) ever reported. These findings highlighted the urgent need for a broad scale assessment of wildlife use of agroforestry sites prior to any further substantial expansion of agroforestry acreage. A range of agroforestry sites was monitored for avian reproductive activity over three seasons. Fifteen species of migratory birds were documented to nest at agroforestry study sites. Avian nests were located in every habitat component of IFDM plots—proving that these sites are capable of attracting both foraging and nesting birds. Selenium-typical, embryonic deformities were documented among nesting shorebirds along with instances of highly elevated egg selenium concentrations. This investigation has confirmed that agroforestry or IFDM sites are not without attendant risks; however, the question regarding the relative utility of this particular drainwater management option is more a function of realized risk to wildlife in light of the available alternatives. IFDM sites have reduced wildlife risks by about 80 percent compared to the alternative of operating a traditional evaporation basin to dispose of drainage water. Short of management alternatives that preclude the generation of seleniferous drainwater in the first place (e.g. land retirement), some form of disposal becomes necessary. In this context, IFDM becomes an attractive option. Management actions at IFDM sites that avoid or minimize avian exposure to selenium are discussed. During this study, as a direct result of preliminary best management practices recommendations provided to site operators, the documented rates of embryo deformity decreased by an order-of-magnitude.

INTRODUCTION

The San Joaquin Valley of California is a semi-arid area characterized by high evapotranspiration that is extensively irrigated with water imported from the Sacramento/San Joaquin Delta. The west-side and southern end of the Valley is often poorly drained, and soil salinization and infiltration of saline water into the root zone of crops affects a significant portion of the area. One option available to growers is installing subsurface tile drains to remove the saline groundwater; however, this water often contains high concentrations of metals and metalloid elements along with the salts and disposal of the drainage water is an issue. A chief element of concern, often present in concentrations shown to have ecotoxicological significance, is selenium (Se).

This region includes more than one million acres (405,000 ha) of irrigated agricultural land projected to require drainage of saline and seleniferous (selenium-laden) shallow groundwater by the year 2010 (San Joaquin Valley Drainage Program, 1990). The total projected volume of drainage water requiring disposal is 1.8 million acre-feet per year (Moore et al., 1990).

Originally, plans for disposing of this potentially toxic wastewater relied on a master drain to the Pacific Ocean for the upper San Joaquin Valley (Interagency Drainage Program, 1979) and on large acreages of evaporation basins for the lower San Joaquin Valley (Moore et al., 1990). By the early 1980's, final construction work on the U.S. Bureau of Reclamation's (Reclamation) master drain was stalled due to increasing political opposition over proposed discharge points. In the mid-1980's, the subsequent discovery of selenium-induced wildlife mortality at Kesterson Reservoir (the master drain's interim discharge point) decisively ended what were already slim chances of completing the master drain to the delta (Clemings, 1996).

Likewise, the discovery of selenium-induced wildlife mortality at evaporation basins in the southern San Joaquin Valley (i.e., Tulare Lake Basin) during the late 1980's has resulted in a functional moratorium on construction of new evaporation basins. Since 1990, the total acreage of evaporation basins declined from about 7,000 acres to about 5,000 acres instead of expanding to the 30,000 acres that had been projected by 1998 (Tanji and Grismer, 1988). It is now apparent that the ultimate acreage of evaporation basins will never approach more than a tiny proportion of the 164,000 acres (66,000 ha) projected for the year 2010 if evaporation basins were the primary means for disposing of agricultural drainage water (Moore et al. 1990).

Nevertheless, the need for subsurface agricultural drainwater disposal remains, and is rapidly approaching a crisis point. Between 1991 and 1997 the acreage of land in the southern San Joaquin Valley with shallow groundwater rising to within 5 feet of the soil surface increased from 159,000 acres (64,000 ha) to 359,000 acres (145,000 ha) (California Department of Water Resources, 1997). Thus, within those 6 years, an additional 200,000 acres (81,000 ha) of agricultural lands were added to the inventory of parcels requiring a disposal option for drainage water in order to stay in production. Currently, Reclamation is undergoing environmental review and planning to provide drainage service for the San Luis Unit (spanning several water districts and including nearly 400,000 acres of land needing drainage disposal).

The most feasible disposal alternative to evaporation basins at present is the irrigation of various combinations of salt tolerant crops, shrubs, and trees with drainage wastewater. At the inception of these plans, eucalyptus trees were commonly utilized, and thus the practice was termed "agroforestry," since these trees in turn provided a potentially marketable crop. During the past fifteen years, agroforestry plantations have increasingly been utilized as an alternative to evaporation basins for the disposal of seleniferous agricultural wastewater (Figure 1). This option is one of the featured alternatives of the final report for the San Joaquin Valley Drainage Program (San Joaquin Valley Drainage Program, 1990), and more than 40 agroforestry drainage water disposal sites have been established since 1985 (Moore et al., 1990).

Most existing agroforestry sites are relatively simple systems consisting of nothing more than a contiguous block (or multiple blocks) of eucalyptus trees utilized to evapotranspire (via irrigation) about 5 acre-feet of drainage waste water per acre per year. The most elaborate management configurations incorporate salt tolerant traditional crops (such as cotton), non-traditional halophyte crops (such as pickleweed), eucalyptus trees, and small terminal solar evaporators with sequential recovery and re-use of drainage waste water (Skorupa, 1998a). These more elaborate systems are referred to as IFDM (Integrated On-Farm Drainage Management), and are also termed drainage "reuse facilities."

Given current trends in rising ground water elevations and the general lack of acceptable disposal options other than agroforestry sites, it is expected that the expansion of agroforestry sites will exponentially accelerate within a 5-10 year planning horizon. Current projections have up to 19,000 acres of IFDM planned for the San Luis Unit of the San Joaquin Valley alone. Although it has been established that agroforestry plantations (like evaporation basins) are wildlife magnets in the extensively cultivated landscape of the San Joaquin Valley (Moore et al., 1990), the potential for contaminant hazards remained poorly documented prior to the inception of this (and other concurrent) investigations.

During 1996, staff from the Sacramento Fish and Wildlife Office Environmental Contaminants Division (SFWO-ECD) collected a small set of waterbird eggs from two agroforestry sites. These samples yielded the highest rates of selenium-induced teratogenesis (embryo deformities) ever reported in the scientific literature (Skorupa, 1998a), and established that the method of furrow irrigation being used was attracting breeding waterbirds. More than 56 percent of 30 assessable embryos were deformed at one site, and both sites that were sampled yielded avian eggs exceeding 25 *u*g Se/g DW (dry weight). The threshold value for embryotoxic effects is only 6 *u*g Se/g DW (Skorupa, 1998a).

Both the bioaccumulation factors for selenium in avian eggs and the exposure-response data for assessable embryos at the two sampled agroforestry sites were consistent with statistical (predictive) relationships rigorously established for seleniferous drainage water in evaporation basins. Despite implementation of wildlife management plans intended to eliminate avian nesting in 1997 by the site managers at the two agroforestry sites sampled in 1996, additional eggs were found by SFWO-ECD staff during brief site visits in the spring of 1998.

These findings highlighted the urgent need for a broad scale assessment of wildlife use of agroforestry sites prior to any further substantial expansion of agroforestry acreage in the San

Joaquin Valley. Such an assessment would determine wildlife exposure to selenium at agroforestry sites, wildlife response to selenium exposure at agroforestry sites, and provide a starting point for formulating potential mitigation strategies. These are the specific objectives of the study reported herein.

METHODS

Data Collection and Analysis

For purposes of risk assessment within this study, avian eggs were chosen for biomonitoring. There are numerous reasons why avian eggs are the optimal matrix for assessing selenium hazards to wildlife (Skorupa, 1998b). Birds are generally sensitive to selenium exposure and eggs—reflecting a period of rapid tissue growth and differentiation—are a sensitive life-stage. The egg provides a very standardized embryonic exposure environment, an easily quantifiable exposure unit, a uniform age of initial exposure, a relatively uniform duration of exposure, and a standardized season of exposure. Unlike other taxa and life stages, avian eggs have little potential to be compromised by survivor-bias (the differential probability of sampling survivors of contaminant exposure) because reproductive impairment occurs at levels of exposure to selenium far below the levels required to cause hen mortality (Heinz, 1996), and eggs with dead or live embryos are equally likely to be sampled by biologists. In contrast, biomonitoring studies utilizing fish, small mammals, or adult birds often inherently bias collections toward sampling only surviving individuals.

Avian reproductive activity at agroforestry sites was quantified using nest searching and nest monitoring techniques well developed via previous selenium investigations (e.g., Ohlendorf et al., 1989). Nest searches were conducted weekly at each site. Species composition and reproductive performance of breeding populations were recorded via standard nest card methods for ground-nesting birds (e.g., Klett et al., 1986) with modifications appropriate for tree-nesting birds (such as the use of telescoping poles with mirrors attached, etc.). Embryo assessments followed procedures used for past evaporation basin studies (e.g., Skorupa, 1998b). All samples were analyzed for selenium by hydride generation atomic absorption spectroscopy (HGAA). A subset of samples were analyzed for metals by inductively-coupled plasma emission spectrometry (ICP scan), for lead by graphite furnace AA, for mercury by cold vapor AA, and for arsenic by HGAA. All tissue values reported are on a dry weight basis.

A range of agroforestry sites was monitored for nesting activity over three seasons. These sites were selected to be representative of existing site management configurations, size and age of tree plantations, and chemical composition of drainage water used for irrigation. Initially, only one egg per clutch was randomly sampled for embryo assessment and analysis. In instances where nesting activity was limited and incidences of deformity indicated that complete reproductive failure was a likely nest fate, additional eggs were salvaged from the clutch. Whenever possible, mid to late stage eggs were collected to maximize the number of samples with assessable embryos.

RESULTS

To date, 15 species of migratory birds have been documented to nest at agroforestry study sites. Nearly 300 avian eggs were randomly sampled for either chemical analysis or effects assessment. Of these sites monitored, four different agroforestry sites are included. Eggs have been collected from all trophic groups represented at the study sites except for raptors; however, pellet castings have been collected from two species on the state of California's sensitive species list, burrowing owl (*Althene cunicularia)* and Swainson's Hawk (*Buteo swansoni*). Both the burrowing owl pellets and the Swainson's hawk pellets contained less than 2 *u*g Se/g DW (dry weight).

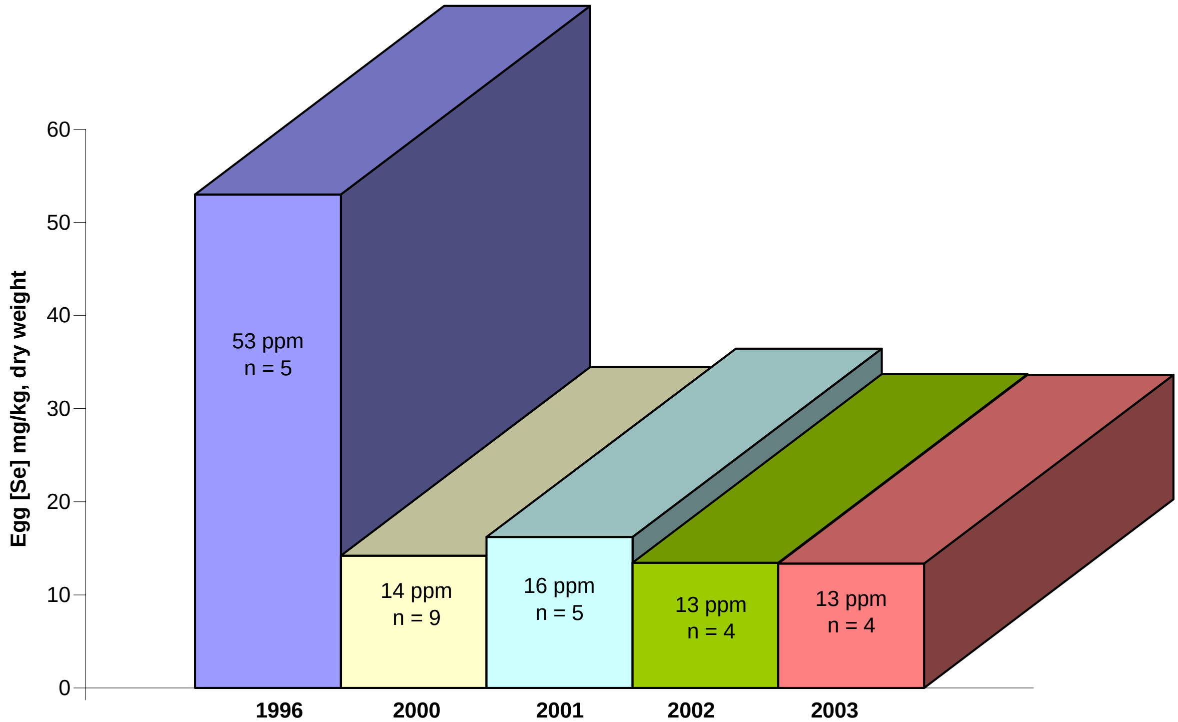
Avian nests have also been located and sampled in every habitat component of the integrated sequential water use type of IFDM plots—proving that these sites are capable of attracting both foraging and nesting birds. Selenium-typical, embryonic deformities were documented among nesting shorebirds, along with instances of highly elevated egg selenium concentrations. Nesting activity varied by site, as evidenced by the relative success of varied field biologists in finding and collecting eggs from the various sample sites. Site-specific results are presented in the sections following.

Red Rock Ranch Demonstration IFDM Site

Baseline sampling of the Redrock IFDM project in 1996 (when the site was being operated solely based on best engineering and agronomic practices) revealed the highest rate of selenium poisoning among breeding shorebirds ever documented—confirming that drainwater reuse areas pose an imminent risk to nesting avifauna. As a result of adaptive incorporation of design features intended to minimize exposure of breeding birds to drainage water, embryo deformity rates were reduced from 57 percent in 1996 to 5.6 percent in 2000, and down further to 0 percent in 2001. The field season of 2002 yielded a deformity rate of 50 percent in stilts; however, this reflects 1 of only 2 assessable embryos collected that year.

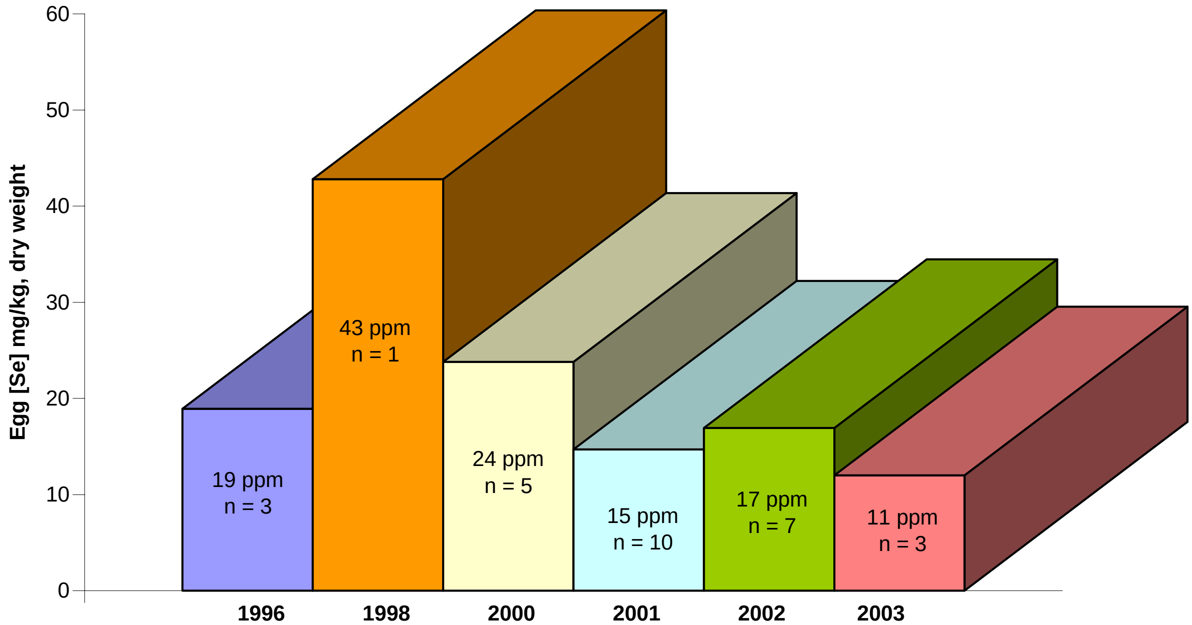
Figure 1 displays geometric mean selenium concentrations in randomly sampled eggs from black-necked stilt (*Himantopus mexicanus*) nests collected during five seasons at the Red Rock Ranch IFDM site. Concentrations in eggs ranged from a high of 53.0 *u*g Se/g DW in 1996 to considerably lower values (ranging around 14 *u*g Se/g DW) during the remaining four seasons in which monitoring was conducted.

Figure 1: Geometric Mean Selenium Concentrations in Black-Necked Stilt Eggs, Red Rock Ranch (Diener Farms, CA)



Eggs from another shorebird species—killdeer (*Charadrius vociferus*)—contained elevated concentrations of Se, though generally not as high as those recorded in 1996 for stilts. These data are presented in Figure 2. Killdeer eggs often contained under 20 *u*g Se/g DW, though sample sizes (for single random eggs per clutch) are low for purposes of statistical inference. Including all eggs collected (which incorporates multiple eggs per clutch) does not appreciably change the results (albeit this only significantly increases the sample size within species and year in roughly half the instances). Nevertheless, it is apparent that selenium exposure for black-necked stilts and killdeer (two shorebird species that forage upon similar invertebrate species) has shown differing patterns over time at the Red Rock site.

Figure 2: Geometric Mean Selenium Concentrations in Killdeer Eggs, Red Rock Ranch (Diener Farms, CA)



Eggs from passerine species (those for which nests were located and samples collected) generally exhibited lower geometric mean selenium concentrations when compared to shorebirds. Some of the more ubiquitous species included the granivorous house finch (*Carpodacus mexicanus*) through the slightly more omnivorous house sparrow (*Passer domesticus*) to Brewer's (*Euphagus cyanocephalus*) and red-winged blackbirds (*Agelaius phoeniceus*), and finally the aerial insectivore, the Western kingbird (*Tyrannus verticalis*). With the exception of Western kingbird and red-winged blackbirds during 2000, geometric mean selenium concentrations in all species and years were near or below 5 *u*g Se/g DW. Data from these species are presented in Figures 3-7, following.

Figure 3: Geometric Mean Selenium Concentrations in Western Kingbird Eggs, Red Rock Ranch (Diener Farms, CA)

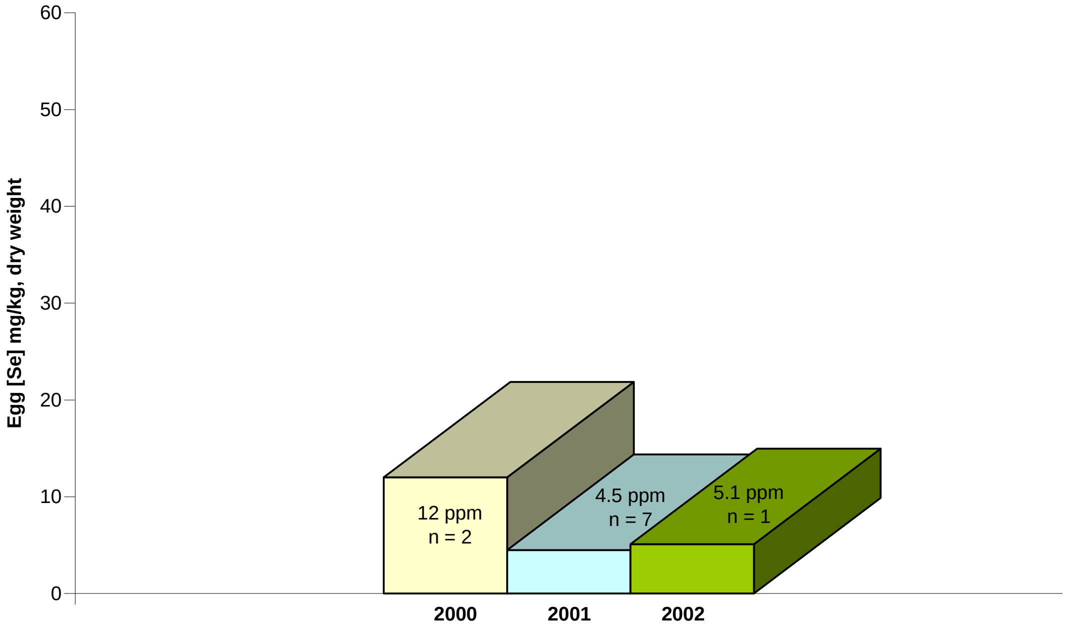


Figure 4: Geometric Mean Selenium Concentrations in House Sparrow Eggs, Red Rock Ranch
(Diener Farms, CA)

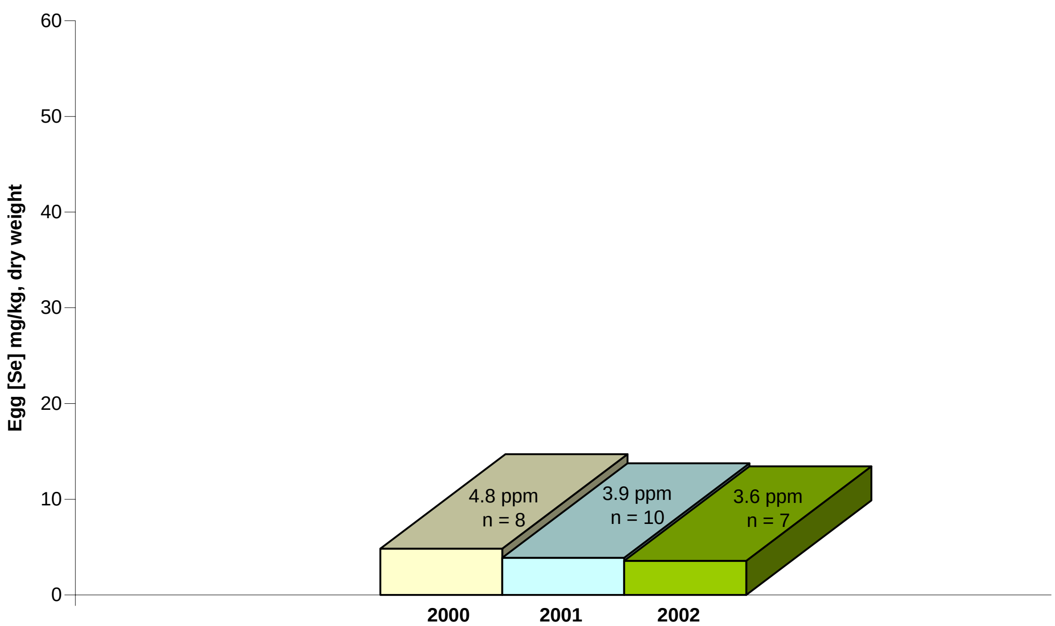


Figure 5: Geometric Mean Selenium Concentrations in Brewer's Blackbird Eggs, Red Rock Ranch (Diener Farms, CA)

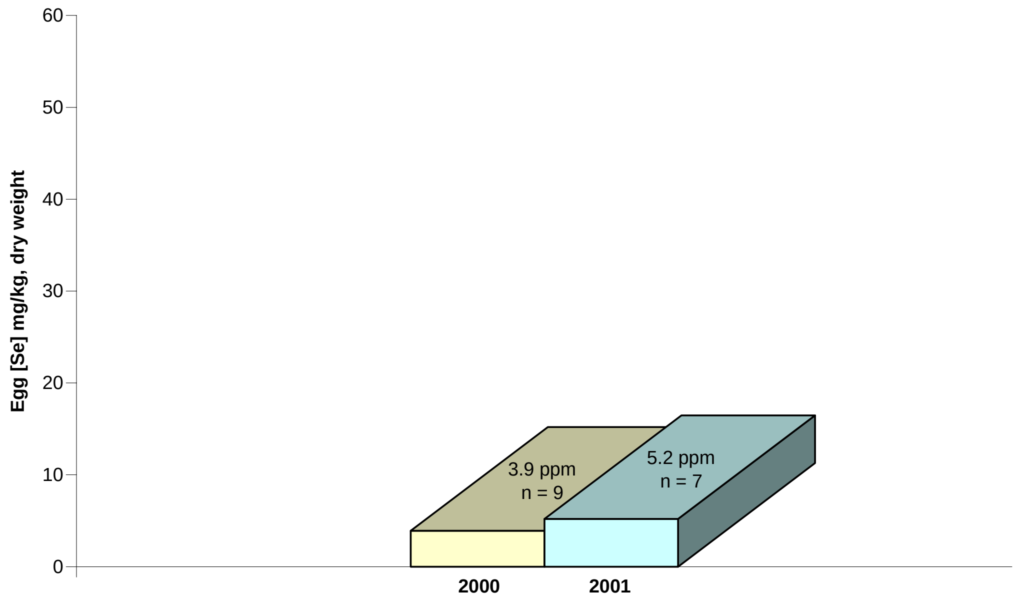


Figure 6: Geometric Mean Selenium Concentrations in Red-Winged Blackbird Eggs, Red Rock Ranch (Diener Farms, CA)

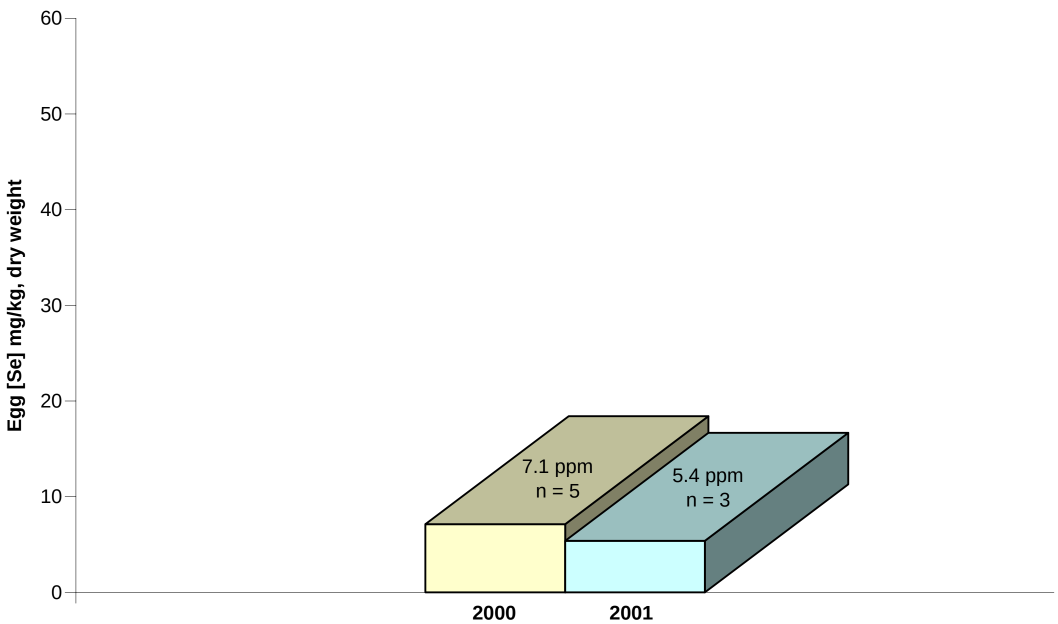
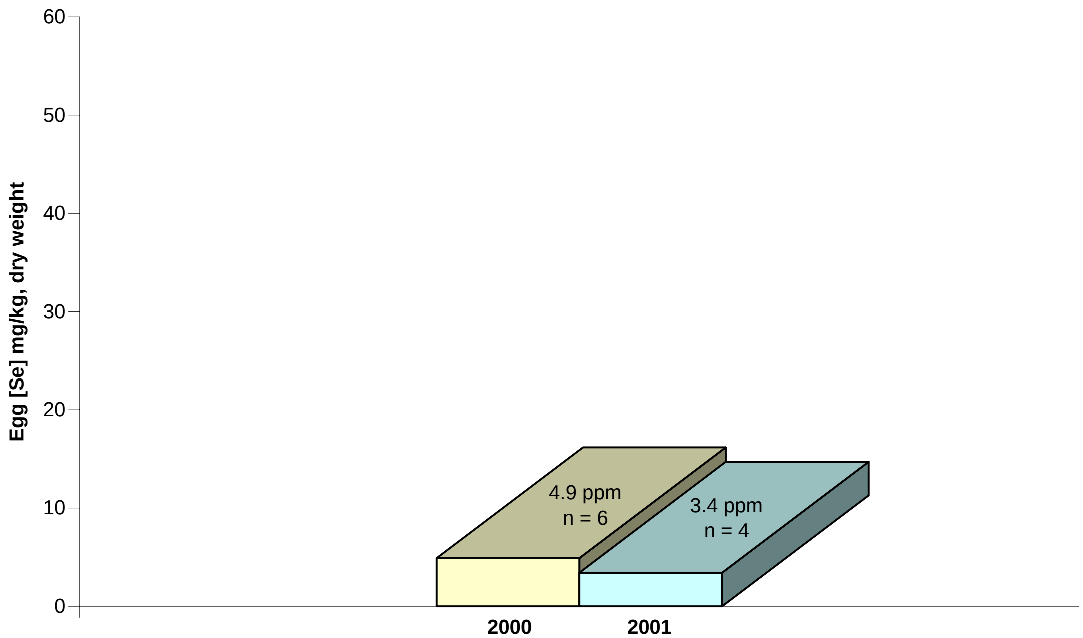


Figure 7: Geometric Mean Selenium Concentrations in House Finch Eggs, Red Rock Ranch (Diener Farms, CA)



Ten percent (1 in 10) of assessable embryos from Brewer's blackbird nests exhibited a deformity; however, embryonic abnormalities were not observed in other passerine species for the duration of the study. Specific rates of teratogenesis in avifauna (all years pooled) included: 15 percent in black-necked stilts (8 of 53), 3 percent in killdeer (1 of 35), 0 percent in American robin (0 of 1), 10 percent in Brewer's blackbirds (1 of 10), 0 percent in brown-headed cowbird (0 of 1), 0 percent in house finches (0 of 3), 0 percent in house sparrows (0 of 6), 0 percent in Loggerhead shrike (0 of 3), 0 percent in red-winged blackbirds (0 of 1), and 0 percent in Western kingbirds (0 of 2). Readers are referred to Appendix A for specific data (enumerated by sample) documenting embryo condition and specific residues in tissues.

Mendota Agroforestry Plot

A total of four eggs were collected from the Mendota Agroforestry site. These included one black-necked stilt egg (31 *u*g Se/g DW), one killdeer egg (5.7 *u*g Se/g DW), and two Western kingbird eggs (9.1 and 9.4 *u*g Se/g DW, respectively). All of these eggs contained assessable embryos, and all four were classified as live normal.

Panoche In-Valley Treatment Site

A total of five eggs were collected from the Panoche IFDM facility during 2001. In two Brewer's blackbird eggs (7.2 and 15 *u*g Se/g DW, respectively) and a single loggerhead shrike egg (7.3 *u*g Se/g DW), all embryos were assessed as live normal. The remaining eggs were from a mallard (*Anas platyrhynchus*; 6.5 *u*g Se/g DW) and Western kingbird (5.5 *u*g Se/g DW), and did not contain embryos of sufficient developmental stage for assessment.

Rainbow Ranch Evaporation Complex

A single black-necked stilt nest was located at the Rainbow Ranch evaporation complex (pond plus IFDM site) during 2001. The stilt nest was located in a newly planted cotton field adjacent to the actual IFDM plots. The adult birds tending this nest were observed foraging in the IFDM-associated open sumps. What proportion of their foraging time was spent at the IFDM sumps is unknown (the sumps are relatively small). It contained an early stage (unassessable) embryo with 6.4 *u*g Se/g DW. Results from monitoring at the Rainbow Ranch site were very encouraging, in that during two field seasons (2001-2002) H.T. Harvey & Associates did not find any nesting activity at the site, and State and Federal agency monitoring found only one nest.

Regional Reference Sites

In addition to the systematic searches of area IFDM facilities, reference eggs were collected from regional sites known or suspected to contain elevated concentrations of selenium. Collections were made at the Britz-Deavenport Farms evaporation pond complex, and from a groundwater seep located near a cotton gin along Mount Whitney Avenue. Reference eggs were also collected from sites along the California Aqueduct and from the Coalinga sewage ponds at Highway 198. Eggs from these sites spanned the gamut from background selenium concentrations to highly elevated selenium concentrations and confirmed deformities (data presented in Appendix A).

DISCUSSION

Risk Assessment

Taxa or species-specific data can be assessed with measured or extrapolated risk thresholds as follows.

Shorebirds:

Shorebird (stilt and killdeer) eggs from Red Rock Ranch IFDM site ranged from 3.9 *u*g Se/g DW to 82 *u*g Se/g DW (n = 124) during all years (spanning 1996-2003). The threshold for hatchability effects in these genera is considered by the Service to be between 6-7 *u*g Se/g DW. All but three eggs from these species collected from Red Rock exceeded this threshold. A single killdeer egg collected from Mendota Agroforestry Plot measured 5.7 *u*g Se/g DW, while a stilt from the same site contained 31 *u*g Se/g DW.

Mallards:

A mallard egg collected from the Panoche facility contained 6.5 *u*g Se/g DW. The most recent analysis of experimental laboratory data for mallards (Ohlendorf, 2003) suggests that at 12.5 *u*g Se/g DW in the egg there is a 10 percent depression in egg hatchability. Field data for mallards collected by FWS (N > 1,000 eggs) suggests that at about 6 *u*g Se/g DW in the egg there is about a 6 percent depression in egg hatchability.

Fairbrother et al. (2000) argue that about 16 *u*g Se/g DW in the eggs is required to cause a 10 percent depression in egg hatchability. The difference between Ohlendorf (2003) and Fairbrother et al. (2000) analyses of experimental laboratory data for mallards is probably related to Ohlendorf basing his analysis on nearly twice as many laboratory data points.

Brewer's Blackbird:

Among 17 Brewer's blackbird eggs randomly collected at the Red Rock demonstration site in 2000-2001, the highest selenium concentration was 11 *u*g/g DW (values ranged from 2.6 to 11 *u*g/g). The highest red-winged blackbird egg at Red Rock contained 8.8 *u*g Se/g DW (n = 8). At the Panoche facility, two Brewer's blackbird eggs collected contained 7.2 and 15 *u*g Se/g DW.

The sensitivity of blackbirds to selenium is unknown. In the absence of more specific information, any eggs exceeding 10 *u*g Se/g DW should be considered a matter of concern, until proven otherwise. Eggs below 6 *u*g Se/g DW, should be considered safe until proven otherwise. These benchmarks represent a range of sensitivities from other avian species based on established dose-response curves from a robust empirical database. Among both blackbird species and all eggs randomly collected from Red Rock Ranch during this investigation, 17 eggs (68 percent) were below the safe threshold, and 1 (4 percent) egg contained sufficient selenium to be of concern.

Western Kingbird:

Among ten kingbird eggs collected at Red Rock in 2000 and 2001, individual samples contained between 4.2 and 13 *u*g Se/g DW. Two kingbird eggs collected at the Mendota Agroforestry demonstration site in 2000 contained 9.1 and 9.4 *u*g Se/g DW. A single egg collected from the Panoche facility contained 5.5 *u*g Se/g DW. Four kingbird eggs collected by the California Department of Fish and Game (CDFG) from Westlake Farms agroforestry plot in 1991 contained 4.2-6.2 *u*g Se/g DW.

The sensitivity of kingbirds to selenium is unknown. In the absence of more specific information, any eggs exceeding 10 *u*g Se/g DW should be considered a matter of concern, until proven otherwise. Eggs below 6 *u*g Se/g DW, should be considered safe until proven otherwise. In total, 80 percent of our randomly sampled eggs from Red Rock IFDM were below the safe threshold, while two eggs (20 percent) exceeded the level of concern.

Loggerhead Shrike:

During 1998 thru 2000 a total of 18 shrike eggs were collected in or adjacent to Kesterson Reservoir. They contained as little as 1.6 *u*g Se/g DW and as much as 14 *u*g Se/g DW (CH2M Hill, 2001). Shrikes were sampled at Red Rock for the first time in 2001, and contained from 3-6.3 *u*g Se/g DW. A single shrike egg from the Panoche reuse facility contained 7.3 *u*g Se/g DW.

The sensitivity of shrikes to selenium is unknown. Other carnivorous species of birds (e.g., screech owls, kestrels, etc.) appear to be less sensitive to selenium than mallards, chickens, and some species of shorebirds (such as killdeer and stilts). The value of 7.4 *u*g/g reported for the Panoche shrike egg is certainly elevated, probably on the order of about 3 times as high as would be expected for a selenium-normal shrike egg, but should be considered unlikely to present appreciable reproductive risk, until proven otherwise.

Raptor Pellets:

Concentrations of selenium in burrowing owl and Swainson's hawk pellets collected and analyzed from the Panoche facility were below detection limits (<2 *u*g Se/g DW), and appear to reflect minimal, if any, elevated selenium exposure. The Panoche burrowing owl pellets contained about the same concentration of selenium as burrowing owl pellets collected from within the city limits of Davis, CA, where selenium exposure should not be elevated.

Based on these limited results, a minimal degree of risk (<10 percent effect) seems very likely for mallards and blackbirds. A relevant question to ask here, is, to what extent this risk is associated with the project as opposed to being the general background risk of having a network of open agricultural drainage ditches in operation (as would probably be the case even without the project). The kingbird and shrike eggs are not likely indicative of any direct reproductive risk, and probably provide a baseline against which to monitor the projects in upcoming years. In the case of shorebirds (higher order consumers within the aquatic food web), it is clear that nesting pairs in at least one site would be expected to incur reproductive losses.

This investigation has confirmed that agroforestry or IFDM sites are not without attendant risks. The sites have clear utility as nesting substrate and foraging habitat for avifauna, and by design concentrate drainwater constituents that may include selenium concentrations of ecotoxicological significance. That these sites are potentially unsafe for avifauna seems quite evident. However, the question regarding the relative utility of this particular drainwater management option is more a function of realized risk to wildlife in light of the available alternatives. Short of management alternatives that preclude the generation of seleniferous drainwater in the first place (i.e., maximizing irrigation efficiency and/or land retirement), some form of disposal becomes necessary. In this context, IFDM becomes an attractive option.

Preliminary calculations indicate that current operating practices at IFDM sites have reduced wildlife risks by about 80 percent compared to the alternative of operating a traditional evaporation basin to dispose of drainage water.

IFDM Management Considerations

Results from this investigation provide useful insights to inform future IFDM management and design. In general, management actions that minimize surface water (including ponded water, flooded furrows, and even exposed sumps and ditches) are helpful in reducing the development of an aquatic food web, and therefore bioaccumulation and exposure to elevated dietary selenium. In turn, sensitive avifauna are simply not attracted to these sites as breeding habitat. Similarly, any unnecessary features that provide cover or nesting substrate to attract breeding birds should be eliminated or minimized to the maximum practical extent.

The observation that stilts and killdeer exhibited differing exposure profiles at the Red Rock demonstration IFDM site highlighted the need for better management of the tailwater sump and tailwater ditches. Most of the improvement in the reproductive performance and chemistry data for stilts at the site is probably a direct result of the avoidance of the use of flood and furrow irrigation in the halophyte zone. The switch in ranks of stilts and killdeer between 1996 and 2000 probably reflects that due to better management of drainage water in the halophyte plots and solar evaporator, the highest risk is now associated with sumps and ditches.

Our avian monitoring has revealed the importance of designing features into the project that allow for quick draining and isolation of standing surface water, even if it originates from rainfall. Such pools are capable of supporting food webs sufficient to bioconcentrate selenium and attract foraging avifauna, and should therefore be minimized during the operation of all IFDM facilities.

Our monitoring has also revealed that habitat features favoring seed-eating passerine birds over shorebirds, aerial insectivores, or litter foraging species tends to present a significantly reduced risk of selenium poisoning. Unnecessary physical structures (such as stacks of baled hay near IFDM sites) can significantly increase the numbers of nesting birds attracted to the site, while tall grasses or vegetation with a similar physical structure appear to minimize wildlife risks.

Future Monitoring Needs

The improved results from management modifications at Red Rock Ranch, and the very limited nesting activity observed for the Rainbow Ranch system, indicate that well-managed IFDM sites have the potential to limit avian nesting activity, and therefore wildlife risk; however, because habitat conditions will likely change as a site matures, continued monitoring is advisable. There is also the potential for unanticipated events, which may lead to new exposure pathways or modified foraging behavior by area wildlife.

During the course of this investigation, a new development arose, reaffirming the need to assess all contaminant exposure pathways at agroforestry sites. In the late summer of 1999 it was reported for the first time that an unusually high level of passerine foraging activity was being noted among eucalyptus groves in California. Upon closer examination, it was found that large aggregations of birds were feeding on the “sugar pills” provided by a recently-arrived insect invader, a small homopteran called the red gum lerp psyllid (*Glycaspis brimblecombei*). Red gum lerp psyllids were first noted infesting eucalyptus trees in California in 1998 (CPPDR 1998). The nymphs of these small, winged bugs feed on eucalyptus leaves, where they secrete aphid-like "honeydew". The honeydew crystallizes into small, white cones (called "lerps") that cover the nymphs on the leaf. These little white "sugar pills" have proven highly attractive to both resident and migratory birds (including neotropical migrants). The result, as reported in a recent issue of the Sacramento Audubon Chapter's newsletter (*The Observer*) is that eucalyptus groves infested with red gum lerp psyllids have turned into "... a three-ringed circus of birds gorging on lerps." Early risk assessments conducted for the San Joaquin Valley agroforestry program found that the highest selenium concentrations in plantation trees occurred in the eucalyptus sap as opposed to the leaves or wood or seeds (Moore et al., 1990).

It is likely that "lerps" are essentially composed of concentrated eucalyptus sap and such processed sap is probably highly concentrated in selenium. Consequently, the recent introduction of red gum lerp psyllids to California eucalyptus groves may have created a new and very potent dietary pathway for selenium exposure of neotropical migrants and other passerine birds residing in and passing through the Central Valley and San Francisco Bay Eco-Region. Initial fieldwork confirmed that at least some of the study sites have been colonized by the red gum psyllid lerp.

Unfortunately, attempts to sample lerps at our study sites were frustrated by analytical constraints and inadequate psyllid densities, making it impractical to find and then collect adequate biomass for chemical determination using the currently accepted methodologies. It is possible that spraying for psyllid control reduced densities at the sites, or indeed some other mechanism (e.g., predation) may have contributed to limit their numbers (Dahlsten et al., 1998). Risks associated with eucalyptus plantations and IFDM continue to be a real possibility, although these remain unquantified to date.

Mitigation for IFDM Associated Wildlife Losses

Documented and realized wildlife losses associated with IFDM operations are limited to effects upon breeding avifauna. Given that, it is reasonable to apply mitigation based on the USFWS Compensation Habitat Protocol (USFWS, 1995) in a relatively unmodified form. In general, this means that the production lost by birds nesting at a given reuse facility will be estimated by observed nesting densities and egg selenium concentrations. In some instances where nesting activity is extremely limited or non-existent (e.g., Rainbow Ranch Evaporation Pond Complex), periodic breeding season monitoring to validate performance may be adequate. In cases where nesting activity has been reliable (e.g., Red Rock Ranch IFDM), quantitative data are available to estimate habitat utility (attractiveness as measured by nest density). These data may be compared to historic values from representative mitigation habitats, or empirical data from the specific compensation habitat provided in association with reuse facilities. In either case, realized nest densities for the most susceptible species (aquatic birds) are likely to remain low enough under best management practices that habitat needs for mitigation should be easily attainable for reuse facility operators. Appendix B presents the full Compensation Habitat Protocol as applied to evaporation basins.

ACCOMPLISHMENTS

Management Action(s)

Results from the fieldwork associated with this study have informed the regulatory process and agricultural management well in advance of the release of this report.

The Service has already had a significant impact on management actions at evaporation basins through direct coordination with basin operators and regulatory agencies. Over the first two field seasons of this study, and as a direct result of preliminary Best Management Practices recommendations provided to site operators, the documented rates of embryo deformity have decreased by an order-of-magnitude.

Chemical and operational mitigation criteria described above can be incorporated into state regulatory permits (Waste Discharge Requirements) for agroforestry sites. Such actions would follow the regulatory model already established over the past decade for drainage water evaporation basins (California State Water Resources Control Board, 1996). Providing sound science to inform drainage and wildlife management is particularly critical for the local agricultural community and state regulators because of anticipated increases in the volume of drainage water requiring disposal. This is also particularly important in light of the exemption of agricultural drainwater from regulation under the Clean Water Act.

The experience and information generated during the course of this and related work by the Service and cooperating partners were instrumental in framing the formulation and development of California SB 1372—legislation requiring the development of specific regulations on the design, construction, and operation of solar evaporators as components of IFDM. Senate Bill 1372, the Agricultural Water Conservation and Management Act, was approved by the Governor in September 2002, and offers an exemption from certain state regulations for agroforestry operations that are operated according to environmentally safe criteria. Substantive portions of the criteria for environmental safety are based on the findings of this study over the first 2 years of fieldwork.

SB 1372 provides a legislative endorsement (and regulatory incentive) in favor of the use of agroforestry over evaporation ponds for disposal of agricultural drainage water—a move that data from this study has documented would reduce wildlife losses from exposure to agricultural drainage water by more than 80 percent. The text of SB1732 is attached as Appendix C. The Service later provided specific input to the State Water Resources Control Board during their implementation of SB 1372. These recommendations as submitted to the Board are attached as Appendix D.

Outreach

The early results from the monitoring at Red Rock Ranch have been so impressive that the San Francisco Estuary Project chose to feature IFDM projects as an example of a “success story” at a March 2001 conference they sponsored titled, “Beyond the Drain: Sustaining Agriculture and Improving Water Quality in California's San Joaquin Valley". The Service made a presentation at this event summarizing the results to date. In addition, presentations of preliminary findings from this study were presented at the University of California Salinity/Drainage Program annual meeting (Sacramento, CA) in late March, 2002, and at The Wildlife Society's Western Section annual meeting (Visalia, CA) in early March, 2002.

In December of 1999, John Diener, landowner for the Red Rock Ranch in the Five Points area of the San Joaquin Valley was presented the Governor's Environmental and Economic Leadership Award for his pioneering commitment to IFDM and efforts towards land reclamation, irrigation efficiency, and drainage reduction. Mr. Diener's site was invaluable to the current investigation. His cooperation and willingness to modify management of the system in light of ongoing discoveries were an inherent part of this success story. An article from *Almond Facts* is attached as Appendix E. Mr. Diener was subsequently recognized as "Irrigator of the Year" by *California Grower* Magazine. Recently, the success story of IFDM and Red Rock Ranch appeared in an *Out and About* article (Spring 2004). A copy of this article is attached as Appendix F.

Partnerships

The California Department of Water Resources (John Shelton, Julie Vance) provided substantial cooperative investment in this study. CDWR provided 2 FTE's (one senior biologist, and one technician) to facilitate data collection, logistical arrangements, and liaison with the farmers cooperating with the study. These contributions were a significant benefit to the project.

The California Department of Food and Agriculture (Dr. Vashek Cervinka) , California Department of Fish and Game (Mr. Frank Wernette), California Regional Water Quality Control Board-Central Valley Region (Mr. Anthony Toto) and Westside Resource Conservation District (Mr. Red Martin) funded parallel studies that provided ancillary data on contaminant levels in water, sediment/soil, vegetation, food chain organisms, reptiles, amphibians, and mammals. In addition, the U.S. Bureau of Reclamation funded detailed monitoring of operational performance of solar evaporators at two agroforestry demonstration sites. This study was closely coordinated with the efforts of the above mentioned agencies to the greatest extent possible, and unrestricted data sharing between agencies was a prominent feature of this project.

These agencies (especially the Regional Board and Department of Food and Agriculture) were instrumental in arranging Service access to agroforestry sites. The site managers (private farmers) and State agencies were committed to working with wildlife specialists (Service and California Department of Fish and Game) to identify and, if possible, resolve wildlife hazards associated with drainage water disposal at agroforestry sites. These studies were on the same order of magnitude as our avian component.

REFERENCES

California Department of Water Resources. 1997. Tulare Basin resources assessment -- preliminary report. Memorandum Report, San Joaquin District, Fresno, CA.

California State Water Resources Control Board. 1996. Petitions regarding Tulare Lake evaporation ponds. Staff Technical Report, Sacramento, CA.

Clemings, R. 1996. *Mirage: The False Promise of Desert Agriculture*. Sierra Club Books, San Francisco, CA.

CPPDR. California Plant Pest and Disease Report. 1998. New State Records. California Dept. of Food and Agriculture, 17(1-3): 4-10.

Dahlsten, D.L., D.L. Rowney, W.A. Copper, R.L. Tassan, W.E. Chaney, K.L. Robb, S. Tjosvold, M. Bianchi, and P. Lane. 1998. Parasitoid wasp controls blue gum psyllid. California Agriculture, 52(1):31-34.

Fairbrother, A. et al. 2000. Egg selenium thresholds in birds: A response to J. Skorupa's critique of Fairbrother et al., 1999. Human and Ecological Risk Assessment, 6:203.

Heinz, G.H. 1996. Selenium in birds. Pp. 453-464 <u>in</u> W.N. Beyer, G.H. Heinz, and A.W. Redmon, (eds.), *Interpreting Environmental Contaminants in Animal Tissues*. Lewis Publishers, Boca Raton, FL.

Interagency Drainage Program (IDP). 1979. Agricultural drainage and salt management in the San Joaquin Valley. U.S. Bureau of Reclamation, California Department of Water Resources, and California State Water Resources Control Board, Sacramento, CA.

Klett, A.T., H.F. Duebbert, C.A. Faanes, and K.F. Higgins. 1986. Techniques for studying nest success of ducks in upland habitats in the Prairie Pothole Region. Resource Publication 158. U.S. Fish and Wildlife Service, Washington, DC.

Moore, S.B., J. Winckel, S.J. Detwiler, S.A. Klasing, P.A. Gaul, N.R. Kanim, B.E. Kesser, A.B. DeBevec, K. Beardsley, and L.K. Puckett. 1990. Fish and wildlife resources and agricultural drainage in the San Joaquin Valley, California (two volumes). San Joaquin Valley Drainage Program, United States Bureau of Reclamation and California Department of Water Resources, Sacramento, CA.

Ohlendorf, H.M. 2003. Ecotoxicology of Selenium. Pp. 465-500 <u>in</u> D.J. Hoffman, B.A. Rattner, G.A. Burton Jr., and J. Cairns Jr. (eds.) *Handbook of Ecotoxicology, Second Edition*. Lewis Publishers, Boca Raton, FL.

Ohlendorf, H.M., R.L. Hothem, and D. Welsh. 1989. Nest success, cause-specific nest failure, and hatchability of aquatic birds at selenium-contaminated Kesterson Reservoir and a reference site. *Condor*, 91:787-796.

San Joaquin Valley Drainage Program. 1990. A management plan for agricultural subsurface drainage and related problems on the westside San Joaquin Valley. U.S. Department of Interior and California Resources Agency.

Skorupa, J.P. 1998a. Selenium poisoning of fish and wildlife in nature: Lessons from twelve real-world examples. Pp. 315-354 *in*: W.T. Frankenberger, Jr., and R.A. Engberg (eds.), *Environmental Chemistry of Selenium*. Marcel Dekker, New York, NY.

Skorupa, J.P. 1998b. Risk assessment for the biota database of the National Irrigation Water Quality Program. Technical Report. U.S. Fish and Wildlife Service, Sacramento Fish and Wildlife Office, Sacramento, CA.

Tanji, K.K., and M. Grismer. 1988. Evaporation ponds for the disposal of agricultural waste water. Final Report to the California State Water Resources Control Board and the U.S. Environmental Protection Agency. Department of Land, Air, and Water Resources, University of California, Davis, CA.

Cover Photo: Shorebirds like black-necked stilts quickly utilize ponded reuse drainwater in the semi-arid San Joaquin Valley. Invertebrates can populate ponded water in furrows, fields, sumps, and ditches within three weeks thus providing a food source for many species of birds.

Appendix A: Data Summary

Appendix A: Raw Analytical Data for Eggs Collected from San Joaquin Valley California IFDM and Reference Sites (1996-2003). Values in ug/g dry weight. (-) = detection limit

Species	Site	Nest	Egg	Parasitism	Year	Stage	Condition	Se	Al	Sb	As	Ba	Be	B	Cd	Ca	Cr	Cu	Fe	Pb	Mg	Mn	Hg	Mb	Ni	P	Na	Sr	S	V	Zn
Black-Necked Stilt	Rainbow Ranch Evaporation Complex	1	1		2001	2	UU	6.4	4		-0.2	1.5	-0.1	4	-0.1		-0.5	3.3	110	-0.2	353	1.5	0.33	-2	-0.5			14		-0.5	62
American Avocet	Britz Farms Deavenport Evap Pond	1	1		1996	0	UU	4.8	1.6	-1	-0.2	0.8	-0.1	14	-0	2980	0.7	3.5	111	-0.1	342	1.6	0.08	-1	-0.3	8450	4260	7.4	5410	2.1	49
American Avocet	Britz Farms Deavenport Evap Pond	1	1		2002		UU	72																							
American Avocet	Britz Farms Deavenport Evap Pond	1	2		2002		UU	84																							
American Avocet	Britz Farms Deavenport Evap Pond	1	3		2002	4	DU	35																							
Black-Necked Stilt	Britz Farms Deavenport Evap Pond	1	1		1998		UU	9.7																							
Black-Necked Stilt	Britz Farms Deavenport Evap Pond	1	1		2001	14	LN	50	3		-0.2	2.2	-0.1	6	-0.1		-0.5	3.8	98	-0.2	531	1.8	0.8	-2	-0.5			18		-0.5	60
Black-Necked Stilt	Britz Farms Deavenport Evap Pond	1	2		2001	14	LN	57																							
Black-Necked Stilt	Britz Farms Deavenport Evap Pond	1	3		2001	15	LN	48																							
Black-Necked Stilt	Britz Farms Deavenport Evap Pond	2	1		2001	16	LA	60	4		-0.2	6.1	-0.1	4	-0.1		-0.5	3.8	92	-0.2	544	2	0.56	-2	-0.5			20		-0.5	62
Black-Necked Stilt	Britz Farms Deavenport Evap Pond	2	2		2001	18	LA	72	4		-0.2	4.5	-0.1	6	-0.1		-0.5	4	110	-0.2	570	2.6	0.64	-2	-0.5			27		-0.5	62
Black-Necked Stilt	Britz Farms Deavenport Evap Pond	2	3		2001	20	LN	16	4		-0.2	9.2	-0.1	10	-0.1		-0.5	4.4	90	-0.2	601	2.4	0.6	-2	-0.5			36		-0.5	63
Black-Necked Stilt	Britz Farms Deavenport Evap Pond	2	4		2001	2	UU	2.9																							
Black-Necked Stilt	Britz Farms Deavenport Evap Pond	3	1		2001	0	UU	41																							
Black-Necked Stilt	Britz Farms Deavenport Evap Pond	3	2		2001	13	LN	46	3		-0.2	1.3	-0.1	4	-0.1		0.7	4.4	100	-0.2	424	1	1.2	-2	-0.5			20		-0.5	62
Black-Necked Stilt	Britz Farms Deavenport Evap Pond	3	3		2001	15	LN	29																							
Black-Necked Stilt	Britz Farms Deavenport Evap Pond	1	1		2002	1	UU	85	-2		-0.2	0.8	-0.1	7	-0.1		-0.5	3.7	110	-0.2	409	2	1.1	-2	-0.5			19		-0.5	52
Black-Necked Stilt	Britz Farms Deavenport Evap Pond	1	2		2002	5	DU	98																							
Black-Necked Stilt	Britz Farms Deavenport Evap Pond	1	3		2002	4	DU	98																							
Black-Necked Stilt	Britz Farms Deavenport Evap Pond	1	4		2002	5	DU	90																							
Black-Necked Stilt	Britz Farms Deavenport Evap Pond	2	1		2002	3	LU	45	-2		-0.2	0.8	-0.1	10	-0.1		-0.5	3.4	110	-0.2	397	2	1.1	-2	-0.5			10		-0.5	54
Black-Necked Stilt	Britz Farms Deavenport Evap Pond	2	2		2002	3	DU	66																							
Black-Necked Stilt	Britz Farms Deavenport Evap Pond	2	3		2002	3	DU	82																							
Black-Necked Stilt	Britz Farms Deavenport Evap Pond	2	4		2002	3	DU	86																							
Black-Necked Stilt	Britz Farms Deavenport Evap Pond	3	1		2002	0	UU	91	-2		-0.2	1.4	-0.1	12	-0.1		-0.5	3.2	98	-0.2	407	2	0.74	-2	-0.5			29		-0.5	57
Black-Necked Stilt	Britz Farms Deavenport Evap Pond	3	2		2002	6	DU	81																							
Black-Necked Stilt	Britz Farms Deavenport Evap Pond	3	3		2002	6	DU	88																							
Black-Necked Stilt	Britz Farms Deavenport Evap Pond	3	4		2002	7	DU	66																							
Black-Necked Stilt	Britz Farms Deavenport Evap Pond	4	1		2002	5	LU	86	-2		-0.2	1.5	-0.1	6	-0.1		-0.5	3.6	130	-0.2	451	2	1.5	-2	-0.5			22		-0.5	57
Black-Necked Stilt	Britz Farms Deavenport Evap Pond	4	2		2002	10	LA	89	-2		-0.2	1.7	-0.1	5	-0.1		-0.5	4.2	150	-0.2	468	2	1.1	-2	-0.5			22		-0.5	62
Black-Necked Stilt	Britz Farms Deavenport Evap Pond	4	3		2002	12	LA	59	-2		-0.2	0.6	-0.1	11	-0.1		-0.5	3.2	120	-0.2	395	2	1.9	-2	-0.5			22		-0.5	49
Black-Necked Stilt	Britz Farms Deavenport Evap Pond	4	4		2002	11	LA	70	-2		-0.2	0.9	-0.1	10	-0.1		-0.5	3.4	120	-0.2	439	2	1.2	-2	-0.5			23		-0.5	55
Black-Necked Stilt	Britz Farms Deavenport Evap Pond	6	1		2002	4	DU	93																							
Black-Necked Stilt	Britz Farms Deavenport Evap Pond	6	2		2002		UU	110																							
Black-Necked Stilt	Britz Farms Deavenport Evap Pond	6	3		2002	5	DU	9.9																							
Black-Necked Stilt	Britz Farms Deavenport Evap Pond	6	4		2002	6	DU	37																							
Black-Necked Stilt	Britz Farms Deavenport Evap Pond	7	1		2002	12	LN	43	-2		-0.2	2.8	-0.1	8	-0.1		-0.5	3.5	85	-0.2	473	2	3	-2	-0.5			24		-0.5	50
Killdeer	Britz Farms Deavenport Evap Pond	1	1		2002	17	LN	25																							
Killdeer	Britz Farms Deavenport Evap Pond	2	1		2002	14	LN	38																							
Killdeer	Britz Farms Deavenport Evap Pond	3	1		2002	12	LN	24																							
Killdeer	Britz Farms Deavenport Evap Pond	3	2		2002	10	LN	23																							
Killdeer	Britz Farms Deavenport Evap Pond	3	3		2002	11	LN	20																							
Killdeer	Britz Farms Deavenport Evap Pond	6	1		2002	14	LN	60																							
American Coot	Red Rock Ranch IFDM Subsite A	1	1		2001	5	LU	5.4	-3		-0.2	6.8	-0.1	-2	-0.1		-0.5	2.3	88	-0.2	428	2.4	0.32	-2	-0.5			8.8		-0.5	63
American Coot	Red Rock Ranch IFDM Subsite A	1	2		2001	3	LU	5.1																							
American Crow	Red Rock Ranch, Diener Farms	1	1		2002	0	UU	5.2																							
American Robin	Red Rock Ranch, Diener Farms	1	1		2000		LN	27																							

Appendix A (Cont'd): Raw Analytical Data for Eggs Collected from San Joaquin Valley California IFDM and Reference Sites (1996-2003). Values in ug/g dry weight. (-) = detection limit

Species	Site	Nest	Egg	Parasitism	Year	Stage	Condition	Se	Al	Sb	As	Ba	Be	B	Cd	Ca	Cr	Cu	Fe	Pb	Mg	Mn	Hg	Mb	Ni	P	Na	Sr	S	V	Zn
Black-Necked Stilt	Red Rock Ranch, Diener Farms	1	1		1996	15	LA	54			-0.1												1.1								
Black-Necked Stilt	Red Rock Ranch, Diener Farms	1	2		1996	23	LN	28			-0.1												1.8								
Black-Necked Stilt	Red Rock Ranch, Diener Farms	1	3		1996	23	LN	48			0.1												1.5								
Black-Necked Stilt	Red Rock Ranch, Diener Farms	1	4		1996	23	LA	59			0.1												1.3								
Black-Necked Stilt	Red Rock Ranch, Diener Farms	2	1		1996	11	LA	50			-0.1												0.28								
Black-Necked Stilt	Red Rock Ranch, Diener Farms	2	2		1996	16	LN	11			-0.1												0.43								
Black-Necked Stilt	Red Rock Ranch, Diener Farms	2	3		1996	16	LN	46																							
Black-Necked Stilt	Red Rock Ranch, Diener Farms	3	1		1996	15	LA	40			-0.1												0.75								
Black-Necked Stilt	Red Rock Ranch, Diener Farms	3	2		1996	18	DA	50			-0.1												0.44								
Black-Necked Stilt	Red Rock Ranch, Diener Farms	3	3		1996	18	DA	68																							
Black-Necked Stilt	Red Rock Ranch, Diener Farms	4	1		1996	24	DA	68			-0.1												1.1								
Black-Necked Stilt	Red Rock Ranch, Diener Farms	6	1		1996	13	LA	57			-0.1												0.44								
Black-Necked Stilt	Red Rock Ranch, Diener Farms	6	2		1996	14	DA	55			-0.1												0.22								
Black-Necked Stilt	Red Rock Ranch, Diener Farms	6	3		1996	12	LN	48																							
Black-Necked Stilt	Red Rock Ranch, Diener Farms	1	1		2000	13	LN	20																							
Black-Necked Stilt	Red Rock Ranch, Diener Farms	2	1		2000	12	LN	12																							
Black-Necked Stilt	Red Rock Ranch, Diener Farms	3	1		2000	12	LN	22																							
Black-Necked Stilt	Red Rock Ranch, Diener Farms	4	1		2000	11	LN	10																							
Black-Necked Stilt	Red Rock Ranch, Diener Farms	1	2		2000	16	LN	16																							
Black-Necked Stilt	Red Rock Ranch, Diener Farms	1	3		2000	16	LN	13																							
Black-Necked Stilt	Red Rock Ranch, Diener Farms	1	4		2000	15	LN	17																							
Black-Necked Stilt	Red Rock Ranch, Diener Farms	3	2		2000	23	LN	22	-6		-0.2	4.1	-0.1	3	-0.3		-0.8	2	11	-2	46	-0.1	0.8	-1	-0.5			33		-0.2	59
Black-Necked Stilt	Red Rock Ranch, Diener Farms	3	3		2000	21	LA	65	-6		-0.2	2	-0.1	3	-0.3		-0.8	2.2	12	-2	59	-0.1	1.3	-1	-0.5			37		-0.2	59
Black-Necked Stilt	Red Rock Ranch, Diener Farms	3	4		2000	23	LN	14																							
Black-Necked Stilt	Red Rock Ranch, Diener Farms	4	2		2000	13	LN	32																							
Black-Necked Stilt	Red Rock Ranch, Diener Farms	4	3		2000	13	LN	17																							
Black-Necked Stilt	Red Rock Ranch, Diener Farms	4	4		2000	13	LN	30																							
Black-Necked Stilt	Red Rock Ranch, Diener Farms	5	1		2000	15	LN	34																							
Black-Necked Stilt	Red Rock Ranch, Diener Farms	5	2		2000	23	LN	36	-6		-0.2	6.2	-0.1	2	-0.3		-0.8	1.7	14	-2	63	-0.1	0.5	-1	-0.5			35		-0.2	62
Black-Necked Stilt	Red Rock Ranch, Diener Farms	5	3		2000	23	LN	41																							
Black-Necked Stilt	Red Rock Ranch, Diener Farms	5	4		2000	23	LN	57																							
Black-Necked Stilt	Red Rock Ranch, Diener Farms	6	1		2000	7	LN	42																							
Black-Necked Stilt	Red Rock Ranch, Diener Farms	6	2		2000	14	LN	18	-6		-0.2	3.1	-0.1	4	-0.3		-0.8	1.1	10	-2	41	-0.1	0.8	-1	-0.5			18		-0.2	47
Black-Necked Stilt	Red Rock Ranch, Diener Farms	6	3		2000	14	LN	45																							
Black-Necked Stilt	Red Rock Ranch, Diener Farms	6	4		2000	14	LA	43	-6		-0.2	1.5	-0.1	3	-0.3		-0.8	1.2	9.3	-2	37	-0.1	1.3	-1	-0.5			12		-0.2	43
Black-Necked Stilt	Red Rock Ranch, Diener Farms	7	1		2000	13	LN	11																							
Black-Necked Stilt	Red Rock Ranch, Diener Farms	7	2		2000	12	LN	30																							
Black-Necked Stilt	Red Rock Ranch, Diener Farms	7	3		2000	11	LN	20																							
Black-Necked Stilt	Red Rock Ranch, Diener Farms	8	1		2000	7	LN	8.2																							
Black-Necked Stilt	Red Rock Ranch, Diener Farms	8	2		2000	13	LN	12																							
Black-Necked Stilt	Red Rock Ranch, Diener Farms	8	3		2000	11	LN	12																							
Black-Necked Stilt	Red Rock Ranch, Diener Farms	8	4		2000	12	LN	8.7																							
Black-Necked Stilt	Red Rock Ranch, Diener Farms	10	1		2000	14	LN	3.5	-6		-0.2	3	-0.1	2	-0.3		-0.8	0.6	11	-2	42	-0.1	0.9	-1	-0.5			17		-0.2	46
Black-Necked Stilt	Red Rock Ranch, Diener Farms	10	2		2000	23	LN	10																							
Black-Necked Stilt	Red Rock Ranch, Diener Farms	10	3		2000	23	LN	9.3																							
Black-Necked Stilt	Red Rock Ranch, Diener Farms	1	1		2001	0	UU	32																							
Black-Necked Stilt	Red Rock Ranch, Diener Farms	1	2		2001	15	LN	27	-3		-0.2	3	-0.1	3	-0.1		-0.5	3.2	81	-0.2	543	1.6	0.86	-2	-0.5			26		-0.5	58
Black-Necked Stilt	Red Rock Ranch, Diener Farms	1	3		2001	13	LN	22																							

Appendix A (Cont'd): Raw Analytical Data for Eggs Collected from San Joaquin Valley California IFDM and Reference Sites (1996-2003). Values in ug/g dry weight. (-) = detection limit

Species	Site	Nest	Egg	Parasitism	Year	Stage	Condition	Se	Al	Sb	As	Ba	Be	B	Cd	Ca	Cr	Cu	Fe	Pb	Mg	Mn	Hg	Mb	Ni	P	Na	Sr	S	V	Zn
Black-Necked Stilt	Red Rock Ranch, Diener Farms	1	4		2001	14	LN	25																							
Black-Necked Stilt	Red Rock Ranch, Diener Farms	2	1		2001	1	UU	13	5		-0.2	2.1	-0.1	-2	-0.1		-0.5	2.7	110	-0.2	340	0.9	0.37	-2	-0.5			10		-0.5	64
Black-Necked Stilt	Red Rock Ranch, Diener Farms	2	2		2001		DU	18																							
Black-Necked Stilt	Red Rock Ranch, Diener Farms	2	3		2001		DU	14																							
Black-Necked Stilt	Red Rock Ranch, Diener Farms	2	4		2001		DU	15																							
Black-Necked Stilt	Red Rock Ranch, Diener Farms	3	1		2001	13	LN	28	4		-0.2	1	-0.1	4	-0.1		-0.5	3.2	66	-0.2	429	2	0.68	-2	-0.5			15		-0.5	50
Black-Necked Stilt	Red Rock Ranch, Diener Farms	3	2		2001	20	LN	26																							
Black-Necked Stilt	Red Rock Ranch, Diener Farms	3	3		2001	13	DN	20																							
Black-Necked Stilt	Red Rock Ranch, Diener Farms	3	4		2001	17	LN	20																							
Black-Necked Stilt	Red Rock Ranch, Diener Farms	4	1		2001	21	LN	7.4	4		-0.2	2.7	-0.1	-2	-0.1		0.6	3.7	120	-0.2	613	1.9	0.98	-2	-0.5			17		-0.5	63
Black-Necked Stilt	Red Rock Ranch, Diener Farms	4	2		2001	16	LN	12																							
Black-Necked Stilt	Red Rock Ranch, Diener Farms	4	3		2001	19	LN	12																							
Black-Necked Stilt	Red Rock Ranch, Diener Farms	4	4		2001	20	LN	7.3																							
Black-Necked Stilt	Red Rock Ranch, Diener Farms	5	1		2001		DU	13	-3		-0.2	0.8	-0.1	3	-0.1		-0.5	3	80	-0.2	372	2.7	1.7	-2	-0.5			14		-0.5	44
Black-Necked Stilt	Red Rock Ranch, Diener Farms	5	2		2001		DU	17																							
Black-Necked Stilt	Red Rock Ranch, Diener Farms	5	3		2001		DU	15																							
Black-Necked Stilt	Red Rock Ranch, Diener Farms	5	4		2001		DU	18																							
Black-Necked Stilt	Red Rock Ranch, Diener Farms	1	1		2002	4	DU	3.9	-2		-0.2	2.7	-0.1	3	-0.1		-0.5	3.8	120	-0.2	407	2	0.36	-2	-0.5			9.2		-0.5	54
Black-Necked Stilt	Red Rock Ranch, Diener Farms	3	1		2002	5	LU	59	-2		-0.2	1.7	-0.1	4	-0.1		-0.5	3.3	120	-0.2	432	1	0.48	-2	-0.5			14		-0.5	62
Black-Necked Stilt	Red Rock Ranch, Diener Farms	3	2		2002	21	LA	82	-2		-0.2	2.4	-0.1	6	-0.1		-0.5	3.8	110	-0.2	673	2	0.45	-2	-0.5			51		-0.5	70
Black-Necked Stilt	Red Rock Ranch, Diener Farms	5	1		2002	2	LU	13	-2		-0.2	2.7	-0.1	4	-0.1		-0.5	3	130	-0.2	383	-1	0.2	-2	-0.5			13		-0.5	66
Black-Necked Stilt	Red Rock Ranch IFDM Subsite D	2	1		2002	14	LN	11	-2		-0.2	1.5	-0.1	5	-0.1		-0.5	2.9	130	-0.2	487	1	0.65	-2	-0.5			17		-0.5	58
Black-Necked Stilt	Red Rock Ranch, Diener Farms	2	1		2003	6	LU	15	-3		-0.2	1.9	-0.1	3	-0.1		-0.5	2.8	110	-0.2	443	1	0.52	-2	-0.5			11		-0.5	56
Black-Necked Stilt	Red Rock Ranch, Diener Farms	3	1		2003	6	LU	9																							
Black-Necked Stilt	Red Rock Ranch, Diener Farms	6	1		2003	0	UU	14																							
Black-Necked Stilt	Red Rock Ranch IFDM Subsite D	1	1		2003	0	UU	17	-3		-0.2	4.2	-0.1	-2	-0.1		-0.5	3.5	88	-0.2	351	1	1.8	-2	-0.5			6.3		-0.5	49
Brewer's Blackbird	Red Rock Ranch, Diener Farms	2	1		2000	8	LN	5.7																							
Brewer's Blackbird	Red Rock Ranch, Diener Farms	7	1		2000	5	LN	2.6																							
Brewer's Blackbird	Red Rock Ranch, Diener Farms	9	1		2000	8	LN	2.6																							
Brewer's Blackbird	Red Rock Ranch, Diener Farms	12	1	1	2000	5	LN	3																							
Brewer's Blackbird	Red Rock Ranch, Diener Farms	15	1		2000	5	LN	3.3																							
Brewer's Blackbird	Red Rock Ranch, Diener Farms	15	2		2000	5	LA	3.6																							
Brewer's Blackbird	Red Rock Ranch, Diener Farms	17	1		2000	5	LN	5.4																							
Brewer's Blackbird	Red Rock Ranch, Diener Farms	21	1		2000	10	LN	6.5																							
Brewer's Blackbird	Red Rock Ranch, Diener Farms	22	1		2000	6	LN	3.6																							
Brewer's Blackbird	Red Rock Ranch, Diener Farms	25	1		2000	10	LN	4.5																							
Brewer's Blackbird	Red Rock Ranch, Diener Farms	5	1		2001	0	UU	11																							
Brewer's Blackbird	Red Rock Ranch, Diener Farms	15	1	1	2001	0	UU	7.9																							
Brewer's Blackbird	Red Rock Ranch, Diener Farms	16	1		2001	0	UU	5.3																							
Brewer's Blackbird	Red Rock Ranch, Diener Farms	17	1	1	2001	2	LU	5.4																							
Brewer's Blackbird	Red Rock Ranch IFDM Subsite A	18	1		2001	0	UU	3.6																							
Brewer's Blackbird	Red Rock Ranch IFDM Subsite A	19	1	1	2001	0	UU	2.7																							
Brewer's Blackbird	Red Rock Ranch IFDM Subsite A	20	1		2001	2	LU	4.2																							

Appendix A (Cont'd): Raw Analytical Data for Eggs Collected from San Joaquin Valley California IFDM and Reference Sites (1996-2003). Values in ug/g dry weight. (-) = detection limit

Species	Site	Nest	Egg	Parasitism	Year	Stage	Condition	Se	Al	Sb	As	Ba	Be	B	Cd	Ca	Cr	Cu	Fe	Pb	Mg	Mn	Hg	Mb	Ni	P	Na	Sr	S	V	Zn
Brown-headed Cowbird	Red Rock Ranch, Diener Farms	2	1	2	2000		LN	3.2																							
Brown-headed Cowbird	Red Rock Ranch, Diener Farms	##	1	2	2000		LU	[6.3]																							
Brown-headed Cowbird	Red Rock Ranch, Diener Farms	##	2		2000		LU	[6.3]																							
Brown-headed Cowbird	Red Rock Ranch, Diener Farms	##	3		2000		UU	[6.3]																							
Brown-headed Cowbird	Red Rock Ranch, Diener Farms	1	1	2	2001	0	UU	3.6																							
Brown-headed Cowbird	Red Rock Ranch, Diener Farms	2	1	2	2001	1	LU	6.3																							
Brown-headed Cowbird	Red Rock Ranch, Diener Farms	3	1	2	2001	0	UU	[3]	[9]		[-0.2]	[6.1]	[-0.1]	[2]	[-0.1]		[-0.5]	[3.3]	[140]	[-0.2]	[385]	[2.6]	[-0.1]	[-2]	[-0.5]			[8.8]		[-0.5]	[69]
Brown-headed Cowbird	Red Rock Ranch, Diener Farms	3	2	2	2001	0	UU	[3]	[9]		[-0.2]	[6.1]	[-0.1]	[2]	[-0.1]		[-0.5]	[3.3]	[140]	[-0.2]	[385]	[2.6]	[-0.1]	[-2]	[-0.5]			[8.8]		[-0.5]	[69]
House Finch	Red Rock Ranch, Diener Farms	1	1		2000		LU	[2.2]																							
House Finch	Red Rock Ranch, Diener Farms	1	2		2000		LU	[2.2]																							
House Finch	Red Rock Ranch, Diener Farms	2	1		2000		LU	[28]																							
House Finch	Red Rock Ranch, Diener Farms	2	2		2000		LU	[28]																							
House Finch	Red Rock Ranch, Diener Farms	4	1		2000		LU	[1.9]																							
House Finch	Red Rock Ranch, Diener Farms	4	2		2000		LN	[1.9]																							
House Finch	Red Rock Ranch, Diener Farms	1	1		2001		LN	3.3																							
House Finch	Red Rock Ranch, Diener Farms	2	1		2001		LN	3.1																							
House Finch	Red Rock Ranch, Diener Farms	3	1		2001	3	LU	3.9																							
House Finch	Red Rock Ranch, Diener Farms	7	1		2001	0	UU	3.4																							
House Sparrow	Red Rock Ranch, Diener Farms	1	1		2000		UU	[5.3]																							
House Sparrow	Red Rock Ranch, Diener Farms	1	2		2000		UU	[5.3]																							
House Sparrow	Red Rock Ranch, Diener Farms	2	1		2000		LN	[5.4]																							
House Sparrow	Red Rock Ranch, Diener Farms	2	2		2000		LN	[5.4]																							
House Sparrow	Red Rock Ranch, Diener Farms	4	1		2000		LN	[5.3]																							
House Sparrow	Red Rock Ranch, Diener Farms	4	2		2000		LN	[5.3]																							
House Sparrow	Red Rock Ranch, Diener Farms	5	1		2000		LU	[3.6]																							
House Sparrow	Red Rock Ranch, Diener Farms	5	2		2000		LU	[3.6]																							
House Sparrow	Red Rock Ranch, Diener Farms	1	1		2001	4	LU	[4.1]	[-3]		[-0.2]	[1.5]	[-0.1]	[8.1	[-0.1]		[-0.5]	[2.8]	[110]	[-0.2]	[472]	[2.5]	[-0.1]	[-2]	[-0.5]			[17]		[-0.5]	[61]
House Sparrow	Red Rock Ranch, Diener Farms	1	2		2001	3	LU	[4.1]	[-3]		[-0.2]	[1.5]	[-0.1]	[8.1	[-0.1]		[-0.5]	[2.8]	[110]	[-0.2]	[472]	[2.5]	[-0.1]	[-2]	[-0.5]			[17]		[-0.5]	[61]
House Sparrow	Red Rock Ranch, Diener Farms	2	1		2001		LN	[4.2]	[4]		[0.3]	[3.6]	[-0.1]	[17]	[0.1]		[-0.5]	[3.5]	[130]	[-0.2]	[719]	[3.4]	[-0.1]	[-2]	[-0.5]			[39]		[-0.5]	[76]
House Sparrow	Red Rock Ranch, Diener Farms	2	2		2001		LN	[4.2]	[4]		[0.3]	[3.6]	[-0.1]	[17]	[0.1]		[-0.5]	[3.5]	[130]	[-0.2]	[719]	[3.4]	[-0.1]	[-2]	[-0.5]			[39]		[-0.5]	[76]
House Sparrow	Red Rock Ranch, Diener Farms	4	1		2001	4	LU	[3.4]	[-3]		[-0.2]	[2.7]	[-0.1]	[11]	[-0.1]		[-0.5]	[3.3]	[100]	[-0.2]	[456]	[2.1]	[-0.1]	[-2]	[-0.5]			[13]		[-0.5]	[58]
House Sparrow	Red Rock Ranch, Diener Farms	4	2		2001	4	LU	[3.4]	[-3]		[-0.2]	[2.7]	[-0.1]	[11]	[-0.1]		[-0.5]	[3.3]	[100]	[-0.2]	[456]	[2.1]	[-0.1]	[-2]	[-0.5]			[13]		[-0.5]	[58]
House Sparrow	Red Rock Ranch, Diener Farms	8	1		2001	5	LU	[3.9]																							
House Sparrow	Red Rock Ranch, Diener Farms	8	2		2001	5	LU	[3.9]																							
House Sparrow	Red Rock Ranch, Diener Farms	9	1		2001	3	LU	[3.9]																							
House Sparrow	Red Rock Ranch, Diener Farms	9	2		2001	1	LU	[3.9]																							
House Sparrow	Red Rock Ranch, Diener Farms	7	1		2002	0	UU	4.3																							
House Sparrow	Red Rock Ranch, Diener Farms	1	1		2002	0	UU	[3.8]																							
House Sparrow	Red Rock Ranch, Diener Farms	1	2		2002	0	UU	[3.8]																							
House Sparrow	Red Rock Ranch IFDM Subsite A	4	1		2002	0	UU	[3.5]																							
House Sparrow	Red Rock Ranch IFDM Subsite A	4	2		2002	0	UU	[3.5]																							
House Sparrow	Red Rock Ranch IFDM Subsite A	30	1		2002	1	LU	[3.1]																							
House Sparrow	Red Rock Ranch IFDM Subsite A	30	2		2002	1	LU	[3.1]																							
Killdeer	Red Rock Ranch, Diener Farms	1	1		1996	0	UU	18																							
Killdeer	Red Rock Ranch, Diener Farms	2	1		1996	10	LN	29																							
Killdeer	Red Rock Ranch, Diener Farms	3	1		1996	9	LN	13																							
Killdeer	Red Rock Ranch, Diener Farms	1	2		1998	14	LN	39																							
Killdeer	Red Rock Ranch, Diener Farms	1	1		1998	13	LN	47																							

Appendix A (Cont'd): Raw Analytical Data for Eggs Collected from San Joaquin Valley California IFDM and Reference Sites (1996-2003). Values in ug/g dry weight. (-) = detection limit

Species	Site	Nest	Egg	Parasitism	Year	Stage	Condition	Se	Al	Sb	As	Ba	Be	B	Cd	Ca	Cr	Cu	Fe	Pb	Mg	Mn	Hg	Mb	Ni	P	Na	Sr	S	V	Zn
Killdeer	Red Rock Ranch, Diener Farms	1	1		2000	25	LN	16																							
Killdeer	Red Rock Ranch, Diener Farms	1	2		2000	25	LN	13																							
Killdeer	Red Rock Ranch, Diener Farms	2	1		2000	8	LN	20																							
Killdeer	Red Rock Ranch, Diener Farms	2	2		2000	25	LN	24																							
Killdeer	Red Rock Ranch, Diener Farms	2	3		2000	23	LN	26																							
Killdeer	Red Rock Ranch, Diener Farms	2	4		2000	23	LN	26																							
Killdeer	Red Rock Ranch, Diener Farms	3	1		2000	16	LN	31																							
Killdeer	Red Rock Ranch, Diener Farms	3	2		2000	14	DN	37																							
Killdeer	Red Rock Ranch, Diener Farms	4	1		2000	14	LN	22																							
Killdeer	Red Rock Ranch, Diener Farms	4	2		2000	13	LN	20																							
Killdeer	Red Rock Ranch, Diener Farms	4	3		2000	13	LN	20																							
Killdeer	Red Rock Ranch, Diener Farms	5	1		2000	14	LN	35																							
Killdeer	Red Rock Ranch, Diener Farms	5	2		2000	14	LA	45																							
Killdeer	Red Rock Ranch, Diener Farms	5	3		2000	14	LN	42																							
Killdeer	Red Rock Ranch, Diener Farms	5	4		2000	13	LN	29																							
Killdeer	Red Rock Ranch, Diener Farms	3	1		2001	0	UU	20																							
Killdeer	Red Rock Ranch, Diener Farms	4	1		2001	0	UU	25																							
Killdeer	Red Rock Ranch, Diener Farms	4	2		2001		UU	24																							
Killdeer	Red Rock Ranch, Diener Farms	4	3		2001		UU	18																							
Killdeer	Red Rock Ranch, Diener Farms	4	4		2001		UU	16																							
Killdeer	Red Rock Ranch, Diener Farms	5	1		2001	25	LN	41	5		-0.2	1.4	-0.1	5	-0.1		-0.5	3.4	95	-0.2	711	1.9	-0.1	-2	-0.5			42		-0.5	62
Killdeer	Red Rock Ranch, Diener Farms	6	1		2001	2	UU	16																							
Killdeer	Red Rock Ranch, Diener Farms	7	1		2001	13	DN	21	3		-0.2	0.7	-0.1	6	-0.1		1	3.7	74	-0.2	486	1.5	0.1	-2	-0.5			21		-0.5	59
Killdeer	Red Rock Ranch, Diener Farms	9	1		2001	13	LN	18	4		-0.2	1.1	-0.1	6	-0.1		-0.5	3.1	79	-0.2	469	1	0.2	-2	-0.5			18		-0.5	53
Killdeer	Red Rock Ranch, Diener Farms	9	2		2001	21	LN	18																							
Killdeer	Red Rock Ranch, Diener Farms	9	3		2001	19	LN	19																							
Killdeer	Red Rock Ranch, Diener Farms	9	4		2001	21	LN	21																							
Killdeer	Red Rock Ranch, Diener Farms	11	1		2001	15	LN	14	-3		-0.2	1.1	-0.1	6	-0.1		-0.5	2.9	120	-0.2	482	1	0.1	-2	-0.5			22		-0.5	64
Killdeer	Red Rock Ranch, Diener Farms	11	2		2001	25	LN	19																							
Killdeer	Red Rock Ranch, Diener Farms	11	3		2001	25	LN	16																							
Killdeer	Red Rock Ranch, Diener Farms	11	4		2001	21	LN	14																							
Killdeer	Red Rock Ranch, Diener Farms	12	1		2001		DU	7.1																							
Killdeer	Red Rock Ranch, Diener Farms	12	2		2001		DU	7.7																							
Killdeer	Red Rock Ranch IFDM Subsite A	2	1		2001	0	UU	6.8																							
Killdeer	Red Rock Ranch IFDM Subsite A	2	2		2001	21	LN	10	-3		-0.2	5.4	-0.1	2	-0.1		0.5	3.8	110	-0.2	690	1.6	0.1	-2	-0.5			37		-0.5	68
Killdeer	Red Rock Ranch IFDM Subsite B	8	1		2001	14	LN	5.6	-3		-0.2	4.5	-0.1	2	-0.1		-0.5	3.6	120	-0.2	594	1.9	0.35	-2	-0.5			17		-0.5	62
Killdeer	Red Rock Ranch, Diener Farms	1	1		2002	26	LN	55																							
Killdeer	Red Rock Ranch, Diener Farms	2	1		2002	2	LU	8.2																							
Killdeer	Red Rock Ranch, Diener Farms	3	1		2002	5	DU	12																							
Killdeer	Red Rock Ranch, Diener Farms	4	1		2002	2	UU	16																							
Killdeer	Red Rock Ranch, Diener Farms	5	1		2002	10	LN	11																							
Killdeer	Red Rock Ranch, Diener Farms	6	1		2002	1	UU	22																							
Killdeer	Red Rock Ranch, Diener Farms	8	1		2002	14	LN	19																							
Killdeer	Red Rock Ranch, Diener Farms	1	1		2003	5	LU	7																							
Killdeer	Red Rock Ranch, Diener Farms	2	1		2003	12	LN	17																							
Loggerhead Shrike	Red Rock Ranch, Diener Farms	1	1		2001		LN	5.9	3		-0.2	1.1	-0.1	7	-0.1		-0.5	2.1	150	-0.2	700	3.6	-0.1	-2	-0.5			23		-0.5	55
Loggerhead Shrike	Red Rock Ranch, Diener Farms	1	2		2001		LN	6.3																							
Loggerhead Shrike	Red Rock Ranch, Diener Farms	1	1		2002		LN	3																							

Appendix A (Cont'd): Raw Analytical Data for Eggs Collected from San Joaquin Valley California IFDM and Reference Sites (1996-2003). Values in ug/g dry weight. (-) = detection limit

Species	Site	Nest	Egg	Parasitism	Year	Stage	Condition	Se	Al	Sb	As	Ba	Be	B	Cd	Ca	Cr	Cu	Fe	Pb	Mg	Mn	Hg	Mb	Ni	P	Na	Sr	S	V	Zn
Mourning Dove	Red Rock Ranch, Diener Farms	1	1		2000	4	LU	2.4																							
Red-winged Blackbird	Red Rock Ranch, Diener Farms	1	1		2000		LU	6.2																							
Red-winged Blackbird	Red Rock Ranch, Diener Farms	2	1	1	2000		UU	8.8																							
Red-winged Blackbird	Red Rock Ranch, Diener Farms	3	1		2000		UU	7.8																							
Red-winged Blackbird	Red Rock Ranch, Diener Farms	4	1		2000		UU	5.3																							
Red-winged Blackbird	Red Rock Ranch, Diener Farms	6	1		2000		DU	8.2																							
Red-winged Blackbird	Red Rock Ranch, Diener Farms	1	1		2001		LU	4.3																							
Red-winged Blackbird	Red Rock Ranch, Diener Farms	2	1		2001		LU	7																							
Red-winged Blackbird	Red Rock Ranch, Diener Farms	3	1		2001		DN	5.2																							
Western Kingbird	Red Rock Ranch, Diener Farms	1	1		2000		LN	13																							
Western Kingbird	Red Rock Ranch, Diener Farms	2	1		2000		LU	11																							
Western Kingbird	Red Rock Ranch, Diener Farms	1	1		2001	1	LU	4.5	4		-0.2	1.1	-0.1	8	-0.1		-0.5	2.4	140	-0.2	348	1.9	-0.1	-2	-0.5			8.7		-0.5	69
Western Kingbird	Red Rock Ranch IFDM Subsite A	2	1		2001	1	LU	5	-3		-0.2	0.4	-0.1	-2	-0.1		-0.5	2.1	100	-0.2	303	2.6	0.1	-2	-0.5			4.1		-0.5	62
Western Kingbird	Red Rock Ranch IFDM Subsite A	3	1		2001	1	LU	4																							
Western Kingbird	Red Rock Ranch IFDM Subsite A	4	1		2001	0	UU	4.2																							
Western Kingbird	Red Rock Ranch IFDM Subsite A	7	1		2001	2	LU	4.8																							
Western Kingbird	Red Rock Ranch IFDM Subsite C	5	1		2001	0	UU	4.8	-3		-0.2	0.8	-0.1	4	-0.1		-0.5	2.7	110	-0.2	329	2.7	-0.1	-2	-0.5			4.8		-0.5	62
Western Kingbird	Red Rock Ranch IFDM Subsite C	6	1		2001	1	LU	4.2																							
Western Kingbird	Red Rock Ranch, Diener Farms	1	1		2002		LN	5.1																							
Black-Necked Stilt	Mendota Agroforestry Plot	1	1		1998	21	LN	31																							
Killdeer	Mendota Agroforestry Plot	1	1		1996	13	LN	5.7																							
Western Kingbird	Mendota Agroforestry Plot	1	1		2000		LN	9.1																							
Western Kingbird	Mendota Agroforestry Plot	2	1		2000		LN	9.4																							
Brewer's Blackbird	Panoche In-Valley Treatment Site	1	1		2001		LN	7.2			-0.5			2									-0.1	2				9.7			
Brewer's Blackbird	Panoche In-Valley Treatment Site	2	1		2001		LN	15			-0.5			7									-0.1	3				32			
Loggerhead Shrike	Panoche In-Valley Treatment Site	1	1		2001		LN	7.3															0.37								
Mallard	Panoche In-Valley Treatment Site	1	1		2001	3	LU	6.5			-0.5			4									0.29	1				14			
Western Kingbird	Panoche In-Valley Treatment Site	1	1		2001		LU	5.5															0.28								
American Avocet	California Aqueduct S of Mt Whitney Ave.	1	1		2001	1	UU	15	-3		-0.2	8.5	-0.1	-2	-0.1		-0.5	2.9	110	-0.2	409	2	0.3	-2	-0.5			9.5		-0.5	52
Black-Necked Stilt	California Aqueduct S of Mt Whitney Ave.	1	1		2001	7	LU	7	-3		-0.2	5.1	-0.1	-2	-0.1		-0.5	2.6	95	-0.2	392	1	1	-2	-0.5			7.6		-0.5	51
Black-Necked Stilt	Cottin Gin off Mt. Whitney Avenue	1	1		2002	7	LU	4.5																							
Black-Necked Stilt	Cottin Gin off Mt. Whitney Avenue	2	1		2002	14	LN	17	-2		-0.2	1.4	-0.1	-2	-0.1		-0.5	3.2	92	-0.2	430	1	0.31	-2	-0.5			7.5		-0.5	47
Black-Necked Stilt	Cottin Gin off Mt. Whitney Avenue	3	1		2002	9	LA	68	-2		-0.2	2.1	-0.1	4	-0.1		-0.5	3.3	94	-0.2	446	1	0.82	-2	-0.5			13		-0.5	59
Black-Necked Stilt	Cottin Gin off Mt. Whitney Avenue	3	2		2002	14	LA	76	-2		-0.2	3	-0.1	4	-0.1		-0.5	3.9	99	-0.2	573	1	1	-2	-0.5			20		-0.5	63
Black-Necked Stilt	Cottin Gin off Mt. Whitney Avenue	3	3		2002	15	LN	32																							
Black-Necked Stilt	Cottin Gin off Mt. Whitney Avenue	3	4		2002	15	LN	22																							
Black-Necked Stilt	Cottin Gin off Mt. Whitney Avenue	5	1		2002	14	LN	70																							
Black-Necked Stilt	Cottin Gin off Mt. Whitney Avenue	6	1		2002	12	LN	4.7	-2		-0.2	4.6	-0.1	-2	-0.1		-0.5	2.7	110	-0.2	456	2	0.58	-2	-0.5			12		-0.5	54
Black-Necked Stilt	Cottin Gin off Mt. Whitney Avenue	6	2		2002	19	LN	4.7																							
Black-Necked Stilt	Cottin Gin off Mt. Whitney Avenue	6	3		2002	18	LN	5																							
Black-Necked Stilt	Cottin Gin off Mt. Whitney Avenue	6	4		2002	18	LN	5.8																							
Black-Necked Stilt	Cottin Gin off Mt. Whitney Avenue	7	1		2002	13	LN	13	-2		-0.2	1.9	-0.1	4	-0.1		-0.5	3.5	100	-0.2	499	1	1.2	-2	-0.5			12		-0.5	56
Black-Necked Stilt	Cottin Gin off Mt. Whitney Avenue	7	2		2002	13	LN	19																							
Black-Necked Stilt	Cottin Gin off Mt. Whitney Avenue	7	3		2002	12	LN	13																							
Black-Necked Stilt	Cottin Gin off Mt. Whitney Avenue	7	4		2002	4	DU	18																							
Black-Necked Stilt	Cottin Gin off Mt. Whitney Avenue	8	2		2002	12	LN	25																							
Black-Necked Stilt	Cottin Gin off Mt. Whitney Avenue	8	3		2002	12	LN	22																							

Appendix A (Cont'd): Raw Analytical Data for Eggs Collected from San Joaquin Valley California IFDM and Reference Sites (1996-2003). Values in ug/g dry weight. (-) = detection limit

Species	Site	Nest	Egg	Parasitism	Year	Stage	Condition	Se	Al	Sb	As	Ba	Be	B	Cd	Ca	Cr	Cu	Fe	Pb	Mg	Mn	Hg	Mb	Ni	P	Na	Sr	S	V	Zn
Black-Necked Stilt	Cottin Gin off Mt. Whitney Avenue	9	1		2002		UU	110																							
Black-Necked Stilt	Cottin Gin off Mt. Whitney Avenue	9	2		2002		UU	85																							
Black-Necked Stilt	Cottin Gin off Mt. Whitney Avenue	9	3		2002	21	LA	77																							
Black-Necked Stilt	Cottin Gin off Mt. Whitney Avenue	10	1		2002	12	LN	33	-2		-0.2	1.9	-0.1	6	-0.1		-0.5	3.6	100	-0.2	448	2	0.34	-2	-0.5			16		-0.5	48
Black-Necked Stilt	Cottin Gin off Mt. Whitney Avenue	10	2		2002	19	LA	42	-2		-0.2	2.2	-0.1	6	-0.1		-0.5	3.6	110	-0.2	594	2	0.32	-2	-0.5			39		-0.5	59
Black-Necked Stilt	Cottin Gin off Mt. Whitney Avenue	10	3		2002	22	LN	6.7																							
Black-Necked Stilt	Cottin Gin off Mt. Whitney Avenue	8	1		2002	13	LN	19	-2		-0.2	0.5	-0.1	3	-0.1		-0.5	3.2	100	-0.2	440	-1	0.63	-2	-0.5			13		-0.5	53
Killdeer	Cottin Gin off Mt. Whitney Avenue	1	1		2002	5	DU	75																							
Killdeer	Cottin Gin off Mt. Whitney Avenue	3	1		2002	20	LN	17																							
Killdeer	Cottin Gin off Mt. Whitney Avenue	4	1		2002	25	LN	27																							
Killdeer	Cottin Gin off Mt. Whitney Avenue	5	1		2002		UU	49																							
Killdeer	Cottin Gin off Mt. Whitney Avenue	5	2		2002		UU	62																							
Killdeer	Cottin Gin off Mt. Whitney Avenue	5	3		2002	7	DA	44	-2		0.4	0.8	-0.1	6	-0.1		-0.5	2.7	130	-0.2	376	2	0.2	-2	-0.5			14		-0.5	60
Black-Necked Stilt	Coalinga (Highway 198) Sewage Ponds	1	1		2002	16	LN	4.1																							
Black-Necked Stilt	Coalinga (Highway 198) Sewage Ponds	3	1		2002	22	LN	4.8																							
American Avocet	68	1	1		2003	17	LN	2.6																							
Rock Dove	70	1	1		2000		UU	0.9																							

Appendix B: Compensation Habitat Protocol for Evaporation Basins that can be Modified and Applied to IFDM Facilities

COMPENSATION HABITAT PROTOCOL
USFWS
FOR DRAINWATER EVAPORATION BASINS
January, 1995

INTRODUCTION

Two compensation protocols are presented here. Both protocols share a common set of general premises (labeled GP-1 to GP-8 below). The two protocols differ with regard to their risk function premises. One is based on the same eggwise risk function premises (labeled EP-1 to EP-4 below) employed in 1991 (Skorupa 1991a), and the other is based on newly available henwise risk function premises (labeled HP-1 to HP-3 below). Both protocols retain most of the conceptual criteria proposed by the U.S. Fish and Wildlife Service (Service) in 1991 (Skorupa 1991a).

The Service has developed a risk-based approach for compensation to increase accuracy, minimize monitoring costs, and provide incentive to minimize contaminant risk. Compensation protocols based primarily on dead-body counts are inadequate. Adverse impacts to wildlife caused by evaporation basins include both lethal and nonlethal impacts (e.g., Euliss et al. 1989; Barnum 1992; CH2M HILL et al. 1993; White 1993). Nonlethal impacts, by definition, cannot be accounted for by body counts. Body counts for each lifestage (embryonic, juvenile, adult) are extremely expensive to obtain and are inherently biased toward underestimating true impacts (i.e., there are numerous circumstances that result in dead bodies going uncounted, but rarely, if ever, is a dead body counted more than once). The Service prefers a risk-based approach that employs easily verified measures of wildlife exposure to contaminants and exposure-response risk functions. Given adequate risk-functions, not only are measures of exposure more reliable (i.e. less uncertain) than body counts, they are orders of magnitude less expensive to obtain.

Any compensation protocol should be based on clearly stated premises that are amenable to empirical validation and, when applicable, periodic re-evaluation. Furthermore, any compensation scheme must be realistic to implement, that is, it should optimize the certainty/cost ratio by relying on data that can be measured with high certainty and can be collected with relatively low cost. Therefore, the protocols developed here are based on measures of selenium concentrations in the eggs of recurvirostrids (stilts and avocets) and nest densities of recurvirostrids. Selenium concentrations in recurvirostrid eggs and recurvirostrid nest densities can be measured with a high degree of replicability (certainty), and usually require only a day per week during the breeding season (per study site) to obtain the necessary samples and/or data. Recurvirostrid eggs sampled at evaporation basins have generally proven to be reliable indicators of basin-specific contaminant conditions (e.g., Ohlendorf et al. 1993; Skorupa 1994), and there exists a substantial base of scientific data from both laboratory and field studies relevant to estimating risk functions (e.g., Ohlendorf et al. 1986; Heinz et al. 1987; Schroeder et al. 1988; Ohlendorf 1989; Williams et al. 1989; Heinz et al. 1989; Whiteley and Yuill 1989; Skorupa and Ohlendorf 1991; CH2M HILL et al. 1993; Ohlendorf et al. 1993).

RISK-BASED APPROACH

Our approach for compensation is based on the degree of basin contamination and the extent of wildlife exposure. Basins exposing more birds to higher concentrations of selenium require more compensation habitat and vice-versa. Presently, this generally translates into two factors being the primary determinants of compensation habitat obligations: (1) the size of a basin (all else equal, bigger basins attract more wildlife), and (2) the concentration of selenium in water discharged to a basin (as reflected in recurvirostrid eggs). As alternative habitats (see alternative habitat protocol) are established and standard design and operating procedures for evaporation basins are modified to discourage use of the basins by wildlife, these changes will translate into reduced compensation obligations through reduced exposure of wildlife.

GENERAL PREMISES (GP)

Basin Design and Operation

(GP-1) On-shore vegetation control at basins will effectively eliminate most nesting habitat for waterfowl.

One caveat applicable to premise GP-1 is that removal of on-shore vegetation at evaporation basins may have minimal impact on the number of breeding ducks that are foraging at evaporation basins because ducks are commonly known to be capable of nesting long distances (miles) away from the nearest shoreline of their foraging areas. One locally specific example of this is illustrated by the only duck nest (a gadwall nest) monitored by the Service on Kern NWR during the dry breeding season of 1989. The nest was more than 3 kilometers (ca. 2 miles) from the nearest known potential shallow water foraging area, an evaporation pond, and the concentration of selenium in a random sample egg (7.3 ppm, or about 3-4 times a normal background concentration) confirmed that the hen was probably foraging for significant amounts of time at the distant evaporation pond.

(GP-2) In-basin control of submergent aquatic vegetation (e.g., widgeon-grass) will effectively eliminate most nesting habitat for eared grebes (*Podiceps nigricollis*).

(GP-3) Removal of all islands and wave-break levees will effectively eliminate most nesting habitat for terns.

The combined implications of the above premises are a shift in species composition of breeding birds at evaporation basins to nearly complete dominance by shorebirds. Recurvirostrids would be, by far, the primary shorebird taxa of focus for compensation purposes. USFWS 1987-1989 nest records revealed that recurvirostrids comprised about 75% of all breeding birds even prior to complete implementation of the above stated premises (e.g., Skorupa et al. 1993; CH2M HILL et al. 1993). With complete implementation, recurvirostrids are expected to comprise greater than 90% of all breeding birds at evaporation basins. Thus, selenium in recurvirostrid eggs is the most appropriate standard for assessing wildlife exposure. Accordingly, recurvirostrid exposure-response data will be preferred for estimating wildlife risks associated with the operation of evaporation basins (recurvirostrids are neither the most sensitive nor least sensitive taxa to selenium).

The focus on recurvirostrid data may not be appropriate during the nonbreeding season when waterfowl and species of shorebirds other than recurvirostrids such as sandpipers and phalaropes are more prominent (e.g., Jehl 1988; CH2M Hill et al. 1993). By default, compensation protocols must rely primarily on breeding season data due to a lack of extensive "response" data for nonbreeding birds. Consequently, compensation obligations can be met by providing breeding season habitat. Therefore, true compensation habitat obligations are necessarily underestimated. Presumably, however, the year-round alternative habitat obligations required for effective hazing and for creating a bird safe local landscape around evaporation basins will eliminate the primary risks to nonbreeding birds such as directly fatal poisoning, impaired ability to migrate, impaired ability to avoid predators, immune suppression, and various long-term demographic consequences associated with impaired body condition (e.g., adult longevity, age of first breeding, fecundity, etc.).

<u>Predation Losses</u>

<u>(GP-4)</u> The inherent viability (= hatchability) of a recurvirostrid egg is a probabilistic function of its selenium content at the time of oviposition.

Accordingly, basin operators are obligated to compensate for all selenium-caused inviability of eggs. The fact that a predator "naturally removes" an already "doomed" egg does not release a basin operator from the obligation to compensate for that egg. A chemically inviable egg's fate (and a basin operator's responsibility) has already been determined at the time of oviposition (i.e., when the egg leaves the hen's body). This is more a question of legal liability with regard to definitions of "take" than a question of biology. From a liability perspective, one must distinguish between the number of eggs chemically destroyed and the net biological impact of that destruction. Under statutes such as the Migratory Bird Treaty Act an operator assumes liability for any verifiable "take" without consideration of whether the "take" has population-level impacts or not (i.e., "take" is unconditionally prohibited).

As a matter of biology, some reviewers of the draft Compensation Habitat Protocol advocated releasing operators from compensating for chemically inviable eggs that are subsequently predated up until the normal "background level" of predation is exceeded. The primary problem with that approach is that background levels of predation depend on the quality of the nesting habitat. Recurvirostrids show a very strong attraction to islands as nesting habitat. Such preferred (high quality) nesting habitat would be associated with near-zero background predation rates under undisturbed natural conditions or artificial conditions that mimic historically pristine conditions. For example, H.T. Harvey and Associates (1995) reported for Westlake Farms' section 3 alternative habitat (which possessed continuously isolated islands throughout the breeding season) a 5% nest predation rate and Sidle and Arnold (1982) reported for an island in the Mud Lake Waterfowl Production Area of North Dakota a 0% nest predation rate. The island they studied was thought to have supported the largest colony of breeding avocets documented in the scientific literature up to that publication date. Subsequently, if the "background level" of nest predation is established based on the good quality nesting habitat that recurvirostrids naturally seek out, the legal and biological perspectives converge on the same outcome, virtually all chemically-induced inviability of eggs should be compensated for.

(GP-5) Eggs lost to predators (or other causes of nest failure) in compensation wetlands do not provide a compensation benefit.

In the extreme case of total loss of eggs to predators in a compensation wetland, it is obvious that no compensation benefit has been provided. The relative habitat utility of compensation wetlands is devalued in direct proportion to predation losses and other sources of nest failure to yield the operational habitat utility. Not only is it important to maximize the attractiveness of compensation habitat to breeding birds (= habitat utility), it is also important to maximize the reproductive output from compensation habitat (= operational habitat utility). Thus, successful efforts to provide predator-safe nesting sites at compensation wetlands will yield higher operational habitat utility and lower compensation habitat obligations.

Relative Habitat Utility

The long-term average density of breeding birds attracted to an evaporation basin or compensation wetland is a measure of the site's attractiveness or utility as nesting habitat (i.e., the degree to which the habitat is utilized for nesting). Relative habitat utility is the attractiveness of one type of habitat, such as evaporation basins, relative to the attractiveness of another type of habitat, such as compensation wetlands. It is important to recognize the distinction between habitat utility and habitat quality. Habitat utility is established by the level of use, whereas habitat quality is established by the outcome of that use. Habitat utility is not a measure of habitat quality.

(GP-6) The primary determinants of habitat utility are predator-safe nesting sites and areas of shallow water supporting at least a threshold density of aquatic invertebrates.

Recurvirostrids exhibit a strong attraction to (predator-safe) islands or perceived islands, such as internal levees of artificial ponds, as nesting sites. Although recurvirostrids are known to utilize a wide variety of nesting substrates (Grinnell et al. 1918; Bent 1927; Johnsgaard 1981), the highest densities of nests occur on islands (e.g., Sidle and Arnold 1982; Salmon et al. 1991).

The densities of birds at saline-sink wetlands are generally believed to be food-limited in some fashion (e.g., Mono Basin Ecosystem Study Committee 1987) and the Service's Waterfowl Management Handbook recommends maintaining a density of at least 100 midge larvae per square meter to "...successfully attract and hold shorebirds." (Eldridge 1992). A study of foraging behavior among black-necked stilts (*Himantopus mexicanus*) at a manmade pond system in Puerto Rico revealed that abundance of invertebrates was a strong determinant of where the stilts were foraging (Cullen 1994). Cullen's study seems particularly relevant because his focal species (black-necked stilt), study site (manmade salt ponds), and primary aquatic invertebrate (waterboatman) all match-up well with Tulare Basin evaporation basins.

(GP-7) On a unit basis, predominantly shallow compensation wetlands with islands will exhibit about 2.5 times the habitat utility for breeding recurvirostrids as a traditional evaporation basin without islands.

In the first season (1994) of nest monitoring at Westlake Farms' demonstration wetland, it was estimated that 2.0 avian nesting attempts per acre were supported within the intensively monitored area (Cell G; Medlin 1994). Between 1987-1993, traditional evaporation basins without islands supported 0.41 to 1.41 avian nesting attempts per acre with a median of 0.81 (N=9 cases of relatively complete nest monitoring effort in space and time; USFWS, unpubl. data; see exhibit titled, Appendix of Unpublished Data). Additional estimates of habitat utility for compensation wetlands are needed to get a good sense for how variable they might be over time and between different sites, but the first-season data from Westlake Farms' demonstration wetland and alternative wetland currently constitute the best available information. The high habitat utility achieved by Westlake Farms in 1994 appears, to some extent, to be dependent on maintaining predominantly shallow wetlands. By comparison, the Corcoran Sewage Ponds, which are physically more similar to evaporation basins (i.e., offer just a near-shore strip of shallow water) supported only 0.67 nesting attempts per acre in 1989 (Skorupa 1991a). Thus, the relative habitat utility of a predominantly shallow compensation wetland with islands is estimated at (2.0)/(0.81)=2.47 times the habitat utility of traditional evaporation basins without islands.

(GP-8) The relative habitat utility of predominantly shallow compensation wetlands is devalued by about 30% due to nest predation and other causes of nest failure.

In the first season (1994) of nest monitoring at Westlake Farms' demonstration wetland, it was estimated that about 50% of avian nesting attempts within the intensively monitored area survived to hatching (Cell G; Medlin 1994). H.T. Harvey and Associates (1995) reported a nesting success rate of 95% for recurvirostrids nesting at Westlake Farms' alternative habitat in section 3. Accordingly the average nest failure rate for these two sites was about 30%. Additional estimates of devaluation factors for the relative habitat utility of compensation wetlands are needed to get a good sense for how variable they may be over time and between different sites, but the first-season data from Westlake Farms' demonstration wetland currently constitute the best available information. Based on currently available data, an operational relative habitat utility of 0.59:1 for evaporation basins versus compensation wetlands is employed in this protocol.

Actual performance at properly designed compensation wetlands may consistently come closer to the 95% nest success observed in section 3 than to the 50% observed at Westlake Farms' section 16 demonstration wetland in 1994 because anti-predator designs, and water delivery capacity were not completed to design specifications at section 16 in time for the 1994 breeding season. As actual performance in designing compensation wetlands up to specification on schedule is demonstrated, the predation devaluation factor will be revised. Presumably, over time, improved management techniques for maintaining predominantly shallow wetlands without compromising the predator safety of nesting sites will be developed so that in the future there will be little devaluation of relative habitat utility at compensation wetlands.

EGGWISE PREMISES (EP)

Eggwise Exposure-Response Risk Functions

(EP-1) There is an elevated probability of contaminant-mediated juvenile mortality due to immune dysfunction when eggs contain 3.9 ppm or more selenium (all selenium concentrations are presented on a dry weight basis).

A study of selenium exposure and the ability of mallard (*Anas platyrhynchos*) ducklings to survive a disease challenge (Whiteley and Yuill 1989) led to the suggestion that disease resistance may be affected more by the selenium concentration in a duckling's egg than by dietary exposure to elevated selenium after the duckling hatches. Duckling mortality following a challenge with duck hepatitis virus 1 (DHV1) was twice as high (67%, N=24 vs. 30%, N=37) among ducklings from eggs that averaged 3.9 ppm selenium than among ducklings from eggs with background concentrations of selenium (averaging 0.4 to 1.7 ppm).

(EP-2) There is an elevated probability of direct embryotoxicity, and an elevated probability of contaminant-mediated post-hatch juvenile mortality (due to depressed growth rates) when eggs contain 10 ppm or more selenium.

The logistic regression for eggs of black-necked stilts reported in Ohlendorf et al. (1986) shows that for individual eggs the threshold for embryotoxicity is about 10 ppm egg selenium (Skorupa and Ohlendorf 1991). By comparison, a population-level (geometric mean) threshold of 8 ppm egg selenium was reported by Skorupa and Ohlendorf (1991). For compensation purposes, individual-level risk functions are the most appropriate functions because they directly determine biological impacts.

Embryonic exposure to 10 ppm or more egg selenium was associated with depressed rates of growth among recurvirostrid chicks (Skorupa et al., unpubl. data; see Appendix of Unpublished Data). Early growth rates are strong predictors of juvenile survivorship in shorebirds (Cairns 1982). Contaminant-depressed growth rates can be expected to cause increased juvenile mortality.

Because the eggs in the study of recurvirostrid chicks were artificially incubated and the chicks were fed only uncontaminated food after hatching, it was demonstrated that egg selenium alone is sufficient to cause post-hatch growth depression in recurvirostrids (as was also found for mallard ducklings by Heinz et al. 1989) and therefore can serve as a direct predictor for such effects.

<u>(EP-3)</u> For eggs containing 3.9 to 9.9 ppm selenium it is estimated that the average long-term probability of contaminant-mediated juvenile mortality is about 10%.

Based on Whiteley and Yuill (1989; see EP-1 for a summary), a <u>minimum</u> contaminant mortality add-on of (67-30%)=37% is the assumed response to a pathogen challenge or similar "stress". It is presumed that this mortality is at least partially compensatory (i.e., compensated for in part by reduced competition and therefore density-dependent increased viability of the survivors; Hill 1988) and that stress "events" are intermittent (not occurring every year). Therefore the effect has been reduced arbitrarily by one-half, or down to 18.5%. Furthermore, it is presumed that not all chicks are exposed to pathogens, parasites, or other stresses during a stress event. Therefore the contaminant-mediated mortality has been arbitrarily reduced again to 10%. Although the resultant "10% premise" is simply an educated guess, a crude guess is still preferable to completely neglecting the empirically demonstrated immunobiological risk for chicks hatched from eggs with 3.9 ppm selenium or more. As more immunobiological research is completed, this educated guess can be revised.

<u>(EP-4)</u> Between about 10 to 100 ppm egg selenium the central probability of embryotoxicity or juvenile mortality is about 30%.

Heinz et al. (1989) experimentally demonstrated that when mallard eggs averaged about 11 ppm, 37 ppm, and 60 ppm selenium (from selenomethionine), production of 6-day-old ducklings declined by about 10%, 45%, and 100% compared to eggs that averaged less than 3 ppm selenium (background levels).

Ohlendorf et al. (1986) presented field data showing that as black-necked stilt eggs go from 10 ppm selenium to 60 ppm selenium the production of viable embryos should decline by about 35% to 70%.

In nature, the percent loss of avian production at the lower end of the 10 ppm to 60 ppm egg selenium range will be higher than suggested by the above studies because the above studies do not fully assess the risk associated with the post-hatch to recruitment phase of the reproductive cycle. For example, the Ohlendorf et al. (1986) data are for losses expected to occur between fertilization and hatch, but at Kesterson Reservoir losses occurring between hatch and recruitment were also thought to be substantial (Ohlendorf 1989; Williams et al. 1989).

Also, at evaporation basins, the upper range of egg selenium extends to about 100 ppm (excluding extreme outliers). That is substantially beyond the upper end of 60 ppm in the response curve for Kesterson Reservoir stilts (Ohlendorf et al. 1986).

In light of the studies by Heinz et al. (1989) and Ohlendorf et al. (1986), and their limitations, the "30% premise" proposed here would have to be considered a low estimate of the central probability for embryo or juvenile toxicity. An apparently low estimate was chosen intentionally because reproductive data for American avocets (*Recurvirostra americana*) indicate less sensitivity to selenium poisoning than is typically exhibited by ducks or stilts (Skorupa et. al. 1993; CH2M HILL 1994). Consequently, the "30% premise" attempts to take that species difference into consideration. Applying a single point-estimate risk function across an order of magnitude of embryo exposure to selenium is imprecise, but is dictated by the imprecision of available eggwise exposure-response data (e.g., see the wide confidence boundaries on Ohlendorf et al.'s (1986) exposure-response curves). As more detailed eggwise exposure-response data for recurvirostrids at evaporation basins become available, this premise could be revised.

COMPENSATION COEFFICIENTS: EGGWISE BASIS

Based on general premises GP-1 to GP-8, and the eggwise risk function premises EP-1 to EP-4, compensation coefficients for each evaporation basin can be calculated using the following equation:

$$CC = HU \times [(F1 \times L1) + (F2 \times L2)]$$

where,

CC = compensation coefficient = the multiple of an evaporation basin's acreage that, on average, would be required in predominantly shallow wetland acreage to replace lost production,

F1 = the weighted proportion of randomly sampled eggs at an evaporation basin containing 3.9 to 9.9 ppm selenium, where all species/year estimates are weighted equally (see example below),

F2 = the weighted proportion of randomly sampled eggs at an evaporation basin, containing 10 or more ppm selenium, where all species/year estimates are weighted equally,

L1 = proportion of production lost when egg contamination is from 3.9 to 9.9 ppm selenium (L1 = 0.10 from premise EP-3),

L2 = proportion of production lost when egg contamination is 10 ppm selenium or more (L2 = 0.30 from premise EP-4),

HU = the relative habitat utility of evaporation basins (HU = 0.59; from premises GP-7 and GP-8).

Egg selenium data for stilts and avocets, and from all years sampled at each evaporation basin, are weighted equally to derive the coefficients F1 and F2 for this first iteration of the calculations. Because there has been no compensation for historic impacts of evaporation basins, all available egg selenium data are utilized to reflect average pre-compensation conditions. As compensation calculations are updated at regular intervals, and egg selenium is systematically monitored at all evaporation basins, the calculations can be based on egg selenium data more uniformly matched to a specific compensation period.

<u>Example Calculation of a Compensation Coefficient</u>

If the proportions of contaminated eggs sampled from each taxa were distributed as shown below:

TAXON-YEAR	PROPORTION OF EGGS WITH 3.9 TO 9.9 PPM SELENIUM	PROPORTION OF EGGS WITH 10 PPM OR MORE SELENIUM
Stilts- Year 1	0.25	0.10
Stilts- Year 2	0.30	0.20
Avocets- Year 1	0.05	0.0
Avocets- Year 2	0.25	0.10
Avocets- Year 3	0.35	0.50

then,

$F1 = (0.25) + (0.3) + (0.05) + (0.25) + (0.35) / 5 = 1.2/5 = 0.24$

and,

$F2 = (0.1) + (0.2) + (0.0) + (0.1) + (0.5) / 5 = 0.9/5 = 0.18$

and,

$CC = 0.59 [(0.24)(.10) + (0.18)(.30)] = 0.047$

In this example, an area of compensation wetlands 4.7% the size of the evaporation basin would be required to compensate for estimated contaminant damage (i.e., 4.7 acres of compensation wetlands per 100 acres of evaporation basin).

Tulare Basin Compensation Coefficients: Eggwise Basis

Based on randomly sampled recurvirostrid eggs collected in 1986-1993 the following compensation coefficients have been calculated for evaporation basins in the Tulare Basin:

EVAPORATION BASIN	SAMPLE SIZE	F1	F2	COMPENSATION COEFFICIENT
Souza	--	----	----	---
Lindemann	--	----	----	---
Britz South Dos Palos	--	----	----	---
Sumner Peck	38	0.04	0.96	0.1723
Britz Davenport 5-Pts.	5	0.33	0.67	0.1381
Stone Land Company	18	0.22	0.17	0.0431
Lemoore Naval Air Station	8	0.26	0.0	0.0153
Westlake Farms North	51	0.16	0.02	0.0130
Fabry Farms	9	0.0	0.93	0.1646
Meyers Ranch	2	N/A	N/A	N/A
Barbizon Farms	--	----	----	---
TLDD North	49	0.27	0.0	0.0159
Westlake Farms South	22	0.86	0.03	0.0561
Liberty Farms	18	0.85	0.10	0.0679
Pryse Farms	71	0.57	0.25	0.0779
Bowman Farms	15	0.33	0.67	0.1381
Morris Farms	29	0.24	0.76	0.1487
Martin Farms	10	0.53	0.47	0.1145
Smith Farms	--	----	----	---
Four-J Corporation	15	0.45	0.48	0.1115
Nickell	--	----	----	---
TLDD Hacienda	34	0.70	0.27	0.0891
TLDD South	62	0.30	0.60	0.1239
Westfarmers	286	0.12	0.83	0.1540
Carmel Ranch	10	0.40	0.0	0.0236
Lost Hills Ranch	13	0.27	0.0	0.0159
Rainbow Ranch	68	0.42	0.57	0.1257
Chevron Land Company	--	----	----	---

Tulare Basin Compensation Acreage: Eggwise Basis

From the compensation coefficients listed above, the following acreages of shallow compensation wetlands would be required to balance the loss of avian production on evaporation basins:

EVAPORATION BASIN	EVAPORATION BASIN	COMPENSATION COEFFICIENT	COMPENSATION ACREAGE
Sousa	10	No Data	No Data
Lindemann	100	No Data	No Data
Britz South Dos Palos	50	No Data	No Data
Sumner Peck	100	0.1723	17
Britz-Davenport 5-Pts	25	0.1381	3
Stone Land Company	210	0.0431	9
Lemoore Naval Air Station	80	0.0153	1
Westlake Farms North	260	0.0130	3
Fabry Farms	7	0.1646	1
Meyers Ranch	59	Insufficient Data	Insufficient Data
Barbizon Farms	95	No Data	No Data
TLDD North	301	0.0159	5
Westlake Farms South	740	0.0561	42
Liberty Farms	(160)	0.0679	11
Pryse Farms	(40)	0.0779	3
Bowman Farms	15	0.1381	2
Morris Farms	35	0.1487	5
Martin Farms	13	0.1145	1
Smith Farms	7	No Data	No Data
Four-J Corporation	25	0.1115	3
Nickell	20	No Data	No Data
TLDD Hacienda	1026	0.0891	91
TLDD South	1832	0.1239	227
Westfarmers	542	0.1540	83
Carmel Ranch	180	0.0236	4
Lost Hills Ranch	90	0.0159	1
Rainbow Ranch	100	0.1257	13
Chevron Land Co.	65	No Data	No Data
TOTALS	**6107** (5760	---	**525**

NOTES: Evaporation basin acreages in parentheses are for sites that routinely had less than the full system capacity flooded up during most of the study period. Other acreages are from an October, 1994, Regional Water Quality Control Board statistical compilation.

HENWISE PREMISES (HP)

Henwise Exposure-Response Risk Functions

(HP-1) For any given exposure category (egg selenium) the magnitudes of embryonic and post-hatch losses are approximately equal.

Heinz et al. (1987) found that when mallard hens were fed diets supplemented with 10 ppm selenium as selenomethionine and the ducklings they produced were fed the same diet (as would occur in nature), there was both a 47% depression in egg hatchability and a 51% depression of post-hatch juvenile survival as compared to a control group. In a follow-up study, Heinz et al. (1989) fed mallard hens diets supplemented with 1, 2, 4, 8, and 16 ppm selenium as selenomethionine, but fed a clean diet to all the ducklings those hens produced. As would be expected, the embryotoxic effects were about the same as in the 1987 study (i.e. at the 8 ppm treatment level there was a 42% depression in egg hatchability), but the depression in post-hatch juvenile survivorship was much lower (only 18%). Field studies at Kesterson Reservoir suggested that, at high levels of contamination, post-hatch losses may greatly exceed embryonic losses (Ohlendorf 1989; Williams et al. 1989). For recurvirostrids, a depression in egg hatchability on the order of 10% was reportedly associated with a 100% depression in juvenile survivorship. Birds hatched in the wild face many stresses and risks that birds hatched in captivity (such as in Heinz's studies) don't face and that can magnify the post-hatch effects of contaminant exposure. Thus, a 1:1 premise for embryonic versus post-hatch adverse effects likely underestimates total reproductive impairment.

Under the premise that embryonic and post-hatch losses follow similar response curves it is possible to estimate total reproductive losses from embryonic losses alone. For example, if the proportion of embryonic losses is represented as "p" then the proportion of embryos surviving to hatch will be 1-p. If post-hatch mortality is about equal to embryo mortality (= p), then proportional post-hatch mortality will equal $p(1-p)$ or $p-p^2$. Thus, total proportional reproductive losses will equal embryo mortality (= p) plus post-hatch mortality (= $p-p^2$), which together add up to $2p-p^2$. Because a rigorous set of embryonic exposure-response data for recurvirostrids, on a henwise basis, has been collected at evaporation basins (Ohlendorf et al. 1993; Skorupa 1994), a fairly precise henwise-based risk function can be developed.

Henwise-based compensation calculations are presented for comparison to the eggwise-based calculations. The henwise-based protocol is statistically cleaner because only hens (not eggs) are independent data points. It also utilizes more detailed exposure-response data that was actually collected from studies of recurvirostrids nesting at evaporation basins. Additionally, it precisely incorporates the substantial species differences in sensitivity to selenium between stilts and avocets. Another advantage is that henwise compensation is the most appropriate approach from a population genetics perspective. Losses attributable to a given number of genetically distinct hens are replaced by an equal number of genetically distinct hens. By comparison, on an eggwise basis, 40 hens that each lost 1 egg could be compensated for by only 10 hens each producing 4 eggs. The disadvantage of the henwise approach is that you cannot compensate for a "partial hen". Any hen that is reproductively impaired, regardless of degree, is compensated for. That disadvantage, however, is counterbalanced by uncertainties regarding effects of selenium exposure on immune dysfunction, adult longevity, and age of first breeding (among other factors), all of which could impose demographic impacts on recurvirostrid populations that this compensation protocol does not take into account.

(HP-2) The long-term ratio of breeding stilts to avocets at evaporation basins is approximately 1:1.

Surveys conducted by the Service during 1987-1989 revealed an overall 1:1 ratio of breeding stilts and avocets (i.e., 2,285 stilt vs. 2,254 avocet nest records; Skorupa et al., unpubl. data; see Appendix of Unpublished Data), although basin-specific ratios can be highly variable from year to year. Likewise, it was estimated that approximately a 1:1 ratio of stilts and avocets was attracted to Westlake Farm's demonstration wetland near Kettleman City during the 1994 breeding season (i.e., estimates of 199 stilt vs. 180 avocet nesting attempts; Medlin 1994).

(HP-3) Weighting the stilt and avocet data equally, estimates of $2p - p^2$ for exposure categories of 0-5 ppm, 5.1-20 ppm, 21-40 ppm, 41-70 ppm, and $\geq$71 ppm egg selenium are: 0.0, 0.1889, 0.2551, 0.5083, and 0.9261 respectively.

The above henwise risk function is based on 354 stilt clutches and 229 avocet clutches that survived to full-term incubation and that also had a randomly selected sample egg analyzed for selenium (Skorupa et al., unpubl. data; see Appendix of Unpublished Data). The data were collected during 1983-1994 at Kesterson Reservoir, Volta Wildlife Management Area, Grasslands Resource Conservation District, and at evaporation basins and reference sites within the Tulare Lake Basin. Clutches were classified as impaired or normal based on whether or not they contained any fail-to-hatch eggs. Based on 141 recurvirostrid clutches with a sample egg containing 0-5 ppm selenium, the background value for p (the proportion of impaired clutches) was estimated as 0.08. By comparison, Holmes (1972) estimated that the normal proportion of impaired clutches among western sandpipers (Calidris mauri) nesting on the Yukon-Kuskokwim Delta of Alaska was 0.09. Like recurvirostrids, western sandpipers are shorebirds that normally produce four-egg clutches. Due to its remoteness, presumably the Yukon-Kuskokwim Delta is a relatively uncontaminated environment. Thus, background p = 0.08 (and background 1-p = 0.92) was taken to represent normal reproductive performance (i.e., zero contaminant-induced reproductive depression), and all measures of reproductive depression for other egg selenium (exposure) categories were calibrated accordingly (i.e., {(calibrated p) = 1 - [(1-raw p)/(0.92)]}).

COMPENSATION COEFFICIENTS: HENWISE BASIS

Based on general premises GP-1 to GP-8, and the henwise risk function premises HP-1 to HP-3, compensation coefficients for each evaporation basin can be calculated using the following equation:

$$CC = HU \times [(F1 \times L1) + (F2 \times L2) + (F3 \times L3) + (F4 \times L4) + (F5 \times L5)]$$

where,

CC = compensation coefficient = the multiple of an evaporation basin's acreage that, on average, would be required in predominantly shallow wetland acreage to replace lost production,

F1 = the proportion of randomly sampled eggs containing 0 to 5 ppm selenium,

F2 = the proportion of randomly sampled eggs containing 5.1 to 20 ppm selenium,

F3 = the proportion of randomly sampled eggs containing 21 to 40 ppm selenium,

F4 = the proportion of randomly sampled eggs containing 41 to 70 ppm selenium,

F5 = the proportion of randomly sampled eggs containing 71 or more ppm selenium,

L1 = proportion of production lost when egg contamination is from 0 to 5 ppm selenium (L1 = 0.0 from premise HP-3),

L2 = proportion of production lost when egg contamination is from 5.1 to 20 ppm selenium (L2 = 0.1889 from premise HP-3),

L3 = proportion of production lost when egg contamination is from 21 to 40 ppm selenium (L3 = 0.2551 from premise HP-3),

L4 = proportion of production lost when egg contamination is from 41 to 70 ppm selenium (L4 = 0.5083 from premise HP-3),

L5 = proportion of production lost when egg contamination is 71 or more ppm selenium (L5 = 0.9261 from premise HP-3),

HU = the relative habitat utility for evaporation basins (HU = 0.59; from premises GP-7 and GP-8).

Tulare Basin Compensation Coefficients: Henwise Basis

Based on randomly sampled recurvirostrid eggs collected in 1986-1993 the following compensation coefficients have been calculated for evaporation basins in the Tulare Basin:

EVAPORATION BASIN	SAMPLE	F1	F2	F3	F4	F5	COMPENSATION COEFFICIENT
Souza	--	----	----	----	----	----	----
Lindemann	--	----	----	----	----	----	----
Britz South Dos Palos	--	----	----	----	----	----	----
Sumner Peck	38	----	0.21	0.16	0.34	0.29	0.3079
Britz Davenport 5-Pts.	5	----	0.80	0.20	----	----	0.1192
Stone Land Company	18	0.94	0.06	----	----	----	0.0067
Lemoore Naval Air	8	0.88	0.12	----	----	----	0.0134
Westlake Farms North	51	0.86	0.12	0.02	----	----	0.0164
Fabry Farms	9	0.11	0.33	0.33	0.22	----	0.1524
Meyers Ranch	--	----	----	----	----	----	----
Barbizon Farms	--	----	----	----	----	----	----
TLDD North	49	0.86	0.14	----	----	----	0.0156
Westlake Farms South	22	0.55	0.45	----	----	----	0.0502
Liberty Farms	18	0.17	0.83	----	----	----	0.0925
Pryse Farms	71	0.38	0.61	0.01	----	----	0.0695
Bowman Farms	15	0.07	0.53	0.40	----	----	0.1193
Morris Farms	29	0.03	0.55	0.28	0.14	----	0.1454
Martin Farms	10	----	0.80	0.20	----	----	0.1192
Smith Farms	--	----	----	----	----	----	----
Four-J Corporation	15	0.13	0.87	----	----	----	0.0969
Nickell	--	----	----	----	----	----	----
TLDD Hacienda	34	0.09	0.85	0.06	----	----	0.1038
TLDD South	62	0.03	0.89	0.06	0.02	----	0.1142
Westfarmers	286	0.01	0.23	0.38	0.33	0.05	0.2091
Carmel Ranch	10	0.90	0.10	----	----	----	0.0112
Lost Hills Ranch	13	1.00	----	----	----	----	0.0000
Rainbow Ranch	68	0.03	0.72	0.18	0.03	0.03	0.1328
Chevron Land	--	----	----	----	----	----	----

Tulare Basin Compensation Acreage: Henwise Basis

From the compensation coefficients listed above, the following acreages of shallow compensation wetlands would be required to balance the loss of avian production on evaporation basins:

EVAPORATION BASIN	EVAPORATION BASIN ACREAGE	COMPENSATION COEFFICIENT	COMPENSATION ACREAGE
Sousa	10	No Data	No Data
Lindemann	100	No Data	No Data
Britz South Dos Palos	50	No Data	No Data
Sumner Peck	100	0.3079	31
Britz-Davenport 5-Pts	25	0.1192	3
Stone Land Company	210	0.0067	1
Lemoore Naval Air Station	80	0.0134	1
Westlake Farms North	260	0.0164	4
Fabry Farms	7	0.1524	1
Meyers Ranch	59	Insufficient Data	Insufficient Data
Barbizon Farms	95	No Data	No Data
TLDD North	301	0.0156	5
Westlake Farms South	740	0.0502	37
Liberty Farms	(160)	0.0925	15
Pryse Farms	(40)	0.0695	3
Bowman Farms	15	0.1193	2
Morris Farms	35	0.1454	5
Martin Farms	13	0.1192	2
Smith Farms	7	No Data	No Data
Four-J Corporation	25	0.0969	2
Nickell	20	No Data	No Data
TLDD Hacienda	1026	0.1038	106
TLDD South	1832	0.1142	209
Westfarmers	542	0.2091	113
Carmel Ranch	180	0.0112	2
Lost Hills Ranch	90	0.00	0
Rainbow Ranch	100	0.1328	13
Chevron Land Co.	65	No Data	No Data
TOTALS	**6107** (5760	---	**555**

NOTES: Evaporation basin acreages in parentheses are for sites that routinely had < the full system capacity flooded up during most of the study period. Other acreages from an Regional Board statistical compilation (10/94).

CONCLUDING DISCUSSION

Based on best available information and empirically testable premises, it is estimated that about 550 acres of shallow nondrainwater wetlands would be needed to compensate for breeding season avian losses on about 5,760 acres of Tulare Basin evaporation basins. Overall, that's a ratio of approximately 0.10 acres compensation for every acre of evaporation pond. For the ten basins (ca. 5,000 acres) that were listed as active by the Regional Water Quality Control Board as of October, 1994, it is estimated that about 490 acres of compensation wetlands would be needed. The cumulative compensation acreage is nearly identical for eggwise versus henwise calculations, however, obligations for individual basins often differ under the two sets of calculations. The henwise risk functions are more responsive to the nonlinear increase in risk associated with increasing exposure to selenium. Consequently, the main difference between eggwise and henwise calculations is that highly contaminated evaporation basins bear a higher proportion of the total obligation for compensation under the henwise protocol. The Service, as well as most reviewers of the draft Compensation Habitat Protocol, prefer the henwise calculations because they are based on more detailed and qualitatively superior (i.e., nonlinear) response functions.

It was envisioned that the task of setting compensation obligations would be a continuous cyclic process whereby there would be an initial iteration of compensation obligations that would be in effect for a 3-year period, then any new data collected or research findings reported during the compensation cycle would be incorporated into an updated iteration of compensation obligations, which in turn would be in effect for another 3-year compensation cycle and so on. The only way to realistically implement such a process is to base the compensation protocol on data that can be measured with reasonable certainty and at low cost. Thus, this protocol relies principally on measures of egg selenium, exposure-response functions, and long-term average comparative habitat utility (which is based on nest densities and therefore is responsive to changes in absolute abundances of breeding birds) for evaporation ponds versus compensation wetlands.

Egg selenium can be measured with greater certainty and precision than any other biological variable potentially relevant to assessing compensation obligations, and therefore provides the single most appropriate and equitable foundation upon which to build a compensation protocol. The structure of the protocol built upon that foundation will change as the state of knowledge regarding exposure-response functions and comparative habitat utility change. Accordingly, research and monitoring resources can be efficiently focused on those topics.

The Service prefers the concept of long-term relative habitat utility (HU) to site-specific absolute counts of birds or nests because site-specific absolute counts vary unpredictably from year-to-year even under relatively constant basin management and are of dubious certainty due to the myriad of potential biases in effect (for several reviews of such biases see the papers in Ralph and Scott 1981). For example, at TLDD South in June, 1990, within the same week, a standard park'n'drive count of birds conducted by two experienced observers (Todd Sloat & William Erickson, UCD Dept. Wildlife and Fisheries

Biology hazing research team) was followed by an intensive on-foot simultaneous count of snowy plovers by 19 observers deployed to achieve rapid complete coverage of the basin. The standard count yielded an estimate of 45 snowy plovers inhabiting the basin, whereas the complete coverage simultaneous count yielded an estimate of 95 snowy plovers inhabiting the basin...more than a 100% difference (Skorupa 1990). Despite the large uncertainty in the accuracy of standard park'n'drive absolute counts, the **relative** utility of habitats can be measured with good certainty if the biases affecting absolute counts are relatively uniform between habitats. If as envisioned by the Service, compensation habitat is concentrated at one or two regional compensation sites of well-documented and relatively constant habitat utility, then changes in HU due to changing nest densities monitored at evaporation basins will directly track absolute numbers of breeding birds.

Additionally, it is important to remember that the compensation protocols presented here do not explicitly address many potential impacts of evaporation basins on avian populations, including:

(1) Historic contaminant-induced losses not previously compensated.

Some basins were operational in the 1970's, and all basins were operational by 1985 (Westcot et al. 1988). The earliest studies (1984-1986) of environmental contamination and avian exposure to contaminants at evaporation basins revealed "potentially harmful levels" of exposure to selenium and impaired avian reproduction (Barnum and Gilmer 1988; Fujii 1988; Schroeder et al. 1988). From those earliest studies in the mid 1980's until the early 1990's avian exposure to selenium has been fairly constant (Skorupa et al., unpubl. data; see Appendix of Unpublished Data). The first compensation wetland, however, was not established until 1994. Consequently, markedly elevated avian exposure to selenium at evaporation basins has gone completely uncompensated for a decade or more.

(2) Contaminant-induced losses not detected among birds nesting outside the normal search radius of biologists conducting nest monitoring.

Agricultural fields and other "cover" habitat within several miles of an evaporation basin could harbor nesting ducks that are foraging at evaporation basins. See discussion of this topic under premise GP-1 above for an example. Biologists monitoring avian nests at evaporation basins rarely search for nests outside the perimeter levees of the basin system. Thus, adverse effects (if any) suffered by nesting ducks or any other species of waterbirds "commuting" to an evaporation basin would not be detected or compensated.

(3) Losses due to hazing during the breeding season.

Losses due to off-road vehicle activity associated with hazing efforts have been documented at one evaporation basin for western snowy plovers (Charadrius alexandrinus) and for recurvirostrids (Skorupa 1991b). These losses were discovered incidentally, and adverse impacts of hazing could easily have gone undetected at other evaporation basins.

(4) Losses due to levee grading, vegetation removal and managed water level fluctuations during the breeding season.

Several incidents of levee grading during the breeding season have been documented at three evaporation basins with the resultant loss of hundreds of recurvirostrid eggs (Skorupa 1991b; Skorupa et al., unpubl. data; see Appendix of Unpublished Data). Vegetation removal at two pond systems during the breeding season has been documented to have caused substantive (but not fully monitored) losses of waterbird eggs (Skorupa et al., pers. comm.). Managed water level fluctuations during the breeding season have also been documented to have caused losses of waterbird eggs (particularly eared grebes and black-necked stilts) at several evaporation basins (Skorupa et al., unpubl. data; see Appendix of Unpublished Data).

(5) Losses due to the use of automobile tires for levee stabilization.

The occurrence of losses of recurvirostrid chicks trapped inside automobile tires used to stabilize basin levees was documented at one evaporation basin (Skorupa et al., unpubl. photographs).

(6) Losses due to other physical barriers such as wave-induced foam, open pit blinds, and experimental shoreline netting.

Most ponds produce a ring of wave-induced foam along downwind shorelines. Foam encrustation of the down or feathers of recurvirostrid chicks has been documented to cause juvenile mortality (Marn and Anthony 1995). Several ponds retain concrete pit blinds, presumably originally intended for duck hunting, that are generally left uncovered. A variety of dead and dying wildlife and other animals have been found trapped in these blinds ranging from recurvirostrid chicks, to long-tailed weasels (Mustela frenata), to domestic sheep (Ovis spp.)(Skorupa et al., pers. obs.). Experimental shoreline netting at one evaporation basin has been documented to cause mortality of juvenile and adult shorebirds (Skorupa et al., unpubl. photographs; Barnum et al., in prep.).

(7) Losses due to contaminants other than selenium.

Although concentrations of trace elements other than selenium in avian eggs at evaporation basins do not exceed concentrations demonstrated to cause embryotoxicity (Ohlendorf et al. 1993), concentrations of arsenic and boron in the food chain at some evaporation basins are high enough to cause post-hatch adverse effects (e.g., Camardese et al. 1990; Hoffman et al. 1990). In addition, the spatial distribution of eared grebe colonies experiencing complete failure of eggs (directly bathed in drainwater) is not explained by the selenium content of the water (Skorupa et al., unpubl. data; see Appendix of Unpublished Data). Finally, in addition to a possible role in the grebe reproductive failures, the high salinity of drainwater has been documented to cause adverse effects (severe feather damage) for ruddy ducks (Euliss et al. 1989).

(8) Secondary hazards to predators of birds and their eggs.

Peregrine falcons (Falco peregrinus), northern harriers (Circus cyaneus), and burrowing owls (Athene cunicularia) have been observed preying on shorebirds at evaporation basins (Skorupa et al., pers. obs.). Gopher snakes (Pituophis catenifer), and mammalian predators have been observed preying on avian eggs at evaporation basins (Skorupa et al., pers. obs.). No studies of secondary hazards have quantified the risk that such predators are exposed to at evaporation basins. A peregrine falcon that was too weak to fly was recovered from a wheat field near an evaporation basin in 1992. A blood sample from the peregrine revealed a markedly elevated concentration of selenium as did feather samples. The peregrine quickly recovered when placed on a clean diet (consistent with selenium poisoning, but not conclusively diagnostic). A fresh cinnamon teal (Anas cyanoptera) carcass that a peregrine falcon was observed feeding from was recovered at the same evaporation basin and found to exhibit markedly elevated selenium concentrations (Detwiler 1991; White 1993; Skorupa et al., unpubl. data; see Appendix of Unpublished Data).

(9) Nonlethal impacts during the breeding season.

Lower mean body weights have been documented for breeding black-necked stilt hens collected from a medium-selenium and a high-selenium evaporation basin as compared to hens collected from a low-selenium evaporation basin (White 1993). The implications, if any, of this generally reduced body condition with regard to average adult longevity or other "fitness" parameters is unknown. Barnum (1992) notes, however, that poor body condition has been linked to lowered fitness (i.e. survival and future reproductive success) in several species of waterfowl.

(10) Lethal and nonlethal impacts occurring outside the breeding season.

There is a general lack of information on this topic. Barnum (1992) summarized available information on trends in body condition of birds wintering at evaporation ponds. He concluded that in general waterbirds wintering on evaporation ponds appeared to exhibit lower overall body condition, significantly enlarged salt glands, and elevated concentrations of breast and/or liver selenium. He further noted a general trend suggesting that increasing selenium exposure results in decreasing body condition; a trend that was statistically significant only for ruddy ducks (Oxyura jamaicensis). Based on a large program of experimental research conducted on behalf of the San Joaquin Valley Drainage Program, it was estimated that survival of wintering birds would be protected by not permitting food items to become contaminated with more than 10 ppm selenium on a dry weight basis (Heinz 1989; Patuxent Wildlife Research Center 1990). The widespread occurrence of food items with greater than 10 ppm selenium at evaporation basins (Moore et al. 1989) establishes the plausibility of substantive biological impacts outside the breeding season. As mentioned earlier, to the extent that such impacts may occur, they may also be partially or wholly alleviated by the provision of year-round alternative habitat as part of hazing and mitigation requirements.

Finally, there is a very important caveat associated with this protocol that was brought to our attention via the review comments of Ms. Carolyn Marn, a Ph.D. candidate at Oregon State University who conducted her Ph.D. research at Tulare Basin evaporation basins (for details see Ms. Marn's letter in the collection of comment letters, USFWS exhibit #10). Ms. Marn outlines mathematically several permutations of regional demographic conditions for avian populations under which our proposed Compensation Habitat Protocol would provide inadequate compensation. Since those conditions require the regional population of birds to behave as a demographically closed population, which the Service currently views as unlikely (especially for species that are not year-round territory holders), the outcomes modelled by Ms. Marn are probably not applicable (but, that has not been factually established). Nonetheless, Ms. Marn's line of reasoning does bring up the issue that if our protocol works regionally because of a demographic subsidy from outside the region, then strictly speaking there may be extra-regional demographic impacts that would constitute yet another class of impacts that this compensation protocol does not explicitly address.

REFERENCES CITED

Barnum, D.A. 1992. Impacts of evaporation ponds on wintering and migrating waterfowl and shorebirds. Memorandum (September 2, 1992) to the Chief, Section of Pacific States Ecology, Northern Prairie Wildlife Research Center, U.S. Fish and Wildlife Service, Dixon, CA. 14 pp, typed.

Barnum, D.A., and D.S. Gilmer. 1988. Selenium levels in biota from irrigation drainwater impoundments in the San Joaquin Valley, California. Lake and Reservoir Management, 4:181-186.

Bent, A.C. 1927. Life Histories of North American Shorebirds (Part I). Smithsonian Institution United States National Museum Bulletin, 142:37-54.

Cairns, W.E. 1982. Biology and behavior of breeding piping plovers. Wilson Bulletin, 94:531-545.

Camardese, M.B., D.J. Hoffman, L.J. LeCaptain, and G.W. Pendleton. 1990. Effects of arsenate on growth and physiology in mallard ducklings. Environmental Toxicology and Chemistry, 9:785-795.

CH2M HILL. 1994. Bird use and reproduction at the Richmond Refinery water enhancement wetland. Technical Report prepared for Chevron Richmond Refinery (November 1994), Richmond, CA. 13 pp, typed.

CH2M HILL, H.T. Harvey and Associates, and G.L. Horner. 1993. Cumulative Impacts of Agriculture Evaporation Basins on Wildlife. Technical Report prepared for California Department of Water Resources (February, 1993), Fresno, CA. 140 pp.

Cullen, S.A. 1994. Black-necked stilt foraging site selection and behavior in Puerto Rico. Wilson Bulletin, 106:508-513.

Detwiler, S.J. 1991. Endangered species sightings at TLDD-Hacienda evaporation ponds. Letter to California Department of Fish and Game (September 30, 1991), Fresno, CA. 2 pp, typed.

Eldridge, J. 1992. Management of habitat for breeding and migrating shorebirds in the Midwest. Waterfowl Management Handbook, Fish and Wildlife Leaflet, 13.2.14:1-6. U.S. Fish and Wildlife Service, Washington, D.C.

Euliss, N.H., Jr., R.L. Jarvis, and D.S. Gilmer. 1989. Carbonate deposition on tail feathers of ruddy ducks using evaporation ponds. Condor, 91:803-806.

Fujii, R. 1988. Water-quality and sediment-chemistry data of drain water and evaporation ponds from Tulare Lake Drainage District, Kings County, California, March 1985 to March 1986. Open-file Report 87-700. U.S. Geological Survey, Sacramento, CA. 19 pp.

Grinnell, J., H.C. Bryant, and T.I. Storer. 1918. The Game Birds of California. University of California Press. Berkeley, CA.

Heinz, G.H. 1989. Selenium poisoning in birds: information from laboratory studies. Research Information Bulletin No. 89-98. U.S. Fish and Wildlife Service, Fort Collins, CO. 4 pp.

Heinz, G.H., D.J. Hoffman, A.J. Krynitsky, and D.M.G. Weller. 1987. Reproduction in mallards fed selenium. Environmental Toxicology and Chemistry, 6:423-433.

Heinz, G.H., D.J. Hoffman, and L.G. Gold. 1989. Impaired reproduction of mallards fed an organic form of selenium. Journal of Wildlife Management, 53:418-428.

Hill, D. 1988. Population dynamics of the avocet (*Recurvirostra avosetta*) breeding in Britain. Journal of Animal Ecology, 57:669-683.

Hoffman, D.J., M.B. Camardese, L.J. LeCaptain, and G.W. Pendleton. 1990. Effects of boron on growth and physiology in mallard ducklings. Environmental Toxicology and Chemistry, 9:335-346.

Holmes, R.T. 1972. Ecological factors influencing the breeding season schedule of western sandpipers (Calidris mauri) in subarctic Alaska. American Midland Naturalist, 87:472-491.

H.T. Harvey and Associates. 1995. Westlake Farms, Inc., 1994 Annual Wildlife Monitoring Report. H.T. Harvey and Associates, Fresno, CA. 44p. + appendices.

Jehl, J.R., Jr. 1988. Biology of the eared grebe and wilson's phalarope in the non-breeding season: a study of adaptations to saline lakes. Studies in Avian Biology, 12:1-74.

Johnsgard, P.A. 1981. The Plovers, Sandpipers, and Snipes of the World. University of Nebraska Press, Lincoln, NE. 493 pp.

Marn, C.M., and R.G. Anthony. 1995. Post-hatch survival of shorebirds at evaporation ponds in the Tulare Basin, CA. Abstract for paper to be presented at 1995 annual meeting of The Wildlife Society. September 12-17, 1995, Portland, OR.

Medlin, J.A. 1994. Preliminary results from nest monitoring conducted at Westlake Farms' demonstration wetland. Letter to Westlake Farms, Inc. (July 1, 1994), Stratford, CA. 9 pp, typed.

Moore, S.B., S.J. Detwiler, J. Winckel, and M.D. Weegar. 1989. Biological residue data for evaporation ponds in the San Joaquin Valley, California. San Joaquin Valley Drainage Program, Sacramento, CA.

Mono Basin Ecosystem Study Committee. 1987. The Mono Basin Ecosystem: Effects of Changing Lake Level. National Academy Press, Washington, D.C. 272 pp.

Ohlendorf, H.M. 1989. Bioaccumulation and effects of selenium in wildlife. Pp. 133-177 in L.W. Jacobs (ed.), Selenium in Agriculture and the Environment. SSSA Special Publication No. 23. American Society of Agronomy and Soil Science Society of America. Madison, WI.

Ohlendorf, H.M., R.L. Hothem, C.M. Bunck, T.W. Aldrich, and J.F. Moore. 1986. Relationships between selenium concentrations and avian reproduction. Transactions of the North American Wildlife and Natural Resources Conference, 51:330-342.

Ohlendorf, H.M., J.P. Skorupa, M.K. Saiki, and D.A. Barnum. 1993. Food-chain transfer of trace elements to wildlife. Pp. 596-603 in R.G. Allen and C.M.U. Neale (eds.), Management of Irrigation and Drainage Systems: Integrated Perspectives. American Society of Civil Engineers, New York, NY.

Patuxent Wildlife Research Center. 1990. Effects of irrigation drainwater contaminants on wildlife. Technical report prepared for U.S. Bureau of Reclamation (July, 1990), Sacramento, CA 38 pp.

Ralph, C.J., and J.M. Scott. 1981. Estimating numbers of terrestrial birds. Studies in Avian Biology, 6:1-630.

Salmon, T.P., R.E. Marsh, T.R. Sloat, and W.A. Erickson. 1991. Effectiveness and cost of minimizing bird use on agricultural evaporation ponds. Technical Report to California Department of Water Resources (November, 1991), Fresno, CA. 118 pp, typed.

Schroeder, R.A., D.U. Palawski, and J.P. Skorupa. 1988. Reconnaissance Investigation of Water Quality, Bottom Sediment, and Biota Associated with Irrigation Drainage in the Tulare Lake Bed Area, Southern San Joaquin Valley, California, 1986-87. U.S. Geological Survey, Water-Resources Investigation Report 88-4001. Sacramento, CA.

Sidle, J.G., and P.M. Arnold. 1982. Nesting of the American avocet in North Dakota. Prairie Naturalist, 14:73-80.

Skorupa, J.P. 1990. Summary of results from 1990 intensive snowy plover survey at TLDD-S. Letter to Point Reyes Bird Observatory (June 16, 1990), Stinson Beach, CA. 1 p, typed.

Skorupa, J.P. 1991a. Review of draft Tulare Basin Cumulative Impacts Report compensation estimates. Letter to H.T. Harvey and Associates (March 21, 1991), Fresno, CA. 15 pp, typed.

Skorupa, J.P. 1991b. Impacts of hazing activities at Westlake Farms' south evaporation ponds near Kettleman City. Letter to California Department of Fish and Game (August 28, 1991), Tulare, CA. 4 pp, typed.

Skorupa, J.P. 1994. Impacts of selenium on the biological systems of the Salton Sea. In: Proceedings of the Salton Sea Symposium, January 13, 1994, Indian Wells, California. Salton Sea Authority, Imperial, CA. 15 pp, typed.

Skorupa, J.P., and H.M. Ohlendorf. 1991. Contaminants in drainage water and avian risk thresholds. Pp. 345-368 in A. Dinar and D. Zilberman (eds.), The Economics and Management of Water and Drainage in Agriculture. Kluwer Academic Publishers, Boston, MA.

Skorupa, J.P., H.M. Ohlendorf, R.L. Hothem, D.L. Roster, R.G. Stein, W.L. Hohman, D. Welsh, C.M. Marn, S.J. Detwiler, J. Winckel, P. Ramirez, J.A. Armstrong, and P.J. Leonard. 1993. Comparative ecotoxicology of selenium for breeding stilts and avocets exposed to irrigation drain water. Abstract for presentation to Annual Meeting of The Wildlife Society: Western Section (February 23-27, 1993), Monterey, CA. 1 p, typed.

Westcot, D.W., S.E. Rosenbaum, B.J. Grewell, and K.K. Belden. 1988a. Water and sediment quality in evaporation basins used for the disposal of agricultural subsurface drainage water in the San Joaquin Valley, California. Central Valley Regional Water Quality Control Board, Sacramento, CA. 49 p.

White, W. 1993. Review comments on revised draft of the Tulare Lake Basin Cumulative Impacts Report for agricultural evaporation ponds. Letter to California Regional Water Quality Control Board (May 10, 1993), Fresno, CA. 16 pp, typed.

Whiteley, P.L., and T.M. Yuill. 1989. Immune function and disease resistance of waterfowl using evaporation pond systems in the southern San Joaquin Valley, California, 1986-89. Final report to U.S. Fish and Wildlife Service, National Wildlife Health Research Center. Madison, WI.

Williams, M.L., R.L. Hothem, and H.M. Ohlendorf. 1989. Recruitment failure in American avocets and black-necked stilts nesting at Kesterson Reservoir, California, 1984-1985. Condor, 91:797-802.

Appendix C: California Senate Bill 1372 (SB 1372) and State Regulations on the Safe Operation of Solar Evaporators for IFDM Systems

BILL NUMBER: SB 1372 CHAPTERED
BILL TEXT

CHAPTER 597
FILED WITH SECRETARY OF STATE SEPTEMBER 16, 2002
APPROVED BY GOVERNOR SEPTEMBER 15, 2002
PASSED THE SENATE AUGUST 28, 2002
PASSED THE ASSEMBLY AUGUST 26, 2002
AMENDED IN ASSEMBLY AUGUST 23, 2002
AMENDED IN ASSEMBLY JULY 2, 2002
AMENDED IN ASSEMBLY JUNE 27, 2002
AMENDED IN SENATE MAY 1, 2002
AMENDED IN SENATE APRIL 4, 2002

INTRODUCED BY Senator Machado
(Coauthors: Senators Alpert and Kuehl)

FEBRUARY 7, 2002

An act to amend Section 25208.3 of, and to add Article 9.7 (commencing with Section 25209.10) to Chapter 6.5 of Division 20 of, the Health and Safety Code, relating to water.

LEGISLATIVE COUNSEL'S DIGEST

SB 1372, Machado. State Water Resources Control Board: agricultural drainage: solar evaporators.

(1) Under the Agricultural Water Conservation and Management Act, water suppliers, as defined, individually, or in cooperation with other public agencies or persons, may institute a water conservation or efficient water management program consisting of farm and agricultural related components. Existing law, the Toxic Pits Cleanup Act of 1984, prohibits a person from discharging liquid hazardous wastes into a surface impoundment if the surface impoundment, or the land immediately beneath the impoundment, contains hazardous wastes and is within 1/2 mile upgradient from a potential source of drinking water.

This bill would require the State Water Resources Control Board to adopt, on or before April 1, 2003, emergency regulations that establish minimum requirements for the design, construction, operation, and closure of solar evaporators, as defined. The bill would require any person who intends to operate a solar evaporator to file a notice of intent with the regional water quality control board. The bill would specify a procedure for the issuance of a notice of authority by the regional board to operate a solar evaporator, including requiring the regional board to inspect the solar evaporator prior to authorizing the operation of the solar evaporator. The bill would prohibit a regional board from issuing a notice of authority to operate a solar evaporator on and after January 1, 2008.

The bill would require any person operating a solar evaporator to submit annually, according to a schedule established by the regional board, groundwater monitoring data and other information deemed necessary by the regional board. The bill would require the regional board to inspect any solar evaporator at least once every 5 years to ensure continued compliance with the provisions of the bill.

The bill would exempt any solar evaporator operating under a valid written notice of authority to operate issued by the regional board, including any facility that the regional board determines is in compliance with the requirements of the bill, from the provisions of the toxic pits act and other specified waste discharge requirements imposed under the Porter-Cologne Water Quality Control Act.

Because the provisions added by the bill would be located within the hazardous waste control laws and a violation of those laws is a crime, the bill would impose a state-mandated local program by creating new crimes regarding the operation of solar evaporators.

(2) Existing law, the toxic pits act, requires the state board to impose a fee upon any person discharging any liquid hazardous waste or hazardous waste containing free liquids into a surface impoundment. The state board is required to collect and deposit the fees in the Surface Impoundment Assessment Account in the General Fund. The money within that account is available, upon appropriation, to the state board and the regional boards for purposes of administering the toxic pits act.

This bill would additionally authorize the board to expend the fees deposited in the account for the purpose of administering the surface impoundments that would be exempted from the toxic pits act by the bill, thereby imposing a tax for purposes of Article XIII A of the California Constitution.

(3) The California Constitution requires the state to reimburse local agencies and school districts for certain costs mandated by the state. Statutory provisions establish procedures for making that reimbursement.

This bill would provide that no reimbursement is required by this act for a specified reason.

THE PEOPLE OF THE STATE OF CALIFORNIA DO ENACT AS FOLLOWS:

SECTION 1. Section 25208.3 of the Health and Safety Code is amended to read:

25208.3. (a) The state board shall, by emergency regulation, adopt a fee schedule that assesses a fee upon any person discharging any liquid hazardous wastes or hazardous wastes containing free liquids into a surface impoundment, except as provided in Section 25208.17. The state board shall include in this fee schedule the fees charged for applications for, and renewals of, an exemption from Section 25208.5, as specified in subdivision (h) of Section 25208.5, from subdivision (a) of Section 25208.4, as specified in subdivision (b) of Section 25208.4, from subdivision (c) of Section 25208.4, as specified in Section 25208.16, and from Sections 25208.4 and 25208.5, as specified in subdivision (e) of Section 25208.13. The state board shall also include provisions in the fee schedule for assessing a penalty pursuant to subdivision (c). The state board shall set these fees at an amount equal to the state board's and regional board’s reasonable and anticipated costs of administering this article.

(b) The emergency regulations that set the fee schedule shall be adopted by the state board in accordance with Chapter 3.5 (commencing with Section 11340) of Part 1 of Division 3 of Title 2 of the Government Code, and for the purposes of that chapter, including Section 11349.6 of the Government Code, the adoption of these regulations is an emergency and shall be considered by the Office of Administrative Law as necessary for the immediate preservation of the public peace, health and safety, and general welfare. Notwithstanding

Chapter 3.5 (commencing with Section 11340) of Part 1 of Division 3 of Title 2 of the Government Code, any emergency regulations adopted by the state board pursuant to this section shall be filed with, but not be repealed by, the Office of Administrative Law and shall remain in effect until revised by the state board.
(c) The state board shall send a notice to each person subject to the fee specified in subdivision (a). If a person fails to pay the fee within 60 days after receipt of this notice, the state board shall require the person to pay an additional penalty fee. The state board shall set the penalty fee at not more than 100 percent of the assessed fee, but in an amount sufficient to deter future noncompliance, as based upon that person's past history of compliance and ability to pay, and upon additional expenses incurred by this noncompliance.
(d) The state board shall collect and deposit the fees collected pursuant to this article in the Surface Impoundment Assessment Account, which is hereby created in the General Fund. The money within the Surface Impoundment Assessment Account is available, upon appropriation by the Legislature, to the state board and the regional boards for purposes of administering this article and Article 9.7 (commencing with Section 25209.10).
SEC. 2. Article 9.7 (commencing with Section 25209.10) is added to Chapter 6.5 of Division 20 of the Health and Safety Code, to read:

Article 9.7. Integrated On-Farm Drainage Management

25209.10. The Legislature finds and declares all of the following:
(a) The long-term economic and environmental sustainability of agriculture is critical to the future of the state, and it is in the interest of the state to enact policies that enhance that sustainability.
(b) High levels of salt and selenium are present in many soils in the state as a result of both natural occurrences and irrigation practices that concentrate their presence in soils.
(c) The buildup of salt and selenium in agricultural soil is an unsustainable practice that degrades soil, harms an irreplaceable natural resource, reduces crop yields and farm income, and poses threats to wildlife.
(d) Salt and selenium buildup can degrade groundwater, especially in areas with perched groundwater aquifers.
(e) Off-farm drainage of irrigation water with high levels of salt and selenium degrades rivers and waterways, particularly the San Joaquin River and its tributaries. This environmental damage presents a clear and imminent danger that warrants immediate action to prevent or mitigate harm to public health and the environment.
(f) Discharge of agricultural drainage water to manmade drains and ponds has resulted in environmental damage, including damage to wildlife. Proposals to discharge agricultural drainage to natural water bodies, including the San Francisco Bay, are extremely expensive and pose threats to the environmental quality of those water bodies.
(g) Water supplies for agricultural irrigation have been reduced significantly in recent years, necessitating increased efforts to use water more efficiently.
(h) Although salt can be collected and managed as a commercial farm commodity, California currently imports salt from other countries.
(i) Integrated on-farm drainage management is a sustainable system of managing salt-laden farm drainage water. Integrated on-farm drainage

management is designed to eliminate the need for off-farm drainage of irrigation water, prevent the on-farm movement of irrigation and drainage water to groundwater, restore and enhance the productive value of degraded farmland by removing salt and selenium from the soil, conserve water by reducing the demand for irrigation water, and create the potential to convert salt from a waste product and pollutant to a commercial farm commodity.

(j) Although integrated on-farm drainage management facilities are designed and operated expressly to prevent threats to groundwater and wildlife, these facilities currently may be classified as surface impoundments pursuant to the Toxic Pits Act of 1984, which discourages farmers from using them as an environmentally preferable means of managing agricultural drainage water.

(k) It is the policy of the state to conserve water and to minimize the environmental impacts of agricultural drainage. It is therefore in the interest of the state to encourage the voluntary implementation of sustainable farming and irrigation practices, including, but not limited to, integrated on-farm drainage management, as a means of improving environmental protection, conserving water, restoring degraded soils, and enhancing the economic productivity of farms.

25209.11. For purposes of this article, the following terms have the following meanings:

(a) "Agricultural drainage water" means surface drainage water or percolated irrigation water that is collected by subsurface drainage tiles placed beneath an agricultural field.

(b) "On-farm" means within the boundaries of a property, geographically contiguous properties, or a portion of the property or properties, owned or under the control of a single owner or operator, that is used for the commercial production of agricultural commodities and that contains an integrated on-farm drainage management system and a solar evaporator.

(c) "Integrated on-farm drainage management system" means a facility for the on-farm management of agricultural drainage water that does all of the following:

(1) Reduces levels of salt and selenium in soil by the application of irrigation water to agricultural fields.

(2) Collects agricultural drainage water from irrigated fields and sequentially reuses that water to irrigate successive crops until the volume of residual agricultural drainage water is substantially decreased and its salt content significantly increased.

(3) Discharges the residual agricultural drainage water to an on-farm solar evaporator for evaporation and appropriate salt management.

(4) Eliminates discharge of agricultural drainage water outside the boundaries of the property or properties that produces the agricultural drainage water and that is served by the integrated on-farm drainage management system and the solar evaporator.

(d) "Regional board" means a California regional water quality control board.

(e) "Solar evaporator" means an on-farm area of land and its associated equipment that meets all of the following conditions:

(1) It is designed and operated to manage agricultural drainage water discharged from the integrated on-farm drainage management system.

(2) The area of the land that makes up the solar evaporator is equal to, or less than, 2 percent of the area of the land that is managed by the integrated on-farm drainage management system.

(3) Agricultural drainage water from the integrated on-farm drainage management system is discharged to the solar evaporator by timed sprinklers or other equipment that allows the discharge rate to be set and adjusted as necessary to avoid standing water within the solar evaporator or, if a water catchment basin is part of the solar evaporator, within that portion of the solar evaporator that is outside the basin.

(4) The combination of the rate of discharge of agricultural drainage water to the solar evaporator and subsurface tile drainage under the solar evaporator provides adequate assurance that constituents in the agricultural drainage water will not migrate from the solar evaporator into the vadose zone or waters of the state in concentrations that pollute or threaten to pollute the waters of the state.

(f) "State board" means the State Water Resources Control Board.

(g) "Water catchment basin" means an area within the boundaries of a solar evaporator that is designated to receive and hold any water that might otherwise be standing water within the solar evaporator. The entire area of a water catchment basin shall be permanently and continuously covered with netting, or otherwise designed, constructed, and operated to prevent access by avian wildlife to standing water within the basin.

25209.12. On or before April 1, 2003, the state board, in consultation, as necessary, with other appropriate state agencies, shall adopt emergency regulations that establish minimum requirements for the design, construction, operation, and closure of solar evaporators. The regulations shall include, but are not limited to, requirements to ensure all of the following:

(a) The operation of a solar evaporator does not result in any discharge of on-farm agricultural drainage water outside the boundaries of the area of land that makes up the solar evaporator.

(b) (1) The solar evaporator is designed, constructed, and operated so that, under reasonably forseeable operating conditions, the discharge of agricultural water to the solar evaporator does not result in standing water.

(2) Notwithstanding paragraph (1), a solar evaporator may be designed, constructed, and operated to accommodate standing water, if it includes a water catchment basin.

(3) The board may specify those conditions under which a solar evaporator is required to include a water catchment basin to prevent standing water that would otherwise occur within the solar evaporator.

(c) Avian wildlife is adequately protected. In adopting regulations pursuant to this subdivision, the state board shall do the following:

(1) Consider and, to the extent feasible, incorporate best management practices recommended or adopted by the United States Fish and Wildlife Service.

(2) Establish guidelines for the authorized inspection of a solar evaporator by the regional board pursuant to Section 25209.15. The guidelines shall include technical advice developed in consultation with the Department of Fish and Game and the United States Fish and Wildlife Service that may be used by regional board personnel to identify observed conditions relating to the operation of a solar evaporator that indicate an unreasonable threat to avian wildlife.

(d) Constituents in agricultural drainage water discharged to the solar evaporator will not migrate from the solar evaporator into the vadose zone or the waters of the state in concentrations that pollute or threaten to pollute the waters of the state.

(e) Adequate groundwater monitoring and recordkeeping is performed to ensure compliance with the requirements of this article.

(f) Salt isolated in a solar evaporator shall be managed in accordance with all applicable laws and shall eventually be harvested and sold for commercial purposes, used for beneficial purposes, or stored or disposed in a facility authorized to accept that waste pursuant to this chapter or Division 30 (commencing with Section 40000) of the Public Resources Code.

25209.13. (a) Any person who intends to operate a solar evaporator shall, before installing the solar evaporator, file a notice of intent with the regional board, using a form prepared by the regional board. The form shall require the person to provide information including, but not limited to, all of the following:

(1) The location of the solar evaporator.

(2) The design of the solar evaporator and the equipment that will be used to operate it.

(3) The maximum anticipated rate at which agricultural drainage water will be discharged to the solar evaporator.

(4) Plans for operating the solar evaporator in compliance with the requirements of this article.

(5) Groundwater monitoring data that are adequate to establish baseline data for use in comparing subsequent data submitted by the operator pursuant to this article.

(6) Weather data and a water balance analysis sufficient to assess the likelihood of standing water occurring within the solar evaporator.

(b) The regional board shall, within 30 calendar days after receiving the notice submitted pursuant to subdivision (a), review its contents, inspect, if necessary, the site where the proposed solar evaporator will be located, and notify the operator of the proposed solar evaporator whether it will comply with the requirements of this article. If the regional board determines that the proposed solar evaporator will not comply with this article, the regional board shall issue a written response to the applicant identifying the reasons for noncompliance. If the regional board determines the solar evaporator will comply with the requirements of this article, the regional board shall issue a written notice of plan compliance to the operator of the proposed solar evaporator.

(c) Any person who receives a written notice of plan compliance pursuant to subdivision (b) shall, before operating the installed solar evaporator, request the regional board to conduct a compliance inspection of the solar evaporator. Within 30 calendar days after receiving a request, the regional board shall inspect the solar evaporator and notify the operator whether it complies with the requirements of this article. If the regional board finds that the solar evaporator does not comply with the requirements of this article, the regional board shall issue a written response to the applicant identifying the reasons for noncompliance. Except as provided in subdivision (e), if the regional board determines that the solar evaporator complies with the requirements of this article, the regional board shall issue a written notice of authority to operate to the operator of the solar evaporator. The regional board may include in the authority to operate any associated condition that the regional board deems necessary to ensure compliance with the purposes and requirements of this article.

(d) No person may commence the operation of a solar evaporator unless the person receives a written notice of authority to operate the solar evaporator pursuant to this section.

(e) (1) On and after January 1, 2008, a regional board may not issue a written notice of authority to operate a solar evaporator pursuant to this section.

(2) The requirements of paragraph (1) do not affect the validity of any written notice of authority to operate a solar evaporator issued by the regional board before January 1, 2008.

(f) The regional board shall review any authority to operate issued by the regional board pursuant to this section every five years. The regional board shall renew the authority to operate, unless the regional board finds that the operator of the solar evaporator has not demonstrated compliance with the requirements of this article.

25209.14. (a) Any person operating a solar evaporator shall annually, according to a schedule established by the regional board pursuant to subdivision (b), submit groundwater monitoring data and any other information that is deemed necessary by the regional board to ensure compliance with the requirements of this article.

(b) Each regional board shall adopt a schedule for the submission of the data and information described in subdivision (a) at the earliest possible time. The regional board shall notify the operator of each solar evaporator of the applicable submission schedule.

25209.15. (a) The regional board, consistent with its existing statutory authority, shall inspect any solar evaporator that is authorized to operate pursuant to Section 25209.13 at least once every five years to ensure continued compliance with the requirements of this article. In conducting any inspection, the regional board may request the participation of a qualified state or federal avian biologist in a technical advisory capacity. The regional board shall include in the inspection report conducted pursuant to this section any evidence of adverse impacts on avian wildlife and shall forward the report to the appropriate state and federal agencies.

(b) If the regional board, as a result of an inspection or review conducted pursuant to this article, determines that a solar evaporator is not in compliance with the requirements of this article, the regional board shall provide written notice to the operator of the solar evaporator of that failure, and shall include in that written notice the reasons for that determination.

(c) Chapter 5 (commencing with Section 13300) of, and Chapter 5.8 (commencing with Section 13399) of, Division 7 of the Water Code apply to any failure to comply with the requirements of this article and to any action, or failure to act, by the state board or a regional board. The regional board may, consistent with Section 13223 of the Water Code, revoke or modify an authorization to operate issued pursuant to this article.

25209.16. (a) For the purposes of Chapter 3.5 (commencing with Section 11340) of Part 1 of Division 3 of Title 2 of the Government Code, including Section 11349.6 of the Government Code, the adoption of the regulations required to be adopted pursuant to Section 25209.12 is an emergency and shall be considered by the Office of Administrative Law as necessary for the immediate preservation of the public peace, health and safety, and general welfare.

(b) Notwithstanding Chapter 3.5 (commencing with Section 11340) of Part 1 of Division 3 of Title 2 of the Government Code, any emergency regulations adopted by the state board pursuant to Section 25209.12 shall be filed with, but not be repealed by, the Office of Administrative Law and shall remain in effect until revised by the state board.

25209.17. Any solar evaporator operating under a valid written notice of authority to operate issued by the regional board pursuant to this article, including any facility operating pursuant to Article 9.5 (commencing with Section 25208) prior to January 1, 2003, that the regional board determines is in compliance with the requirements of this article, is not subject to Article 9.5 (commencing with Section 25208) or Sections 13260 or 13263 of the Water Code. Upon determining pursuant to this section that a facility is a solar evaporator in compliance with this article, the regional board shall, as appropriate, revise or rescind any waste discharge requirements or other requirements imposed on the operator of the facility pursuant to Article 9.5 (commencing with Section 25208) or Section 13260 or 13263 of the Water Code.

SEC. 3. No reimbursement is required by this act pursuant to Section 6 of Article XIII B of the California Constitution because the only costs that may be incurred by a local agency or school district will be incurred because this act creates a new crime or infraction, eliminates a crime or infraction, or changes the penalty for a crime or infraction, within the meaning of Section 17556 of the Government Code, or changes the definition of a crime within the meaning of Section 6 of Article XIII B of the California Constitution.

BARCLAYS OFFICIAL CALIFORNIA CODE OF REGULATIONS

TITLE 27. ENVIRONMENTAL PROTECTION

DIVISION 2. SOLID WASTE

SUBDIVISION 1. CONSOLIDATED REGULATIONS FOR TREATMENT, STORAGE, PROCESSING OR DISPOSAL OF SOLID WASTE

CHAPTER 7. SPECIAL TREATMENT, STORAGE, AND DISPOSAL UNITS

SUBCHAPTER 6. SOLAR EVAPORATORS

ARTICLE 1. SOLAR EVAPORATOR REGULATIONS

[NOTE: REGULATIONS IN THIS ARTICLE WERE PROMULGATED BY THE STATE WATER RESOURCES CONTROL BOARD (SWRCB), ARE ADMINISTERED BY THE APPROPRIATE REGIONAL WATER QUALITY CONTROL BOARD (RWQCB), AND ARE APPLICABLE TO THE OWNER OR OPERATOR OF A SOLAR EVAPORATOR FOR THE
MANAGEMENT OF AGRICULTURAL DRAINAGE WATER DISCHARGES FROM AN INTEGRATED ON-FARM DRAINAGE MANAGEMENT SYSTEM (IFDM).]

This database is current through 06/16/06, Register 2006, No. 24.

s 22900. SWRCB - Applicability.

(a) General - This article applies to the discharge of agricultural drainage water from Integrated On-Farm Drainage Management (IFDM) systems to solar evaporators as defined in s22910. No SWRCB-promulgated parts of the Division 2 of Title 27 and Division 3, Chapter 15 of Title 23 of the California Code of Regulations (CCR) shall apply to the discharge of agricultural drainage water from IFDM systems to solar evaporators unless those sections are specifically referenced in this article. Any person who intends to operate a solar evaporator after November 22, 2004 shall comply with the requirements of this article before a Notice of Plan Compliance and Notice of Authority to Operate (s25209.13 of Article 9.7 of the Health and Safety Code) will be issued by a Regional Water Quality Control Board (RWQCB).

s 22910. SWRCB - Definitions.

For purposes of this article, the following terms have the following meanings:

(a) "Adequately protected" means that:

(1) Avian wildlife have no access to standing water in a water catchment basin.

(2) Standing water does not occur in a solar evaporator outside of a water catchment basin, under reasonably forseeable operating conditions.

(3) The solar evaporator, including the water catchment basin, does not become a medium for the growth of aquatic and semi-aquatic macro invertebrates that could become a harmful food source for avian wildlife, under reasonably forseeable operating conditions.

(b) "Agricultural drainage water" means surface drainage water or percolated irrigation water that is collected by subsurface drainage tiles placed beneath an agricultural field.

(c) "Avian Wildlife Biologist" means any State or federal agency biologist, ecologist, environmental specialist (or equivalent title) with relevant avian wildlife monitoring experience (as determined by the RWQCB), or any professional biologist, ecologist, environmental specialist (or equivalent title) possessing valid unexpired State and federal collecting permits for avian wildlife eggs.

(d) "Boundaries of the solar evaporator" or "boundaries of a solar evaporator" means the outer edge of the solar evaporator or any component of the solar evaporator, including, but not limited to, berms, liners, water catchment basins, windscreens, and deflectors.

(e) "Certified Engineering Geologist" means a registered geologist, certified by the State of California, pursuant to section 7842 of the Business and Professions Code.

(f) "Hydraulic conductivity" means the ability of natural and artificial materials to transmit water. The term is expressed as a measure of the rate of flow through a unit area cross-section of material. The unit of measure is cm/sec.

(g) "Integrated on-farm drainage management system" means a facility for the on-farm management of agricultural drainage water that does all of the following:

(1) Reduces levels of salt and selenium in soil by the application of irrigation water to agricultural fields.

(2) Collects agricultural drainage water from irrigated fields and sequentially reuses that water to irrigate successive crops until the volume of residual agricultural drainage water is substantially decreased and its salt content significantly increased.

(3) Discharges the residual agricultural drainage water to an on-farm solar evaporator for evaporation and appropriate salt management.

(4) Eliminates discharge of agricultural drainage water outside the boundaries of the property or properties that produces the agricultural drainage water and that is served by the integrated on-farm drainage management system and the solar evaporator.

(h) "Liner" means:

(1) a continuous layer of natural or artificial material, or a continuous membrane of flexible and durable artificial material, or a continuous composite layer consisting of a membrane of flexible artificial material directly overlying a layer of engineered natural material, which is installed beneath a solar evaporator, and which acts as a barrier to vertical water movement, and

(2) a material that has appropriate chemical and physical properties to ensure that the liner does not fail to contain agricultural drainage water because of pressure gradients, physical contact with the agricultural drainage water, chemical reactions with soil, climatic conditions, ultraviolet radiation (if uncovered), the stress of installation, and the stress of daily operation, and

(3) a material that has a minimum thickness of 40 mils (0.040 inches) for flexible artificial membranes or synthetic liners.

(4) The requirements of this definition are applicable only if a liner is used to meet the requirements of s22920(c).

(i) "Nuisance" means anything which meets all of the following requirements:

(1) Is injurious to health, or is indecent or offensive to the senses, or an obstruction to the free use of property, so as to interfere with the comfortable enjoyment of life or property.

(2) Affects at the same time an entire community or neighborhood, or a considerable number of persons, although the extent of the annoyance or damage inflicted on individuals may be unequal.

(3) Occurs during, or as a result of, the treatment or disposal of wastes.

(j) "On-farm" means within the boundaries of a property, geographically contiguous properties, or a portion of the property or properties, owned or under the control of a single owner or operator, that is used for the commercial production of agricultural commodities and that contains an IFDM system and a solar evaporator.

(k) "Pollution" means an alteration of the quality of the waters of the state by waste to a degree which unreasonably affects either of the following:

(1) The waters for beneficial uses.

(2) Facilities which serve these beneficial uses.

(l) "Reasonably foreseeable operating conditions" means:

(1) within the range of the design discharge capacity of the IFDM system and the authorized solar evaporator system as specified in the Notice of Plan Compliance and Notice of Authority to Operate (s25209.13 of Article 9.7 of the Health and Safety Code),

(2) precipitation up to and including the local 25-year, 24-hour storm, and

(3) floods with a 100-year return period. Operation of a solar evaporator in exceedance of design specifications is not covered by "reasonably foreseeable operating conditions," and therefore would constitute a violation of the Notice of Authority to Operate.

(m) "Regional Board" and "RWQCB" means a California Regional Water Quality Control Board.

(n) "Registered Agricultural Engineer" means an agricultural engineer registered by the State of California, pursuant to section 6732 of the Business and Professions Code.

(o) "Registered Civil Engineer" means a civil engineer registered by the State of California, pursuant to section 6762 of the Business and Professions Code.

(p) "Registered Geologist" means a geologist registered by the State of California, pursuant to section 7842 of the Business and Professions Code.

(q) "Solar evaporator" means an on-farm area of land and its associated equipment that meets all of the following conditions:

(1) It is designed and operated to manage agricultural drainage water discharged from the IFDM system.

(2) The area of the land that makes up the solar evaporator is equal to, or less than, 2 percent of the area of the land that is managed by the IFDM system.

(3) Agricultural drainage water from the IFDM system is discharged to the solar evaporator by timed sprinklers or other equipment that allows the discharge rate to be set and adjusted as necessary to avoid standing water within the solar evaporator or, if a water catchment basin is part of the solar evaporator, within that portion of the solar evaporator that is outside the basin.

(4) The combination of the rate of discharge of agricultural drainage water to the solar evaporator and subsurface tile drainage under the solar evaporator provides adequate assurance that constituents in the agricultural drainage water will not migrate from the solar evaporator into the vadose zone or waters of the state in concentrations that pollute or threaten to pollute the waters of the state.

(r) "Standing water" means water occurring under all of the following conditions:

(1) to a depth greater than one centimeter,

(2) for a continuous duration in excess of 48 hours,

(3) as a body of any areal extent, not an average depth, and

(4) under reasonably forseeable operating conditions.

(s) "Subsurface drainage tiles" or "subsurface tile drainage" means any system of subsurface drainage collection utilizing drainage tiles, perforated pipe, or comparable conveyance, placed below the surface of any IFDM system area including the solar evaporator.

(t) "Unreasonable threat" to avian wildlife means that avian wildlife is not adequately protected.

(u) "Vadose zone" means the unsaturated zone between the soil surface and the permanent groundwater table.

(v) "Water catchment basin" means an area within the boundaries of a solar evaporator that is designated to receive and hold any water that might otherwise be standing water within the solar evaporator. The entire area of a water catchment basin shall be permanently and continuously covered with netting, or otherwise designed, constructed, and operated to prevent access by avian wildlife to standing water within the basin. A water catchment basin may include an enclosed solar still, greenhouse or other fully contained drainage storage unit. For the purposes of this definition, the term "within the boundaries of a solar evaporator" shall include a solar still, greenhouse, or other fully contained drainage storage unit adjacent to or near the portion of the solar evaporator that is outside the catchment basin.

(w) "Waters of the state" means any surface water or groundwater, including saline water, within the boundaries of the state.

s 22920. SWRCB - Solar Evaporator Design Requirements.

(a) Registered Professionals - Solar evaporators shall be designed by a registered civil or agricultural engineer, or a registered geologist or certified engineering geologist.

(b) Flooding - A solar evaporator shall be located outside the 100-year floodplain, or shall be constructed with protective berms/levees sufficient to protect the solar evaporator from overflow and inundation by 100-year floodwaters, or shall be elevated above the maximum elevation of a 100-year flood.

(c) Protection of Groundwater Quality - Solar evaporators shall be immediately underlain by at least 1 meter of soil with a hydraulic conductivity of not more than 1 x 10 -6cm/sec above the zone of shallow groundwater at any time during the year. The surface of the solar evaporator shall be a minimum of five-feet (5 ft.) above the highest anticipated elevation of underlying groundwater. A solar evaporator may be constructed on a site with soils that do not meet the above requirement, with subsurface tile drainage under or directly adjacent to the solar evaporator, a liner, or other engineered alternative, sufficient to provide assurance of the equivalent level of groundwater quality protection of the above soil requirement.

(d) Discharge to the Facility - All discharge to the solar evaporator shall be agricultural drainage water collected from the IFDM system or recirculated from the solar evaporator as a component of the IFDM system. No agricultural drainage water from the IFDM system or the solar evaporator may be discharged outside the boundaries of the solar evaporator

(e) Facility Size - The area of land that makes up the solar evaporator may not exceed 2 percent of the area of land that is managed by the IFDM system.

(f) Means of Discharge to the Facility - Discharge of agricultural drainage water from the IFDM system to the solar evaporator shall be by timed sprinklers or other equipment that allows the discharge rate to be set and adjusted as necessary to avoid standing water in the solar evaporator, outside a water catchment basin. The sprinklers shall be equipped with screens or shields or other devices as necessary to prevent the drift of agricultural drainage water spray outside the boundaries of the solar evaporator.

(g) Water Catchment Basin - A water catchment basin may be required:

(1) As a component of a solar evaporator if standing water would otherwise occur within the solar evaporator under reasonably foreseeable operating conditions, or

(2) If a solar evaporator is constructed with a liner. In this case, a water catchment basin shall be designed with the capacity to contain the maximum volume of water that the solar evaporator would collect under reasonably forseeable operating conditions. A water catchment basin is not required for a solar evaporator that does not have a liner, if it is demonstrated that standing water will not occur under reasonably foreseeable operating conditions.

(h) Avian Wildlife Protection - The solar evaporator shall be designed to ensure that avian wildlife is adequately protected as set forth in s22910(a) and (v).

s 22930. SWRCB - Solar Evaporator Construction Requirements.

(a) Registered Professionals - Construction of solar evaporators shall be supervised and certified, by a registered civil or agricultural engineer, or a registered geologist or certified engineering geologist, as built according to the design requirements and Notice of Plan Compliance (s25209.13 of Article 9.7 of the Health and Safety Code).

s 22940. SWRCB - Solar Evaporator Operation Requirements.

(a) Limitation on Standing Water - The solar evaporator shall be operated so that, under reasonably forseeable operating conditions, the discharge of agricultural drainage water to the solar evaporator will not result in standing water, outside of a water catchment basin. Agricultural drainage water from the IFDM system shall be discharged to the solar evaporator by timed sprinklers or other equipment that allows the discharge rate to be set and adjusted as necessary to avoid standing water in the solar evaporator.

(b) Prevention of Nuisance - The solar evaporator shall be operated so that, under reasonably forseeable operating conditions, the discharge of agricultural drainage water to the solar evaporator does not result in:

(1) The drift of salt spray, mist, or particles outside of the boundaries of the solar evaporator, or

(2) Any other nuisance condition.

(c) Prohibition of Outside Discharge - The operation of a solar evaporator shall not result in any discharge of agricultural drainage water outside the boundaries the solar evaporator.

(d) Salt Management - For solar evaporators in continuous operation under a Notice of Authority to Operate issued by a Regional Water Quality Control Board, evaporite salt accumulated in the solar evaporator shall be collected and removed from the solar evaporator if and when the accumulation is sufficient to interfere with the effectiveness of the operation standards of the solar evaporator as specified in this section. One of the following three requirements shall be selected and implemented by the owner or operator:

(1) Evaporite salt accumulated in the solar evaporator may be harvested and removed from the solar evaporator and sold or utilized for commercial, industrial, or other beneficial purposes.

(2) Evaporite salt accumulated in the solar evaporator may be stored for a period of one-year, renewable subject to an annual inspection, in a fully contained storage unit inaccessible to wind, water, and wildlife, until sold, utilized in a beneficial manner, or disposed in accordance with (3).

(3) Evaporite salt accumulated in the solar evaporator may be collected and removed from the solar evaporator, and disposed permanently as a waste in a facility authorized to accept such waste in compliance with the requirements of Titles 22, 23, 27 and future amendments of the CCR, or Division 30 (commencing with Section 40000) of the Public Resources Code.

(e) Monitoring - Monitoring and record keeping, including a groundwater monitoring schedule, data, and any other information or reporting necessary to ensure compliance with this article, shall be established by the RWQCB in accord with s25209.14 of Article 9.7 of the Health and Safety Code.

(f) Avian Wildlife Protection - The solar evaporator shall be operated to ensure that avian wildlife is adequately protected as set forth in s22910(a) and (v). The following Best Management Practices are required:

(1) Solar evaporators (excluding water catchment basins) shall be kept free of all vegetation.

(2) Grit-sized gravel (<5 mm in diameter) shall not be ued as a surface substrate within the solar evaporator.

(3) Netting or other physical barriers for excluding avian wildlife from water catchment basins shall not be allowed to sag into any standing water within the catchment basin.

(4) The emergence and dispersal of aquatic and semi-aquatic macro invertebrates or aquatic plants outside of the boundary of the water catchment basin shall be prevented.

(5) The emergence of the pupae of aquatic and semi-aquatic macro invertebrates from the water catchment basin onto the netting, for use as a pupation substrate, shall be prevented.

(g) Inspection - The RWQCB issuing a Notice of Authority to Operate a solar evaporator shall conduct authorized inspections in accord with s25209.15 of Article 9.7 of the Health and Safety Code to ensure continued compliance with the requirements of this article. The RWQCB shall request an avian wildlife biologist to assist the RWQCB in its inspection of each authorized solar evaporator at least once annually during the month of May. If an avian wildlife biologist is not available, the RWQCB shall nevertheless conduct the inspection. During the inspection, observations shall be made for compliance with s22910(a) and (v), and the following conditions that indicate an unreasonable threat to avian wildlife:

(1) Presence of vegetation within the boundaries of the solar evaporator;

(2) Standing water or other mediums within the solar evaporator that support the growth and dispersal of aquatic or semi-aquatic macro invertebrates or aquatic plants;

(3) Abundant sustained avian presence within the solar evaporator that could result in nesting activity;

(4) An apparent avian die-off or disabling event within the solar evaporator;

(5) Presence of active avian nests with eggs within the boundaries of the solar evaporator.

If active avian nests with eggs are found within the boundaries of the solar evaporator, the RWQCB shall report the occurrence to the USFWS and DFG within 24 hours, and seek guidance with respect to applicable wildlife laws and implementing regulations. Upon observation of active avian nests with eggs within the boundaries of the solar evaporator, all discharge of agricultural drainage water to the solar evaporator shall cease until (a) the nests are no longer active, or (b) written notification is received by the owner or operator, from the RWQCB, waiving the prohibition of discharge in compliance with all applicable state and federal wildlife laws and implementing regulations (i.e., as per applicable exemptions and allowable take provisions of such laws and implementing regulations.)

s 22950. SWRCB - Solar Evaporator Closure Requirements.

(a) For solar evaporators ceasing operation through discontinuance of operation or non-renewal of a Notice of Authority to Operate issued by a RWQCB, closure and post-closure plans shall be prepared and submitted to the RWQCB and approved by the RWQCB prior to closure. Closure plans shall conform to one of the following three requirements to be selected and implemented by the owner or operator:

(1) Evaporite salt accumulated in the solar evaporator may be harvested and removed from the solar evaporator and sold or utilized for commercial, industrial, or other beneficial purposes or stored for a period of one-year, renewable subject to an annual inspection, in a fully contained storage unit inaccessible to wind, water, and wildlife, until sold, utilized in a beneficial manner, or disposed in accordance with (3). After the removal of accumulated salt, the area within the boundaries of the solar evaporator shall be restored to a condition that does not pollute or threaten to pollute the waters of the state, that does not constitute an unreasonable threat to avian wildlife, and that does not constitute a nuisance condition. Clean closure may be accomplished in accord with s21090(f) and s21400 of CCR Title 27.

(2) The solar evaporator may be closed in-place, with installation of a final cover with foundation, low-hydraulic conductivity, and erosion-resistant layers, as specified in s21090 and s21400 of CCR Title 27. Closure in-place shall include a closure plan and post-closure cover maintenance plan in accord with s21090 and s21769 of CCR Title 27.

(3) Evaporite salt accumulated in the solar evaporator may be collected and removed from the solar evaporator, and disposed permanently as a waste in a facility authorized to accept such waste in compliance with the requirements of Titles 22, 23, 27 and future amendments of the CCR, or Division 30 (commencing with Section 40000) of the Public Resources Code. After the removal of accumulated salt, the area within the boundaries of the solar evaporator shall be restored to a condition that does not pollute or threaten to pollute the waters of the state, that does not constitute an unreasonable threat to avian wildlife, and that does not constitute a nuisance condition.

s 23001. Purpose of the Landfill Closure Loan Program.

The purpose of the Landfill Closure Loan Program (Program) is to provide loans to operators of older-technology, unlined landfills who desire to close their landfills in order to avoid or to mitigate potential environmental problems being caused or threatened by continued operation of the landfill.

Appendix D: USFWS Comments to California State Water Resources Control Board on Best Management Practices for IFDM and Solar Evaporators

United States Department of the Interior

FISH AND WILDLIFE SERVICE
Sacramento Fish and Wildlife Office
2800 Cottage Way, Room W-2605
Sacramento, California 95825-1846

IN REPLY REFER TO:
FWS/EC-03-053

MAY 9 2003

Stan Martinson
Chief, Division of Water Quality
State Water Resources Control Board
P.O. Box 100
Sacramento, California 95812-0100

Dear Mr. Martinson:

At your request of March 14, 2003, the U.S. Fish and Wildlife Service (Service) is providing input to three questions regarding Senate Bill 1372 which requires the State Water Resources Control Board (State Board) to develop regulations on the design, construction, operation, and closure of solar evaporators as components of Integrated On-Farm Drainage Management (IFDM) Systems. Senate Bill 1372 specifies that the new regulations ensure that avian wildlife is adequately protected by considering best management practices recommended by the Service and utilizing technical advice from the Service and others with regard to establishing inspection guidelines for the Regional Water Quality Control Board (Regional Board). To this end you asked three specific questions for us to answer:

> 1) What constitutes "adequate protection" for avian wildlife in the design and operation of solar evaporators as defined by SB 1372?
>
> 2) What best management practices (BMPs) for solar evaporators do you recommend at this time?
>
> 3) What are your recommendations for inspection guidelines that may be used to "identify observed conditions relating to the operation of a solar evaporator that indicate an unreasonable threat to avian wildlife?"

The Service has been studying the effects of drainwater evaporation ponds on avian wildlife in the San Joaquin Valley for nearly 15 years. Since 1996, we have been studying the effects of solar evaporators associated with IFDM Systems on avian and other wildlife in cooperation with landowners, the California Department of Water Resources, the

Central Valley Regional Board, the California Department of Fish and Game, and others. The answers to your questions, as per our current state of knowledge of the impacts of solar evaporators to avian wildlife, are below.

What constitutes "adequate protection" for avian wildlife in the design and operation of solar evaporators as defined by SB 1372?

The Service recommends that adequate protection is provided for avian wildlife when the operation of a solar evaporator, and the entire IFDM system enabled by operation of a solar evaporator, does not present physical or ecological pathways for excessive avian exposure to harmful chemicals contained in agricultural drainage water. Such pathways are most likely to be associated with bodies of standing water that support aquatic invertebrates and/or aquatic plants. Other terrestrial pathways are possible, but less likely. To adequately protect avian wildlife, the Service recommends that the establishment of such exposure pathways or avian access to such exposure pathways must be avoided or eliminated. Also, the effectiveness of avoidance measures must be adequately monitored to ensure that avian wildlife are protected. Adequate monitoring means monitoring of sufficient frequency to have reasonable confidence that any substantive avian exposure event would be detected.

What best management practices (BMPs) for solar evaporators do you recommend at this time?

To protect wildlife potentially at risk at solar evaporators, the following BMP's are recommended:

(1) Solar evaporators (outside of catchment basins) should be kept free of all vegetation.

(2) Use of grit-sized ($\leq$ 5 mm diameter) gravel as a surface substrate accessible to avian wildlife should be avoided within the perimeter of a solar evaporator.

(3) Water catchment basins in solar evaporators should be managed and controlled adequately to prevent the emergence and dispersal of aquatic invertebrates or plants outside the boundary of a catchment basin (including the use of catchment basin netting as a pupation substrate for emerging aquatic invertebrates).

(4) Netting or other physical barriers for excluding avian wildlife from water catchment basins in solar evaporators should not be allowed to sag into the water column of a water catchment basin.

(5) In the event that avian wildlife establish any nests with eggs inside the perimeter of a solar evaporator, all discharges to the solar evaporator should cease until,

(a) there is/are no longer any active nest(s) present, or

(b) written notification is received from a California Regional Water Quality Control Board waiving prohibition of discharge in compliance with all applicable state and federal wildlife laws and implementing regulations (i.e., as per applicable exemptions and allowable take provisions of such laws and implementing regulations).

(6) Solar evaporators should be subject to unannounced visits for wildlife monitoring purposes at least once annually during the month of May by a qualified avian biologist approved by a California Regional Water Quality Control Board. Within 7 days of such a monitoring visit the avian biologist should submit to the Regional Water Board a written report documenting the,

(a) presence or absence of standing water,

(b) presence or absence of avian wildlife nests with eggs,

(c) presence or absence of emerging or otherwise dispersing aquatic invertebrates or plants from a water catchment basin,

(d) presence or absence of vegetation anywhere within the perimeter of a solar evaporator, and

(e) any other general observations deemed relevant to managing and minimizing risks to any species of wildlife associated with a solar evaporator (including, but not limited to, lists of all wildlife species detected at a solar evaporator).

(7) In the event that avian nests with eggs are discovered within the perimeter of a solar evaporator during a monitoring visit, such result of monitoring should be communicated to the appropriate staff of a California Regional Water Quality Control Board within 24-hours. The Regional Water Board should immediately forward any such notifications to the appropriate staff of the California Department of Fish and Game and the Service and seek guidance with regard to applicable wildlife laws and implementing regulations.

Definition:

"Avian biologist" means any state or federal agency biologist, ecologist, environmental specialist (or equivalent title) with relevant avian wildlife monitoring experience (as determined by a Regional Water Board), or any professional biologist, ecologist, environmental specialist (or equivalent title) possessing valid unexpired state and federal collecting permits for avian wildlife eggs.

What are your recommendations for inspection guidelines that may be used to "identify observed conditions relating to the operation of a solar evaporator that indicate an unreasonable threat to avian wildlife?"

We recommend the following guidelines to identify conditions that indicate an unreasonable threat to avian wildlife:

(1) Anytime there is a condition of avian accessible standing water of any depth that supports aquatic invertebrates and/or aquatic plants at any time of year, but even more so between February 1st and August 31st.

(2) Anytime there is a condition of abundant sustained avian presence anywhere within the IFDM system where re-use of highly saline (outside the tolerance limits of traditional market crops) drainage water is enabled by operation of the solar evaporator, until the exact nature of that avian activity is determined.

(3) Anytime an apparent avian die-off or disabling (such as salt encrustation) event is detected, until the apparent cause of the event is determined and remedied (including mortality from entanglement in netting at water catchment basins or by avian chicks moving through netting mesh).

(4) Anytime during the core breeding season (April-June) that there is a condition of gross habitat manipulation or conversion (such as discing, mowing, thinning, etc.) anywhere within the IFDM system where re-use of highly saline (outside the tolerance limits of traditional market crops) drainage water is enabled by operation of the solar evaporator.

We appreciate the opportunity to assist the State Board with protecting avian wildlife in the San Joaquin Valley and at the same time allow sustainable agriculture to thrive. Should you have additional questions please contact Dr. Joseph Skorupa or Mr. Tom Maurer at (916) 414-6590.

Sincerely,

David L. Harlow

David L. Harlow
Acting Field Supervisor

cc:
Manager, U.S. Fish and Wildlife Service, California/Nevada Operations Office, Sacramento, California
Anthony Toto, Central Valley Regional Water Quality Control Board, Fresno, California

United States Department of the Interior

FISH AND WILDLIFE SERVICE
Sacramento Fish and Wildlife Office
2800 Cottage Way, Room W-2605
Sacramento, California 95825-1846

REPLY TO ATTENTION TO:
FWS/EC-03-066

JUL 15 2003

Celeste Cantu, Executive Director
State Water Resources Control Board
P.O. Box 100
Sacramento, California 95812-0100

Dear Ms. Cantu:

On March 18 of this year, the U.S. Fish and Wildlife Service (Service) received a request from the State Water Resources Control Board (SWRCB) for input and comment on Senate Bill (SB) 1372, which requires the SWRCB to develop emergency regulations regarding the design, construction, operation, and closure of solar evaporators as components of Integrated on-Farm Drainage Management (IFDM) Systems. The focus of this request was to answer three questions relating to Section 25209.12(c) of SB 1372, which specifies that the new regulations shall include requirements to ensure that:

"Avian wildlife is adequately protected. In adopting regulations pursuant to this subdivision, the state board shall do the following:

1. Consider and, to the extent feasible, incorporate best management practices recommended or adopted by the United States Fish and Wildlife Service.

2. Establish guidelines for the authorized inspection of a solar evaporator by the regional board pursuant to Section 25209.15. The guidelines shall include technical advice developed in consultation with the Department of Fish and Game and the United States Fish and Wildlife Service that may be used by regional board personnel to identify observed conditions relating to the operation of a solar evaporator that indicate an unreasonable threat to avian wildlife."

The Service responded to the SWRCB's questions in a letter dated May 9, 2003, (File No. FWS/EC-03-053). This letter included a definition of what constitutes "adequate protection" for avian wildlife in the design and operation of solar evaporators as defined by SB 1372, several recommendations for best management practices (BMPs) for solar evaporators, and recommendations for inspection guidelines. The Service understood that the information provided in this letter would be incorporated into the subsequent emergency regulations proposed by the SWRCB.

During a recent SWRCB workshop (July 1, 2003), the SWRCB was to consider a resolution adopting the proposed emergency regulations required by SB 1372. Unfortunately, the Service was unaware of this workshop and did not attend, nor did we know the proposed regulations were available for review and comment prior to the July 1 workshop. We have since obtained and reviewed the proposed regulations, and are pleased to find many of our recommendations were included. However, critical components of our recommendations necessary to adequately protect avian wildlife were not included as the regulations are currently proposed. We would like to take this opportunity to clarify the positions outlined in our May 9 letter, and request that the SWRCB take steps to modify the proposed emergency regulations so that avian wildlife are adequately protected.

In our May 9 letter, we pointed out that solar evaporators and IFDM systems are only possible because of each other; that is, they are both components of one system to manage pollutants in agricultural drainage water. This is apparent in the definition of an IFDM system given in SB 1372, which specifically states that the system does four things, including: (3) "Discharges the residual agricultural drainage water to an on-farm solar evaporator for evaporation and appropriate salt management." Because of this interdependence, it is not possible to fully consider protection of avian wildlife by only focusing on one component of the system. As the function of the IFDM system is to sequentially concentrate pollutants as the irrigation water is re-used through plots of increasingly salt-tolerant vegetation, the potential for adverse impacts to avian wildlife exists in areas other than the solar evaporator. In order to ensure that avian wildlife is adequately protected from the design and operation of a solar evaporator, consideration needs to be given to those IFDM components (*i.e.*, irrigation plots of halophytes and salt-tolerant crops and grasses) whose function is to concentrate the agricultural drainage water pollutants prior to discharge into the solar evaporator.

In response to the question of what constitutes adequate protection for avian wildlife in the design and operation of solar evaporators, the Service recommended that adequate protection would be achieved when pollutant exposure pathways (*i.e.*, bodies of standing water that support aquatic invertebrates or plants) are prevented **in the solar evaporator and the entire IFDM system**. The definition of "adequately protected" in the currently proposed regulations makes no mention of any IFDM system components other than solar evaporators and water catchment basins. However, not including other aspects of the full system may not ensure adequate protection, as the IFDM components where salt-tolerant vegetation is irrigated may be especially attractive to nesting shorebirds (Vance and Skorupa, 2003). The water used to irrigate these plots will have elevated pollutant concentrations (*e.g.*, selenium) and, if allowed to stand and support aquatic invertebrates or plants, can cause detrimental effects in nesting birds. To avert any potential misunderstanding that avian wildlife will be adequately protected in an IFDM system if the emergency regulations pertaining strictly to solar evaporators are followed, the Service requests that the definition of "adequately protected" under Section 22910 of the proposed regulations be modified to include that avian wildlife have no access to standing water in IFDM system plots where halophytes or salt-tolerant crops or grasses are grown.

Section 22940 of the proposed SWRCB regulations, "Solar Evaporator Operation Requirements," states that solar evaporators shall be operated so that, under reasonably foreseeable operating conditions, the discharge of agricultural drainage water to the solar evaporator will not result in standing water, outside of a catchment basin. This limitation is appropriate to protect avian wildlife that might otherwise be attracted to standing water in the evaporators; however, to fully protect avian wildlife, the limitation must also be placed on other areas of the IFDM system where pollutant concentrations in re-used drainage water are expected to be highly elevated. While pollutant concentrations in these re-use areas may not be as high as in water ultimately discharged into the solar evaporators, concentrations can reach levels at which severe toxicological impacts to birds would be expected (Vance and Skorupa, 2003).

The Service recognizes that the proposed emergency regulations before the SWRCB are intended to meet the requirements of SB 1372 for the design, construction, operation, and closure of solar evaporators. As noted, however, these evaporators are only one part of a larger system designed to provide safe re-use and disposal of contaminated agricultural drainage water. In order to ensure that re-use and disposal are accomplished in a manner that adequately protects avian wildlife, the entire system needs safeguards to prevent excessive avian exposure to drainage water pollutants. If safeguards are only put in place for solar evaporators, the risk to avian wildlife may merely be relocated to other areas of the IFDM system. To address this issue, the Service requests that Section 22940 of the proposed emergency regulations be modified to include a limitation on standing water in IFDM system plots where halophytes or salt-tolerant crops or grasses are grown.

Also in response to the SWRCB's initial request for input and comments, the Service provided recommendations for inspection guidelines that may be used to "identify observed conditions relating to the operation of a solar evaporator that indicate an unreasonable threat to avian wildlife." Similar to our response on what constitutes adequate protection, the Service discussed the IFDM system areas where highly saline drainage water is re-used on salt-tolerant vegetation. These recommendations were not included in the proposed emergency regulations prepared for the July 1 workshop. Instead, Section 22940(g) of the proposed regulations focuses only on inspection of the solar evaporators. While the language in SB 1372 and the proposed regulations could suggest that only the solar evaporator component of the IFDM needs to be addressed, the Service believes the intent of the language concerning protection of avian wildlife has a broader scope. As we have pointed out, ensuring protection only at the final step in the IFDM process, and not including conditions at preceding steps in the process, may result in severe toxicological effects to avian wildlife. To this end, the Service believes the inspection guidelines should include a provision for the drainage water re-use areas of the IFDM system. Inspecting these additional areas should not be burdensome, as they will still be within the property boundaries defined under 22910(i), and may help to prevent unreasonable threats to avian wildlife. We request the SWRCB reconsider including into the proposed emergency regulations the inspection guideline recommendations provided in our May 9 letter.

Thank you for your consideration of these comments. Should you have further questions about the Service's position on these issues, please contact Mr. Daniel Russell at (916) 414-6590.

Sincerely,

David L. Harlow
Acting Field Supervisor

cc:
Mary Ellen Mueller, U.S. Fish and Wildlife Service, California/Nevada Operations Office, Sacramento,
CA
Arthur G. Baggett, Jr., Chair, State Water Resources Control Board, Sacramento, CA
Stan Martinson, State Water Resources Control Board, Sacramento, CA
Wayne Verrill, State Water Resources Control Board, Sacramento, CA
Anthony Toto, Central Valley Regional Water Qaulity Control Board, Fresno, CA
Julie Vance, California Department of Water Resources, Fresno, CA
Andy Gordus, California Department of Fish and Game, Fresno, CA

REFERENCES

Vance, J. and J. Skorupa. 2003. Potential avian selenium exposure of current and proposed drainage water management in the San Joaquin Valley. Powerpoint presentation at the San Joaquin Valley Natural Communities Conference, March 27, 2003. California State University, Bakersfield, California.

Appendix E: Almond Facts, January/February 2000

John and Georgene Diener with Governor's Award.

John Diener pioneers innovative land and water reclamation system

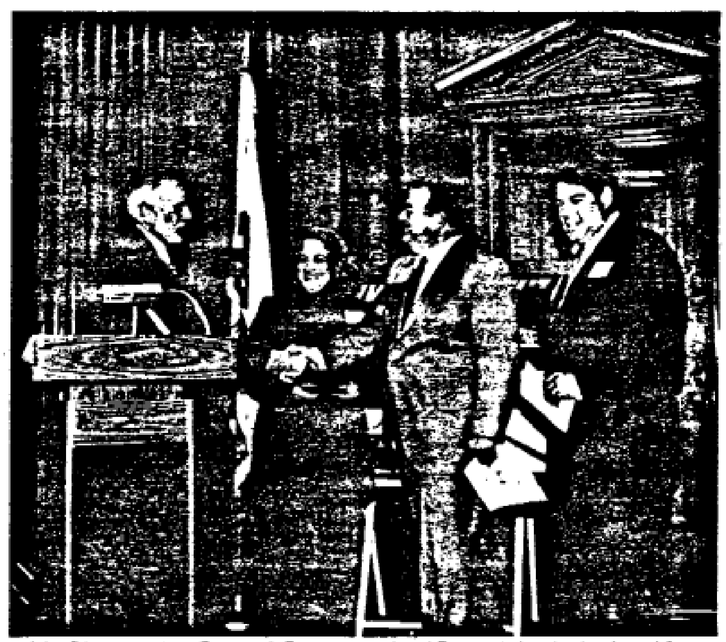
While environmentalists and others called for permanent retirement of salt-laden San Joaquin Valley farmland and opposed drainage plans that would send the salty runoff to the San Joaquin-Sacramento Delta, Blue Diamond member John Diener figured there must be a solution to the salinity problem. There had to be an answer that would preserve the rich farmland for agriculture, without damaging the environment.

Risking his resources on a 640-acre parcel near Five Points, southwest of Fresno, he poured hundreds of thousands of dollars into an innovative system that cleansed the land, harvested the runoff, produced marketable crops, and salvaged the collected salts for potential commercial use. Diener's solution to the area's salt problem earned a 1999 Governor's Environmental and Economic Leadership Award.

His success is also opening the way for other growers to renew their land to grow valuable crops on acreage previously considered too salty for commercial agriculture.

Governor's Praise

Last December, John Diener mounted the stage in Sacramento to accept the Governor's Award from



John Diener receives Governor's Environmental and Economic Leadership Award from California EPA Secretary Winston Hickox and Secretary for Resources Mary Nichols.

California Environmental Protection Agency Secretary Winston Hickox and Secretary for Resources Mary Nichols. The award is the state's most prestigious environmental honor. Recipients are chosen from California organizations and companies "for excellence in protecting the environment and conserving natural resources, while at the same time promoting compatible, sustainable economic development."

A statement by Governor Gray Davis for the occasion said, "Increasingly, there is a recognition that what is good for the environment is also good for business. I am pleased to honor organizations and individuals that demonstrate exemplary practices in protecting the environment in ways that promote economic benefits."

What Diener accomplished met those goals exactly. According to the award announcement, "Mr. Diener developed an innovative system for agricultural management of drainage water, salts and selenium as economic resources. This system protects the environmental quality of water in rivers and in the Delta. Diener converted his saline land into prime agricultural land capable of producing high yields of crops in a sustainable way. His farm provides an outstanding example of ecologically sound practices for other growers in the area."

A Revolutionary Idea

Tens of thousands of acres of Westside farmland battle a salt problem. The lack of an efficient drain to carry away salt-laden runoff and perched water dooms those acres to eventual abandonment. Public concern about potential environmental degradation of local streams and the Delta, and selenium contamination of the Kesterson Wildlife Refuge, severely limit growers' options for purging their land of salts.

Diener grew up farming in the Five Points area, took an agricultural economics degree from UC Davis, and launched his own farming operation on the Westside in 1980. Over the years leading up to that point, he had seen a lot of good land lost to salt intrusion, but he figured there must be a way around the problem. He envisioned creating an irrigation management system that would reclaim the land and use and reuse the irrigation water without releasing any drainage from his property.

Rows of salt-tolerant eucalyptus intercept subsurface flows of salt-laden water. These two-year-old trees are thriving.

Launches Project

He began putting his ideas to work in 1989 with the purchase of a 640-acre parcel on the Westside. It was too salty for most crops and sat over a perched water table as shallow as 10 feet below the surface. But it had "potential," said Diener. "It is good soil, prime Panoche loam, the kind of ground that could grow four bales of cotton or 50 tons of tomatoes."

As a member of the board of directors of the Westside Resource Conservation District, Diener was accustomed to working closely with the USDA's Natural Resource Conservation Service on ways to help farmers reclaim land. Putting that experience and his excellent contacts in state and federal resource agencies to work, he designed his project as a working laboratory. His goal from the outset was to develop techniques to help farmers manage their resources more effectively while dealing with salinity problems.

Attacking the perched water table first, Diener drilled 25 shallow wells at 1,300 foot intervals to determine the source of the water. The information gathered from the wells provided the data for a topographical map of the water table and a chart of the seasonal flows of water under his land. He discovered that water was draining from the west onto his land where it lay trapped above impervious layers underlying the lighter surface soil. Capillary action caused the salinity to rise to the surface.

To develop an effective irrigation and drainage system, he would have to stop the flow of subsurface water onto his land. But how? Diener credits Vashek Cervinka of the Department of Water Resources with devising the solution: Plant eucalyptus trees on the upslope margin of the property to intercept the water as it crossed onto Diener's land. The thirsty trees are able to use water carrying eight- to ten-thousand parts per million (ppm) of total dissolved salts. The water moving onto the property registered in the two- to three-thousand ppm range. The trees were planted. Soon the downslope flows tapered off, and within a few years the rapidly growing trees captured the majority of the intrusion.

Salt-tolerant grasses thrive on the saline runoff, leaving only a trickle of brine for the solar still.

due is considered a waste product to be hauled away and dumped. Diener thinks the salt, which is primarily sodium sulfate, could be a commercial product. He points out that one and one-half million tons of it are used commercially in the US each year, and half of that is imported. He plans to produce a clean product that can be bagged and sold to commercial users.

The field of black plastic will, however, soon be history. It is scheduled to be replaced this year by a greenhouse solar still, which will provide the necessary evaporation under cover, thereby keeping the birds out and the salt clean.

Results Prove the Concept

Has this elaborate, innovative reclamation project met its goals? Yes, and then some, says Diener. The deep leaching of the three 150-acre fields washed the salts out of the fertile ground, readying it for high-value commercial crops. In 1998, the first of the three fields produced a fine crop of broccoli. Diener estimates that the salt content of the soil in the field averages around 680 ppm of total dissolved salts. Three years earlier, he says, 30 acres of that field wouldn't even grow grain. "We planted it to wheat before we tiled it and didn't get a truckload of grain off it," he recalls.

Today the three reclaimed fields grow a wide variety of row crops on rotation, including tomatoes, broccoli, lettuce, onions, garlic, string beans, cotton and wheat. Eventually, Diener plans to expand his almond, pistachio and grape operations to the cleaned-up ground.

Cost Effective?

Will the investment in the land and reclamation system pay for itself? Diener says that one year of tomato production paid off the improvement costs, after three years of leaching the ground.

It has been a commercial success, but Diener has larger hopes. He wants what he has shown to be a viable approach to reclaiming salt-threatened land to have practical application on other farms facing the same problem. He estimates that there are nearly 12 thousand acres of prime farmland in his area that will be too salty to farm in a few years, plus some 50 thousand acres of marginal land made so by perched water tables. He is working to get approval of a generalized permit from government regulatory agencies so that other farmers can attempt similar reclamation projects.

And to make it even more accessible and environmentally friendly, the entire project was designed to be passive. "It does not require a lot of commercial energy to run it or to fuel an evaporation system," he explains. Gravity, sunlight and natural plant processes are the principal inputs.

"This is the first attempt by anyone to manage the water on-farm and do it in an environmentally safe as well as economically feasible manner," he says. "We have proved that it can be done."

Now others can follow his lead.

Diener's almond acreage may be expanded to include a portion of the reclaimed land "when the market looks right," he said.

Appendix F: Out and About, Spring 2004

Irrigation Ponds, Selenium, and Waterbirds

Partnerships test new management and lead to legislation

BY TOM MAURER AND JOE SKORUPA

JOE SKORUPA/USFWS

A cooperative demonstration project with farmers helped reduce the exposure of birds to selenium found in drainage water and yield new legal protections for wildlife.

Irrigation in California's San Joaquin Valley has brought cotton, grapes, and asparagus to an arid land, but this prosperity does not come without problems. Most west side valley soils do not adequately drain irrigation water. Over time, the shallow groundwater reaches the root zones of plants, building up salts and killing the crop. In the most troubled areas, pumps move salty water down miles of buried drainage pipe to 100 to 1,000-acre ponds to evaporate. This salty water contains selenium, an essential nutrient in small quantities, but toxic at slightly higher levels.

JOE SKORUPA/USFWS

In this arid climate, any surface water quickly attracts shorebirds and waterfowl. It was not long before Fish and Wildlife Service biologists documented death and deformities in many bird species caused by the selenium in the ponds.

In an effort to reduce the impacts of these large evaporation ponds, a few farmers began to manage the drain water on a small scale. Good intentions aside, these early integrated on-farm drainage management (IFDM) systems allowed too much water to collect on fields and ponds, attracting birds to selenium-contaminated food in the water. The California Department of Food and Agriculture recognized the potential of IFDM systems and came to the Service and the California Department of Water Resources for technical assistance. The three agencies then recruited farmers and other agencies willing to work on a demonstration project.

Service biologists from the Environmental Contaminants Division in Sacramento designed a study to determine if birds living on or near IFDM systems were exposed to harmful levels of selenium. The U.S. Bureau of Reclamation, California Department of Fish and Game, California Regional Water Quality Control Board, and the Westside Resource Conservation District funded parallel studies to collect data on selenium in water, soil, vegetation, invertebrates, reptiles, and mammals. Unrestricted data sharing between these partners is a prominent feature of this project.

The project required constant feedback between Service biologists, other agency staff, and the farmers to coordinate data collection and real-time adaptive management of the systems. Close coordination with the farmers allowed monitoring personnel to be present when significant agricultural actions occurred, such as flood irrigating or crop harvesting. When the monitoring revealed something new, we immediately contacted the farmers to relay the results and make management recommendations. Each year, with positive attitudes and a strong desire to be good wildlife stewards, the farmers worked hard to modify their IFDM systems and, as a result, we have now documented significant reductions in selenium exposure to birds and other wildlife.

Other farmers and drainage professionals have learned of the projects' financial and environmental success through word of mouth, facility tours, project reports, presentations at annual University of California salinity drainage program conferences, and an article in *Currents*, a newsletter of the U.C. Center for Water Resources. John Diener, one of our original volunteer growers, received recognition for his successful demonstration project by winning the "Irrigator of the Year" award from the *California Grower Magazine.*

In response to the encouraging results of this project, the California State Legislature passed a bill in 2003 to streamline the permitting process for the small evaporation ponds associated with IFDM systems. The new law requires the California State Water Resources Control Board to implement wildlife protection standards in direct consultation with the Service. The law and regulations also provide incentives for farmers to develop more IFDM systems. The Department of Water Resources, with our assistance, has also developed a Best Management Practices guidance document for avoiding wildlife impacts at IFDM systems.

None of this would have been possible without strong partnerships and outreach. With the Service's help, farmers can now grow highly-valued crops on once salty farmland — and protect San Joaquin Valley's wildlife.

GARY ZAHM/USFWS

Partners watched black-necked stilts throughout the project. As adjustments were made, the rate of embryo deformity in stilt eggs declined from more than 50% to zero.

Tom Maurer is chief of the Investigations and Prevention Branch of the Environmental Contaminants Division within the Sacramento Fish and Wildlife Office and Dr. Joseph Skorupa is a Clean Water Act biologist in the Division of Environmental Quality, USFWS/Washington Office.