Public Economic Benefits of Reducing Salinity Discharges: Evidence from California's San Joaquin Valley

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Introduction

The San Joaquin Valley, long the heart of California's agricultural industry, has a climate similar in many ways to those of interior Australia and parts of the Middle East, and like those areas has experienced a gradual increase of salinity in its groundwater and surface waters. For many years dating back to when an extensive network of pumps and canals was developed for water conveyance to and through the Valley in the 1930s, the principal economic activity has been commercial agriculture. Today the Valley remains heavily agricultural, though it is also a hub of non-agricultural business, as well as urban and suburban development. All of these activities have contributed to the accumulation of salinity because typically water used by businesses, households, and farmers returns to the region's groundwater and surface waters with a little more salt and minerals than before it was used. This phenomenon is especially pronounced because, unlike most other areas of California, in large parts of the San Joaquin Valley water does not flow to the ocean. Instead, impermeable clay layers in the subsoil cause water to remain in the Valley, and it is reused over and over as it is pumped from the ground and the surface to meet the region's water needs.

Relatively little is known about the effects of increasing salinity on Valley economic activity, and most of what is known is applicable to businesses and agriculture rather than to households and residents. Households and residents can be expected to experience two types of effects, broadly, related to the gradual buildup of salinity. The first is “private” costs, incurred

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personally either through accelerated household appliance and water fixture replacement cycles, or to finance the efforts of public agencies (such as municipal water management agencies) to mitigate the increases in salinity of public water supply.[2] The second set of effects are more public in nature, as the long-term buildup of salinity is expected to cause changes in land use and, potentially, in environmental quality.[3] They include reductions in land used for agricultural production, considered by many a quasi-public good because of the desirability of maintaining Valley land in production agriculture both because of tourism opportunities it affords and its importance to the regional economy (e.g., Abdulla; Fleisher and Tsur; Pruckner; UC AIC). These reductions could occur either in a planned way (through land retirement programs) or through land abandonment, as salinity reduces crop yields and agricultural profitability. Other changes in public goods to be expected if the trend in salinity increase continues unabated are changes in the number and size of Valley wetlands that support local wildlife and migrating waterfowl populations; and, potentially, changes in Valley air quality if agricultural land abandonment is widespread, because more bare soil will be exposed for greater periods during the year to the region's regular and at times very strong winds. These indirect effects of salinity increase may be important because of the scale of the potential effects, and because many people could be affected (and might be willing to fund programs to prevent those effects from occurring).

The purpose of this paper is to provide some recent empirical evidence on the potential economic costs of changes in public or quasi-public goods availability and quality as a consequence of increasing surface and groundwater salinity, which (to our knowledge) has not

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[2] There is a small literature that presents engineering economics estimates of the magnitudes of these private costs (e.g., Ragan et al.; Cismowski et al.; Coe; BEEI; Andersen and Kleinman; D'Arge and Eubanks; and Lohman and Milliken).

[3] A number of authoritative reports have documented the basis for expecting such land use changes (US Fish and Wildlife Service ; Cismowski et al.;Williams and Alemi) over periods of 30-40 years.

been done previously. We do this by assessing the public's willingness to pay to prevent salinity increases beyond their levels in 2007, using two complementary approaches, contingent valuation and choice experiments. As part of the application of these methods, the best available scientific information about the potential consequences of long term increases in salinity on the three regional public goods noted above was explained to respondents. Thus, they were aware that paying to prevent future increases in Valley salinity levels was expected also to have predictable effects on the amount of land in production agriculture and in wetlands, as well as on particulate concentrations in Valley air (reflected in the most common indicator of its health consequences, the number of premature deaths caused).

The questions asked in the two data collection approaches are complementary, and they are combined in estimation to provide a more comprehensive evaluation of the salinity willingness to pay problem than could be done with either alone. Repeated mixed logit (RXL) models are used to estimate the choice probabilities associated with whether respondents are willing to pay for salinity management. The approach yields estimates of both monthly willingness to pay for salinity management and incremental willingness to pay for changes in land in agriculture, land in wetlands, and premature deaths.

The remainder of this paper is organized as is as follows. The next section provides an overview of the literature on the effects of salinity build-up, the survey design, and the data collected and used in estimation. We then describe our RXL model of respondents' program selections. Following the discussion of our modeling approach, we present estimation results and preliminary findings regarding willingness to pay for San Joaquin Valley salinity management (the prevention of future salinity increases) and for incremental changes in the associated public and quasi-public goods. In the last section, we set out directions for future work.

Survey Design and Data Collection

The design of a study to measure household willingness to pay for prevention of increased salinity of San Joaquin Valley water presents a number of challenges. First, the salinity problem itself may not be noticed by the average person in day-to-day life, because it occurs very gradually over long time periods. The ways in which it might be most directly observed by a typical Valley resident (e.g., through household drinking water) are mitigated by the actions of public authorities, in this case public water supply agencies required to meet drinking water standards. Second, many of its potential effects are not well known or understood, partly because it is difficult to extrapolate current trends into the relatively distant future, and partly because over longer periods, many other factors may shift either autonomously or in response to the problem. Third, a number of the consequences of salinity to the average Valley resident may be indirect, by causing changes in land use (e.g., for agriculture or residential development) and habitat for wildlife. People may well care about these land use changes, and be willing to pay to avoid their occurrence if they are perceived to be adverse, but the linkage to salinity increases is subtle.

These considerations led to a fairly extensive pre-testing procedure, with twenty-two pretest interview sessions conducted in the San Joaquin and Sacramento Valley cities of Stockton, Fresno, and Davis (all in California), which probed Valley residents about their knowledge of the Valley salinity problem and their attitudes toward it. Two major observations emerged from this process: 1) while the salinity problem was not well-known to respondents, it was easily understood and intuitively sensible to them, recognized as a problem to be taken seriously; and 2) among the public goods changes that might occur with increased salinity, by far the most important was the potential for degraded air quality from increased particulates concentrations if production agricultural land were abandoned. Air quality is now a considerable health concern, particularly in the southern San Joaquin Valley (e.g., Hall et al.), and while particulates (and other pollutants) are regulated under both State and Federal standards, these are exceeded frequently for short periods of time.

Relevant Literature on the Effects of Salinity Increases

In the literature on salinity in the Central Valley and other parts of the world (Australia, Israel), relatively few studies make quantitative assessments of the prospective long-term effects of salinity increases. California's San Joaquin Valley is an exception, because of the economic importance of the industries and resources affected. There, a few studies have helped to increase public awareness of the trend toward increasing salinity of ground and surface water, and have suggested measures to help mitigate salinity increases and their effects (US Fish and Wildlife Service; Cismowski et al.; Williams and Alemi). The "Rainbow Report" (US Fish and Wildlife Service), in particular, was an ambitious effort to project the expected effects of increased salinity on the Valley over a relatively long (50-year) period, from 1990-2040, and to recommend plans for halting the salinity increase. While its projections necessarily are fairly speculative, it stands as the best projection (to our knowledge) by knowledgeable scientists and professionals of what the expected effects of increased salinity on the San Joaquin Valley could be.

Prominent among the effects of doing nothing to reduce salinity increases, for which quantitative projections were made, were changes in acreage devoted to agricultural production, as the water table in some areas, notably in the Westlands Water District, rises and becomes more saline. As many as 500,000 acres of irrigated agricultural lands could go out of production, reducing the total Valley agricultural lands from some 2.4 million acres in 1990 to 1.9 million acres in 2040. Changes in cropping patterns are also anticipated, from less salt-tolerant crops to more salt-tolerant crops, and projections were made of changes in economic returns from to commercial agricultural production and processing enterprises. A key issue highlighted in the Rainbow Report was how the changes in agricultural land use occur, whether by planned retirement or abandonment of farmland. Retirement of land, ideally, is the outcome of a managed process and is expected to reduce groundwater levels and permit revegetation and rehabilitation of the land for wildlife habitat. Abandonment, in contrast, may result in considerably less vegetative cover on former agricultural lands, and a greater exposure of the surface soil to winds, which could lead to increases in airborne particulates.

Other land use changes anticipated by the Rainbow Report from increasing Valley salinity include a reduction in the amount of seasonal and permanent wetlands, and an increase in land used for residential and commercial development (though this will largely proceed with or without increases in salinity). The amount of seasonal and permanent wetlands could fall to as little as 24,000 acres, compared with 88,000 acres in 1990.

In addition, the prospect of land abandonment under no salinity management (US Fish and Wildlife Service) suggests a connection between agricultural land use changes and air quality changes. Because of the likelihood that abandoned agricultural land would have bare soil exposed to Valley winds for long periods during the year, the prospect of atmospheric particulate concentrations increasing as an indirect consequence of agricultural land going out of production is not unreasonable. This, combined with the overriding importance placed on air quality by

Valley residents, suggested air quality changes as a third dimension of salinity management plans.

Thus, in light of both the available scientific information on possible long-term effects on Valley land use due to salinity, and the responses and concerns of focus group participants, it was decided to frame the household willingness to pay for salinity management around three main indirect dimensions: 1) changes in agricultural land use; 2) changes in seasonal and permanent wetlands; and 3) changes in air quality. It is the public goods aspects of each of these that are relevant for measuring household willingness to pay.

Wetlands and improved air quality are, by their nature, public goods (i.e., goods that the public as a whole may benefit from), so it is unsurprising to expect that some households would be willing to pay for them. In contrast, agricultural land use is, in one sense, largely private; i.e., changes in land use will occur as a result of private landowners making their own decisions based on profitability and other considerations. On the other hand, the general public may care about agricultural land use changes because of a desire to preserve a way of life, or because of third-party effects (concerns about economic harm to rural communities or agriculture-dependent industries). Consumers may also be willing to pay to maintain larger agricultural acreages because they perceive this will prevent rises in food prices that might occur if agricultural production diminished.

To determine levels of these three public goods indirectly provided by salinity management, the Rainbow Report analysis was used where possible. As noted earlier, the Report made explicit projections of both agricultural land changes and of wetlands changes under both a Salinity Management Plan that would halt the increase in salinity, and under No Management. Based on these (and modifying somewhat for the passage of time since 1990), the salinity management plan proposed in the willingness to pay analyses would halt the expected increases in Valley salinity from 2007 through 2040. It would also prevent a reduction of 400,000 acres in agricultural cropland, from 2.3 million acres to 1.9 million acres, and a reduction of 64,000 acres of seasonal and permanent wetlands, from 88,000 to 24,000. To develop plausible scenarios for air quality changes due to land abandonment (which also was projected in the Rainbow Report), it is necessary to consult recent work on attaining air quality standards in the Valley.

Hall et al. analyze the expected economic benefits of achieving attainment of the PM-2.5[4] 24-hour and annual air quality standards in the San Joaquin Valley, by linking the required reductions in particulates to a changes in health symptoms, and then applying value or cost estimates to these. In the study, which is typical of air pollution economic cost studies, 97% of the economic cost of air pollution is due to premature deaths in the population of adults aged 30 years or older. Meeting the ambient air quality standard requires a reduction in PM-2.5 concentration from 73.2 to 65.5 micrograms per cubic meter ($\mu g/m^3$). Employing a widely-used standard methodology due to Pope et al., this translates to a 4.6% decrease in premature deaths in the San Joaquin Valley, which they estimate to be 460 per year. The baseline level of annual premature deaths implied by this analysis is approximately 10,400.

To get a plausible (though, like the other estimates, speculative) estimate of what might happen to particulate concentrations with land abandonment, the San Joaquin Valley Air Quality Management District (SJVAQMD) particulate management plan for PM-10 was consulted.[5] According to the Emissions Inventory for San Joaquin Valley PM-10 (Table 3-5), 46% of Valley

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[4] This refers to very small particulates that are 2.5 microns or less in diameter. The other common particulate regulated by state and federal air pollution authorities is PM-10, particles 10 microns or smaller in diameter.

[5] There is currently no PM-2.5 management plan in place, though one is being formulated by the SJVAQMD. Agricultural operations typically produce larger (PM-10) particles, so the PM-10 plan and emissions inventory are especially relevant. As there appears to be no recent economic study of the benefits of attaining the PM-10 standard, the Hall et al. study was used instead.

PM-10 emissions are attributable to agriculture and food processing operations. Given an abandonment, in the extreme, of 17% of agricultural cropland in the Valley (400,000 acres out of about 2.3 million), and assuming cover vegetation 50% of the time under production agriculture and none under abandonment, an additional wind exposure of bare soil roughly equivalent to 8% of the current acreage would be possible. This is a slightly larger percentage increase than the percentage decrease in PM-10 analyzed in the Hall et al. report (7.7 $\mu g/m^3$ reduction from a baseline of 73.2). Thus it seems not unreasonable that land abandonment could cause another 460 premature deaths annually, for a total of 10,900 compared to 10,400 today. Put another way, this would be a 4.8% increase in particulate concentration from a 17% increase in land abandonment.

To summarize, then, the salinity management plan, by halting the rise in salinity, would have the following indirect effects on public good provision from 2007-2040: 1) prevent a reduction in agricultural cropland from 2.3 to 1.9 million acres; 2) prevent a reduction in seasonal and permanent wetlands from 88,000 to 24,000 acres; and 3) prevent an increase in premature deaths from 10,400 per year to 10,900 per year.

The Willingness to Pay Question Formats

Two nonmarket valuation strategies were incorporated into the household survey: contingent valuation (CV) and choice experiments (CEs). The two approaches are complementary, and may be used together provide more information about the features of the good being valued. Contingent valuation seeks to place a monetary value on a specific, well-defined management plan, usually by varying the amount of money people are asked to pay for it randomly across the sample. Choice experiments, in contrast, vary the features of the management plan, including its cost, and ask respondents to choose which they prefer from a series of comparisons of different management plans with different features.

Since the contingent valuation presents a single plan to respondents, the projections of changes in agricultural cropland, permanent and seasonal wetlands, and premature deaths from air pollution that were developed above were used. The contingent valuation had two basic versions, a single bound version (one willingness to pay question) and a double bound version (two questions, an initial question plus follow-up), with household cost per month being the only feature that varied, ranging from $3 to $54 depending on the specific payment format used. There were a total of 14 different payment formats, with each respondent only receiving a single contingent valuation format (Table 1).

The same basic design values for a salinity management plan motivated the choice of the levels of program features (or attributes) in the choice experiments. Choice experiments usually have additional, counterfactual, levels of each attribute of the program, to increase the variation in programs that respondents make choices between. Also, unlike contingent valuation, choice experiments usually ask respondents to make several comparisons between programs with different attribute levels. Depending on the complexity of the program being valued, as many as 16 choice experiments per respondent are done. Our choice experiments asked respondents to make either 3 or 5 comparisons, and for each comparison to choose their preferred one from among three salinity management options. One option in each comparison was no salinity management, which had the No Plan attribute values listed in Table 1. The other two plans in each comparison, Plan A and Plan B, would limit the increase in salinity from 2007-2040 and had different attribute values selected from the list in Table 1, and the Plan A and Plan B attributes changed over the different comparisons. Since the number of possible combinations of

4 attributes, each taking 3 levels, is $3^4 = 81$, which is greater than the number of survey versions used, an orthogonal design based on the Addelman 3^4 design, with cyclical generation and swaps to remove dominance and improve efficiency, was used (Bunch et al.; Huber and Zwerina; Arora and Huber). This resulted in 9 different choice formats with 3 alternatives, and these were distributed approximately equally among the 14 survey versions, with 11 versions having 5 comparisons and 3 having 3 comparisons (though approximately equal numbers of each were represented in the overall survey).

After completing the focus groups and interviews, a pre-test survey was mailed to 150 randomly selected households in the San Joaquin Valley. For sampling purposes in the full survey, the San Joaquin Valley was divided into six strata, depending on geography (North, Central, South) and community size (urban and rural). A random sample of 1,000 households was drawn, with approximately equal numbers from each of the six strata. The survey was conducted following the principles of the Total Design Method (Dillman). Of the 1,000 surveys sent in the initial mailing, 882 were deliverable, and a total of 391 completed surveys were returned, for a response rate (percentage of deliverables) about 44%. Despite extra effort to reach Hispanic households,[6] a sizeable chunk of which are transient due to job requirements, the response rate among this group (roughly 34% of the total) was 26%, while the response rate for non-Hispanic households was 53%. Of the 391 returned surveys, responses from 375 households contained at least one useable choice occasion, and a total of 1,824 choice occasions were used in the estimation sample.

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[6] Since a significant proportion of San Joaquin Valley residents speak Spanish in their homes, the letter accompanying the first round of surveys contained a sentence at the bottom written in Spanish, asking households to check the adjacent box if they would like a survey version in Spanish. For the next 2 mailings, Hispanic names were identified in the mailing list, and these households received both English and Spanish cover letters and surveys. In total, 20 households completed and returned Spanish versions of the survey.

The Model

Individuals' preferences for public goods like seasonal and permanent wetlands and quasi-public goods like agricultural land are likely to vary within a population. To capture taste variation we use a repeated mixed logit (RXL) model as the basis for our willingness-to-pay estimates. In an RXL model, individuals are modeled as making decisions sequentially, which fits the panel structure of the data. Because the contingent valuation responses can be interpreted as a choice experiments with a restricted set of alternatives (i.e., the status quo with one, rather than two, program options), the two data sets are combined for purposes of estimation.

The core of the RXL model is an individual's conditional indirect utility:

$$U_{ijt} = V(X_{ijt}) + \varepsilon_{ijt}, \quad i = 1,\ldots,N; \quad j = 0,\ldots,J; \quad t = 1,\ldots,T \tag{1}$$

Here i indexes individuals, j indexes choice alternatives, and t is the choice occasion. Explanatory variables observable to the researcher are collected in X_{ijt}, and the error terms ε_{ijt} are IID Type 1 Extreme Value (EV1). We model individual i's utility from salinity management alternative j at time t as follows

$$V(X_{ijt};\beta_i) = \begin{cases} \mu_p + \beta_i' x_{ijt} + \sigma_p \zeta_1 + \sigma_{np} \zeta_3 & \text{for } j = 2 \\ \mu_p + \beta_i' x_{ijt} + \sigma_p \zeta_1 + \sigma_{np} \zeta_4 + \sigma_{cv} d_{cv} \zeta_6 & \text{for } j = 1 \\ \beta_i' x_{ijt} + \sigma_{np} \zeta_2 + \sigma_p \zeta_5 + \sigma_{cv} d_{cv} \zeta_7 & \text{for } j = 0 \end{cases} \tag{2}$$

A maximum of 3 alternatives are presented to an individual during a single choice occasion in our sample. Under this structure, the alternative index value of zero is reserved for the "No Plan" alternative. Here x_{ijt} contains only variables describing salinity management outcomes under alternative j faced by an individual on occasion t. The model also includes a fixed, alternative-specific constant μ_p for the choice of management vs. no management.

Our model captures two sources of individual heterogeneity. Random parameters β_i are assumed to be independent and randomly distributed in the population. We also include a set of independent, mean-zero normally-distributed error components $\zeta_1, \ldots, \zeta_7$ for two purposes. The first is our implementation of a mixed logit analogue to the nested logit structure using dispersion parameters σ_p and σ_{np} suggested by Walker et al. These parameters allow us to model variance specific to utility over salinity management and the status quo, respectively, and induce correlation between the two salinity management utilities. Finally, following Hensher et al., we allow for differences in scale across the CV and CE components of the data set by including the dispersion parameter σ_{cv}, which is activated by an indicator d_{cv} for choice CV occasions.[7]

The model is estimated following procedures discussed by Greene and Hensher and by Train. Briefly, consider a generic RXL model where individual *i*'s utility of alternative j on choice occasion t is $U_{ijt} = \beta_i' x_{ijt} + \varepsilon_{ijt}$, and *i*'s parameter vector β_i is distributed with density $f(\beta_i|\theta)$. Here the ε_{ijt} are once again IID EV1, and θ collects all parameters of the density for β_i. Conditional on β_i, the probability that an individual is observed making choice sequence $\mathbf{k} = \{k_1, \ldots, k_T\}$ is

$$S_{i\mathbf{k}}(\beta_i) = \prod_{t=1}^{T} \left(\frac{e^{\beta_i' x_{ijt}}}{\sum_{j=0}^{J} e^{\beta_i' x_{ijt}}} \right). \tag{3}$$

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[7] Since during CV choice occasions alternative *j* is censored, a term including σ_{cv} is not incorporated into the utility statement for alternative 2.

Since β_i is not observed by the econometrician, it is necessary to integrate over its support to obtain the unconditional probability of observing choice sequence **k**, $P_{i\mathbf{k}}$:

$$P_{\mathrm{ik}}(\theta) = \int S_{\mathrm{ik}}(\beta_i) f(\beta_i \mid \theta) \mathrm{d}\beta_i \tag{4}$$

Since a closed form solution for $P_{i\mathbf{k}}(\theta)$ is usually unavailable, it must be approximated through simulation. This is accomplished by calculating

$$SP_{i\mathbf{k}}(\theta) = \frac{1}{R}\sum_{r=1}^{R} S_{\mathrm{ik}}\left(\beta_i^{r|\theta}\right) \tag{5}$$

Here $\beta_i^{r|\theta}$ is the r^{th} draw from $f(\beta_i|\theta)$. The simulated probability $SP_{ik}(\theta)$ is an unbiased estimator of the true probability $P_{ik}(\theta)$, with variance decreasing in the number of draws R. The simulated log-likelihood for the RXL model is

$$SLL(\theta) = \sum_{i=1}^{N}\sum_{\mathbf{k}} \delta_{i\mathbf{k}} \ln SP_{i\mathbf{k}}(\theta) \tag{6}$$

Here $\delta_{i\mathbf{k}} = 1$ when an individual *i* is observed selecting choice sequence **k**. In our analysis we Modified Latin Hyper Cube Sampling (MLHS) as the basis for draws from the parameter distribution. This technique provides random draws that deliver a more accurate approximation of the choice probabilities than independent random draws (Hess et al.).

For preliminary welfare evaluations, we use the sample mean unconditional compensating variation (CV) of a shift from the status quo to a particular scenario:

$$CV_i = \frac{V\left(X_i^1\right) - V\left(X_i^0\right)}{\beta^M} \tag{7}$$

where X_i^1 and X_i^0 are explanatory variables associates with the deviation from the status quo and the status quo, respectively, and β^M is marginal utility of income.[8]

Results

Estimation results are reported in Table 2. Model 1 assumes salinity management variables have fixed coefficients, while model 2 introduces random coefficients on program attributes (other than monthly cost). The coefficient on premature deaths due to poor air-quality is log-normally distributed in model 2 so the variable is scaled by negative one in that specification. The coefficients on land in agricultural production and land in seasonal and permanent wetlands are triangularly distributed in model 2.

In both model 1 and model 2, variables related to salinity management have the expected sign and with the exception of the dispersion parameter for land in seasonal and permanent wetlands are significant at the 1% level. The insignificant dispersion parameter on land in seasonal and permanent wetlands is evidence against the presence of taste heterogeneity for that public good. The variable capturing scale differences between the contingent valuation and choice experiment components of the data, σ_{cv}, is significant at the 5% level in both specifications. However, in each case a straightforward likelihood ratio test fails to reject the restriction of σ_{cv} to one at the same significance level. These findings taken together provide evidence against the presence of scale differences between the CV and CE responses.

We experimented with a variety of distributions for the salinity management program variables. Our preferred specification for the purpose of welfare analysis is model 2. A

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[8] Both of the RXL specifications in the next section include the monthly cost of the salinity management alternative with a fixed coefficient.

straightforward pair-wise application of the likelihood dominance criterion (Pollak and Wales) indicates that model 2 dominates model 1.

Table 3 reports estimates of the mean unconditional willingness-to-pay for incremental changes public goods produced by salinity management based on our preferred specification. Mean monthly willingness-to-pay for each good is positive, as are lower bounds on the associated 95% confidence intervals. Mean monthly willingness to pay for an increase in 1 million acres of land in agricultural production or a decrease in 1,000 premature deaths is approximately $25, and about $0.22 for one thousand additional acres of seasonal and permanent wetlands.

Discussion

The household-level costs and benefits of salinity management is an important topic about which relatively little is known, particularly in the United States. There are two broad categories of costs of salinity to households: (1) the increases in the cost of operating, maintaining, and replacing household appliances and plumbing, and (2) possible changes in a variety of public goods whose availability or quality may be affected by increases in salinity. The first category has received some, though not extensive, attention in the literature, while the second has, to our knowledge, received little or no attention. To help bridge the gap in information about the expected costs of salinity increases, this paper analyzes data from a survey of willingness to fund salinity management plans conducted among households in the San Joaquin Valley of California. Our preliminary findings are that willingness to pay for salinity management programs is low, but marginal increases in associated public goods generate statistically-significant positive willingness to pay. Should this former result withstand scrutiny from extensions to our econometric analysis (discussed below), several factors may be at work.

One is the relatively low household incomes in the Valley, which are considerably below the statewide average. Second is the subtle, long-term nature of salinity as an environmental management problem; that is, salinity accumulation occurs at a relatively long time scale, and its effects are difficult to detect by the average household. Third, evidence from pretest interviews suggests a higher-than-typical skepticism about the efficacy of government programs generally. These elements may be underpinning to our preliminary finding that willingness to pay for salinity management *without* the associated public negative (as indicated by the statistically significant and relatively large negative management constant μ_p in both model 1 and model 2). When sufficiently large amounts of the public goods are also produced by salinity management, willingness to pay becomes positive, but this may be at levels of the public goods that are infeasible to produce.

We intend to extend our preliminary analysis in a number of directions. Our first priority is to study the distributions of individual-level willingness-to-pay for a particular public good or salinity management policy (Greene et al.). There are also several possible extensions to the repeated mixed logit model that we employ, including, for example, allowing for state dependence engendered by the order of the contingent valuation module of the survey relative to the choice experiments. The idea would be to test for a similar state-dependence effect that has been examined in studies that estimate models using combined revealed and stated preference data (Whitehead et al.). Finally, Campbell presents a method for uncovering determinants of individual willingness-to-pay in a second-stage analysis based on random effects models. This approach may yield substantial additional insights into the structure of preferences among San Joaquin Valley residents for salinity management, for example differences between urban and rural Valley residents.

References

Abdalla, C. W. "What the Public Values about Farm and Ranch Land." Workshop Summary, Northeast Regional Center for Rural Development, Regional Rural Development Paper No. 23, 2004, 33pp.

Andersen, J.C., A.P. Kleinman, et al. (1978). *Salinity Management Options for the Colorado River*. Water Resources Planning Research Report P-78-003, Utah State University, Logan, Utah: Utah Water Research Laboratory.

Arora, N., and J. Huber. (2001). "Improving Parameter Estimates and Model Prediction by Aggregate Customization in Choice Experiments." *Journal of Consumer Research* 28, 273-83.

Black & Veatch Consulting Engineers. (1967). "Economic Effects of Mineral Content in Municipal Water Supplies." Research and Development Progress Report No. 260. Washington, D.C.: US Department of the Interior, Office of Saline Water.

Bookman-Edmonston Engineering, Inc. (1999). "Background Data and Analysis for Salinity Economic Impact Model." *Salinity Management Study*, Metropolitan Water District of Southern California and United States Bureau of Reclamation.

Bruvold, W.H. & J.J. Daniels. (1990). Standards for Mineral Content in Drinking Water. *Journal AWWA*, 82, 59-65

Bruvold, W.H., Mitchell Jr., & N. Raymond. (1976). "Consumer Evaluation of the Cost and Quality of Domestic Water." *Technical Completion Report Contribution #139*. Water Resources Center, University of California, Berkeley, CA.

Bunch, D. S., J. J. Louviere, and D. Anderson. (1996). "A Comparison of Experimental Design Strategies for Multinomial Logit Models: The Case of Generic Attributes." Working Paper 11-96, Graduate School of Management, University of California, Davis.

Campbell, D. (2007). "Willingness to Pay for Rural Landscape Improvements: Combining Mixed Logit and Random-Effects Models." *Journal of Agricultural Economics* 58(3): 467-483.

Cismowski, G., W. Cooley, L. Grober, J. Martin, M. Mccarthy, R. Schnagl, and A. Toto. (2006). "Salinity In The Central Valley: An Overview." Central Valley Regional Water Quality Control Board, May 2006.

Coe, J.J. (1982). *Water Quality Related Consumer Costs in Domestic Water Use*. PhD Dissertation, Department of Civil and Environmental Engineering, University of Southern California.

Dillman, Don A. (1978). *Mail and Telephone Surveys: The Total Design Method*, New York: John Wiley and Sons.

D'Arge, R.C., & L. Eubanks. (1978). "Municipal and Industrial Consequences of Salinity in the Colorado River Service Area of California." in J.C. Andersen, A.P. Kleinman, eds. *Salinity Management Options for the Colorado River*, Logan, Utah: Utah Water Research Laboratory, June 1978, 253-277.

Fleischer, A., and Y. Tsur. "Measuring the Recreational Value of Agricultural Landscape." Working paper, Department of Agricultural Economics and Management, The Hebrew University of Jerusalem.

Greene, W.H. and D.A. Hensher. (2007). "Heteroscedastic Control for Random Coefficients and Error Components in Mixed Logit." *Transportation Research Part E* 43: 610-623.

Greene, W.H., D.A. Hensher, and J.M. Rose. (2005). "Using Classical Simulation-Based Estimators to Estimate Individual WTP Values: A Mixed Logit Case Study of Commuters." Chapter 2 in R. Scarpa and A. Alberini eds. *Applications of Simulation Methods in Environmental and Resource Economics*, New York: Springer-Verlag.

Hall, J. V., V. Brajer, and F. W. Lurmann. (2006). "The Health and Related Economic Benefits of Attaining Healthful Air in the San Joaquin Valley." Institute for Economic and Environmental Studies, California State University, Fullerton, March 2006.

Hensher, D.A., J.M. Rose, and W.H. Greene. (2008). "Combining RP and SP Data: Biases in Using the Nested Logit 'Trick' – Contrasts with Flexible Mixed Logit Incorporating Panel and Scale Effects. *Journal of Transportation Geography* 16: 126-133.

Hess, S., K.E. Train, and J.W. Polak. (2006). "On the Use of a Modified Latin Hypercube Sampling (MLHS) Method in the Estimation of a Mixed Logit Model for Vehicle Choice." *Transportation Research Part B* 40: 147-163.

Howson, L.R. (1962). Economics and Water Softening. *Journal AWWA*, February.

Huber, J., and K. Zwerina. (1996). "The Importance of Utility Balance in Efficient Choice Designs." *Journal of Marketing Research* 33: 307-317.

Krinsky, I. and A.L. Robb. (1986). "On Approximating the Statistical Properties of Elasticities." *The Review of Economics and Statistics* 68(4): 715-719.

Lohman, L.C., J.G. Milliken, *et al*. (1988). *Estimating Economic Impacts of Salinity of the Colorado River*. Littleton, CO: Milliken Chapman Research Group for the Bureau of Reclamation.

Orange County Water District. (1972). "Water Quality and Consumer Costs." Irvine, CA.

Pope C.A., R.T. Burnett, M.J. Thun, E.E. Calle, D. Krewski, K. Ito and G.D. Thurston. (2002) "Lung Cancer, Cardiopulmonary Mortality, and Longterm Exposure to Fine Particulate Air Pollution," *Journal of the American Medical Association* 287(9): 1132-1141.

Polak, R.A. and T.J. Wales. (1991). "The Likelihood Dominance Criterion: A New Approach to Model Selection." *Journal of Econometrics* 47: 227-242.

Pruckner, G.J. "Agricultural Landscape Cultivation in Austria: An Application of the CVM." *European Review of Agricultural Economics* 22 (1995): 173-190.

Ragan, G.E., C.J. Makela, & R.A. Young. (1993). *Improved Estimates of Economic Damages from Residential Use of Mineralized Water*. Colorado Water Resources Research Institute: Fort Collins.

San Joaquin Valley Air Pollution Control District. (2006). "2006 PM10 Plan: San Joaquin Valley Strategy for Meeting Federal Air Quality Requirements for Particulate Matter 10 Microns and Smaller." February, 2006.

Train, Kenneth. (2009). *Discrete Choice Methods with Simulation*. Cambridge, U.K.: University Press. Second edition.

US Fish and Wildlife Service, California Department of Fish and Game, and California Department of Water Resources. (1990). "A Management Plan for Agricultural Subsurface Drainage and Related Problems on the Westside San Joaquin Valley." Final Report of the San Joaquin Valley Drainage Program, September 1990.

University of California Agricultural Issues Center (UC AIC). "Agriculture's Role in the Economy." Chapter 5 in *The Measure of California Agriculture*, Davis CA, August 2009. Available at http://aic.ucdavis.edu/publications/moca/moca09/moca09.pdf.

Walker, J.L., M. Ben-Akiva, and D. Buldoc. (2007). "Identification of Parameters in Normal Error Component Logit-Mixture (NECLM) Models." *Journal of Applied Econometrics* 22: 1,095-1,125.

Whitehead, J.C., S.K. Pattanayak, G.L. Van Houtven, and B.R. Gelso. (2008). "Combining Revealed and Stated Preference Data to Estimate the Nonmarket Value of Ecological Servies: An Assessment of the State of the Science." *Journal of Economic Surveys* 22(5): 872-908.

Williams, C., and M. Alemi. October 2002. "Agricultural Drainage in the San Joaquin Valley: A Gap Analysis." San Joaquin Valley Drainage Implementation Program.

Table 1. Levels of the Salinity Program Attributes Used in the Contingent Valuation and Choice Experiments

Contingent Valuation		
Attribute	No Plan	Management Plan
Land in agricultural cropland (million acres)	1.9	2.3
Land in seasonal and permanent wetlands (thousand acres)	24	88
Air quality effects (thousand premature deaths/year)	10.9	10.4
Cost to your household (dollars/month)	0	3 to 54[a]
Choice Experiments		
Attribute	No Plan	Management Plan A and B
Land in agricultural cropland (million acres)	1.9	2.1, 2.3, 2.5
Land in seasonal and permanent wetlands (thousand acres)	24	57, 88, 112
Air quality effects (thousand premature deaths/year)	10.9	10.1, 9.5, 8.9
Cost to your household (dollars/month)	0	9, 15, 28

Note: *a.* Monthly cost varies by treatment (single bound vs. double bound) and question number (in the double bound version).

Table 2. Estimation Results (Robust Standard Errors in Parentheses)

Variable	Parameter[a]	Model 1[b]	Model 2[c]
Land in agricultural cropland (million acres)	Mean coefficient	2.2782 (0.4962)	2.1368 (0.6908)
	Dispersion coefficient	- -	11.5564 (1.4890)
Land in seasonal and permanent wetlands (thousand acres)	Mean coefficient	0.0144 (0.0031)	0.0189 (0.004)
	Dispersion coefficient	- -	0.0049 (0.0305)
Air quality effects[d] (thousand premature deaths/year)	Mean coefficient	-1.6513 (0.1667)	0.4623 (0.1342)
	Dispersion coefficient	- -	0.8001 (0.1120)
Cost (dollars/month)	Mean coefficient	-0.0674 (0.0131)	-0.0906 (0.0178)
μ_p	Mean coefficient	-3.3369 (0.6931)	-3.8278 (0.7664)
σ_p	Dispersion coefficient	-2.9203 (0.2903)	2.592 (0.4213)
σ_{np}	Dispersion coefficient	0.4558 (0.1671)	-0.7932 (0.2149)
σ_{cv}	Dispersion coefficient	1.5207 (0.4757)	1.259 (0.6031)
Log-likelihood at convergence:		-1,151.74	-1,105.2773

Notes: *a.* For triangularly distributed parameters, the dispersion coefficient is the spread of the variable's distribution (or $\sqrt{6}$ times the standard deviation of the associated parameter distribution). For log-normally distributed variables, the dispersion coefficient is the standard deviation of the natural log of the variable.

b. Both model 1 and model 2 were estimated using 5,000 MLHS draws.

c. In model 2, the coefficients on land in agricultural cropland and land in seasonal and permanent wetlands are assumed to follow a triangular distribution. The coefficient on air quality effects is log-normally distributed.

d. Air quality effects are scaled by -1 in model 2 since the coefficient is log-normally distributed.

Table 3. Willingness-to-pay for Incremental Changes

Policy Variable	MWTP (2007 dollars/month)	95% CI[a]
Land in agricultural cropland (million acres)	24.8942	(7.1024, 48.8444)
Land in seasonal and permanent wetlands (thousand acres)	0.2172	(0.1027, 0.3897)
Air quality[b] (thousand premature deaths/year)	25.0233	(16.9166, 37.7491)

Notes: *a*. Confidence interval calculated following Krinsky and Robb using 2,000 draws.
b. The value reported here is for a *reduction* of 1,000 premature deaths per year.

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