Unfortunately, times have changed since those contracts were entered into. Today, the practical effect of granting any such M&I priority is to reduce the quantity of water available for irrigation purposes in many, if not most, years, as opposed to only occasionally during extreme drought conditions. We believe that new contracts and policies should provide an equal footing between irrigation and M&I uses except to the extent that water is needed to meet M&I public health and safety demands during extreme droughts.

We would point out that M&I Contractors do have alternatives if they wish to achieve greater reliability than is otherwise available from the project. They can consider and pursue water reallocation programs, such as Santa Clara has done with the San Luis Delta-Mendota Water Authority and certain of its members. They can also develop and/or participate in water banking programs, such as Santa Clara and other urban agencies have done with Semitropic Water Storage District. The effect of the November 20th draft policy, made worse if modified as suggested by some M&I Contractors, would be to provide M&I Contractors with more water at the expense of irrigation supplies. We believe that M&I Contractors should share equally in the water losses to the project resulting from on-going regulatory constraints. To do otherwise only accommodates and encourages urban growth with less expensive CVP supplies to the detriment of hard-working farmers and precious agricultural lands.

We would also like to note that the State Water Project has eliminated M&I priorities under the Monterey Amendments. In the same way that these amendments both allowed for transfer of state water supplies from agriculture to M&I and provided that they would be treated equally in times of shortage, so too should federal supplies provided under CVPIA transfer provisions treat the apportionment of shortages between agricultural and M&I users (i.e. equally).

Accordingly, we urge you to reconsider the draft M&I policy and develop a policy which does not impair the irrigation purposes of the Project, except to the extent that supplies are required to meet health and safety needs of our urban areas in times of extreme drought. Furthermore, if you should proceed with a policy similar to that presented in the November 20, 2000 draft, we implore you not shift additional burdens to irrigation as has been suggested by some M&I Contractors. Thank you for the opportunity to comment on this draft policy. 23

Very truly yours,

William D. Harrison

William D. Harrison
General Manager

Cc: John Davis
Board of Directors
Ernest Conant
CVPWA
SLDMWA

Del Puerto WATER District

P.O. Box 98 • Westley, CA 95387-0098 Fax (209) 892-4469 • Phone (209) 892-4470

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BRS 5/22/01

January 9, 2001

Ms. Betty Riley-Simpson
Department of the Interior
Bureau of Reclamation, Regional Office
2800 Cottage Way
Sacramento, CA 95825-1898

RE: Proposed M&I Water Shortage Policy (December 22, 2000 draft)

Dear Ms. Riley-Simpson:

We understand that you intend to finalize a policy regarding M&I water shortages and are seeking comments on a draft policy dated December 22, 2000.

Our reading of this most recent draft shows little and no substantial change from the November 20th draft on which we commented by letter dated November 30, 2000 (copy attached). The current draft policy continues to raise serious and complex legal and policy issues, and by this letter we reiterate and incorporate the comments and concerns detailed in this previous letter.

While we appreciate the fact that proposed policy continues to limit its applicability only to the quantities of projected M&I demand as of September 1994 and maintains that irrigation water converted to M&I use after that date will be subject to the same shortage allocation as irrigation water, our comments and concerns still have not been adequately addressed.

As you know, this draft policy fundamentally reallocates agricultural water service supplies to urban contractors, thereby placing an additional burden on agricultural contractors and the rural communities they support. To our knowledge there has been no analysis of the impacts associated with such a policy and, consequently, no exploration of possible mitigation measures has been undertaken. Without such analysis and consideration, we remain seriously opposed to any policy that would further impair the efficiency of the project for irrigation purposes.

Thank you for the opportunity to provide additional comment on this draft policy.

24

Very truly yours,

William D. Harrison

William D. Harrison
General Manager

Cc: Lester Snow
John Davis
Ernest Conant
CVPWA
SLDMWA

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Del Puerto WATER District

P.O. Box 1596 • Patterson, CA 95363-1596

Fax (209) 892-4469 • Phone (209) 892-4470

November 26, 2001

Bureau of Reclamation
Attention: Alisha Sterud, MP 400
2800 Cottage Way
Sacramento, CA 95825-1898

RE: Comments on Draft CVP M&I Water Shortage Policy

Dear Ms. Sterud:

This letter conveys the comments of the Del Puerto Water District on the draft CVP M&I Water Shortage Policy as noticed in the Federal Register on October 30, 2001.

The current September 11, 2001 draft policy continues to raise serious and complex legal and policy issues, and by this letter we incorporate the comments and concerns detailed in our letter dated November 30, 2000 and reiterated in our letter of January 9, 2001 (both attached). The concerns expressed in these letters remain inadequately addressed and are, in fact, exacerbated by new language and concepts in the current proposed policy. 25

We note here that while the proposed policy purports to limit its applicability only to the quantities of projected M&I demand as of September 1994 and maintains that irrigation water converted to M&I use after that date will be subject to the same shortage allocation as irrigation water, new language has been added that would allow the conversion of subsequently transferred, assigned or converted agricultural supplies to M&I reliability provided that there are either no, or fully mitigated, adverse effects. We continue to maintain that the proposed policy fundamentally reallocates agricultural water service supplies to urban contractors and further submit that there is no mitigation possible for the inevitable resulting loss of agricultural water supplies. The adverse effects of such a policy on agricultural water supplies are magnified by the application of deeper shortages on an ever-smaller base supply. To include such language is tantamount to suggesting that one can farm without water. There is no justification or rationale for such language. If M&I contractors know that the reliability of converted water retains its original agricultural status as it must to avoid additional impacts, they are in a position to plan for and acquire the quantities they need to assure the desired level of reliability.

The proposed policy is also of serious concern insofar as it provides for adjustments in "historical use" based on "population growth" and/or the "number or demand of industrial, commercial, and other entities the contractor serves". Reclamation has never similarly considered increasing contract supplies or reliability to agricultural contractors based on increased acreage planted to permanent crops or the number of farms or farm families served. The point here is that the proposed policy quite clearly favors urban growth and water supply demand at the direct and ever-increasing expense of irrigation water supplies. 26

We reiterate that adoption of this proposed policy cannot be justified or enforced in light of Section 9(c) of the 1939 Act (43 USC §485(c)) which provides in part:

> "No contract relating to municipal water supply or miscellaneous purposes or to electric power or power privileges shall be made unless, in the judgment of the Secretary, it will not impair the efficiency of the project for irrigation purposes."

The District remains seriously opposed to this and any other policy that would further impair the efficiency of the project for irrigation purposes.

Thank you for the opportunity to provide comment on this proposed policy. 27

Very truly yours,

William D. Harrison

William D. Harrison
General Manager

Cc: Kirk Rodgers
John Davis
Ernest Conant
CVPWA
SLDMWA

Del Puerto WATER District
P.O. Box 1596 • Patterson, CA 95363-1596
Fax (209) 892-4469 • Phone (209) 892-4470

April 22, 2005

(Via FAX 1-916-978-5094)

Mr. David Lewis
Bureau of Reclamation
2800 Cottage Way, MP 730
Sacramento, CA 95825

RE: Comments on Draft Environmental Assessment (EA) and Finding of No Significant Impact (FONSI) for the CVP M&I Water Shortage Policy (Shortage Policy)

Dear Mr. Lewis:

The Del Puerto Water District (District) submits the following comments on the Draft Environmental Assessment for the Central Valley Project M&I Water Shortage Policy dated March of 2005. 28

The Del Puerto Water District is a CVP contractor located south of the Delta. Its contract providing for up to 140,210 acre-feet of CVP water is used almost exclusively to serve irrigation purposes within the District. CVP water is the sole source of supply for the vast majority of District users. Fully one half of the District's 40,000 irrigated acres are planted to permanent crops. The reliability of the District's water supplies to irrigate these plantings is crucial to our survival and that of the agricultural communities in which we live and who depend upon these supplies for their economic well-being. As such, the District has a vital if not crucial interest in the proposed policy and the subject documents.

Comments

The EA is a seriously flawed document that in no way supports a finding of no significant impact. We strongly urge the Bureau of Reclamation to withdraw the proposed Draft EA and the proposed FONSI, to reconsider the purpose and need for such a policy in view of Reclamation law and to prepare a legally adequate analysis of all of the alternatives.

Previous draft policies, going back to the 1993 draft interim policy up to and including that of September 11, 2001, have raised serious legal issues and policy concerns which the District has detailed in our letters dated November 30, 2000, January 9, 2001 and November 26, 2001 (attached). Not only does it appear that the issues and concerns expressed in our previous comment letters have been totally ignored, they are, in fact, exacerbated by new language and concepts contained in the now proposed alternative.

The newly proposed policy no longer limits its applicability to the quantities of CVP water identified for M&I uses as of September 30, 1994 (as did the September 2001 proposal), but it increases the already significant impact on agricultural water supplies of the prior proposal by applying the policy to the quantities identified under Water Needs Assessments predicated on the amount of water that M&I Contractors estimate could be beneficially used by the year 2025. (Page 1-3) According to the subject documents, these assessments show many M&I contractors equaling or exceeding their full Contract Totals by the year 2025 (Page 1-3) thereby magnifying the policy's adverse effect on agricultural water supplies through the application of ever-greater shortages on an ever-smaller base of irrigation supplies.

The proposed policy fundamentally and, by it own repeated acknowledgement, reallocates agricultural water service supplies to urban contractors and offers no mitigation for the resulting loss of agricultural water supplies. (ES-3, 3-2) 28

We reiterate our previous claim that adoption of the proposed policy cannot be justified or enforced in light of Section 9(c) of the 1939 Act (43 USC §485(c)) which provides in part:

> "No contract relating to municipal water supply or miscellaneous purposes or to electric power or power privileges shall be made unless, in the judgment of the Secretary, it will not impair the efficiency of the project for irrigation purposes."

While the District has been willing to acknowledge that some priority should be given for M&I purposes that are needed to protect public health and safety, and that fish and wildlife purposes might also be subject to "human health and safety" requirements as has been provided for by Section 3406(b)(2)(C) of the CVPIA, we would also point out that the reason that the OCAP 2004 described the allocation of CVP water supply for the 253 water service contracts and the Sacramento River Settlement Contracts in the following manner:

> "Those water service contracts had many varying water shortage provisions. In some contracts, M&I and agricultural use shared shortage equally. In most of the larger M&I contracts, agricultural water was shorted 25% of its contract entitlement before M&I water was shorted, and then both shared shortages equally." (Page 1-1, 2)

is because there are only a few water service contracts which reasonably could have been entered into with a Secretarial determination that such priorities would not impair the efficiency of the project for irrigation purposes.

We would also grant that "as the CVP system was being developed there were no shortage allocation because actual demands were less than the water supply each year." (Page 1-2) Unfortunately, as the subject document points out, "water allocations to contractors located south of the Delta have been most affected by changes in operations by legislative and regulatory changes." (Page 2-1) Today, the practical effect of granting any such M&I priority is to further reduce the quantity of water available for irrigation purposes to contractors located south of the Delta in many, if not most, years, as opposed to only occasionally during extreme drought conditions. The Draft EA seriously errors when it states that the alternatives will result in "changes for Irrigation CVP water service contractors" in only "9 of the 72 years" modeled. (Page 5-45) It will, in fact, have a significant impact in virtually every year, especially for south of the Delta irrigation contractors. The extent of the total reduction should be modeled and clearly identified in the analysis. 28

We continue to contend that new contracts and the policies referenced in them, in accord with Reclamation Law and historical contractual language and understanding, should provide an equal footing between irrigation and M&I uses except to the extent that water is needed to meet M&I public health and safety demands during extreme droughts or as can be provided without impact to irrigation supplies.

In this regard, the EA seriously errors in establishing a No Action Alternative baseline as that defined by the operational criteria in the OCAP 2004. (Page ES-3) To our knowledge, no previous draft policy establishing anything other than an equal sharing of shortages between M&I and irrigation water has been the subject of environmental review and the impacts to irrigation supplies of the current No Action Alternative have never been analyzed. The No Action Alternative as the environmental baseline used to measure the impacts of the policy is both legally inadequate and improperly defined. The subject analysis thoroughly masks and minimizes the effects of the proposed alternative, particularly for South of the Delta water contractors, by failing to measure its effects against the true, no-policy, no-M&I preference alternative.

Even without the appropriate baseline analysis, the adverse effects of such a policy on agricultural water supplies are significant. To mention that concepts to increase M&I CVP water service contract deliveries include: "storage of additional water during wet years" along side of reductions of deliveries to Irrigation CVP Water Service Contractors, and then, to immediately dismiss this concept as "not possible with existing facilities", not only begs the question but ignores and serves to dismiss out-of-hand a number of viable concepts. (Pages ES-3, 3-2)

Other alternatives available to M&I Contractors if they wish to achieve greater reliability than is otherwise available from the project are 1) including willing seller/willing buyer transfers provided for under CVPIA, 2) water reallocation programs, such as Santa Clara Valley Water District (SCVWD) has done with the San Luis Delta-Mendota Water Authority and certain of its members, and 3) the development and/or participation in water banking programs, such as SCVWD and other urban agencies have done with Semitropic Water Storage District.

To base a proposed FONSI on the following statement:

> "At the expected frequency of no or very little CVP irrigation water deliveries associated with this alternative, it is likely that farmers without affordable and accessible alternative water supplies will be subject to <u>significant financial burdens</u>. Farmers may fallow crops, resulting in lost farm revenue and related jobs. Farmers with permanent crops would be most vulnerable to <u>losing high valued investments</u>. Loss of agricultural employment would affect lower income population and minority

populations more than other populations in the state." (Page 5-45, emphasis added)

is not only unjustifiable, it is quite simply incomprehensible.

To adopt such a policy is tantamount to suggesting that one can farm without water. There is no justification or rationale for such taking the proposed policy position. If M&I contractors know that the reliability of existing and converted water supplies retains its original agricultural status, as it must to avoid these unacceptable and significant impacts, they are in a position to plan for and acquire the quantities they need to assure the desired level of reliability.

28

Reclamation has never similarly considered increasing contract supplies or reliability to agricultural contractors based on increased acreage planted to permanent crops or the number of farms or farm families served. The point here is that the proposed policy quite clearly favors urban growth and water supply demand at the direct and ever-increasing expense of irrigation water supplies.

The District remains seriously opposed to this and any other policy that would further impair the efficiency of the project for irrigation purposes.

In addition to these and the attached comments, the District wishes to incorporate by reference the comments provided you by and on behalf of Westlands Water District.

Your thoughtful consideration of these comments is appreciated.

Sincerely,

William D. Harrison

William D. Harrison
General Manager

Cc: Board of Directors
Ernest Conant, Esq.
Tom Birmingham, Westlands Water District

An Assessment of Models for Measuring the Economic Impact of Changes in Delta Water Supplies

David Sunding
Professor, UC Berkeley
Principal, The Brattle Group

Max Auffhammer
Associate Professor, UC Berkeley
Academic Advisor, The Brattle Group

October 24, 2012

This report assesses the extant models for measuring the economic impacts of changes in water supplies from California's Sacramento-San Joaquin Delta. For the urban sector, the principal models are the Least-Cost Planning Simulation Model (LCPSIM), and the more recent Supply-Demand Balance Simulation Model (SDBSIM). The latter model is currently being used to measure the economic benefits of the Bay-Delta Conservation Plan. The principal agricultural impact model is the Statewide Agricultural Production Model (SWAP). This model is the latest in several generations of programming models that measure the change in agricultural resource allocation resulting from changes in surface water supplies in California.

For both urban and agricultural models, the report describes the major features of the model framework, in particular the data and calibration methods used in constructing and applying the models. The report also critically assesses each model and lists areas for further investigation.

On balance, we find that the SDBSIM and SWAP models produce credible estimates of the economic impact of changes in Delta water deliveries. That said, there is room for improvement on many levels. The SWAP model is a structural programming model that relies on a large number of assumptions. It is non-econometric and does not produce standard errors that allow the analyst to assess the statistical significance of results. SWAP is not integrated with a groundwater model, and thus it does not account for changes in groundwater pumping caused by fluctuations in surface water deliveries. As a result, it may underestimate the long-term effects of reductions in Delta deliveries. Further, this report details a number of concerns related to calibration of the SWAP model that may have a large influence on its results.

I. IMPACT MODELS FOR THE URBAN SECTOR

This section describes two models for measuring the economic impact of changes in urban water supply reliability. The first model is the Least-Cost Planning Simulation Model (LCPSIM) developed by the California Department of Water Resources. Until recently, this model was the default framework for assessing urban water reliability, especially on the State Water Project. In the past two years, a new framework has been developed by The Brattle Group, working in conjunction with the Metropolitan Water District and the State Water Contractors. The new framework is the Supply-Demand Balance Simulation Model (SDBSIM). It possesses a number of distinct advantages over LCPSIM.

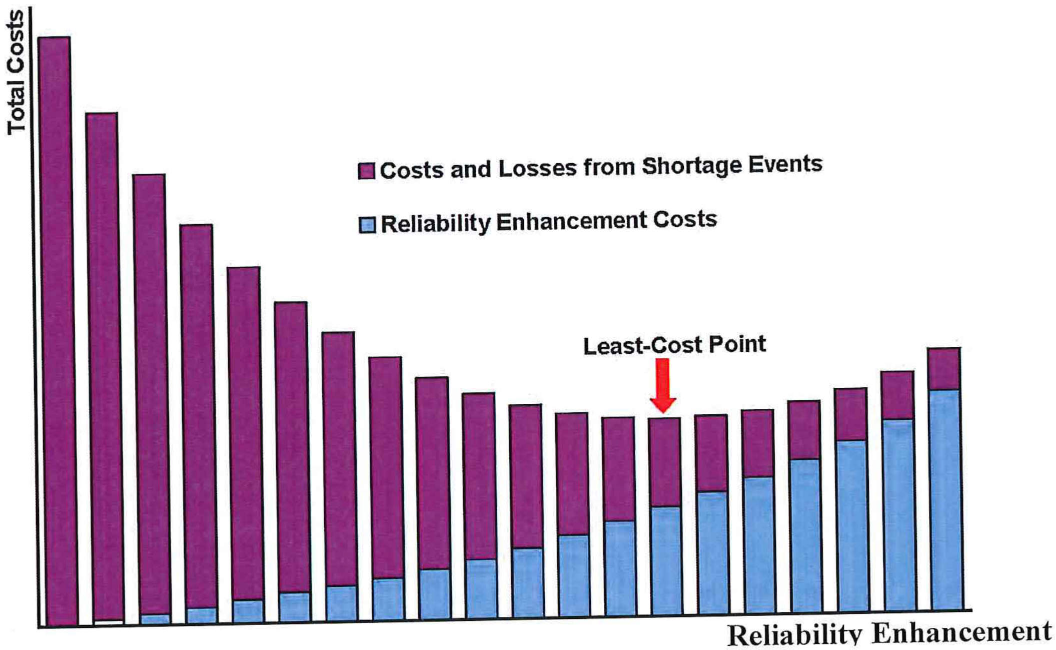
I.A. Least Cost Planning Simulation Model

LCPSIM is a yearly time-step simulation model that was developed and maintained by the California Department of Water Resources and CH2MHill to estimate the economic benefits and costs of improving urban water service reliability at the regional level. The model is similar to load-planning models used in the electricity industry, and simulates a dynamically optimal portfolio of water supplies. LCPSIM has been developed for two regions in California: the South Coast and the San Francisco Bay Area.

Figure 1 LCPSIM Model Regions

The primary objective of the LCPSIM model is to develop an economically efficient regional water management plan by minimizing the total cost of reliability management. Figure 2 illustrates LCPSIM's cost minimization objective. The total cost is the sum of two categories: the cost of reliability enhancement and the cost of unreliable service associated with water shortage events. The cost of reliability enhancement is comprised of three elements: the cost of conservation and recycling, the cost of system operations, and the cost of buying and transferring water. The cost of unreliability is the welfare cost to consumers of a water shortage.[1] This is the

Figure 2 The Effect of Increasing Reliability on Total Cost[2]



value to society of foregone water use that would have otherwise been consumed if not for a shortage. LCPSIM optimizes the degree of reliability over the entire simulation period by determining the portfolio of reliability-enhancing investments that minimizes the cost of these investments plus the cost of shortage in the event that demand cannot be satisfied.

A priority-based objective, mass balance-constrained linear programming solution is used to balance water use with water supply. The model relies on specifically identified demand levels (e.g. year 2020 level) and assesses the water supply portfolio separately given the supply conditions of each hydrologic year between 1922 and 2003.[3] The model keeps track of deliveries to users, deliveries to and from carryover storage, water transfers, and shortage event-related conservation and water allocation programs. Shortages are assumed to be the difference between total demand and the available supply. The LCPSIM allocates the shortages across the

1 To access these parameters in LCPSIM: (1) cost of reliability enhancement options: from the RUN/VIEW menu, select VIEW SUMMARY RESULTS and then FULL DISPLAY; (2) system operation costs: from the RUN/VIEW menu, select VIEW LC INCREMENT RESULTS; (3) cost of buying and transferring water: from the RUN/VIEW menu, select VIEW OPERATION TRACE (Excel only) and open the LC Result Report sheet; and (4) cost of a water shortage: from the RUN/VIEW menu, select VIEW OPERATION TRACE (Excel only) and open the LC Result Report sheet.

2 LCPSIM manual- http://www.water.ca.gov/economics/downloads/Models/LCPSIM_Draft_Doc.pdf.

3 LCPSIM manual- http://www.water.ca.gov/economics/downloads/Models/LCPSIM_Draft_Doc.pdf.

different customer classes according to a overall economic cost minimizing rule such that the most shortage is allocated to the sector with the least economic value for water. The highest percentage rate of shortages are allocated to customers who demand water for large landscaping purposes. The next highest shortage is allocated to residential use, followed by commercial, and then industrial. This is because there are less economic impacts from a shortage to the residential sector than there would be to businesses, where a shortage may result in serious adverse economic impacts such as layoffs. Once the shortages are apportioned, the economic losses for all sectors within a region are calculated using a single residential user loss function.

The economic losses are then evaluated against the cost of potential alternative supplies, or reliability enhancement, that could be used to mitigate the water shortages. In the short-run, the model assumes that water transfers and currently existing storage, conservation and recycling programs are available to deal with periodic shortage. In the long-run, the model allows for water supply reliability to be achieved through demand reduction and through supply augmentation from investments including recycling, groundwater storage and recovery, and water transfers. These investments are assumed to reduce frequency, magnitude, and duration of shortage events.[4] They all require capital expenditures to complete, and will take a number of years to implement. The unit costs of these investments vary considerably, and are described in detail in the LCPSIM manual.[5]

The LCPSIM finds the optimal trade off between the cost of alternative supplies and the economic impacts of a water shortage. The alternative supplies are assumed to be employed if the cost of implementation is less than that of the economic impacts from the shortage that results from not having access to these alternative supplies. Alternative supplies are assumed to be realized up until the point that the cost of implementation exceeds the corresponding economic loss given a water shortage. The LCPSIM runs through this process for each of the 82 hydrologic conditions in order to create an expected optimal balance of reliability enhancement and economic loss impacts.

I.B. Supply – Demand Balance Simulation Model

SDBSIM is a probabilistic water portfolio simulation model that apportions and values shortages at the level of the retail agency. The SDBSIM evaluates water shortages in several sectors[6] given demand levels over time and water supply availability for each of the SWP urban agencies. The model runs 83 different trials for each agency by rotating through a historical hydrologic sequence. The shortage and demand outputs are then used to calculate the value of losses to consumers associated with a shortage given a constant elasticity of demand and avoided marginal cost of service.

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4 http://www.waterplan.water.ca.gov/docs/meeting_materials/ac/01.20.05/LCPSIM-description.pdf.

5 LCPSIM manual- http://www.water.ca.gov/economics/downloads/Models/LCPSIM_Draft_Doc.pdf.

6 All sectors are comprised of single-family residential, multi-family residential, CII (commercial, industrial and institutional), and agriculture.

Forecasting Agency-Level Supply, Demand and Shortages

The water supplies considered in the SDBSIM model consist of the local and imported supplies. Local supplies are comprised of groundwater, local surface water, recycled water, and desalinated water. Imported supplies for Southern California come from the Los Angeles Aqueduct, Colorado River supplies and State Water Project (SWP). Imported supplies for Northern California come from the Hetch Hetchy system, Central Valley Project, and the State Water Project. Individual agencies may have specific import sources; for example, Zone 7 receives imported water from Byron Bethany Irrigation District and the San Diego County Water Authority receives water from Imperial Irrigation District. Estimates of future SWP deliveries from the Delta are forecasted using DWR's CALSIM II model, a generalized water resource simulation that generates hydrological time series forecasts of large, complex river basins.

The projected water demands used in SDBSIM are forecasted using disaggregated econometric models, which capture the impacts of long-term socioeconomic trends on retail demands at the water agency level.[7] These models incorporate projections of demographic and economic covariates that are either forecasted by the agencies themselves or provided by the regional planning agencies Southern California Association of Governments (SCAG) and San Diego Association of Governments (SANDAG).[8] Projections of the covariates are then used to forecast water demand, after which the demand forecasts are adjusted according to expected implementation of conservation programs by individual water agencies. The models forecast demand in five-year intervals for each of the following sectors: single family residential, multifamily residential, commercial/industrial/institutional (CII), and unmetered users. Linear interpolations are generated for the interim years; this results in annual forecasts by sector for each of the SWP urban agencies.

SDBSIM uses an indexed sequential Monte-Carlo simulation method to measure the supply-demand balance outcomes for forecasted years given the pattern of historical hydrologic conditions between years 1922 and 2004. It adjusts the demand and supplies of a forecasted year given a past year of hydrologic conditions, then takes the next sequential forecasted year and adjusts the demand and supplies for that year given the next sequential historical hydrologic year conditions, and so on. For example, SDBSIM would adjust the forecasted demand and supplies for the year 2012 given the hydrologic conditions of the year 1922, and adjust the forecasted demand and supplies of year 2013 given the hydrologic conditions of year 1923, and so on. By preserving the series of climate patterns, or "hydrologic trace", the model is able to capture the operation of storage resources that are drawn upon and refilled over the forecast horizon given a probabilistic sequence of hydrologic conditions. The model then starts over and shifts the hydrologic year by one for each forecasted year. That is, it will adjust the 2012 forecast given the 1923 historical hydrologic conditions, and accordingly will adjust 2013 given 1924 conditions, and so forth. This shifting process is done 83 times such that each forecasted year is evaluated under each hydrologic condition, while still preserving the order of the hydrologic

7 The demand for the MWD agencies are forecasted using the MWD – MAIN model. Demand for each of the remaining SWP agencies are forecasted in-house by the agencies.

8 The Metropolitan Water District of Southern California, *Integrated Water Resources Plan: Technical Appendix*, 2010 Update. The underlying figures of the 2010 MWD-MAIN models, with the exception of water rates, rely on the SCAG's 2007 Regional Transportation Plan (TRP-07) and SANDAG's Series 11 Forecast.

conditions, resulting in 83 different reliability outcomes for each forecast year. The model considers the hydrologic conditions of 2004 to be followed by those of year 1922. Thus, when forecasting using a trace that starts with a late hydrologic year, it simply loops back around to the beginning of the climate cycle.

For each year, the SDBSIM model compares the forecasted demand to the sum of available projected local supplies and imported supplies less conservation savings in order to assess the disparity between the amount of water desired and the amount that can be provided. If a shortage exists, the SDBSIM model may release additional supplies from storage or transfer programs until supply and demand are balanced or until these supplies are exhausted. A net shortage for the year results if the gap between supplies and demands is too large to be balanced by storage and transfer programs. If a surplus exists, the SDBSIM model may allocate surplus water to various storage accounts until all storage capacity is used; any remaining surplus supplies are considered unused or "wasted" and are not available for use in subsequent years of the forecast.

There exists considerable uncertainty regarding future hydrological conditions. For example, it is unknown if a major drought like the one experienced in 1924 or 1977 will occur in 2025 or 2050. The timing of such extreme weather patterns may have a significant effect on the value of infrastructure that secures water supply reliability. The advantage of SDBSIM's indexed sequential Monte-Carlo simulation method is that it can account for supply uncertainty by considering 83 different sets of forecasted hydrological time series data and the corresponding supply availability. As suggested earlier, each time series of supply data represents a possible draw from historical hydrological conditions. For example, one SDBSIM simulation uses as input the annual hydrologic conditions from 1922-1960, another SDBSIM simulation uses as input from 1923-1961. In subsequent simulations each year from 1924 to 2004 is considered as the starting year to initialize supply conditions in 2012.[9] In this way, water supply availability between 2012-2050 is computed under a wide range of potential hydrological conditions. Thus, the model produces probabilistic water supply availability given a distribution of potential hydrologic conditions, while also having the ability to predict supply under certain hydrologic conditions.

Valuing Urban Water Supply Reliability

The loss framework utilized in the SDBSIM considers the economic impacts related to water supply interruptions, and emphasizes how water shortages will likely affect ratepayers. The welfare losses during a shortage are determined by the size of the shortage, the forecasted demand, the price elasticity of demand, the utility's pricing structure, and the source of supply unreliability that dictates the avoided marginal maintenance and delivery costs during a shortage.

An important feature of the analysis is that that urban water utilities typically recover capital costs through volumetric prices such that rates are set above marginal cost. The SDBSIM loss

9 The ordering of years for historical hydrological data is preserved because there is dependence in conditions across years. Hydrological data does not exist beyond 2004. When a simulation requires a time series of hydrologic input data beyond 2004, the time series reverts back to 1922 as the year of hydrological conditions following 2004.

framework recognizes that capital costs are sunk costs, and thus only avoided marginal costs are considered in the loss calculation. Further, it is important to remember that water utilities are public entities so that the impacts of shortages on utilities translate into impacts on ratepayers. In other words, all the welfare loss resulting from a shortage falls on the consumer.

The economic loss calculation in SDBSIM incorporates prevailing water rates in each utility. Water rates combined with observed consumption levels at the prevailing rates provide information about the value of water to households at a single point on the demand curve. Because SDBSIM addresses the economic losses resulting from reducing water consumption below baseline levels, it is necessary to characterize the demand curve at low levels of consumption. The SDBSIM economic loss calculation therefore requires making inferences on consumer willingness to pay for water units at successively higher levels of water rationing, as households are forced to dispense with increasingly higher valued uses of water. To characterize these values, SDBSIM relies on regional water consumption data to estimate demand schedules across households in geographic regions served by individual water purveyors using an econometric model that is capable of explaining water consumption as a function of variables such as rates, income, urban density, and climatic conditions. By comparing agencies over time, and from one place to another, the econometric model traces out more complete demand information than could be gained by looking at a single agency at a single moment in time. As described in subsequent subsections, the results of the statistical analysis are robust and significant at conventional levels used for hypothesis testing.

Theory

The theoretical underpinnings of the SDBSIM loss framework are detailed in the paper by Brozovic, Sunding and Zilberman (2007), who derive an equation for measuring consumer willingness to pay to avoid water service disruptions.[10] Specifically, residential water demand elasticities are estimated for each of n retail utilities under a specification of constant elasticity of demand given by:

$$P_i = A_i Q_i^{\frac{1}{\varepsilon_i}}, \qquad i = 1,2,3,\ldots,n, \tag{1}$$

where ε_i is the elasticity of water demand in utility i and A_i is a parameter that scales the magnitude of demand to the price in each agency.

Let P_i^* and Q_i^* respectively denote the retail water price and quantity of water consumed by residential households in utility i under baseline conditions (prior to water rationing). For a given water shortage with an available level of water given by $Q_i(r_i) < Q_i^*$, it is helpful to define the relationship between these quantities in terms of the percentage of water that is rationed in agency i, r_i, as:

$$Q_i(r_i) = (1 - r_i)Q_i^*. \tag{2}$$

[10] Brozovic, N., D. Sunding and D. Zilberman, Estimating Business and Residential Water Supply Interruption Losses from Catastrophic Events, Water Resources Research 43, W08423, 2007 doi:10.1029/2005WR004782.

Making use of equations (1) and (2), consumer willingness to pay to avoid a supply disruption of magnitude $r_i \cdot Q_i^*$ in agency i can be calculated as follows:

$$W_i(r_i) = \int_{Q_i(r_i)}^{Q_i^*} P_i(Q) dQ_i = \int_{Q_i(r_i)}^{Q_i^*} A_i Q_i^{\frac{1}{\varepsilon_i}} dQ_i = \frac{\varepsilon_i}{1+\varepsilon_i} P_i^* Q_i^* [1 - (1 - r_i)^{\frac{1+\varepsilon_i}{\varepsilon_i}}] \tag{3}$$

Consumer willingness to pay to avoid a supply disruption in equation (3) can be calculated for each region by constructing an aggregate demand curve to represent the residential water segment (see equation (1)). For regions in which residential customers pay volumetric water rates, P_i^* is the volumetric rate in region i, Q_i^* is the total quantity of water delivered to residences at that price in region i prior to a supply disruption, and ε_i is the elasticity of water demand for region i, which can be estimated from observations of rates and quantities in the region over time along with covariates such as income and weather conditions.

Consumer willingness to pay to avoid a supply disruption in equation (3) depends on the prevailing retail price charged to consumers in each region under baseline supply conditions, P_i^*. Intuitively, the reason for this is that the value of water conservation activities to households in regions with higher water rates is larger than the value of conservation in regions with lower water rates, thus consumers facing higher water rates under baseline supply conditions have greater motivation to engage in conservation activities prior to rationing relative to consumers facing lower baseline water rates. Water conservation is more forthcoming at lower water rates than at higher water rates, and consumer willingness to pay to avoid a given magnitude disruption in water supply is accordingly larger in regions with higher baseline water rates.

The measure of welfare indicated in equation (3) does not account for the avoided costs of service delivery during a shortage. Economic losses that result from water shortage in a given market are mitigated to the extent that delivering a smaller quantity of water reduces the system-wide cost of water service. Because the overall cost of service includes large fixed costs that do not vary with the amount of water delivered through the system (e.g., infrastructure costs, repair and maintenance, administrative expenses, etc.), the avoided cost that results from water shortage is relatively small in relation to total cost. The reduction in the cost of water service that occurs in response to a one-unit reduction in water deliveries is the avoided *marginal* cost of service. Examples of components of avoided marginal cost include the energy and chemical costs of treating water units that are no longer delivered, the reduction in conveyance costs, and the decrease in energy and chemical costs of wastewater treatment that arise from a smaller level of water delivery.

The SDBSIM loss framework assumes that the marginal cost of service delivery is a relatively constant and that it is common across retailers; the delivery cost per unit of water is assumed to be c.[11] This assumption is reasonable—given the lack of data one cannot reject the hypothesis that the cost of service delivery are identical. Once accounting for the avoided cost of service delivery the measure of losses for consumers in retailer i of year t becomes

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[11] Avoided marginal cost of service is assumed to be $250 per acre-foot.

$$L_i(r_i) = \frac{\varepsilon_i}{1+\varepsilon_i}\hat{P}_i^* Q_i^* \left[1 - (1 - r_i)^{\frac{1+\varepsilon_i}{\varepsilon_i}}\right] - r_i \cdot Q_i^* \cdot c \quad (4)$$

This framework is easily applied to situations in which shortages may occur in multiple years within a retailer, and across multiple retailers. The framework is also extended in SDBSIM to non-residential sectors including commercial & industrial, agricultural and other uses.

Econometric Model of Urban Water Demand

The econometric model of water demand embedded in SDBSIM is based on a data set covering 119 California water retailers from 1994 to 2011. Although not every retailer is represented in every year, there are over 1,200 price-consumption observation points used to estimate the price elasticity of demand. Data is acquired from direct contact with retailers; price and consumption data are augmented with information obtained from BAWSCA annual reports; consumption data is augmented with data received from the California Department of Water Resources.

The SDBSIM framework links retailer-level price and consumption with demographic variables such as income, household size and lot size (a measure of need for outdoor water use) as well as annual measures of temperature and rainfall. SDBSIM de-means retailer-level consumption to account for shocks common to all retailers within a given year. This modification of the underlying data allows for a comparison of changes in consumption across years due to price changes without confounding changes in statewide hydrological conditions; otherwise, it would be impossible to compare consumption changes in a wet year to consumption changes in a dry year.

After accounting for changes in consumption due to demographic, weather and year-to-year fluctuations in demand, the econometric model of SDBSIM examines the within retailer relationship between any unaccounted for consumption changes and changes in price. In this way it considers a time series of price and consumption data for each retailer to form an overall estimate of consumer willingness to pay to avoid water shortages. Due to the large sample size and consistent relationship between consumption and price, it is possible to perform statistical tests of the price elasticity of demand.

In the literature on residential electricity demand, evidence from consumer electricity consumption in California shows that higher income households have, on average, a lower price elasticity of demand.[12] The SDBSIM econometric model is consistent with similar results in the residential water sector—lower income areas are more responsive to changes in price than higher income areas. As a consequence, higher income areas are more willing to shoulder the burden of avoiding a shortage than relatively lower income areas. The relationship identified by the model between the price elasticity of demand and median income in a service area is statistically significant, which allows the researcher to confidently estimate retailer specific measures of willingness to pay to avoid residential water shortages. As discussed above, accounting for such

12 Reiss, Peter and Matthew White. 2005. "Household Electricity Demand, Revisited." Review of Economic Studies, 72, p. 853-883.

heterogeneity across retailers is necessary to accurately characterize welfare losses during a shortage. Assuming that all areas value shortage avoidance identically may result in a severe underestimation of welfare losses during a shortage. SDBSIM produces accurate estimates of aggregate welfare losses that can be disaggregated to the agency or retailer level.

Price – Consumption Data Set

The data set used to estimate the SDBSIM econometric model is based on single-family residential Fiscal Year (FY) consumption and prices in 119 California water retailers. The dataset includes 93 retailers in MWDSC service areas and 27 retailers in Northern California (26 agencies belonging to the Bay Area Water Supply and Conservation Association and San Francisco Retail managed by the San Francisco Public Utilities Commission). For the retailers located in the MWDSC service area and San Francisco Retail, historical consumption and rate data from FY 1995-96 through FY 2010-11 were collected directly from retailers with the exception of retailers belonging to MWDOC[13] and SDCWA, for which data was acquired from annual surveys conducted by the wholesale member agencies. For BAWSCA agencies, water consumption and water rates were taken from the BAWSCA Annual Surveys over the period FY 1995-96 through FY 2010-11. The Public Water System Statistics, a survey conducted annually by the Department of Water Resources, is used for retail-level consumption in cases when retailers were not able to provide this data.

SDBSIM uses the sales and accounts data to construct a measure of average monthly household consumption. Average annual single-family household consumption levels for each water agency are calculated by dividing the total single-family residential consumption level for the fiscal year by the number of single-family residential accounts for the given fiscal year. A monthly average consumption level is created by dividing the yearly average by twelve. The construction of the price variable used in SDBSIM requires some additional explanation. In addition to price variation across retailers and time, there is variation in the types of price schedules consumer face. In particular, California retailers use both uniform rate pricing and increasing block pricing. In the former scheme, there is just one uniform rate applied to all water consumed. In the latter, prices depend on how much water has already been consumed in a given month. For example, a retailer using increasing block tiered pricing may charge $1/ccf for the first five ccf in a month, $1.25/ccf for the sixth through twentieth ccf, and $3/ccf for all subsequent units consumed within a month.

Consistent with the conceptual discussion above, SDBSIM uses an equilibrium price of water equal to the price charged ($/ccf) to a residential customer on the median tier in a given year. If the volumetric price ($/ccf) is uniform across all units consumed, then price is set equal to the uniform rate. If there is an increasing block tier structure, then the median rate of all the tiers is assigned as the price. The equilibrium quantity consumed is taken as the monthly average consumption level.

Our price and consumption data set is linked to retailer-specific measures of median income. Retailer-specific measures of median income were constructed based on the 2000 Census using

13 "Water Systems Operations and Financial Information". April 2011. Municipal Water District of Orange County. Accessible: www.mwdoc.com