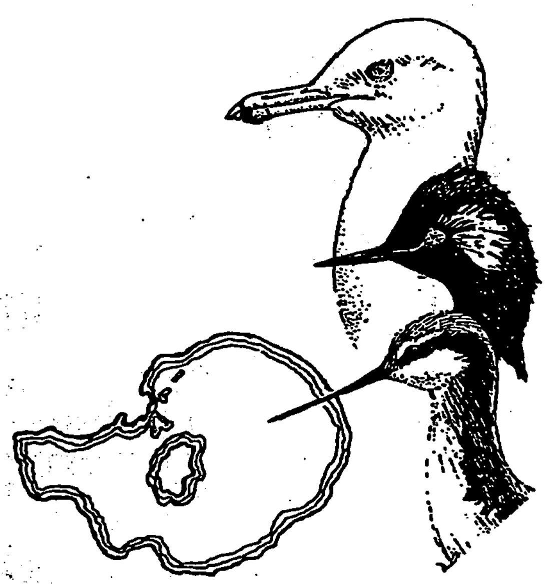

Draft Environmental Impact Report for the Review of the
Mono Basin Water Rights
of the City of Los Angeles
California State Water Resources Control Board
Division of Water Rights
Sacramento, California

Appendix X. Economics



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Appendix X. Economics

This appendix provides details of the methods used to estimate recreation benefits, Mono Lake preservation values, and water and power supply costs.

RECREATION BENEFITS

Recreation benefits associated with changes in streamflows and lake levels were estimated for directly affected recreation areas. Statistical analyses were performed on survey data obtained from onsite interviews at Mono Lake, the lower tributaries, Grant Lake reservoir, and Lake Crowley reservoir. Survival analysis was performed using logistic models on the discrete choice responses to willingness-to-pay questions. Estimates of the mean and median willingness-to-pay values were calculated and used to estimate the recreation benefits of hydrologic conditions associated with the project alternatives.

The steps followed to estimate recreation benefits and the statistical results of the willingness-to-pay analysis for each directly affected recreation areas (excluding Upper Owens River where no survey was conducted) are identified in Tables X-1 through X-9.

MONO LAKE PRESERVATION VALUES

Social benefits of maintaining resource conditions associated with alternative lake levels at Mono Lake were analyzed based on a survey of California households. The data collected in the survey were analyzed using statistical models and the results were then expanded to the statewide population. The details of the survey design and data analysis are described below.

Survey Design

The contingent valuation methods (CVM) was selected as the technique best able to measure WTP for resource conditions. CVM is a widely accepted method for valuing both recreation and other nonmarketed benefits of environmental resources. CVM has been recommended by the U.S. Water Resources Council as one of two preferred methods for valuing outdoor recreation in federal benefit-cost analysis. CVM is capable of measuring the value of outdoor recreation under alternative levels of resource conditions and is the only method currently available to measure other components of total economic value, such as option, existence, and bequest values.

The basin notion of CVM is that a realistic but hypothetical market for "buying" use or preservation of a nonmarketed natural resource is described to an individual. The individual is then asked to use the market to express his or her valuation of the resource. Key features of the market include a description of the resource being preserved, a means of payment (often called payment vehicle), and the value elicitation procedure.

For the Mono Lake study, three resource conditions were described to survey participants. These conditions corresponded to lake levels of 6,375 feet, 6,390 feet, and 6,410 feet and were based on available information about wildlife conditions, tufa towers, lake access, visibility, and lake surface area. Respondents were then asked if they would be willing to pay different amounts to see programs implemented to maintain these lake levels and associated resource conditions. A referendum-type survey format was used in which payment would be made for state-sponsored bonds to buy additional water supplies for Mono Lake.

The goal for survey completion was 600 California households. The survey included an initial telephone contact, a mailing of survey materials that visually depicted and described the resource conditions associated with the programs, and a followup in-depth interview by telephone that lasted about 15 minutes, on average. Copies of the survey scripts, summary statistics from the survey, and details about the sampling procedures are available on request.

Statistical Model and Results

Following the methodology described in Hanemann (1984) and Hanemann, Kanninen, and Loomis (1991), we analyzed the responses to the discrete choice contingent valuation (CV) data using a statistical model that is derived from an underlying utility maximization (Figure X-1). In the present application to the Mono Lake CV, where we are valuing several programs (i.e., several lake levels), we have extended the standard discrete-response model to allow for the possibility of a nonzero correlation in the values that respondents place on the various programs. We refer to this as the Correlated Discrete-Response CV Model.

A preliminary analysis of the responses to the CV survey shows that most of the respondents regarded Program C (lake elevation 6,410 feet) as inferior to either Program A (lake elevation 6,375 feet) or Program B (lake elevation 6,390 feet). Because of this, we decided to analyze Program C separately from the two other programs.

Programs A and B

The new correlated response model is applied to the data on Programs A and B. The starting point for the correlated response model, as for the conventional discrete response model, is an underlying (indirect) utility function associated with each of those outcomes, which we index with the subscript t: the default, no-action label level ($t = 0$), the improvement associated with Program A ($t = 1$), and the improvement associated with Program B ($t = 2$). We employ the following Box-Cox formulation for the indirect utility function:

$$(1) \qquad u_t = \alpha_t + \beta_t \left(\frac{y^\lambda - 1}{\lambda} \right) + \epsilon_t \qquad t = 0,1,2.$$

where y is the respondent's income, α_t β_t and λ are parameters to be estimated, and the ϵ_ts are stochastic terms reflecting the random component of the respondents' preferences for outcome $t = 0, 1, 2$. This formulation nests the two specific models that have been used most frequently in the existing literature: the linear model (corresponding to $\lambda = 1$), where

$$(2) \qquad u_t = \alpha_t + \beta_t y + \epsilon_t \, .$$

and the log model (corresponding to $\lambda = 0$), where

$$(3) \qquad u_t = \alpha_t + \beta_t \ln y + \epsilon_t$$

The Box-Cox model can also be regarded as a form of CES utility function in income and the environmental commodity. For the time being, we will assume that $\alpha_t > \alpha_0$ $t = 1, 2$ and $\beta_t > \beta_0$, $t = 1, 2$ but below we will consider the possibility that $\beta_t = \beta_0$, $t = 1, 2$.

Define $a_t \equiv (\alpha_t - \alpha_0)$, $b \equiv (\beta_t / \lambda)$, and $\eta_t \equiv (\epsilon_t - \epsilon_0)$. Let W_t denote the respondent's WTP for raising the level of Mono Lake from the no-action level (i.e., lake elevation 6,372 feet) to level $t = 1$ or 2. It follows from (1) that the formula for W_t is

$$(4) \qquad W_t = y - \left[\frac{\beta_0}{\beta_t} y^\lambda + \left(\frac{\beta_t - \beta_0}{\beta_t} \right) - \frac{a_t}{b_t} - \frac{\eta_t}{b_t} \right]^{\frac{1}{\lambda}} .$$

Since it depends on an η_t, which is a random variable, WTP is itself a random variable. If the median of η_t is zero, then

$$(5) \qquad \text{Median}(W_t) = y - \left[\frac{\beta_0}{\beta_t} y^\lambda + \left(\frac{\beta_t - \beta_0}{\beta_t} \right) - \frac{a_t}{b_t} \right]^{\frac{1}{\lambda}} .$$

We assume that the random variables (η_1, η_2) are jointly distributed with mean zero, variances σ_1^2 and σ_2^2, and correlation ρ. More specifically, we assume that (η_1, η_2) are - bivariable normal, with correlation ρ. The parameters σ_1, σ_2 and ρ are to be estimated from the data, subject to restrictions on their identifiability. It is the presence of the (potentially nonzero) correlation coefficient, ρ, that distinguishes this correlated response model from the conventional discrete-response models that already exist in the literature. The Mono Lake CV survey employed a bid design that involved sometimes single-bounded responses and sometimes double-bounded responses. Starting with the former, the probability that an individual responds "Yes" to the question, "If Program A costs \$x per household per year, would you be willing to vote in favor of it?" is given by

(6)
$$\begin{aligned}\Pr\{\text{YES to \$}x\text{ for Program A}\} &= \Pr\{W_1 \geq x\} \\ &= \Pr\{\eta_1 \geq g_1(x)\} \\ &= \text{Pj}\{\upsilon_1 \geq \bar{g}_1(x)\}\end{aligned}$$

where

$$\upsilon_1 \equiv \eta_1 / \sigma_1, \quad \bar{g}_1(x) \equiv g_1(x)/\sigma_1,$$

and

(7)
$$\bar{g}_1(x) = -\frac{a_1}{\sigma_1} + \frac{b_0}{\sigma_1}\left(\frac{y^{\lambda} - 1}{\lambda}\right) - \frac{b_1}{\sigma_1}\left(\frac{(y - x)^{\lambda} - 1}{\lambda}\right).$$

Similarly, if the individual responds "Yes" to the question, "If Program B costs \$z per household per year, would you be willing to vote in favor of it?" the probability of this response is given by

(8)
$$\begin{aligned}\Pr\{\text{YES to \$}z\text{ for Program B}\} &= \Pr\{W_2 \geq z\} \\ &= \Pr\{\upsilon_2 \geq \bar{g}_2(\text{x})\}\end{aligned}$$

where $\upsilon_2 \equiv \eta_2 / \sigma_2$ and

(9)
$$\bar{g}_2(z) = \frac{-a_2}{\sigma_2} + \frac{b_0}{\sigma_2}\left(\frac{y^{\lambda} - 1}{\lambda}\right) - \frac{b_2}{\sigma_2}\left(\frac{(y - z)^{\lambda} - 1}{\lambda}\right).$$

The probability that an individual responds "Yes" to a bid of \$x for Program A but "No" to a bid of $z > x$ for that same Program is given by

(10)
$$\begin{aligned}&P_1\{\text{YES to \$}x\text{ and NO to \$}z\text{ for Program A}\} \\ &\quad = P_1\{z \geq W_1 \geq x\} \\ &\quad = P_1\{\bar{g}_1(z) \geq \upsilon_1 \geq \bar{g}_1(x)\}.\end{aligned}$$

An analogous formula, involving $\bar{g}_2(z)$ and $\bar{g}_2(x)$, would describe the double-bounded response probability for Program B. The random variables υ_1 and υ_2 have means of zero, variances of unity, and a correlation coefficient ρ.

It follows from (7) and (9) that not all of the model parameters are separately identifiable. While ρ and λ are identified, not all of parameters a_1, a_2, b_0, b_1, b_2, σ_1, σ_2 are identified. Thus, for example, from (7) one obtains estimates of a_1/σ_1, b_0/σ_1, and b_1/σ_1, while, from (9), one obtains estimates of a_2/σ_2, b_0/σ_2, and b_2/σ_2; in addition, one can estimate the ratio $\sigma_1/\sigma_2 = [(b_0/\sigma_1) / (b_0/\sigma_2)]$. Similarly, for the purpose of computing the median WTP in (5), one can estimate the ratios $\beta_0/\beta_1 = [(b_0/\sigma_1) / (b_1/\sigma_1)]$ and $a_1/b_1 = [(a_1/\sigma_1) / (b_1/\sigma_1)]$.

All of the above applies to the general model in which $\beta_0 \neq \beta_1 \neq \beta_2$. A special case is the <u>restricted</u> model in which it is assumed that $\beta_0 = \beta_1 = \beta_2 \equiv \beta$. In that case, the formula for WTP in (4) simplifies to

(4')
$$W_t = y - \left[y^\lambda - \frac{a_t}{b} + \frac{\eta_t}{b}\right]^{\frac{1}{\lambda}} \qquad t = 1,2,$$

where $b \equiv \beta/\lambda$, with

(5')
$$\text{Median}(W_t) = y - \left[y^\lambda - \frac{a_t}{b}\right]^{\frac{1}{\lambda}} \qquad t = 1,2.$$

The single and double-bounded response probabilities are given by (6), (8), and (10), where the functions $\overline{g}_t(x)$ simplify to

(7')
$$\overline{g}_1(x) = \frac{-a_1}{\sigma_1} + \frac{b}{\sigma_1}\left(\frac{y^\lambda - 1}{\lambda}\right) - \frac{b}{\sigma_1}\left(\frac{(y-x)^\lambda - 1}{\lambda}\right)$$

(9')
$$\overline{g}_2(z) = \frac{-a_2}{\sigma_2} + \frac{b}{\sigma_2}\left(\frac{y^\lambda - 1}{\lambda}\right) - \frac{b}{\sigma_2}\left(\frac{(y-z)^\lambda - 1}{\lambda}\right).$$

Again, not all of the model parameters are separately identifiable. From (7') one obtains estimates of (a_1/σ_1) and (b/σ_1), while from (9') one obtains estimates of (a_2/σ_2) and (b/σ_2).

With the double-bounded format there are three bids: an initial bid (x_S) and two followup bids, one higher (x_U) than the initial bid and the other lower (x_L). If the respondent answers "Yes" to the first bid, the higher followup bid is used; if he answers "No", the lower followup bid is used. Thus, for a given program, four outcomes are possible: Yes-Yes, No-No, Yes-No, and No-Yes. With two programs - A and B - 16 (= 4 x 4) possible sets of response outcome are possible. For example, there is a response of Yes-Yes for A and Yes-No for B if the following inequalities are satisfied:

(11)
$$\upsilon_1 \geq \overline{g}_1(x_U) \quad \text{and} \quad \overline{g}_2(z_U) > \upsilon_2 \geq \overline{g}_2(z_S)$$

where z denotes a bid used for Program B, and x a bid for Program A. Under the stochastic specifications adopted here, $(\upsilon_1\ \upsilon_2)$ are standard bivariate normal with correlation coefficient ρ. Let $\phi\ (\upsilon_1\ \upsilon_2)$ be the standard bivariate normal density. Then, the probability that the inequalities in (11) hold is given by

$$(12)\qquad \int_{g_1(x_U)}^{\infty} \int_{g_2(z_S)}^{\bar{s}_2(z_U)} \phi(\upsilon_1, \upsilon_2) d\upsilon_1 d\upsilon_2 .$$

This and the other response probabilities can be expressed in terms of the standardized bivariate normal cumulative distribution function $\Phi(\cdot\,,\cdot)$ using the conclusion that

$$(13)\qquad \int_a^b \int_c^d \Phi(x,y)dxdy = \Phi(b,d) + \Phi(a,c) - \Phi(a,c) - \Phi(a,d) - \Phi(b,c).$$

The likelihood function for the responses for Programs A and B is built up from (11) - (13) for each of the 16 possible response outcomes.

The correlated response model was estimated by maximum likelihood using the GAUSS Program on a PC applied to the responses for Programs A and B. Two features stand out from the results. First, the linear (and logarithmic) models can be rejected in favor of the general, Box-Cox model: the parameter λ consistently took a value of around 0.8 - 0.9, which is quite close to the value $\lambda=1$, which implies a linear model, but it was always significantly different from unity (and zero). Second, we could not reject the hypothesis that $\beta_2 = \beta_1 = \beta_0$ (i.e., the data support the restricted model). The maximum likelihood coefficient estimates (and asymptotic standard errors and t-statistics) for the restricted, Box-Cox model are shown in Table X-10; these are the estimated values for the parameters in equations (7') and (9'). Using the formula in (5') together with an income level of y = \$35,000, which is the median for the sample of respondents to the statewide survey (and close to the 1990 Census), the median WTP is estimated to be \$96.38 for Program A and \$110.68 for Program B.

Table X-10. Correlated Response Model Coefficient Estimates
(Programs A and B)

Parameters	Estimates	Standard Error	Estimated Standard Error
C	0.8533	0.0233	36.654
a_1/σ_1	0.9647	0.1127	8.561
b/σ_1	0.3286	0.0477	6.889
a/σ_2	0.8407	0.0661	12.713
b/σ_2	0.2494	0.0251	9.956
λ	0.8712	0.0105	83.150

Program C

For Program C, we employed the conventional, double-bounded (univariate) discrete-response model outlined in Hanemann, Kanninen, and Loomis (1991). However, instead of the linear-logistic model employed there, we use the Box-Cox formulation in (1) combined with normal distribution (i.e., a double-bounded probit model). As with Programs A and B, we found that the model with $\beta_0 = \beta_1$ fits best. The estimation procedure is equivalent to fitting the $g_i(x)$ function in (7'). Using maximum likelihood, the coefficient estimates are shown in Table X-11.

Table X-11. Coefficient Estimates for Program C

Parameters	Estimates	Standard Error	Estimated Standard Error
a/σ	0.1373	0.0826	1.663
b/σ	0.1347	0.0704	1.913
λ	0.8975	0.0632	14.200

The median WTP for the sample, estimated using the formula in (5') and the sample median income of $35,000 is $26.21. The *population* median WTP, calculated using the formula in (20) and a population median income of $36,000, is zero.

Extrapolation to the Statewide Population

The estimates of median WTP developed above need to be extrapolated from the sample of California households covered by the survey to the set of *all* California households to derive a statewide estimate of WTP for the programs. Two important issues need to be considered in making this extrapolation: households with a language barrier and non-responding households. Because the survey was conducted entirely in English, households in which nobody over 18 could speak English were unable and thus ineligible to participate. Out of 1,158 households contacted during the telephone survey, 125 households (10.8%) were in this category. The survey cannot be considered representative of such non-English-speaking households; they may or may not place the same value on protecting wildlife resources and habitat at Mono Lake as the English-speaking households, but we cannot tell from the survey. To be conservative, we will assume that non-English-speaking households place *no* value on Mono Lake, and we will exclude them from the statewide population to which the WTP values are extrapolated.

(18) $$\gamma = Pr\ \left(b(y - x*)^{\lambda} - by^{\lambda} + a_t\ \leq\ \eta_t \right)$$

or

$$\gamma\ =\ Pr\left(\frac{b}{\sigma_t}\,(y - x*)^{\lambda} - \frac{b}{\sigma_t}\,y^{\lambda} + \frac{a_t}{\sigma_t}\ \leq\ \upsilon_t \right).$$

where υ_t is a standard univariate normal random variable. Now, with $\gamma\ =\ 0.441$, the standard normal distribution yields

(19) $$\Pr\ (\ \upsilon_t\ \geq 0.148)\ =\ 0.441.$$

Hence,

$$\frac{b}{\sigma_t}\,(y - x*)^{\lambda} - \frac{b}{\sigma_t}\,y^{\lambda} + \frac{a_t}{\sigma_t}\ \ =\ 0.148.$$

It follows that

(20) $$x*\ =\ y - \left[y^{\lambda} - \frac{a_t}{b} + 0.148*\frac{\sigma_t}{b} \right]^{\frac{1}{\lambda}}.$$

We evaluate this using the coefficient estimates in Table X-10 and a value of y = \$36,000 for income. This corresponds approximately to the statewide median income: according to the 1990 census, the median household income in 1989 in California was \$35,789. The result is an estimate of \$81.90 for population median WTP Program A and \$91.16 for Program B. These population median WTPs are then applied to the estimated 9,276,530 English-speaking households; this yields aggregate statewide estimates of \$759.7 million for Program A and \$845.6 million for Program B.

In principle, these are *annual* values. The survey was framed in terms of willingness to pay an increase in state taxes for all residents of California over the next 20 years. On this basis, these values for Programs A and B could be extrapolated over any planning period. However, there are strong grounds for questioning whether these annual payments should be extended over a long time period. Everyone can state with some confidence what they would be willing to pay *now* for something, but they cannot say with certainty what they would be willing to pay in the future. Individuals cannot know now how they will feel about public programs in the future (i.e., 5 years from now) nor what demands on their budget will subsequently arise. A conservative approach would be to take the CV responses as expressions of a commitment for the *near future* and to discount the WTP values in later years in some way that reflects the increased uncertainty associated with future preferences. This approach would significantly reduce the average annual WTP values over the 20-year analysis period. Rather than actually perform this discounting, we show in Chapter 3N, "Economics", that the overall economic optimum (i.e., the lake level alternative up to which the marginal benefit curve exceeds the marginal cost curve) is not sensitive to substantial discounting of marginal benefits, even to the point of reducing them by as much as 80%.

Application to the Mono Lake Alternatives

The estimates of willingness to pay by California households described above need to be applied to the alternatives that were evaluated in the EIR. The survey asked about WTP for three programs: to maintain the lake at 6,375 feet, to increase the lake level to 6,390 feet, and to increase the lake level to 6,410 feet. In all cases, the default lake level was 6,372 feet.

The alternatives for the EIR are actually target lake levels below which the lake would not drop. Consequently, lake levels would be maintained above the target in almost all years and would exceed the target by several feet in most years. Because these conditions were not known at the time that the survey was conducted and therefore were not explained to survey respondents, a conservative approach to applying the estimates of willingness to pay for different lake levels is taken.

It is assumed that the base condition that households would want to maintain is that associated with the 6,372-Ft Alternative. The median lake level associated with this alternative is 6,375 feet (Table 3J-13), which is 1 foot below the median for the point of reference. With this level as a baseline, it is assumed that the estimated WTP for Program A would apply to avoiding conditions associated with the No-Restriction Alternative, which would allow the lake to decline to a median of 6,354 feet over the long term. For the 6,377-Ft to 6,390-Ft Alternatives, the marginal WTP to go from Program A ($81.90) to Program B ($91.16) is used. This value of $9.26 is divided by the change in lake elevation (15 feet) between the two programs to obtain a WTP per 1-foot change in lake elevation ($0.62). This value is then multiplied by the change in elevation between the EIR alternatives and the estimated number of English-speaking households (9,276,530) in the state to obtain an estimate of total WTP for the 6,377-Ft, 6,383-Ft, and the 6,390-Ft Alternatives.

After the adjustment for nonrespondents, the median WTP to obtain Program C (6,410 feet) was $0. Consequently, no value could be assigned to the 6,410-Ft Alternative. Also, no value was assigned to the No-Diversion Alternative because no survey data were collected for this alternative, which is higher than the 6,410-Ft Alternative.

The results of applying these procedures are reflected in the benefit-cost summary table (Table 3N-14) in Chapter 3N, "Economics".

WATER SUPPLY AND POWER GENERATION COSTS

The methods used to estimate water supply and power generation costs are described in Chapters 3L and 3M, respectively. The worksheets that show the annual and total changes in water supply and power generation costs for the point of reference and alternatives are included in Table X-12.

CITATIONS

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