APPENDIX 1

Adult Avian Mortality Compensation Protocol

Adult-Mortality Specific Risk Assessment and Mitigation Approaches for Evaporation Basins used to Dispose of Seleniferous Subsurface Agricultural Drainwater

Presented to the Mitigation Work Group, San Luis Drainage Feature Re-Evaluation (U.S. Bureau of Reclamation, U.S. Fish and Wildlife Service, URS Corporation, California Department of Fish and Game, California Central Valley Regional Water Quality Control Board)

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Admonition:

This Fish and Wildlife Coordination Act report and associated documents are intended to assist the Bureau of Reclamation in the preparation of the San Luis Drainage Feature Re-Evaluation, Environmental Impact Statement and associated Record of Decision. The risk analysis associated with the Service's Fish and Wildlife Coordination Act report is specific to the San Luis Drainage Feature Re-evaluation and the potential operation of evaporation basins constructed to provide drainage service to the San Luis Unit. The information and analysis contained herein is for technical planning purposes only, and do not constitute official policy of the U.S. Fish and Wildlife Service with respect to take or mitigation for take of migratory birds protected under the Migratory Bird Treaty Act of 1918 (16 USC 703-712; Ch.128; July 13, 1918; 40 Stat.755). The Service is providing this information pursuant only to the Fish and Wildlife Coordination Act (16 USC 661-667e; the Act of March 10, 1934; Ch 55; 48 Stat.401).

The Service remains committed to the Fish and Wildlife Service Mitigation Policy which states that it is Service policy to recommend, in order of preference, avoidance and minimization of impacts to fish and wildlife resources, before compensation for losses. The prescriptions for mitigation acreage provided by the report and the models contained herein would be applicable under this third (least preferable) tier of compensation. The protocols provided herein are meant to be conceptually accurate and scientifically defensible, and are intended to stand independent of issues regarding the legality of mitigation for take of migratory birds protected by the Migratory Bird Treaty Act.

The prescriptions within this model offer estimates of mitigation habitat required to offset population losses associated with the introduction and operation of evaporation facilities into the landscape mosaic of the San Joaquin Valley. Despite the intellectual rigor inherently tied to such issues as meta-population ecology, optimal foraging theory, dose-response and ecotoxicology; and the involved algebraic quantitative modeling presented within this model, these prescriptions should not be mistaken as confident predictions. What is represented herein is a best scientific estimate.

Background

Currently, about 4,700 acres of evaporation ponds are in private operation in the Southern San Joaquin Valley. During the late 1980's, researchers confirmed that elevated selenium concentrations in these ponds were impacting the reproductive success of shorebirds and waterfowl nesting at these sites, similar to the results found at the closed Kesterson Reservoir. By the mid-'90's, the Service published mitigation protocols (USFWS, 1995a; 1995b) based on the concept of "landscape assimilative capacity," or a dilution effect that was postulated from the analytical results (duck eggs at Kesterson, from a waterborne concentration at over 100 ppb Se had the same Se residues as those from a Tulare Basin pond at around 10 ppb—it was hypothesized that ducks at Kesterson were diluting their exposure in the adjacent clean refuge wetlands).

The 1995 protocols essentially look at the losses in production associated with Se exposure in the predominant group of birds nesting at the ponds (shorebirds). The practice involves the provision of "alternative" habitat in the immediate vicinity of evaporation basins to draw away birds from the ponds and dilute their dietary exposure (thereby reducing reproductive losses). The underlying risk assessment feeding the current Service protocols is robust with respect to the dose-response information (the curve for these birds contains around 1000 data points apiece), but somewhat weak with respect to predicting habitat use (from the parameter K, or habitat attractiveness). Additionally, it is based on the black-necked stilt, a bird about half as Se-tolerant to egg-borne exposure as the American avocet, but twice as tolerant as ducks. This decision was driven by the predominance of these species among nesting birds on the evaporation basins (other species would be protected by association since the same habitat would have utility for more than a single species).

Two protocols were developed, an alternative habitat protocol based on the dilution phenomenon noted above, and a compensation protocol, aimed at the direct replacement of lost production that remains an unavoidable consequence of operation (having factored in dilution to the best practical extent via the provision of alternative habitat). Currently, evaporation ponds each have a prescribed acreage of mitigation based on the acreage of the basin, and the extent of contamination in the ponds. Mitigation acreage prescriptions in the Service Alternative Habitat protocol (USFWS, 1995b) range from zero mitigation to slightly greater than a one to one evaporation pond to mitigation habitat acreage ratio. Currently, pond operators are providing from 0.1 to 0.5 acres of mitigation habitat per acre of evaporation basin (pers. comm., A. Toto).

The mitigation protocols were submitted for peer-review in 1995, and adopted as part of the WDR's within the State permitting process. Several pond operators ceased operations as a result, while others decided to forge ahead with their own mitigation. These agreements form the *de facto* Service policy with respect to the operation and mitigation for evaporation ponds for disposal of subsurface agricultural drainwater. Operators are expected to monitor avian use of the ponds (biweekly censuses), and collect a total of five shorebird eggs a year to validate residues (and project effects). The protocols initially were meant to be iterative, and reviewed on five-year intervals. Mitigation plans have been submitted on a 3 year interval to the Regional Board, however no update or review of the protocols has been implemented by the Service since their development ten years ago.

Limitations of Existing Protocols

The existing Service mitigation protocols focus solely upon reproductive losses amongst black-necked stilts and American avocets. During the inception of these protocols, it was suggested that maintaining the prescribed acreages of clean alternative and compensation habitat year-round would provide sufficient mitigation for other impacts due to the operation of the evaporation ponds. This decision was probably more a function of convenience than anything else, considering how little data exists to quantify non-breeding season impacts.

The problem with this approach lies in part with the nature of mitigation habitat created – in particular, some of the most numerous species on existing evaporation ponds (namely diving birds such as ruddy ducks, American coots, and eared grebes) are not well served by the habitat most suitable for shorebirds. Furthermore, at least two of these species are likely more sensitive to Se exposure; and therefore, estimates of required mitigation acreages based on impacts to shorebirds may be under-protective. Because of the design of the proposed San Luis Drainage Feature Re-evaluation (SLDFR) evaporation basins, proper mitigation should take into account possible effects to species that dive while foraging.

The second limitation of the approach utilized in the current Service protocols is that they focus upon mitigation based on an analysis of breeding season losses (replacing egg production). However, many species expected to be affected by the proposed evaporation ponds do not breed in the San Joaquin Valley in appreciable numbers, and therefore the provision mitigation habitat to enhance reproduction is an impractical strategy. A large number of birds potentially exposed to the proposed evaporation basins are migrants and/or winter residents that will not be expected to breed at evaporation basins properly managed to control emergent or suspended vegetation (e.g., cattails and wigeongrass).

Since it is generally accepted that the rate of depuration of Se from the body is fairly rapid, breeding impacts from low to moderate Se exposure in these migrants are not thought to be significant. Higher or longer duration exposures, however, might negatively impact fitness (body condition – potentially resulting in smaller clutch size and lower hatchling weight and survival) and adult survival; and harmful residues in eggs could still manifest if adult body burdens are initially high from overwinter exposure on the ponds. These effects are currently not directly quantified or mitigated (although provision of clean habitat in mitigation will again by association meet this end, only to an unknown extent).

Another significant issue is the difference (demographically speaking) between risk assessment models based on production in terms of hatched eggs (fecundity) versus the endpoint of adult mortality (survival). For example, using data from the literature (Alisauskas and Arnold, 1994;

Kiel, 1955; Gorenzel et al., 1982; Ryder, 1963) for survival probabilities in the American Coot (see Table 1, following), one can calculate the probability of a hatchling surviving up to the "average" breeding age.

Table 1: Probability of Survival to Respective Lifestages in the American Coot

	Eggs Laid	To hatch	To fledge	Recruitment	Year 2	Year 3	Year 4	Year 5	Year 6
	1.0	0.752	0.564	0.248	0.122	0.060	0.029	0.014	0.007
#/pair	11	8.272	6.204	2.730	1.338	0.655	0.321	0.157	0.077

According to this constructed life table, it takes roughly 8 eggs to produce one average adult coot (assumed to be 2 years old based on median probability given the survival life table below). Given a hatchability rate around 75 percent, this one adult represents roughly 6 hatchlings. The loss of a two-year old adult coot thus corresponds to a reproductive loss of ~75 percent of a full clutch of eggs approaching total reproductive failure for that given season. The loss of a breeding age individual from the population thus exceeds significantly the impact of losing a single egg or even hatchling. Given this demographic reality, proper mitigation should, in addition to minimizing and compensating for reproductive losses, factor in adult mortality and favor the avoidance and/or minimization of exposure. Short of this, compensation addressed at the level of adult survival and fitness will provide more practical benefits from a demographic perspective (on a population level).

Because of the limitations of the 1995 protocols, and to finalize the risk assessment being conducted within the SLDFR to quantify adult avian mortality, the Service determined that the Mitigation Working Group and this evaluation were the appropriate vehicle to develop additional protocols to handle mitigation specific to non-breeding effects. This process has evolved in cooperation with the CDFG, Reclamation, and the Regional Board. Reclamation provided additional funding to the Service and a scope of work to complete the risk assessment and mitigation modeling represented in this white paper. As of this writing, the adult avian mortality protocol is undergoing peer review by Dr. Joseph Skorupa of the Service (the primary author of the 1995 protocols) and Dr. Harry Ohlendorf of CH_2M Hill (the research biologist who conducted the foundational work documenting the effects of selenium on aquatic birds at Kesterson Reservoir).

Protocol Derivation and Preparation—Adult Mortality Endpoint

The tasks associated with the preparation of mitigation protocols for adult mortality require the following steps:

1) Derive a dose-response curve for Se exposure and adult mortality from the established database
2) Model habitat selection given the existing and proposed habitat mosaic

3) Estimate losses from the dose-response curve and habitat use estimates (exposure) given existing database and factoring in time (duration of exposure)
4) Derive compensation to offset projected losses

Compensation

How much acreage is required to replace losses incurred due to operation of the evaporation basins? A crude estimate often suggested involves creation of one acre of clean habitat for each acre of contaminated habitat. The underlying reasoning is likely that this is a one-to-one replacement that will sustain an equal number of birds at the one site to those that are lost at the other. But this strategy does not withstand scrutiny once a careful analysis of the underlying dynamics involved in natural systems is undertaken.

This one-to-one compensation may not be protective when the degree of contamination and the relative use functions for each habitat are considered. For example, if a contaminated habitat is sub-acutely toxic, even short term exposure could lead to mortality among exposed individuals. Alternatively, the mitigation habitat might be so attractive, or the redesigned evaporation ponds so unattractive, that avian use at the disposal basins may decline to near zero; and exposure is no longer a matter of practical concern.

In reality, realized mortality from contaminant exposure is a multivariate function resulting from the interaction of the following variables:

a) Degree of contamination of evaporation pond
b) Degree of contamination (or cleanliness/quality) of alternative habitat choices
c) Acreage of evaporation ponds
d) Acreage of alternative habitat choices
e) The use patterns dictated by ecology of exposed populations (and habitat selection by individual birds within the population)
f) The status of the population (what is the severity of underlying stressors?)
g) The sensitivity of each particular species (may be related to lifestage, sex, feeding ecology, etc.)
h) The form or chemical species of the particular contaminant, and the particular system dynamics that govern movement of the contaminant within various environmental compartments

Some of these parameters are readily quantified (e.g., the acreage of evaporation basins). Some may be reasonably modeled (e.g., the degree of contamination at the proposed ponds). Some might be estimated. But our confidence in the accuracy of our estimates is often not high (e.g., partitioning of exposed populations in the new habitat mosaic, and the status of the underlying population).

If habitats are at carrying capacity (saturated), and resource limitations drive the population, then density-dependence would be a predominant factor dictating adult survival. This scenario would suggest that natural systems will sustain a certain number of individuals based on the available resources (e.g., wetlands), and population numbers will completely track habitat availability. A simple interpretation would suggest in this instance that evaporation ponds, albeit contaminated, are still a net demographic benefit since at least some birds are sustained (even though a large majority may die). The underlying assumption herein is that a bird that goes anywhere else than the evaporation pond is already condemned to death (since every other habitat unit is already exhausted by the use of another individual).

But this interpretation would not be consistent with actual dynamics in natural systems. In reality, birds make choices as to what habitats they will spend time inhabiting, and these choices are based upon the perceptual filter of each individual. Habitat *quality* is a very important variable to consider, and the degree to which wild populations may accurately perceive quality and select from available habitat choices "intelligently" dictates the fitness of that population.

Dispersal and habitat selection within a metapopulation is subject to good options (quality population "sources"), and poor options (net population "sinks"). Certain choices lead to an associated rate of survival. The reality is that if a given bird is not utilizing an evaporation basin to forage, it will still find other options, and have a probability of survival associated with the quality of those other choices. Alternative habitat choices are out there, and birds attracted to the nuisance of evaporation basins, or to the benefit of mitigation habitat, do not automatically die if the ponds don't sustain them. The individual that moves to another habitat (off the ponds) will experience another area with some associated rate of survival that is in part connected to the availability of food resources for which it may compete. But this individual will not compete altogether unsuccessfully (now you just have one more mouth to feed in the new habitat). That particular habitat is selected among the suite of available choices, and its eventual use is dictated by the sum of individual choices made by members of the population trying to optimize their habitat selection while minimizing energy expenditure to find sustenance, and thereby maximize survival.

Therefore, the availability of quality habitat, and the accuracy with which individuals within the population identify and use such habitat, is what distinguishes a vibrant and sustainable population. However, while individual fitness and survival (in part) follows the optimization function of successful habitat selection, the nefarious character of environmental contamination is that it is often a hidden parameter that kills silently. Individuals within the population often cannot tell, from any perceptually-relevant ecological signal, that a contaminated habitat is a bad place to inhabit. As is the case historically with evaporation basins, when the habitat is nutrient-enriched and a prolific net producer of available prey, the very signal that attracts them (high prey density) is the same perceptual cue that draws birds to the exposure that can lead to their demise.

What the SLDFR project is doing is altering the landscape, and avian use functions and survival will be altered accordingly. This shift is what must be equilibrated. Habitat Evaluation Procedure-based approaches operate upon underlying assumptions about equivalency of habitat utility, but in this instance we aren't destroying native habitat and replacing with other wetlands. The difference with contamination effects is that we are degrading an overall habitat mosaic by presenting potential population sinks into the range of available options.

Moreover, there are potential emergent properties associated with the large-scale transformation of the Pacific Flyway that large evaporation pond/mitigation complexes may manifest. Specifically, it is possible that the creation of significant acreage of evaporation ponds and mitigation wetlands may alter regional migratory patterns as the San Joaquin Valley ends up "holding" individual birds that may have otherwise flown onwards to the coast, wintered on the Salton Sea, or even continued on to Mexico (among other options). It is impossible to predict with accuracy or precision to what extent these will be a consequence of the project.

The net influence of the addition of evaporation basins to a landscape is that more birds will be choosing lesser quality habitat, possibly leading to population declines. Given this fact, a mitigation scenario that is not dependent on the underlying knowledge of population status, or predictions about consequences of regional landscape changes (and indeed, questions about density-dependence and the degree of saturation of existing habitat) is preferable to one that must quantify or estimate these parameters.

This is why we must model risk based on habitat selection, overlain with the component of adult survival. Mitigation to equilibrate population losses and gains would include factors that decrease use of evaporation ponds, strategies to decrease the acreage of evaporation ponds, increasing the acreage of mitigation (clean) wetlands, and increasing the attractiveness (and therefore use) of clean mitigation habitat. In three of the four above elements, Reclamation has indicated these will already be implemented to the maximum practical extent during project planning. The task of the risk assessment and the models defined herein is to answer that fourth element--- to quantify, to our best available scientific ability, the mitigation acreage necessary to compensate for projected bird losses at the evaporation ponds.

The central question becomes how to model the increased survival of those other birds that shall replace the individuals lost to mortality associated with the SLDFR evaporation basins. It has been mentioned already how egg production is an impractical compensatory strategy for adult mortality, since it takes a large number of eggs to functionally replace a breeding age adult. Additionally, it has been mentioned that many of the wintering species in the San Joaquin Valley are not prolific breeders in the region (they tend to nest further north). We therefore need to enhance survival of adults (population-wide) as mitigation for adult mortality on the ponds. For each bird lost, we must create and/or enhance mitigation habitat such that another survives *that otherwise would not have* if the project were not in place. What this means in practice is that the regional landscape must be improved in equal measure to the degradation construction and operation of the ponds reflects.

The revised protocols herein involve the derivation of a quantitative model to equilibrate the meta-population level losses with gains through the provision of clean habitat. This will be of sufficient quality to enhance survival in equal measure (to our best scientific estimate) to the projected losses as a consequence of pond construction and operation. These acreages should be seen as compensatory mitigation specific to adult mortality. Breeding season effects, should any be expected, are best compensated (or minimized) using the established protocols (USFWS 1995a, 1995b) until empirical data or sufficient analyses are available to suggest otherwise.

MODEL A: Density-Independent Population Partitioning Model

Derivation and Calculations

As discussed above, habitat selection is a multivariate function that involves site selection from the perspective of the unit of each individual bird. The filter each individual may utilize, or indeed, the behavior of any given population of a particular species, is a matter of much conjecture and theoretical speculation (see, among others: MacArthur and Pianka, 1966; Emlen, 1966; McNamara, 1982; McNair, 1983; Pyke, 1984; Clark and Mangel, 1984; Schoener, 1987).

While understanding such relationships ideally monitors the behavior of each individual and the parameters driving its habitat selection, biologists can also crudely estimate the end results of population-level selection by doing censuses. This measure, if done accurately, would represent the population-level partitioning (the summation of all individual habitat selections at that moment in time). The ratio of preference for each particular habitat choice reflects the relative affinity an individual will exhibit to each habitat choice (i.e., just how attractive is X unit of habitat type A). In this fashion, the distribution of a given population of birds reflects a partitioning function similar to the behavior of chemicals based on their particular physical and electromagnetic properties. This partition coefficient has been expressed as K in the current Service mitigation protocols (USFWS 1995a; 1995b) for the case of affinity for mitigation habitat relative to evaporation basins.

If K was equal for all habitat types (or, mathematically $K = 1$), then density would be completely explained by acreage of habitat. Whether or not this is the case may well be a function of how carefully we define habitat. For example, it may be true that avocets are distributed in even proportion to the availability of saline wetlands with a depth of 2-10 cm water, a soft substrate, and invertebrate density exceeding X grams per square meter. But we shall never be able to quantify or validate this hypothetical situation without empirical data from a research effort of completely impractical magnitude.

Moreover, it is reasonable to presume that other factors besides simple physical properties of a particular site determine actual use. These would include: density of available prey items, proximity to other attractive habitat, the degree of predation pressure or other disturbance factors, among others. So it is safe to say that this relationship is complex and multivariate, and we can confidently postulate that K is not a random variable. In other words, birds do exhibit habitat selection that is not simply a function of the proportionate availability of each broad habitat category.

So what is exhibited in nature is reflected by a partitioning function of individuals within a population based on a two-fold relationship. The first is simply a function of *available habitat*. Overlain upon this is *selection*, which manifests as a realized distribution pattern according to the affinity of the respective species for the available habitat. These two variables can be expressed in units of acreage (Ac_x) for each respective habitat type, and as the affinity or partitioning coefficient (K_x) for each habitat type.

Thus we define the following variables:

N The number of birds extant in that population (or guild, etc.)

Ac_b The acreage of available habitat in existence before a project (baseline)
Ac_{ep} The acreage of evaporation basins proposed as part of the project
Ac_{mh} The acreage of mitigation habitat to be constructed as part of the project

In the simplest sense mentioned above (where population dispersion is random), the population will be distributed in equal proportion to any defined habitat type, so that the proportion of the population in a given habitat type (x) would be represented by:

$$\frac{Ac_x}{Ac_\Sigma}$$

Proportional values are derived in the context of the whole, in other words, relative to the total extent of habitat. These proportional use values can be calculated for any particular habitat type, though for purposes of expedience and ease of calculation it is sufficient herein to consider only the three above (i.e., evaporation ponds, mitigation habitat, and the status quo conditions [baseline]). In this case, then, Ac_Σ would be the sum acreage for all habitat types:

$$Ac_\Sigma = Ac_b + Ac_{ep} + Ac_{mh}$$

What we are interested in estimating is the total number of birds using each habitat type, for it is from this value that we determine eventual population-level impacts. This value can be calculated by multiplying the population size (N), by the proportion in each habitat "compartment."

$$\frac{NAc_x}{Ac_\Sigma}$$

So in this *non-selective* random dispersion scenario, the population will be distributed between respective habitat types according to this function:

$$N = N*Ac_b*Ac_\Sigma^{-1} + N*Ac_{ep}*Ac_\Sigma^{-1} + N*Ac_{mh}*Ac_\Sigma^{-1}$$

In plain language, this says that the total number of birds in the population (N) will be the sum of all birds partitioned into each respective habitat type based solely on the acreage of habitat available.

But few would argue that avian distribution is random, and it is generally accepted that birds partition within the environment based on affinities for specific habitat conditions. Fortunately, all competing conditions and decisions are expressed by the realized population distribution in the available habitat. In other words, to the extent that we can measure the non-randomness in distribution of birds within a given environment, we have captured the relative value of the habitat selection function.

In the breeding bird protocols, this value was denoted as K, and so herein they shall be defined as:

K_b The affinity of individuals within the population for habitat other than the evaporation basins and mitigation habitat ("other available habitat")
K_{ep} The affinity of individuals within the population for evaporation basins relative to other available habitat
K_{mh} The affinity of individuals within the population for mitigation habitat relative to other available habitat

Note here that there is a slight modification in terms, as we are now comparing habitat affinity relative to "baseline," which is pre-project conditions. This value can be set at 1 (K_b = 1), but now K values for evaporation basins are scaled relative to this benchmark. Thus, K_{mh} will be a different numerical value than K in the breeding bird protocols (since mitigation habitat K has previously been scaled relative to evaporation basins). As will become evident at the end of this discussion, this distinction is not so critical by the final derivation since the ratio of K_{ep} to K_{mh} still drives the final quantification of mitigation acreage.

The partitioning function above is now weighted by the increased affinity each population exhibits towards a particular habitat, or:

$$\frac{K_x Ac_x}{Ac_t}$$

This value is now a bivariate function dependent upon total acreage overlain by habitat *selection*. For ease of explanation, let us consider this value U_x, or the attraction (realized use) function for birds towards habitat type X. This value can be conceptualized as the functional footprint of the respective habitat type (i.e., the weighted acreage of that given habitat type, based on its attractiveness to individual birds within each population).

Following the analysis above, while factoring in the variable of habitat selection (preference) to the function, the number of birds partitioning to each respective habitat type is now reflected by:

$$\frac{N^*K_x^*Ac_x}{Ac_t}$$

Or, from the shorthand above, as following:

$$NU_x$$

So in the *selective* bivariate model, the population will partition by:

$$N = N^*U_b + N^*U_{ep} + N^*U_{mh}$$

The next important variable to quantify and introduce to the model is ***Survival***. This parameter is the fundamental variable of interest for the derivation of a protocol dealing with adult mortality.

Following the delineations above:

S_b Baseline survival rate (conditions reflecting pre-project population status)

S_{ep} The survival rate associated with exclusive use of evaporation basins during the duration of expected exposure for each respective species or guild

S_{mh} The survival rate associated with exclusive use of ideal habitat (in which it is presumed mitigation habitat will be managed optimally). It is presumed (and imperative) that this value exceeds baseline conditions, or else the project itself is unmitigable.

It follows that the number of birds (N) surviving (S) that partition to any given habitat (U) is reflected by:

$$N^*S_xU_x$$

The purpose of compensation is to equally offset losses incurred from building the new evaporation basins. Or, put in model terms, to balance survival before and after construction of the facilities. This condition will be achieved when the total number of birds that survived before the project was constructed would survive within the new landscape presented by the evaporation basin and mitigation habitat.

Mathematically, this relationship is achieved when:

$$N^*S_b = N^*S_{ep}^*U_{ep} + N^*S_{mh}^*U_{mh} + S_b(N - NU_{ep} - NU_{mh})$$

This relationship expresses the case when the total number of birds surviving under pre-project conditions ($N^* S_b$) equals the total number surviving at the evaporation basins ($N^*S_{ep}^*U_{ep}$) plus the total number surviving at the mitigation wetlands ($N^*S_{mh}^*U_{mh}$) plus the total number surviving in all other habitat, less the individuals who have now relocated from this "other" habitat to the new habitat created by evaporation ponds and mitigation habitats $S_b(N - NU_{ep} - NU_{mh})$.

Factoring in Sb to the parenthetical function on the right side of the equation above, it follows that, at equilibrium:

$$N^*S_b = N^*S_{ep}^*U_{ep} + N^*S_{mh}^*U_{mh} + N^*S_b - N^*S_b\text{-}U_{ep} - N^*S_b\text{-}U_{mh}$$

And factoring out N from the right half of the equation:

$$N^*S_b = N^*(S_{ep}^*U_{ep} + S_{mh}^*U_{mh} + S_b - S_b\text{-}U_{ep} - S_b\text{-}U_{mh})$$

N is now canceled out on each side, yielding:

$$\mathbf{S_b = S_{ep}{*}U_{ep} + S_{mh}{*}U_{mh} + S_b - S_b{\cdot}U_{ep} - S_b{\cdot}U_{mh}}$$

Isolating S_b to the left hand side of the equation, we derive:

$$\mathbf{S_b - S_b + S_b{\cdot}U_{ep} + S_b{\cdot}U_{mh} = S_{ep}{*}U_{ep} + S_{mh}{*}U_{mh}}$$

Therefore:

$$\mathbf{S_b{\cdot}U_{ep} + S_b{\cdot}U_{mh} = S_{ep}{*}U_{ep} + S_{mh}{*}U_{mh}}$$

Now isolating and factoring out $\mathbf{U_x}$ values to simplify, we derive:

$$\mathbf{S_b{\cdot}U_{mh} - S_{mh}{*}U_{mh} = S_{ep}{*}U_{ep} - S_b{\cdot}U_{ep}}$$

then

$$\mathbf{U_{mh}{*}(S_b - S_{mh}) = U_{ep}{*}(S_{ep} - S_b)}$$

Expanding $\mathbf{U_x}$ values now for final derivations of the model:

Recall that $\mathbf{U_{ep} = K_{ep}Ac_{ep}/Ac_{\Sigma}}$; and $\mathbf{U_{mh} = K_{mh}Ac_{mh}/Ac_{\Sigma}}$; therefore:

$$\mathbf{\frac{K_{mh}Ac_{mh}{*}(S_b - S_{mh})}{Ac_{\Sigma}} = \frac{K_{ep}Ac_{ep}{*}(S_{ep} - S_b)}{Ac_{\Sigma}}}$$

$\mathbf{Ac_{\Sigma}}$ cancels out on both sides of the equation, leaving:

$$\mathbf{K_{mh}Ac_{mh}{*}(S_b - S_{mh}) = K_{ep}Ac_{ep}{*}(S_{ep} - S_b)}$$

The variable we are interested in deriving during the risk assessment is acreage of mitigation habitat needed to achieve this equilibrium state—in other words, solving algebraically for $\mathbf{Ac_{mh}}$. This final derivation becomes:

$$Ac_{mh} = \frac{K_{ep}Ac_{ep}(S_{ep} - S_b)}{K_{mh}(S_b - S_{mh})}$$

To the extent that we can accurately estimate the true values for the above variables, compensation will be achieved at the balance point of the equation above. At this equilibrium state, population losses will be offset by the gains achieved through the provision of optimal habitat with performance characteristics as defined above.

Identification and selection of model input values

From the model equation above, it is clear that three main classes of variables must be estimated as input parameters to the model. These include: the projected evaporation pond acreage (Ac_{ep}); K values for mitigation habitat (K_{mh}); and survival estimates for baseline (existing) conditions (S_b), the evaporation basins (S_{ep}), and mitigation habitat (S_{mh}). Following the breakdown already established for this current risk assessment, final model outputs shall be generated for each specific avian guild of interest (shorebirds, dabbling ducks, and diving birds).

For purposes of this white paper, the figures used will be either from those presented in the Draft EIS, or as part of materials presented to the Mitigation Work Group through URS Corporation. These include, acreage estimates, K values, dietary exposure estimates from the bioaccumulation model jointly developed with Service input, projected wildlife residence times (in part) suggested by URS, and the influent waterborne [Se] projections provided by Reclamation (namely, assuming ≤10 µg/kg total recoverable [Se]). All other input variables are defined and explained herein.

Running the Model

Calculation for Diving Bird Guild:

K estimates

To date, the risk assessment process for SLDFR has used a projected K estimate of 2.0 (i.e., that mitigation habitat is twice as attractive as evaporation basins) for the diving birds guild. This value was chosen since the empirical database (from censuses under the scenario where available mitigation habitat wasn't designed explicitly for deeper water foragers) does not capture a reliable estimate for K in the diving birds guild (existing values would predict densities at evaporation ponds perhaps ten times that observed at the mitigation wetlands).

While this approach (assuming a K value of 2) was used as a default starting point during the initial Service protocol derivation to represent habitat selection in shorebird guilds, it isn't supported in the special circumstance of diving ducks. Specifically, it may be significantly under-protective if habitat managers are unsuccessful in replicating high quality wintering habitat to draw away foraging divers. On the one hand, habitat designed specifically for these birds will presumably contain all the elements that render such habitat attractive and useful (e.g., margins with emergent vegetation, open water sections, high benthic productivity). However, evaporation ponds are also highly productive ecosystems, and historical census data has proven that this habitat type is extremely attractive to diving birds.

Therefore, for purposes of the diving bird calculation, it is assumed herein that K_{ep} and K_{mh} are approximate (both habitats are of equal attractiveness). We believe that absent data to suggest otherwise, this assumption represents a more logical starting point. Mathematically within the model, the ratio of each variable thereby cancels the other out ($K_{ep} \div K_{mh} = 1$), and their influence can be disregarded for this particular calculation.

Survival estimates

Review of the various *Birds of North America* species accounts for diving birds reveals that no empirical data are available for adult survival in the species of interest most appropriate to this risk model (i.e., eared grebes or ruddy ducks). Data for other diving bird species known to frequent the evaporation ponds is also very limited to non-existent. Survival data for American coots appears in the life table analysis above, but the figures specific to this particular bird are likely not reflective of ducks (demographically speaking, the coot is probably more an *r*-selected bird than ruddy ducks- or characterized by higher fecundity and lower adult survival and lifespan).

However, another vexing data limitation makes this particular shortcoming less important specifically, we have no empirical data from which to project expected survival rates associated with mitigation habitats (optimal conditions). For the mitigation to work, this value must exceed baseline survival rates. This value can only be a speculative estimate until monitoring produces actual figures for input to the model.

Nevertheless, regardless of the actual values selected, the actual *difference* between optimal and baseline survival rates (S_b- S_{mh}), and between survival on evaporation basins and baseline (pre-project; S_{ep}- S_b) conditions are the final determinants within the mathematical calculation. The magnitude of the difference between pre-project survival and baseline is simply reflected in the mortality associated specific to selenium exposure (the figure derived from the dose response modeling). The magnitude of the difference between baseline survival and that observed at the optimally-managed mitigation habitats is a function of the specific enhancement expected in ideal habitat versus available (more marginal) choices. Therefore, the accuracy of the specific underlying baseline survival value becomes less critical in an absolute mathematical sense. One metric is modeled from the risk assessment, while the other is simply a projection using a most reasonable guess.

Despite data limitations, at least for dabbling duck species, some information is available in the peer-reviewed literature. Overwinter survival rates summarized by URS included figures for dabbling ducks approximating 0.7 (70 percent) (see Hestbeck, 1993; Fleskes et al., 2002). Fleskes et al (2002) observed a mean over-winter survival rate in SJV northern pintails of 70.8 percent. Miller et al. (1995) observed a survival rate of 87.9 percent in the Sac Valley and Bay/Delta for this same species. One possible approach is to use the Sacramento Valley survival rates observed as reflective of "optimal" conditions expected by inhabiting mitigation wetlands specifically designed for diving birds within the San Joaquin Valley. Using these figures, inhabiting mitigation habitat continually over winter would predict an *improvement* in survival rates by 17.1 percentage points over baseline (pre-project) conditions.

Another possible strategy would be to run the model at two plausible extremes- ~5 percent improvement reflecting modest gains, and ~25 percent improvement, representing more or less complete over-winter survival (within a realistic range of survivorship values that allows for some density-independent mortality factors). The outer bounds of these two figures would theoretically reflect a plausible range of expected mitigation obligations (other things, such as K values, and dose-response predictions being equal).

For purposes of providing a precise estimate of mitigation required to compensate for adult mortality associated with the SLDFR project, the enhancement in survival rates associated with optimally-managed mitigation habitat will be assumed to exceed baseline (pre-project) survival by 10 percent. The reasoning behind this figure is that the difference between Miller's Sac Valley/Delta pintails and those from the San Joaquin Valley may be overly generous given that the estimate is based on a dabbling duck species, and the Sacramento Valley's habitat mosaic (consisting of thousands of acres of State and Federal refuges amidst a mosaic of agricultural habitat ideally suited to this particular guild). There is also rightful concern about placing too much faith in two studies for only one species across such a broad risk assessment as that involved in the current SLDFR planning process. This benchmark value will be *assumed* to approximate ten percent (and applied to all guilds within the current analysis).

Dose-Response

The Draft EIS incorporated a mortality assumption for birds using the evaporation basins based on a No-Observed Adverse Effects Level (NOAEL) of 10 ppm dietary exposure in mallards derived by Heinz and Fitzgerald (1993). It is predicted that exposure to diets between 10-15 ppm exceeding sixteen weeks would lead to adult mortality. Here, as with all areas associated with the risk assessment for the endpoint of adult mortality, the selection of a dilution standard set at 10 ppm dietary Se should be further considered.

The first issue to address is the extrapolation of dose-response from one species to another. Standard EPA methodology for converting toxicity thresholds between different species suggests the use of uncertainty factors to account for differences in sensitivity. Typically, the factor used is a ten-fold margin of safety (however, these are usually associated with more stringent public health related issues).

Within a known taxa —shorebirds—there is at least a two-fold difference in embryonic tolerance (Skorupa, 1998). The black-necked stilt is roughly twice as sensitive to embryonic Se exposure as its close sister species, the American avocet. Ducks themselves are again about half as tolerant as stilts (based on empirical data). Chickens and quail appear to be about half as tolerant as mallards. The mechanisms for these differences are not known to date, as the specific mechanism for Se's toxicodynamic behavior has yet to be verified. But it is clear that even within and between orders of avian taxa, a wide range of tolerances are possible. This reality argues for the utilization of uncertainty factors when comparing between avian genera.

Considering established EPA methodology and the empirically observed variability in species-specific Se tolerances, and allowing for the fact that mallards are on the more sensitive end of the spectrum, it seems reasonable to incorporate a safety factor of 2 to extrapolate between Heinz and Fitzgerald's mallards to other duck species. In the case of the more tolerant shorebirds, an argument for a relaxed uncertainty factor of 0.5 (halving the mallard curve) could be made. However, given the attendant uncertainty in so many parts of the risk assessment, and the empirical database that suggests very high affinity within these guilds to mitigation habitats (meaning mitigation prescriptions for adult mortality in these species are likely to be modest), foregoing a relaxed uncertainty factor seems the more responsible decision.

An argument for some lower effects standard than the one estimated in Heinz and Fitzgerald (1993) is already suggested within the literature. Fairbrother and Fowles (1990) observed increased alanine aminotransferase (ALT) activity and suppression of delayed-type hypersensitivity (DTH) to tuberculin in mallards dosed with 2.2 mg/L selenomethionine through drinking water. ALT is released into blood as an indicator of liver or heart damage. DTH is a test of immune response to previously sensitized individuals (in this case, to tuberculin). Skorupa et al. (1996) cites the above study to support a 5.5 ppm dry weight dietary exposure threshold for immunotoxic effects in mallards (wherein the authors converted from a waterborne route of administration to a food basis using figures provided by Gary Heinz). If this value reflects a real effect from Se exposure, *and* one of biological significance, it would represent a Lowest Observed Effects Level (LOEL) and the NOAEL would be even lower (though only one dose of selenomethionine was administered).

In addition to uncertainty factors for inter-specific extrapolations, such variables as inter-individual difference, inter-sex corrections (where males or females may be more sensitive), seasonal corrections, and uncertainty factors for immunotoxic compounds have been used routinely in many risk assessments. Similarly, it can be reasonably argued that birds under lab conditions may not be subject to the same stressors associated with free-living animals (e.g., disease challenge, resource limitation, predation pressure, other chemical stressors, etc.). So this factor would also argue for a lower threshold in order to be substantially protective of wild birds.

While there is support in the literature for the contention that male duck survival is higher than that observed in females for both Northern pintail and Canvasbacks (Reinecker, 1985; Reinecker, 1987), it has not been shown to be the case for Se (as no studies have been conducted to determine differences in sensitivity by sex). Furthermore, it isn't clear whether this differential rate of survival (if extant) has any relationship to contaminant-induced mortalities. Therefore, during this current risk assessment, no uncertainty factor is used to extrapolate from Heinz and Fitzgerald's male mallards to protect wild female avifauna.

The remaining issue to consider for incorporation includes the aforementioned uncertainty factor to translate from lab to field conditions. Considering that the observed LOEL in the Heinz/Fitzgerald studies was estimated at 15 ppm, and Skorupa's estimate from the Fairbrother/Fowles study of an LOEL of 5.5 ppm, an uncertainty factor of 3 for the endpoint of immunotoxicity is suggested. Since a large part of the uncertainty involving extrapolation from lab to field conditions involves the endpoint of immunocompetence (and the stressor of disease challenge that can be a proximate cause of mortality), this uncertainty factor of 3 seems reasonable to scale from the LD values derived by Heinz from sub-acute exposures.

Under traditional approaches, these values together (a UF of 2 for inter-specific protection and a UF of 3 for Se as an immunotoxicant) actually argue for a dilution standard for adult survival more along the lines of 2 ppm, d.w. in the diet (technically, 10 ÷ 6, or perhaps 15 ÷ 6). It could be argued that the steep curve for Se as a substance with a very narrow margin of safety would require less stringent (or at least non-multiplicative) uncertainty factors. Yet the narrowness of this same curve could conversely be used to argue for conservatism in establishing risk thresholds, so it becomes a matter of judgment on the part of the risk assessor. Suffice it to say for purposes of this discussion that sub-acute adult male lethality derived from lab studies is a crude and extreme benchmark upon which to base a risk assessment, and some correction in the form of uncertainty factors is strongly suggested. An UF of at least 2 seems warranted, and for concordance with State action levels for monitoring, a dilution standard of 4 for adult/juvenile protection seems like a more realistic standard than 10 mg/kg.

Within this current analysis however, the derivation of an appropriate dilution standard is actually less important, considering the relative uncertainty involved in defining actual exposure (both dose and duration) associated with the projected SLDFR evaporation basins. The important variable of interest for calculation of mitigation acreages through this model is realized survival, and this estimate is based on the accurate definition of dietary dose, duration of exposure, and finally the dose-response curve (for that final endpoint of adult mortality) that will be realized in a wild population for each species utilizing the SLDFR evaporation ponds.

<u>Exposure Analysis</u>

The current risk assessment process has provided a best-available-scientific estimate for the variables of dietary dose (captured through Service technical comments and incorporated into the current Draft EIS), and herein pertaining to dose-response. Duration of exposure is a significant area with little available data, and for this variable we are unfortunately left with nothing short of rough speculation. These limitations should be kept in mind by planners when applying the outputs from this particular model to actual implementation of project mitigation. Thorough monitoring, and flexible adaptive management plans (with contingencies) are strongly encouraged as associated prudent measures.

In the current risk analysis, URS projected that 25 percent of birds would forage exclusively at evaporation basins for ≥16 weeks. While there are basically no empirical data to support this assumption, there is also none to refute it. For purposes of this analysis, this figure therefore seems to be as reasonable as another—with the provided caveat that (as with some of the survival figures above), the number is simply an assumption. For purposes of the initial mitigation acreage calculation, this exposure profile will be maintained.

The exposure prediction presented in the Draft EIS assumed as much as 10 percent increased mortality associated with longer-term exposure at the evaporation basins [technically, based on the LOAEL of 15 ppm in Heinz and Fitzgerald (1993), an LD_{10} was derived for what could be considered continual over-winter exposure]. Figure 1 presents the dose-response curve from Heinz and Fitzgerald with the values corrected from a fresh weight to dry weight basis to be consistent with the bioaccumulation model previously derived.

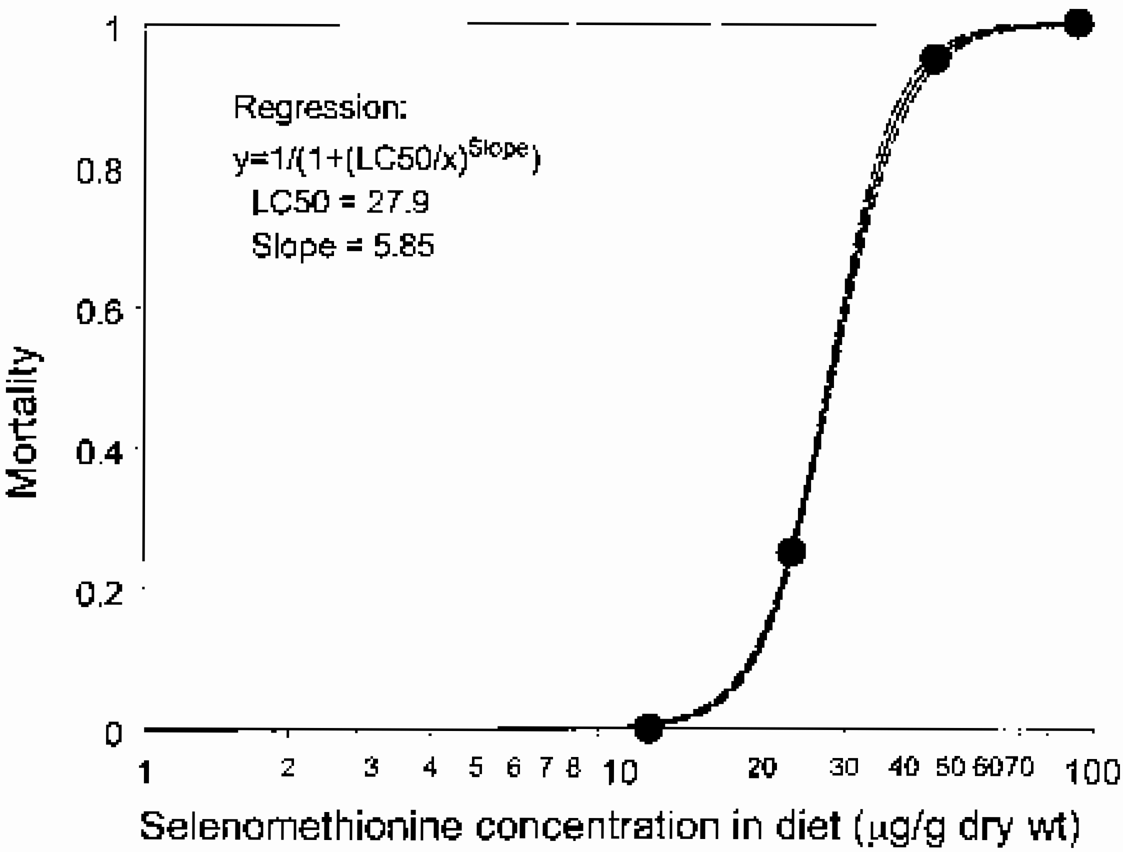

Figure 1. 16 week exposure starting in November. Adult male mallards. Dashed lines indicate 95% confidence interval.

Using an UF of 2 for the above curve yields the same slope, only the LD_{50} is now half that of the original curve (LD_{50} = 14.0). This relationship is presented as Figure 2.

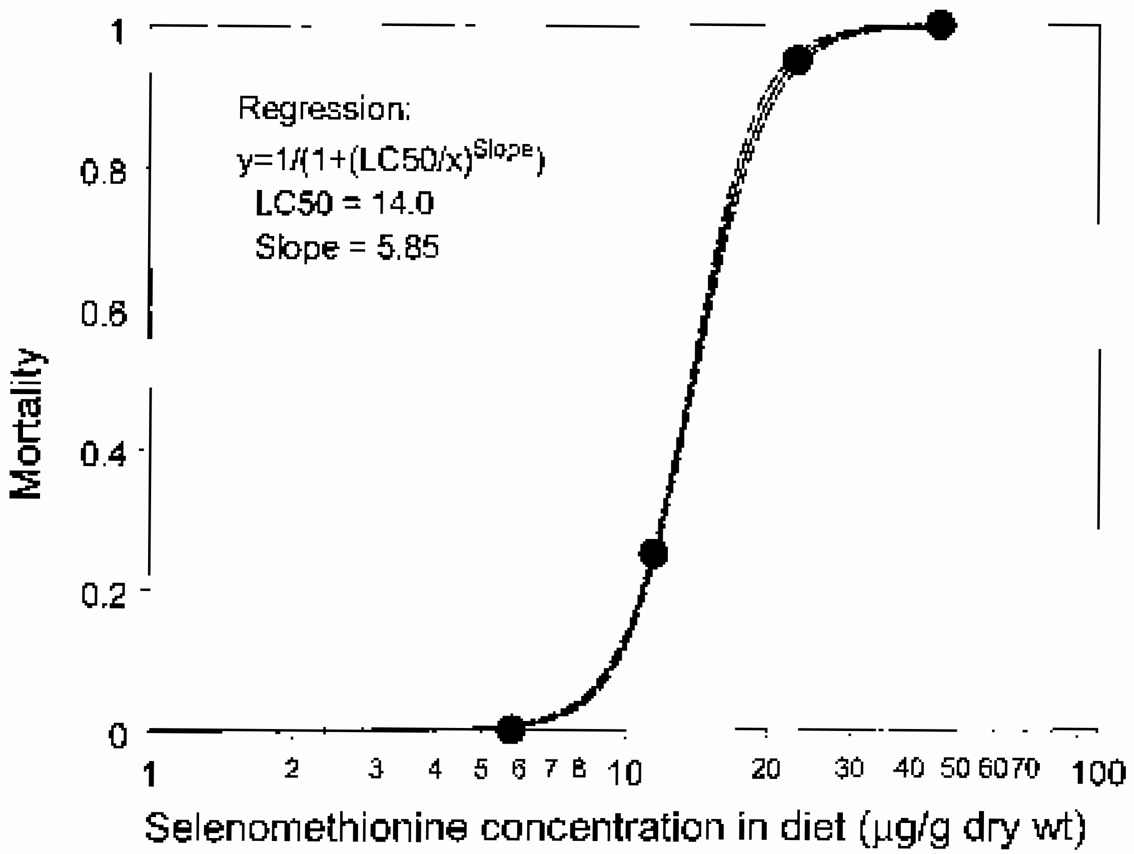

Figure 2. 16 week exposure with 2X margin of safety.

URS has predicted that diving birds will be exposed to dietary [Se] at 13.7 mg/kg d.w. given an influent waterborne [Se] of 10 µg/L during the breeding season. Using this dietary exposure and the equation for the Heinz/Fitzgerald dose-response curve approximates an LD_2 without an uncertainty factor, or an LD_{47} at an UF of 2. So at the concentrations predicted in the last iteration of the risk assessment 47 percent of 25 percent yields 11.75 percent mortality associated with this exposure scenario. However, there is a logical extension from the above considerations that has yet to be considered.

Closer analysis of the Heinz and Fitzgerald (1993) study reveals that much of the mortality associated with Se exposure manifested by week 8. In the high dose group, all birds had already died by this point. In the lowest observed effect treatment group (20 mg/kg), one bird died early (week 6), and another by week 13 (two birds died after 14 weeks, and another by the end of the experiment). It is evident that some mortality may result from shorter duration exposure than simply that connected to full over-winter site fidelity, and this element is not yet captured in the risk analysis.

If we assume that another 25 percent of the individuals within the population stayed between 4-16 weeks, there is still mortality associated with that component of the population. Since the designation of duration exposure is already fraught with significant uncertainty, a rough approximation of the numbers of lost individuals from that intermediate-term exposure might be estimated by applying the eight week exposure data to that other 25 percent of the population. For purposes of this admittedly crude analysis, mortality estimates (if any) from exposure durations less than four weeks are ignored. The dose-response curve for an eight-week duration of exposure is presented in figure 3.

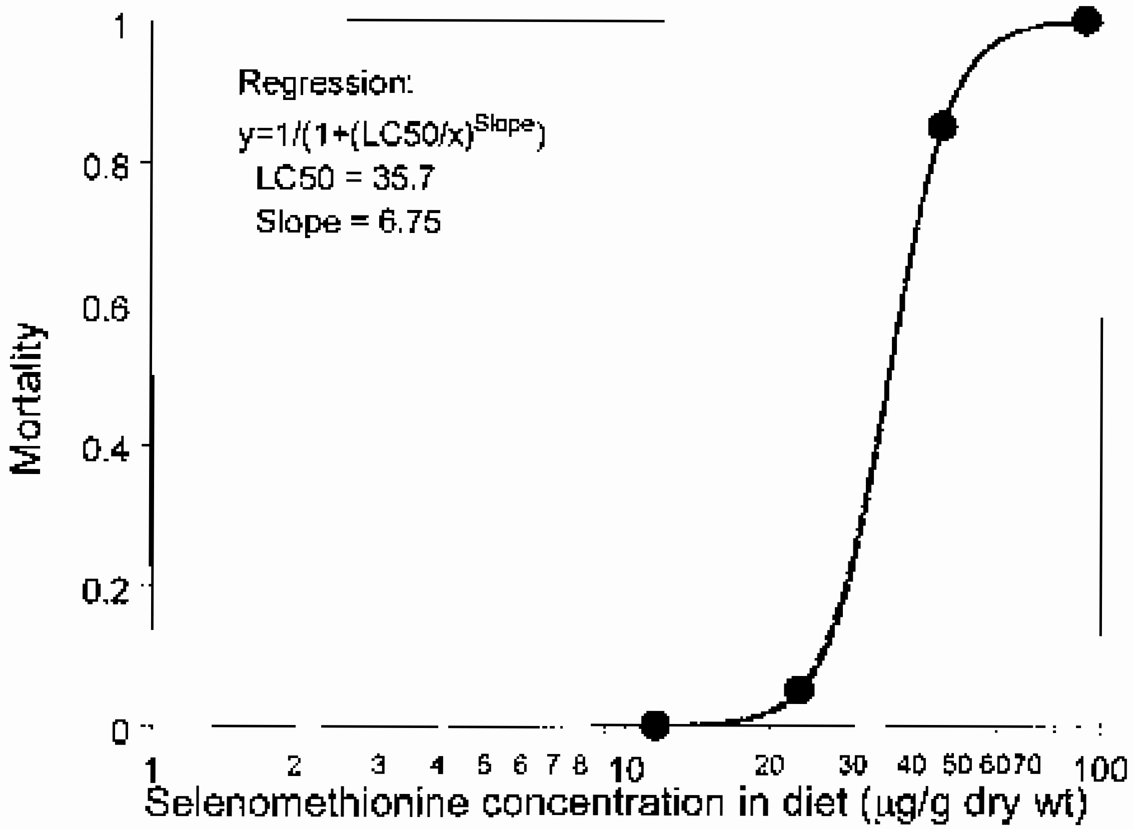

Figure 3. 8 week exposure.

Using the same 13.7 mg/kg d.w. dietary exposure and the equation for the Heinz/Fitzgerald 8-week dose-response curve approximates an $LD_{0.2}$ without an uncertainty factor, and an LD_{14} at an UF of 2. So at the concentrations predicted in the last iteration of the risk assessment 14 percent of 25 percent yields an additional 3.6 percent mortality associated with this exposure scenario.

Using this justification, let us finally presume that mortality at the evaporation basin will yield a mortality rate of 15.35 percent due to Se exposure. Subtracting that additional mortality rate from the above estimate of a baseline survival (rate 0.708) yields a S_{ep} value of 0.55 that shall be applied to both the diving bird and dabblers guild to account for component duck species.

Under this circumstance, the final mitigation acreage needed for the In-Valley Alternative to equilibrate breeding season population losses in the diving birds guild would be:

$$Ac_{mh} = \frac{K_{ep}Ac_{ep}(S_{ep} - S_{b})}{K_{mh}(S_{b} - S_{mh})}$$

$$Ac_{mh} \quad \frac{1*3290(0.5537 - 0.708)}{1*(0.708 - 0.808)}$$

Or,

$$Ac_{mh} = 5080 \text{ acres (rounded to nearest 10 ac)}$$

The prediction listed in Table G-7 (Appendix G of Draft EIS) lists a projected winter dietary concentration of 11.8 mg/kg Se. Using the same methods above, and an uncertainty factor of 2, we get an LD_{27} and LD_{06} for sixteen week, and eight-week exposure groups, respectively. This calculates to an additional mortality of 8.25 percent. Subtracting from 70.8 percent, this yields an estimate of 62.55 percent. Factoring these estimates into the equation yields:

$$Ac_{mh} = \frac{1*3290(0.6253 - 0.708)}{1*(0.708 - 0.808)}$$

Or,

$$Ac_{mh} \quad 2720 \text{ acres (rounded to nearest 10 ac)}$$

Using these same figures above for survival, and the dietary exposure predictions from the Draft EIS (Table G-7, Appendix G), derivations for the other bird guilds are presented in Table 2 for the full treatment In-Valley scenario, and the Water Needs Alternative Scenario.

Table 2: Mitigation Acreage estimations using the Compensation Habitat Mortality Protocol.*

IN-VALLEY

Diving Birds (UF = 2)	Ac_{cp}	K_{cp}	K_{ah}	S_b	Dose	LD 8 week	LD 16 wk	S_{cp}	S_{ah}	Ac_{ah}
Spring Migration	3290	1	1	0.708	13.7	0	0	0.708	0.808	**0**
Breeding Season	3290	1	1	0.708	13.7	0.1435513	0.4735773	0.5537	0.808	**5,076**
Fall Migration	3290	1	1	0.708	11.8	0.0576573	0	0.6936	0.808	**474**
Wintering	3290	1	1	0.708	11.8	0.0576573	0.2730559	0.6253	0.808	**2,720**
Dabbling Ducks (UF = 2)	Ac_{cp}	K_{cp}	K_{ah}	S_b	Dose	LD 8 week	LD 16 wk	S_{cp}	S_{ah}	Ac_{ah}
Spring Migration	3290	1	3.7	0.708	13.1	0	0	0.708	0.808	**0**
Breeding Season	3290	1	8.7	0.708	13.1	0.1102303	0.4090791	0.5782	0.808	**491**
Fall Migration	3290	1	2.5	0.708	8.7	0.0077591	0	0.7061	0.808	**26**
Wintering	3290	1	8	0.708	8.7	0.0077591	0.0594061	0.6912	0.808	**69**
Shorebirds (UF = 1)	Ac_{cp}	K_{cp}	K_{ah}	S_b	Dose	LD 8 week	LD 16 wk	S_{cp}	S_{ah}	Ac_{ah}
Spring Migration	3290	1	6	0.708	15.3	0	0	0.708	0.808	**0**
Breeding Season	3290	1	4.6	0.708	15.3	0.0032714	0.0289017	0.7	0.808	**58**
Fall Migration	3290	1	0.6	0.708	15.3	0.0032714	0	0.7072	0.808	**45**
Wintering	3290	1	1.2	0.708	15.3	0.0032714	0.0289017	0.7	0.808	**221**

WATER NEEDS

Diving Birds (UF = 2)	Ac_{cp}	K_{cp}	K_{ah}	S_b	Dose	LD 8 week	LD 16 wk	S_{cp}	S_{ah}	Ac_{ah}
Spring Migration	2150	1	1	0.708	13.7	0	0	0.708	0.808	**0**
Breeding Season	2150	1	1	0.708	13.7	0.1435513	0.4735773	0.5537	0.808	**3,317**
Fall Migration	2150	1	1	0.708	11.8	0.0576573	0	0.6936	0.808	**310**
Wintering	2150	1	1	0.708	11.8	0.0576573	0.2730559	0.6253	0.808	**1,778**
Dabbling Ducks (UF = 2)	Ac_{cp}	K_{cp}	K_{ah}	S_b	Dose	LD 8 week	LD 16 wk	S_{cp}	S_{ah}	Ac_{ah}
Spring Migration	2150	1	3.7	0.708	13.1	0	0	0.708	0.808	**0**
Breeding Season	2150	1	8.7	0.708	13.1	0.1102303	0.4090791	0.5782	0.808	**321**
Fall Migration	2150	1	2.5	0.708	8.7	0.0077591	0	0.7061	0.808	**17**
Wintering	2150	1	8	0.708	8.7	0.0077591	0.0594061	0.6912	0.808	**45**
Shorebirds (UF = 1)	Ac_{cp}	K_{cp}	K_{ah}	S_b	Dose	LD 8 week	LD 16 wk	S_{cp}	S_{ah}	Ac_{ah}
Spring Migration	2150	1	6	0.708	15.3	0	0	0.708	0.808	**0**
Breeding Season	2150	1	4.6	0.708	15.3	0.0032714	0.0289017	0.7	0.808	**38**
Fall Migration	2150	1	0.6	0.708	15.3	0.0032714	0	0.7072	0.808	**29**
Wintering	2150	1	1.2	0.708	15.3	0.0032714	0.0289017	0.7	0.808	**144**

* **Exposure assumptions are calculated as above for wintering birds, but assuming only 8 weeks for fall migration, and 4 weeks for spring migration (yielding no mortality estimate, but reproductive impairment from Se bioconcentration in body tissues isn't precluded).**

Uncertainty and Sensitivity Analysis

Given the considerable data limitations with respect to bioaccumulation, and remnant uncertainties related to the efficacy and influence of Se pre-treatment, we cannot with reasonable scientific confidence say what wildlife mortality will be associated with the proposed SLDFR evaporation ponds. Given that significant engineering innovations (e.g., vertical sheet pile) are being discussed as potential pond design elements, we can't say for guilds such as shorebirds, and perhaps dabbling ducks, that K values won't differ significantly from projections based on the census data available to date. Despite the considerable investment over the past decades in research into the ecotoxicology of Se, so much is still unknown or poorly understood.

These limitations vex the process of risk assessment, and although scientists may prepare and offer our best available estimate, we still have to acknowledge this uncertainty. By the time we have come to a precise prescription of mitigation acreage, we can not responsibly infer from such precision or the rigor of intellectually-complex conceptual risk modeling that our estimate is anything more than a best guess. In the face of scientific uncertainty, the appropriate interpretation is not that risk doesn't exist, but more that the degree of acceptable risk is policy decision, the prudence of which will only be known in hindsight.

While the conceptual model herein predicts a compensatory mitigation equilibrium within the confines of the underlying assumptions, we still do not definitively know whether realized mortality at the ponds might be as high as, for example, 80 percent (20 percent survival), or even as low as 35 percent (65 percent survival —nearing our estimated baseline). As mentioned above, we can't say for sure whether K values will be much different than predicted —either because additional data using increased sampling frequency will reveal our current estimates are inaccurate, or simply because design and management at the SLDFR ponds will render conditions there different than those at current privately-owned evaporation facilities.

For purposes of this particular sensitivity analysis, uncertainty associated with our projections for dietary exposure are not included (these, however, are also not insignificant). A discussion about uncertainty factors and the attendant variability with respect to dose-response has already been presented above. Herein, the focus shall be upon the elements specific to the variables in the final mitigation acreage equation.

To exhibit the influence of each variable on the model output, several runs of the model can be conducted, each varying one or another parameter and observing the attendant influence on prescribed mitigation habitat acreage. This process reveals that both survival and K values are sensitive parameters within the model, and can lead to widely variable mitigation prescriptions based on the input values chosen. Example calculations (using a realistic range of possible input values) follow.

$$Ac_{mh} = \frac{K_{ep} Ac_{ep} (S_{ep} - S_b)}{K_{mh} (S_b - S_{mh})}$$

Varying Survival at the Evaporation Basins (from mortality of 5% to 70%)

Using K values assumed 1:1 and acreage from the In Valley Alternative:

$$Ac_{mh} = \frac{K_{ep}Ac_{ep}(0.658 - 0.708)}{K_{mh}(0.708 - 0.808)} = \textbf{1,645 ac}$$

$$Ac_{mh} = \frac{K_{ep}Ac_{ep}(0.008 - 0.708)}{K_{mh}(0.708 - 0.808)} = \textbf{23,030 ac}$$

Associated Variability: 14-fold
Associated Uncertainty: Moderate to High (depending on efficacy of treatment)

Varying Survival at Mitigation Habitats (from 5% to 20% enhancement)

$$Ac_{mh} = \frac{K_{ep}Ac_{ep}(0.658 - 0.708)}{K_{mh}(0.708 - 0.758)} = \textbf{3,290 ac}$$

$$Ac_{mh} = \frac{K_{ep}Ac_{ep}(0.658 - 0.708)}{K_{mh}(0.708 - 0.908)} = \textbf{823 ac}$$

Associated Variability: 4-fold
Associated Uncertainty: High (no empirical data).

Varying K Values (from 2:1 to 1:10)

Using acreage values from the In Valley Alternative and 10 percent mortality and enhancement:

$$Ac_{mh} = \frac{2*Ac_{ep}(0.608 - 0.708)}{1(0.708 - 0.808)} = \textbf{6,580 ac}$$

$$Ac_{mh} = \frac{1*Ac_{ep}(0.608 - 0.708)}{10(0.708 - 0.808)} = \textbf{329 ac}$$

Associated Variability: 20-fold
Associated Uncertainty: Moderate (depending on accuracy of current census data, and design/operation changes at proposed ponds).

We have empirical data from which to capture the variability associated with K estimates (though we have a caveat with pond redesign). The data used for the bioaccumulation modeling has an associated confidence interval (but this is qualified by the prospect of treatment, and projected lower waterborne [Se] with possible changes in chemical form). The extant empirical database that relates embryonic Se sensitivity is available for several avian species, and within this is observed an 8-fold (at least) range of tolerances. Whether this can be extrapolated to adult mortality is a matter of conjecture, but this in addition to the imposition of safety or uncertainty factors can provide some sort of boundaries on mitigation projections.

This rough sensitivity analysis suggests that both survival values and K estimates are important parameters within the model (even at a range of reasonable expectations amongst the varied input values). The pivotal issue revolves around the relative investment required to influence each respective parameter. In theory, Se pre-treatment may reduce mortality associated with the ponds (provided the benefits are not negated by making the Se more bioavailable). One might presume that improving survival at mitigation habitats within the range of realistic projections involves diminishing returns— in that each incremental percentage point enhancement will become increasingly costly. As this range spans simply a four-fold variability, it may prove that significant expenditures towards optimizing habitat quality to some nth degree are less prudent investments (unless these measures are inexpensive relative to higher cost technologies such as Se pretreatment). Considering that factors that influence K values also directly influence the variable of exposure (that in turn defines mortality associated with Se toxicosis), measures that render evaporation ponds less attractive to the maximum extent practical are probably wise investments.

Assumptions and Limitations

Following are the assumptions and conditions of this model:

1) This is a density-independent model. It is designed to provide a habitat mosaic to equilibrate losses, based on augmenting adult survival. It does not incorporate actual estimated densities at evaporation or mitigation facilities, or projections of actual (numeric) losses. This has the benefit of bypassing concerns such as underlying population status, and the possibility that birds that otherwise would not utilize the San Joaquin Valley may be attracted by the additional habitat represented by the new ponds. This has the cost that– as in the case of breeding prescriptions for deepwater birds (that are not expected to nest at the ponds in high numbers so long as proper vegetation control is maintained) – under certain circumstances mitigation needs may seem high when a relatively fewer number of birds are actually at risk. In the case of birds with higher affinity for alternative habitats and lower expected losses (e.g., shorebirds), there may be mitigation habitat prescriptions that are so limited in extent that resource depletion may become a complicating factor.
2) For purposes of the calculations presented herein, the projections based on the analysis presented in the Draft EIS for dietary Se bioaccumulation by guild were adopted. While the Service assisted with the derivation of this particular model, certain assumptions were later superimposed that were not consistent with the suggestions of Service technical staff. Specifically, the bioaccumulation model was run using input values that assumed Se pretreatment would produce waterborne [Se] at 10 ppb or better. The Service has commented on the treatment methodology already, and refers readers to the planning aid memoranda (USFWS, July 2003; USFWS, November 2004) for further information.

3) For purposes of projecting enhancement associated with mitigation habitats, a figure of 10 percent additional adult survival (above baseline) was attributed to the prescribed mitigation acreage. There is much uncertainty associated with this estimate.
4) For purposes of the dose-response analysis, this model accepts the URS projection of 25 percent of birds staying ≥16 weeks at the ponds, and furthers this projection to associate another 25 percent with 4-16 week residence time at the contaminated sites. This figure probably varies significantly by species, and is very much a guess. A very high degree of uncertainty is associated with this variable.
5) An uncertainty factor of 2 was used to relate the Heinz/Fitzgerald curve to realized mortality on the ponds. Review of the data, and established EPA protocol, justify at least this level of protection (perhaps more). This debate aside, there is less (relative) uncertainty associated with this estimation.
6) It is assumed that the K values provided by URS from biweekly census data (collected as part of WDR's for mitigation monitoring at existing Tulare ponds) are reflective of future conditions at the SLDFR ponds. This presumes first that they are accurate themselves; and second, that conditions at the new ponds will be similar to those at existing evaporation basins. However, Reclamation is discussing significantly different pond design alternatives (e.g., sheet piling and vertical walls), and intensive water management to deter use of the ponds by dabbling and wading species. It also remains to be quantified what influence an aggressive level of hazing may have on avian use of evaporation ponds (hazing conducted by private pond operators tends to be rather sporadic). If these are implemented and properly managed, it is possible that bird use will be significantly lower than estimated by historic census data.

MODEL B: Density-Dependent Numeric Replacement Model

A different derivation and compensation model can be based upon the alternate extreme--i.e., that population regulation is purely density-dependent, and that available habitats are saturated. However, this model stops short of the unrealistic conclusion that *any* additional habitat (no matter how contaminated, so long as some birds survive) is a population benefit. Instead, it expands from a numeric estimate of loss following the risk assessment above. Then, utilizing the realized density data represented in the estimates from the available censuses, we assume this value is the functional carrying capacity of the mitigation habitats. The projected number of birds lost at the evaporation basins (from the risk assessment above) is then equilibrated by the provision of habitat to support the same number of birds in kind.

The derivation for this calculation follows:

Taking

$\mathbf{D_{ep}}$	as the density of birds measured on evaporation basins (based on census data)
$\mathbf{D_{mh}}$	as the density of birds on mitigation habitats (from historic census data)
$\mathbf{Ac_{ep}}$	as acreage of proposed evaporation ponds (using Draft EIS projections)
$\mathbf{LD_x^{16\ week}}$	as proportion of birds expected to die at > 16 weeks exposure on the ponds—reflecting a projected 25 percent of the metapopulation (as derived above).
$\mathbf{LD_x^{8\ week}}$	as the proportion of birds expected to die at 8 weeks exposure (serving as the midpoint estimate for birds inhabiting the ponds from 4-16 weeks)—reflecting 25 percent of the metapopulation (as derived above).

Herein, D_{ep} is taken from the *mean plus two standard deviations* value from historic evaporation pond census data. This is meant to be a conservative estimate to capture the upper 95 percent confidence boundary for expected number of exposed individuals. Values used for D_{mh} are *mean* data at the alternative habitats, since this is a theoretical best estimate of actual sustained carrying capacity of these habitats (under the specific model assumptions). The LD_x values are derived as above, and are listed in Table 2. Ac_{ep} is again taken from projections in the Draft EIS.

Following the assumptions within this model, the number of birds expected to die from exposure at the SLDFR ponds would be estimated by:

$$\mathbf{D_{ep} * Ac_{ep} * 0.25(LD_x^{16\ week} + LD_x^{8\ week})}$$

This equation reflects the number of birds using the ponds multiplied by the mortality estimates (derived using the same conditions explained in Model A, above). Table 3 displays these mortality estimates by guild and season as projected for the full *In Valley* and *Water Needs* alternatives.

Table 3: Number of Birds Expected to Die from Se Exposure at the SLDFR Evaporation Ponds Under Two Example Alternatives and Assuming 10 µg/L [Se] in Pond Water.

Season	Bird Category	Mean Density	Mean +2sd Density	*In Valley Alternative*	*Water Needs Alternative*
			Ac_{ep}	3,290	2,150
				Mortality (# birds)	Mortality (# birds)
Spring Migration (Feb-Apr)	Dabblers	1.474	6.408	0	0
	Divers	1.748	6.226	0	0
	Breeding Shorebirds	0.491	2.812	0	0
	Nonbreeding Shorebirds	1.244	5.659	0	0
Breeding (May-Jul)	Dabblers	0.458	2.567	1,097	717
	Divers	0.187	1.197	607	397
	Breeding Shorebirds	0.702	2.887	76	50
	Nonbreeding Shorebirds	0.894	5.231	138	90
Fall Migration (Aug-Oct)	Dabblers	0.954	4.211	27	18
	Divers	0.697	4.151	197	129
	Breeding Shorebirds	1.218	5.874	16	10
	Nonbreeding Shorebirds	2.295	8.997	24	16
Winter (Nov-Jan)	Dabblers	1.355	8.541	472	308
	Divers	1.972	8.639	2,350	1,536
	Breeding Shorebirds	0.625	4.115	109	71
	Nonbreeding Shorebirds	2.957	35.535	940	615
			Total	6,054	3,956

The next derivation involves a simple calculation following from the condition that the new habitat provided as mitigation will have to sustain an equal number of birds to those lost at the evaporation basins. This is reflected in solving the equation:

$$\textbf{Mortality} \div \mathbf{D_{mh}} = \textbf{Number of birds sustained by mitigation habitat}$$

However, recall that there is some baseline level of mortality associated with even the "optimal" mitigation habitat. While the conditions of this particular model dictate that "new" habitat will generate "new" birds, it will not be in a one-to-one ratio unless survival in the new habitat is 100 percent. So, in reality, to sustain an equal *realized* number of birds to the numbers lost at the contaminated sites, we must provide habitat to sustain a larger initial subset of individuals—this is functionally a numeric replacement model (not a population dispersion model as is Model A). In other words, we must divide by the factor S_{mh} (assumed herein to be 0.808). So,

$$Ac_{mh} = \text{Mortality} \div D_{mh} \div S_{mh}$$

Tables 4a-4d display the mitigation prescriptions from both models by guild and season for all four *In Valley* disposal alternatives. In addition, they contain an estimate of the number of birds that would be sustained by this mitigation habitat under the assumed relationships above.

The Merged (Carrying-Capacity Adjusted Population Partitioning) Model

The Service recommends an approach to compensatory mitigation that utilizes both models simultaneously, with preference going to the higher acreage prescription. Rather than utilize one or the other model, it is preferable to meet the higher of the two obligations, and compensate for the conditions under both sets of assumptions. Where the number of birds projected lost at the evaporation basins exceeds the carrying capacity of the Model A mitigation habitat acreage, the higher value dictated by Model B is selected as the mitigation prescription, and presented in the last column of Tables 4a-4d. Effectively, the mitigation would then protect the exposed population (a number that is indeterminate) in a density-independent fashion. However, it would do this while maintaining a check on the reasonableness reflected in the density-independent acreage prescription (ensuring this mitigation habitat will provide adequate carrying capacity to sustain this minimum level of birds).

The Service recommends that these figures be used to reflect our best scientific estimate for the impacts associated with Se exposure to adult birds using the evaporation basins, and should be considered the minimum theoretical benchmark for provision of habitat to compensate population-level losses associated with the operation of these ponds. Note that in the case of breeding season comparisons, the final figures presented in Tables 4a-4d should be compared to estimates based on the current USFWS (1995a, 1995b) protocols; and here again, the higher prescription would be the minimum acreage to provide compensation.

No protocols have been derived to compensate for losses of juvenile birds, or for exposure and effects to spring migrants that may be impacted by foraging at the ponds on their way to their breeding grounds. If Se pretreatment fails to meet targeted performance standards, these risks become more significant, and should be revisited.

With respect to habitat categories, the provision of habitat would be *inclusive* as compensation for both adult survival and reproductive impairment (i.e., the same acreage suffices for both), within guilds (so all species within that grouping would be protected by the same acreage), but not between guilds. In other words, the Service still believes that habitat for each guild should be provided in discrete units, so that dabbling ducks and shorebirds have independent obligations. The prescriptions for these guilds are not so excessive that this issue should prevent planners from ensuring that density-dependent effects (e.g., inter-specific competition) do not render mitigation habitats less suitable due to resource depletion.

Table 4a: Mitigation Acreage Estimates from Both Models for the In-Valley Alternative

Season	Bird Category	Mean Density (birds/ac)	Model A Mitigation Acreage Needed	Number Birds Sustained by Model A Output	# Lost w/95% CI	Model B Mitigation Acreage Needed	Compensatory Acreage Under Merged Model
Spring Migration (Feb-Apr)	Dabblers	3.02	0	0	0	0	0
	Divers	0.02	0	0	0	0	0
	Breeding Shorebirds	2.36	0	0	0	0	0
	Nonbreeding Shorebirds	7.60	0	0	0	0	0
Breeding (May-Jul)	Dabblers	1.23	491	606	1,097	1,100	1,100
	Divers	0.02	5,076	951	607	4,014	5,076
	Breeding Shorebirds	2.40	58	138	76	39	58
	Nonbreeding Shorebirds	2.07	58	119	138	83	83
Fall Migration (Aug-Oct)	Dabblers	1.45	26	37	27	23	26
	Divers	0.01	474	331	197	349	474
	Breeding Shorebirds	1.96	45	88	16	10	45
	Nonbreeding Shorebirds	4.93	45	221	24	6	45
Winter (Nov-Jan)	Dabblers	2.40	69	165	472	244	244
	Divers	0.07	2,720	5,364	2,350	1,475	2,720
	Breeding Shorebirds	1.57	221	346	109	86	221
	Nonbreeding Shorebirds	4.42	221	975	940	263	263

Table 4b: Mitigation Acreage Estimates from Both Models for the Groundwater Quality Alternative

Season	Bird Category	Mean Density (birds/ac)	Model A Mitigation Acreage Needed	Number Birds Sustained by Model A Output	# Lost w/95% CI	Model B Mitigation Acreage Needed	Compensatory Acreage Under Merged Model
Spring Migration (Feb-Apr)	Dabblers	3.02	0	0	0	0	0
	Divers	0.02	0	0	0	0	0
	Breeding Shorebirds	2.36	0	0	0	0	0
	Nonbreeding Shorebirds	7.60	0	0	0	0	0
Breeding (May-Jul)	Dabblers	1.23	431	532	963	966	966
	Divers	0.02	4,459	835	534	3,526	4,459
	Breeding Shorebirds	2.40	51	121	67	35	51
	Nonbreeding Shorebirds	2.07	51	104	122	73	73
Fall Migration (Aug-Oct)	Dabblers	1.45	22	33	24	20	22
	Divers	0.01	417	291	173	307	417
	Breeding Shorebirds	1.96	39	77	14	9	39
	Nonbreeding Shorebirds	4.93	39	194	21	5	39
Winter (Nov-Jan)	Dabblers	2.40	61	145	414	214	214
	Divers	0.07	2,389	4,712	2,064	1,296	2,389
	Breeding Shorebirds	1.57	194	304	96	75	194
	Nonbreeding Shorebirds	4.42	194	856	826	231	231

Table 4c: Mitigation Acreage Estimates from Both Models for the Water Needs Alternative

Season	Bird Category	Mean Density (birds/ac)	Model A Mitigation Acreage Needed	Number Birds Sustained by Model A Output	# Lost w/95% CI	Model B Mitigation Acreage Needed	Compensatory Acreage Under Merged Model
Spring Migration (Feb-Apr)	Dabblers	3.02	0	0	0	0	0
	Divers	0.02	0	0	0	0	0
	Breeding Shorebirds	2.36	0	0	0	0	0
	Nonbreeding Shorebirds	7.60	0	0	0	0	0
Breeding (May-Jul)	Dabblers	1.23	321	396	717	719	719
	Divers	0.02	3,317	621	397	2,623	3,317
	Breeding Shorebirds	2.40	38	90	50	26	38
	Nonbreeding Shorebirds	2.07	38	78	90	54	54
Fall Migration (Aug-Oct)	Dabblers	1.45	17	24	18	15	17
	Divers	0.01	310	216	129	228	310
	Breeding Shorebirds	1.96	29	57	10	7	29
	Nonbreeding Shorebirds	4.93	29	144	16	4	29
Winter (Nov-Jan)	Dabblers	2.40	45	108	308	159	159
	Divers	0.07	1,778	3,505	1,536	964	1,778
	Breeding Shorebirds	1.57	144	226	71	56	144
	Nonbreeding Shorebirds	4.42	144	637	615	172	172

Table 4d: Mitigation Acreage Estimates from Both Models for the Drainage-Impaired Area Alternative

Season	Bird Category	Mean Density (birds/ac)	Model A Mitigation Acreage Needed	Number Birds Sustained by Model A Output	# Lost w/95% CI	Model B Mitigation Acreage Needed	Compensatory Acreage Under Merged Model
Spring Migration (Feb-Apr)	Dabblers	3.02	0	0	0	0	0
	Divers	0.02	0	0	0	0	0
	Breeding Shorebirds	2.36	0	0	0	0	0
	Nonbreeding Shorebirds	7.60	0	0	0	0	0
Breeding (May-Jul)	Dabblers	1.23	190	234	423	425	425
	Divers	0.02	1,959	367	234	1,550	1,959
	Breeding Shorebirds	2.40	22	53	29	15	22
	Nonbreeding Shorebirds	2.07	22	46	53	32	32
Fall Migration (Aug-Oct)	Dabblers	1.45	10	14	10	9	10
	Divers	0.01	183	128	76	135	183
	Breeding Shorebirds	1.96	17	34	6	4	17
	Nonbreeding Shorebirds	4.93	17	85	9	2	17
Winter (Nov-Jan)	Dabblers	2.40	27	64	182	94	94
	Divers	0.07	1,050	2,071	907	569	1,050
	Breeding Shorebirds	1.57	85	134	42	33	85
	Nonbreeding Shorebirds	4.42	85	376	363	102	102

References Cited

Alisauskas, RT; Arnold, TW. 1994. American Coot. Pp. 127–143 in Migratory shore and upland game bird management in North America (T. C. Tacha and C. E. Braun, eds.). Int. Assoc. Fish Wildl. Agencies, Allen Press, Lawrence, KS.

Clark, CW.; Mangel, M. 1984. Foraging and flocking strategies: Information in an uncertain environment. Amer. Natural. 123(5):626-641.

Emlen, JM. 1966. The role of time and energy in food preference. Amer. Natural. 100:611-617.

Fairbrother, A., and J. Fowles. 1990. Subchronic effects of sodium selenite and selenomethionine on several immune functions in mallards. Arch. Env. Contam. Toxicol., 19:836-844.

Fleskes, JP; Jarvis, RL; Gilmer, DS. 2002. September-March survival of female northern pintails radiotagged in San Joaquin Valley, California. J. Wildl. Manage. 66(3): 901-911.

Gorenzel, WP; Ryder, RA; Braun, CE. 1982. Reproduction and nest site characteristics of American Coots at different altitudes in Colorado. Condor 84: 59-65.

Heinz, G.H., and M.A. Fitzgerald. 1993. Overwinter survival of mallards fed selenium. Arch. Env. Contam. Toxicol. 25(1) 90-94.

Hestbeck, JB. 1993. Survival of northern pintails banded during winter in North America. J. Wildl. Manage. 57: 590-596.

Kiel, WH., Jr. 1955. Nesting studies of the coots in southwestern Manitoba. J. Wildl. Manage. 19: 189-198.

MacArthur, RH; Pianka, ER. 1966. On optimal use of a patchy environment. Amer. Natural. 100:603-609.

McNair, JN. 1983. A class of patch use strategies. Amer. Zool. 23:303-313.

McNamara, J. 1982. Optimal patch use in a stochastic environment. Theor. Popul. Biol. 21:269-288.

Miller, MR; Fleskes, JP; Orthmeyer, DL; Newton, WE; Gilmer, DS. 1995. Survival of adult female northern pintails in Sacramento Valley, California. J. Wildl. Manage. 59(3): 478-486.

Pyke, GH. 1984. Optimal foraging theory: A critical review. Ann. Rev. Ecol. Syst. 15:523-575.

Reinecker, WC. 1987. urvival and recovery rate estimates of Northern Pintail banded in California, 1948-79. Calif. Fish and Game 73: 230-237.

Reinecker, WC. 1985. An analysis of Canvasbacks banded in California. Calif. Dep. Fish Game Bull. 71: 141–149.

Ryder, RA. 1963. Migration and population dynamics of American Coots in western North America. Proc. Int. Ornithol. Congr. XIII: 441-453.

Schoener, TW. 1987. A brief history of optimal foraging ecology Pp. 5-69 *in* Foraging Behavior (A.C. Kamil, J.R. Krebs, H.R. Pulliam, eds.). Plenum Press, New York and London.

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

U.S. Fish and Wildlife Service. 1995a. Compensation Habitat Protocol For Drainwater Evaporation Basins, January 1995. U.S. Fish and Wildlife Service, Sacramento California. 26 pp.

U.S. Fish and Wildlife Service. 1995b. Alternative Habitat Protocol For Drainwater Evaporation Basins, March 1995. U.S. Fish and Wildlife Service, Sacramento, California. 11 pp.

U.S. Fish and Wildlife Service, Jul 2003. Fish and Wildlife Coordination Act Planning Aid Memorandum on the San Luis Drainage Feature Re-Evaluation Plan. *Memorandum* to Regional Director, U.S. Bureau of Reclamation, Sacramento, California from Assistant Field Supervisor, Sacramento Fish and Wildlife Office, Sacramento, California. 20 pages plus attachments.

U.S. Fish and Wildlife Service, Nov 2004. Fish and Wildlife Service Comments and Recommendations on the San Luis Drainage Feature Re-Evaluation Plan. *Memorandum* to Regional Director, U.S. Bureau of Reclamation, Sacramento, California from Assistant Field Supervisor, Sacramento Fish and Wildlife Office, Sacramento, California. 20 pages plus attachment.

Personal Communications

Toto, Anthony. Water Resources Control Engineer, California Regional Water Quality Control Board, Fresno, California

Appendix A: Full Model Run with Ten Percent Exposure Parameter Adjustment

Amended and added
1/11/2006

In response the Reclamation's comments (via the November 17, 2005 URS memorandum) that the model as presented above may be "overly conservative," the model was run with an adjustment to the one parameter with the most attendant uncertainty—namely the population exposure prediction. Specifically, instead of assuming that 25 percent of the exposed population would forage exclusively on the evaporation ponds for ≥16 weeks (and another 25 percent for 8-16 weeks), these figures were amended to assume 10 percent of the birds would reside at the ponds for these intervals.

The uncertainty associated with this modeling effort has been discussed. While the 10 percent assumption may make more intuitive sense to this author, it too is purely speculative. As a result, all model outcomes are qualified. However, given a choice, it is my professional opinion that these amended model output figures should represent the starting point for mitigation. In other words, this is the level of mitigation that would, to our best scientific predictive ability, compensate for expected wildlife losses on the ponds using the endpoint of adult mortality.

The model presented herein is meant to be a step-wise and logical approach to predicting adult mortality associated with Se exposure on the future SLDFR evaporation ponds. As each parameter and assumption is weighed and presumed reasonable or represents our best available guess, the outcome should speak for itself. To the extent that we acknowledge uncertainty attending each of these estimates and assumptions, we admit uncertainty associated with the final output.

The issue of "conservatism" is a matter of perspective. The Service's role as steward for fish and wildlife resources dictates that we err on the side of precaution, and protection. In the end, the strength of our scientific predictions with respect to the SLDFR risk assessment is constrained by both the quality and quantity of the underlying data, and the limitations of our understanding of the dynamics and variability inherent in evaporation pond systems. No amount of modeling, no matter how carefully constructed or thoroughly debated, can fully bridge the gaps of unavailable data or limitations in the complex field of ecology.

What figures follow in these tables are, to the best of my ability as a scientist, the acreage estimates which I believe represent the most prudent level of mitigation which Reclamation should provide as their "initial estimate" for adult mortality compensation. For feasibility costing purposes (consistent with the proposal as anticipated within the Final EIS as currently prescribed in the December 11, 2005 URS memo) I would recommend doubling this amount. In any one season, these initial estimate figures remain below a 1:1 ratio for evaporation basin to mitigation acreage.

Lastly, it should be noted that this risk assessment is Se-specific. The documented (but poorly quantified) mortality rates associated with the endpoints of salt toxicosis and salt encrustacean are not factored into the risk assessment; and so to the extent that the Se mortality model is conservative in favor of safety, it serves to buffer the population-level effects of these other known but unaccounted risks.

Table A: Mitigation Acreages to Compensate for Adult Mortality at SLDFR Evaporation Ponds by Guild.

Season	Bird Category	In Valley Alternative 3290 ac Evap Ponds acres mitigation needed	Groundwater Quality 2890 ac Evap Ponds acres mitigation needed	Water Needs Alternative 2150 ac Evap Ponds acres mitigation needed	Drainage Impaired Lands 1270 ac Evap Ponds acres mitigation needed
Spring Migration (Feb-Apr)	Dabblers	0	0	0	0
	Divers	0	0	0	0
	Shorebirds	0	0	0	0
Breeding (May-Jul)	Dabblers	440	386	287	170
	Divers	2,030	1,784	1,327	784
	Shorebirds	33	29	22	13
Fall Migration (Aug-Oct)	Dabblers	10	9	7	4
	Divers	190	167	124	73
	Shorebirds	18	16	12	7
Winter (Nov-Jan)	Dabblers	97	86	64	38
	Divers	1,088	956	711	420
	Shorebirds	105	92	69	41

- Acreages presented in the table reflect the higher of two estimates provided by the Model A and Model B (the "density-independent" and "density-dependent" compensation protocols). Note that these acreages are not to be confused with alternative or compensation habitat obligations as prescribed by the existing 1995 reproductive impairment protocols. However, habitat provided for impacts to breeding avifauna may be used to serve the dual purpose of compensating for projected losses of adults from the population. It is recommended that breeding season acreages provided to either dilute or compensate for reproductive losses associated with the ponds include best management practices to be functionally attractive, and sustainable for breeding birds (which may include actual provision of this habitat in months preceding the actual breeding season).

APPENDIX 2

COMMON NAME	SCIENTIFIC NAME
Plants	
acacia	*Acacia* spp.
alkali blite	*Suaeda moquini*
alkali bulrush	*Scirpus maritimus*
alkali heliotrope	*Helitropium curassavicum*
alkali popcornflower	*Plagiobothrys leptocladus*
alkali sacaton	*Sporobolus airoides*
alkali weed	*Cressa truxillensis* var. *vallicola*
barley	*Hordeum* spp.
Bermuda grass	
Blennosperma	*Blennosperma nanum*
blue elderberry	*Sambucus caerulea*
Buckwheat	*Polygonum spp.*
California blackberry	*Rubus vitifolius*
California sycamore	*Plantanus racemosa*
casuarina	*Casuarina* spp.
cattail	*Typha latifolia*
clover	*Trifolium depauperatum*
cottonwood	*Populis spp*
Creeping wild rye	*Leymus triticoides*
Dock	*Rumex spp.*
Downingia	*Downingia bella*
eucalyptus	*Eucalyptus* spp.
flowering quillwort	*Lilaea scilloides*
foxtail	*Alopecurus howellii*
foxtail fescue	*Festuca megalura*
Goldenbush	*Isocoma acradenius*
Gum plant	*Grindelia camporum*
hairgrass	*Deschampsia danthonoides*
Hardstem bulrush	*Scirpus acutus*
hedge hyssop	*Gratiola ebracteata*
Hoary nettle	*Urtica diocia*
horned pondweed	*Zannichellia palustris*
iodine bush	*Allenrolfea occidentalis*
locoweed	*Astragalus tener*
loosestrife	*Lythrum hyssopifolia*
Meadowfoam	*Limnanthes douglasii* var. *rosea*
mesquite	*Prosopsis* spp.

Naverretia	*Navarretia intertexta,*
oats	*Avena fatua*
peppergrass	*Lepidium latipes*
perennial pepperweed	*Lepidium latifolium*
Pickleweed	*Salicornia pacifica*
poison hemlock	*Conium maculatum*
Primrose	*Boisduvalia glabella=Epilobium pygmaeum*
purple needlegrass	*Stipa pulchra*
quillwort	*Isoetes orcuttii*
red brome	*Bromus rubens*
ripgut brome	*Bromus rigidus*
Rush	*Juncus uncialis*
Salt grass	*Distichlis spicata*
Saltbush	*Atriplex* spp.
sandwort	*Arenaria californica*
Smartweed	*Polygonum spp.*
soft chess	*Bromus mollis*
spikerush	*Eleocharis spp.*
swamp timothy	*Crypsis schoenoides*
Tall fescue	*Festuca arundinacea*
Tamarisk	*Tamarix aphylla*
Toad rush	*Juncus bufonius*
valley oak	*Quercus lobata*
Watergrass	*Echinochloa colonum*
white brodiaea	*Brodiaea hyacinthina*
widgeongrass	*Ruppia maritima*
wild millet	*Setaria spp.*
wild rose	*Rosa californica*
willow	*Salix spp.*
woolly marbles	*Psilocarphus brevissima*
Insects and Invertebrates	
brine flies	*Ephydridae spp.*
brine shrimp	*Artemia spp.*
Midges	*Chironomidae spp.*
water boatmen	*Corixidae spp.*
Fish	
American shad	*Alosa sapidissima*
black bullhead	*Ameiurus melas*
black crappie	*Pomoxis nigromaculatus*
Bluegill	*Lepomis macrochirus*
Carp	*Cyprinus carpio*

Chinook salmon	*Oncorhynchus tshawytscha*
Fathead minnow	*Pimephales promelas*
Goldfish	*Carassius auratus*
green sunfish	*Lepomis cyanellus*
Inland silverside	
largemouth bass	*Micropterus salmoides*
mosquito fish.	*Gambusia affinis*
Red shiner	
Sacramento blackfish	*Orthodon microlepidotus*
Steelhead	*Oncorhynchus mykiss*
striped bass	*Morone saxatilis*
Sturgeon	*Acipenser spp.*
threadfin shad	*Dorosoma petenense*
white catfish	*Ameiurus catus*
Birds	
American avocet	*Recurvirostra americana*
American coot	*Fulica americana*
American crow	*Corvus brachyrhynchos*
American kestrel	*Falco sparverius*
American robin	*Turdus migratorius*
bald eagle	*Haliaeetus leucocephalus*
black-bellied plover	*Pluvialis squatarola*
black-necked stilt	*Himantopus mexicanus*
white-tailed kite	*Elanus caeruleus*
blue grosbeak	*Guiraca caerulea*
blue-winged teal	*Anas discors*
Brewer's blackbird	*Euphagus cyanocephalus*
brown-headed cowbird	*Molothrus ater*
burrowing owl	*Athene cunicularia*
cinnamon teal	*Anas cyanoptera*
Dunlin	*Calidris alpina*
eared grebe	*Podiceps auritus*
ferruginous hawk	*Buteo regalis*
gadwall	*Anas strepera*
golden eagle	*Aquila chrysaetos*
great blue heron	*Ardea herodias*
great horned owl	*Bubo virginianus*
greater yellowleg	*Tringa melanoleuca*
house finch	*Carpodacus mexicanus*
house sparrow	*Passer domesticus*
Killdeer	*Charadrius vociferus*
least sandpiper	*Calidris minutilla*

lesser yellowleg	*Tringa flavipes*
long-billed dowitcher	*Limnodromus scolopaceus*
Mallard	*Anas platyrhynchos*
mourning dove	*Zenida macroura*
Northern harrier	*Circus cyaneus*
Northern pintails	*Anas acuta*
Northern shovelers	*Anas clypeata*
peregrine falcon	*Falco peregrinus*
Redhead	*Aythya americana*
red-tailed hawk	*Buteo jamaicensis*
red-winged blackbird	*Agelaius phoeniceus*
rough-legged hawk	*Buteo lagopus*
ruddy duck	*Oxyura jamaicensis*
short-eared owl	*Asio flammeus*
song sparrow	*Melospiza melodia*
Swainson's hawk	*Buteo swainsoni*
Western kingbird	*Tyrannus verticalis*
Western sandpiper	*Calidris mauri*
Western snowy plover	*Charadrius melodus*
white-crowned sparrow	*Zonotrichia leucophrys*
Wilson's phalarope	*Phalaropus tricolor*
yellow-rumped warbler	*Dendroica coronata*
Mammals	
blacktailed jackrabbit	*Lepus californicus*
brush rabbit	*Sylvilagus bachmani*
California ground squirrel	*Citellus beecheyi*
California vole	*Microtus californicus*
Coyote	*Canis latrans*
deer mouse	*Peromyscus maniculatus*
desert cottontail	*Sylvilagus auduboni*
house mouse	*Mus musculus*
kangaroo rat	*Dipodomys spp.*
Longtail weasel	*Mustela frenata*
Muskrat	*Ondatra zibethica*
roof rat	*Rattus rattus*
Raccoon	*Procyon lotor*
San Joaquin kit fox.	*Vulpex macrotis mutica*
Southern grasshopper mouse	*Onychomys torridus*
Western harvest mouse	*Reithrodontomys megalotis*
Reptiles and Amphibians	
blunt-nosed leopard lizard	*Gambelia silus*

Bullfrog	*Rana catesbeiana*
giant garter snake	*Thamnophis gigas*
gopher snake	*Pituophis catenifer*
Pacific treefrog	*Hyla regilla*
side-blotched lizard	*Uta stansburiana*
Western fence lizard	*Sceloporus occidentalis*
Western spadefoot toad	*Scaphiopus hammondii*
Western yellow-bellied racer	*Coluber constrictor mormon*

REVIEW COMMENT SHEET
Fish and Wildlife Coordination Act Report,
San Luis Drainage Feature Re-Evaluation Report

SEND TO: Jerry Robbins	DATE OF DOCUMENT: March 2006
COMMENTOR Michael Nepstad, Deputy Regional Environmental Officer	ORGANIZATION/PHONE NO. OF COMMENTER Bureau of Reclamation, 916-978-5041
TITLE OF DOCUMENT: Fish and Wildlife Coordination Act Report, San Luis Drainage Feature Re-Evaluation Report	DATE: March 22, 2006

Page No.	**Recommended Changes** ***(Exact wording of suggested change)***	**Action/Disposition *** **(How Addressed)**
ii	The statement that "…and Reclamation has agreed that the specific siting of facilities associated with SLDFR are subject to future consultations with the Service under section 7 of the Endangered Species Act…" is incorrect. The biological opinion issued by the Service on March 16, 2006 for the SLDFR concluded a jeopardy analysis and provided a take statement for the construction and operation of the SLDFR. No additional "site specific" section 7 consultation is required.	
v	Reclamation response to Service Recommendations 1 and 3 is already in FEIS, sections 2.11.4 and 2.11.4.1.	
	My response to Service recommendation 2, 4, and 5 is that the mitigation work group is still developing mitigation measures and methods in an ongoing collaborative process.	
	My response to Service recommendation 6 is that the purpose of the SLDFR is to provide drainage service and not to recover species, so it would be inappropriate for a SLDFR technical team to expend time and resources of species or areas outside of the authority of the project. However, Reclamation is working toward recovery of species in the San Joaquin Valley through a number of programs under the CVPIA, jointly with the Service.	
	My response to Service recommendation 7 is that the biological opinion was completed on March 16, 2006.	