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Charles Borda

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Economic Impacts from Salinity in the Lower Colorado River Basin

by

Charles Borda

U.S. Department of the Interior
Bureau of Reclamation
Technical Service Center
Environmental Resources Services
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Denver, Colorado

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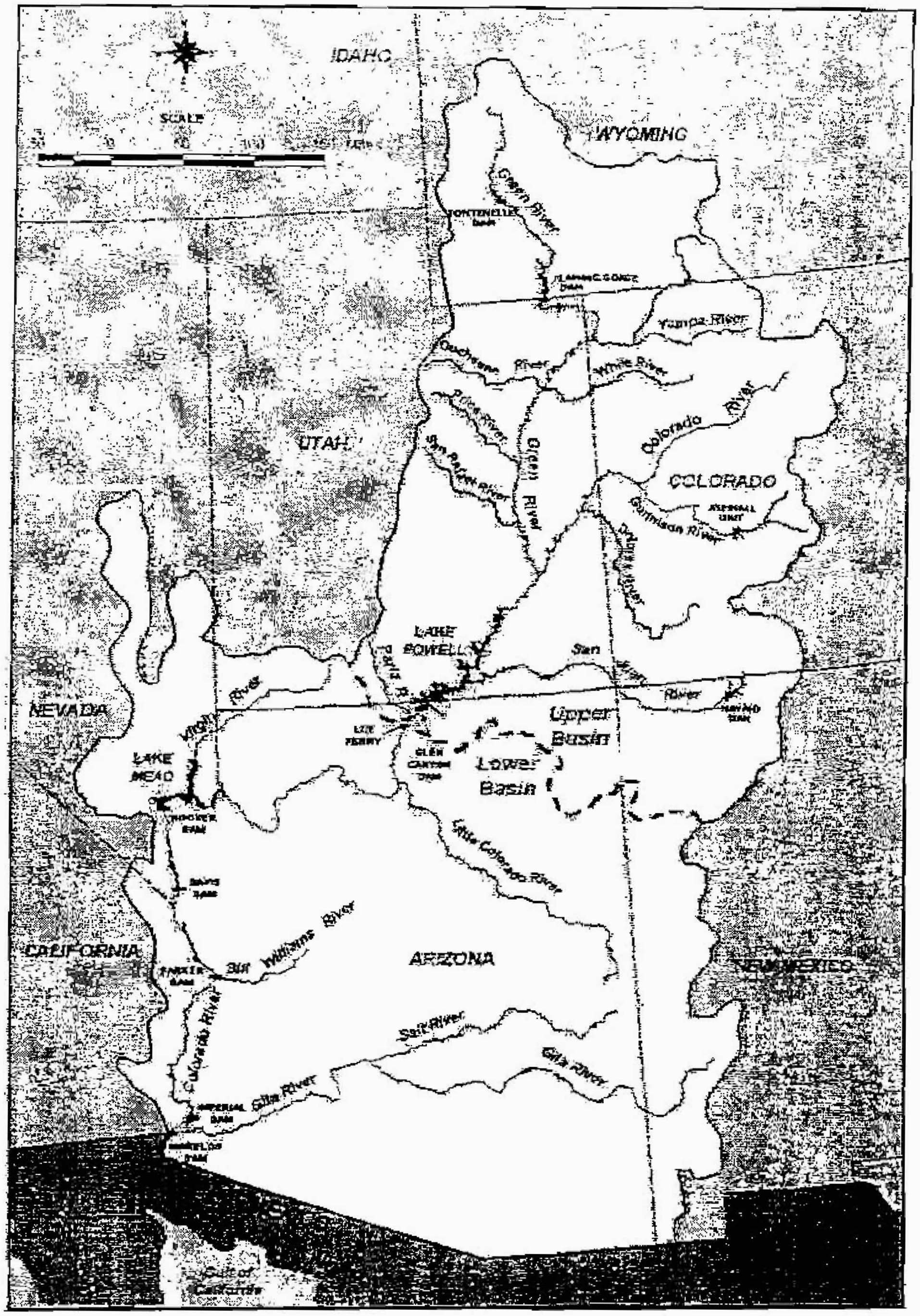

Figure 1 – Map of the Colorado River Basin.

Introduction

This guidebook presents information on the development of methodologies to estimate the economic impacts of salinity in the Lower Colorado River Basin. The first section presents the historical development of methods used to estimate the economic damages from research studies conducted during the 1970's, 1980's, and 1990's.

The second section will describe how the current spreadsheet salinity damage model works and the data requirements necessary for estimating damages or avoided costs.

The third section will present most current damage estimates based on the latest salinity levels in the Lower Colorado River Basin

Colorado River Basin Salinity

The Colorado River Basin covers 244,000 square miles and takes in portions of seven western states that have some of the driest climatic conditions in the United States (See Figure 1). The Colorado River provides water to irrigate nearly 4.0 million acres and supports over 27,000,000 municipal and industrial (M&I) water users. The river also provides water for about 2.3 million people and 500,000 acres in Mexico where it drains into the Gulf of California.[1] The average salinity in the Colorado River has fluctuated over the last 60 years, from as low as 600 TDS[2] to as high as 900 TDS. Two conditions occur which cause the salinity levels to increase in the river system. The first condition is what is called salt loading, where natural salts and return flow from irrigation and M&I water use drain into the Colorado River. The other condition is where the river supply (flow) is reduced by additional human development (river depletions) or drought conditions that cause increased concentrations of the salts due to a lower volume of water in the river system. Research has indicated that without some reduction in the salt loading of the river system, salinity levels will increase as future human development occurs in the lower river basin.

Two actions by Congress in the 1970's have resulted in the need to reduce the salinity levels in the Colorado River Basin. In 1972, Congress passed amendments to Clean Water Act, which required the states to adopt with EPA approval basin wide salinity standards. The second congressional action was passage of the Colorado River Basin Salinity Control Act in 1974. This Act was in response to treaty obligations with Mexico, which required a given Colorado River supply to meet water quality requirements agreed to in the treaty. Under this Act (Title I), a desalinization plant would be built to treat irrigation drainage water from the Welton-Mohawk Irrigation District which lies along the U.S. - Mexico border. Also, under this act salinity control projects were approved for funding to try and reduce the salt loading in the upper portion of the Colorado River Basin (Title II). It was recognized by Congress and the participating western states (WY, CO, UT, NM, NV, AZ, CA) that some of salt loading into the Colorado River was occurring naturally on federally managed lands. Because of this condition, Bureau of Reclamation (Reclamation), Natural Resource Conservation Service (USDA), and the Bureau of Land Management (USDI) are involved in projects to reduce salinity in the Colorado River Basin.

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[1] U.S. Bureau of Reclamation, Quality of Water Colorado River Basin, Progress Report 21, January 2003, page 1.
[2] TDS refers to total dissolved solids which are measured by milligrams per liter of water

2. Development of Salinity Damage Methodologies

In the 1970's and 1980's, as salinity control projects were being proposed and studied, there was a need to evaluate the economic damages from high salinity levels in the Colorado River Basin. It was recognized that high salinity levels can adversely affect crop yields, household appliances and industrial production. At that time, there had been little economic research into what the dollar value of these salinity damages were.

Typically, agricultural economic damages are estimated by taking the difference in gross crop values due to changes in crop yield from salinity. For household appliances, estimates on the changes in the useful life of water appliances such as water heaters, dish washers etc at different salinity levels are determined and are used to calculate the average cost of an appliance based on the useful life. A similar approach is taken with industrial water and public water utility production process. The useful life of water using equipment is determined and the relationship of salinity to this useful life is determined. The average cost based on the useful life of the equipment is compared at different salinity levels to estimate the dollar damages from salinity.

In 1978, a report titled, "Salinity Management Options for the Colorado River" by Jay C. Anderson and Alan P. Kleinman presented a series of research papers on 1) economic damages caused at various salinity levels to agricultural and municipal and industrial water users and 2) economic costs of salinity control measures by upstream water uses. From these studies, statistical models were developed based on salinity levels and the relationships between salinity and agricultural and M&I water usage. In the summary of the report, it was estimated that salt concentrations (mg/l) from 900 TDS to 1400 TDS range at Imperial Dam, AZ, resulted in agricultural damages of $33,100 per mg/l annually (1978 dollars). For M&I, it was estimated for the Los Angeles area alone, the range in damages was $880 million to $1.44 billion (1978 dollars). Further, it was estimated that a 10-mg/l reduction in salinity would result in a cost savings of about $1.12 million per year or $112,000 per mg/l to M&I water users. This report presented methodologies for estimating salinity economic damages and the ability to determine the benefits (avoided costs) of salinity reduction. Future studies would use similar methodologies to estimate salinity damages and the benefits to salinity reduction.

A study conducted by Robert Young and K. L. Leathers included in the report estimated the costs of salinity reduction in the Grand Valley. A comparison was made between structural control measures such as canal lining to nonstructural measures such as modification of on farm irrigation and crop production practices. From this study, it was apparent the costs of salt reduction for non structural measures ($1.40 – $2.54 per ton of salt removed) were far less than the structural measures ($14 - $30 per ton of salt removed). The authors did acknowledge there were certain limitations to the study due limitations on hydrologic and soil data for the area and the potential for irrigation efficiency on crop yields. Still this study did bring into the debate methods to estimate non structural salinity costs related to agricultural damages to high salinity.

Another report, "Colorado River Salinity, Economic Impacts on Agricultural, Municipal, and Industrial Users December, 1980", by Alan P. Kleinman and F. Bruce Brown expanded on the work from the earlier report and summarized the benefits from salinity reduction for agriculture and M&I water use in the lower Colorado River Basin. The authors estimated a range of economic damages at different salinity levels (800 TDS to 1,400 TDS). The range of annual damages was approximately from $244,300 per mg/l to $326,100 per mg/l in 1976 dollars. Converted to annual damages per ton of salt (generally, 1 mg/l equals 10,000 tons of salt), the range is $24.43 to $32.61 per ton. This report outlined the methodology to be used to evaluate the economic benefits from salinity control projects being proposed under the Colorado River Basin Salinity Control Program.

The next study, "Estimating Economic Impacts of Salinity of the Colorado River", February 1988 by Loretta Lohman, J.Gordon Milliken, William Dorn, and Kyle Tuccy drew from the previous work by Kleinman and others. The purpose of the study was to update the data used previously in the above-mentioned studies, to account for other salinity damages, and develop a computer program that would estimate present and future salinity damages in the lower Colorado River Basin.

In the final report by Lohman, et.al, the salinity-crop yield functions for primary salt sensitive crops were updated as well as the associated crop prices. Crop acreages were updated for agricultural areas (Central Arizona, Yuma, AZ, LaPaz County AZ, Imperial County, CA and parts of Riverside County, CA) in the lower basin that receive Colorado River water for irrigation. M&I damages were estimated for metropolitan areas that receive Colorado River water (Phoenix, Tucson, Las Vegas, and Southern California areas served by Metropolitan Water District of Southern California-MWD). For household appliances, salinity-useful life functions (assuming a new appliance) and prices were updated. Additional salinity damage functions were developed for household water treatment systems, soaps and detergents, and automotive radiators. For commercial damage estimates, the calculation was based on an extrapolation factor of the area population and household damage estimates.

Salinity damage functions based on the relationship to useful life of water facilities were developed for water and wastewater utilities in the metropolitan areas that receive Colorado River water in the lower basin. Salinity damage functions were also developed for industrial water use such as water processing, boiler systems, cooling towers, etc.

Another area that was considered in estimating salinity damages was related to governmental regulatory policies that are imposed on regional water utilities to meet certain water quality standards. The calculations were based on costs incurred by Southern California water utilities.

A computer model (IBM PC format) was developed to calculate salinity damages using a 500 TDS baseline (EPA drinking water quality standard) given the input data for agricultural (crop yields and prices), metropolitan populations, household appliance prices and salinity levels.

In the report, it was estimated that the total annual damages related to salinity based on a ten-year average (1977–1985) salinity level of 767 TDS (compared to the 500 TDS baseline) was $310.8 million in 1986 dollars. This annual damage averages out to be about $1.2 million per mg/l or $116 per ton of salt. The increase in salinity damages as compared to previous studies is due to a number of factors. These factors include additional salinity damage functions that were not considered in the past (i.e. automotive radiators), additional salt sensitive crops and increased irrigation acreages, metropolitan population increases, increased cost of household appliances over time, and the inclusion of water utility costs and policy related costs to meeting regional water quality standards.

In 1993, a research report conducted by Guy Ragan, Carol Makela, and Robert Young, investigated methods for estimating the economic damages to residential water use in the Arkansas River basin in southeastern Colorado. The purpose of this study was to develop a more accurate methodology to estimate the economic damages from salinity. This research study conducted extensive surveys (approximately 3,000 questionnaires) of households, appliance repair and plumbing businesses as it relates to water using household appliances and replacement at different salinity levels. From the survey responses, a more extensive collection of data than previous studies was collected. This data was used to develop statistical models that could estimate the appliance life as a function of salinity.

The important difference in this study is that the analysis accounts for existing appliances in the household where as past studies based the average life on new appliance in the calculation of economic salinity damages. It was found from the survey data that by including existing household appliance data in the statistical analysis, the average product life of the appliance was longer resulting in lower average annual replacement costs at varying salinity levels. Another difference is that the annual average cost per household is discounted to reflect the present value of the average annual cost of the appliance. While the methodology developed from this study appears to be better, the reliance of collecting survey data can be costly particularly when applying it to large urban areas in the southwest such as Los Angeles, Phoenix, or Las Vegas.

Recent Research

From 1988 to 1997, the computer program developed from the Lohman, et.al. study was used to estimate the benefits of salinity reduction under the Colorado River Basin Salinity Control Program. The dollar benefits were indexed (Consumer Price Index) to the year that salinity levels were measured on the lower Colorado River basin. Using this updated version of the computer program resulted in salinity control benefits as high as $300 per ton of salt removed from the basin. The original computer program was difficult to run given that the software was developed in 1986 and there was a growing concern that the data in the computer model was believed to be out of date. An effort was made by Reclamation to convert the 1988 computer model into a spreadsheet format that was more user - friendly and to update the data. Research was conducted to revise the salinity-crop yield functions and to include additional crop-yield functions in the spreadsheet model. Also, irrigated acres and crop prices were updated. During this time period, MWD was initiating a regional urban water management plan that addressed water quality issues related to groundwater and recycled water in their service area. MWD needed an economic model to estimate the costs of salinity to their member water agencies and Reclamation collaborated with MWD to update and revise the M&I components of the spreadsheet model.

In updating the model, the research indicated that at high salinity levels, water using appliances or equipment was not impacted as much as in the past due to technological improvements. Household items such as waste water pipes (mostly plastic type piping today), toilet-flushing mechanisms, and clothes replacement were not affected by high salinity levels and were dropped from the spreadsheet model. Local research in the Los Angeles area on automotive radiators (a major source of M&I damages in the previous model) indicated significantly less damages to newer post-1985 vehicles). This is primarily due to improved cooling systems and the use of more plastic and aluminum parts. This item was also eliminated from the updated model.

In revising the spreadsheet model, MWD was able to obtain data for commercial water use in their service area. Most of the commercial water use was for sanitary, cooling, irrigation, kitchen, laundry, and other uses. Salinity cost functions for commercial water use were developed based on the relationship of salinity to water using commercial equipment. This was an improvement from the previous model that simply identified commercial salinity damages as a function of household damages.

Municipal water utility salinity damage functions were revised based on recent capital and O&M costs estimates. Research indicated that wastewater facilities were not impacted by increases in salinity levels due to the use of more corrosive resistant materials. The salinity damage function for wastewater facilities was eliminated from the spreadsheet model.

Again, MWD was able to obtain industrial water use data for their service area and developed salinity cost functions based on the relationship of salinity to water using equipment. This was an improvement from the previous model, which estimated the industrial damages based on average per capita capital and O&M expenditures as it related to salinity in the industrial sector for metropolitan areas in the study.

Salinity cost functions were developed to estimate the costs of meeting regional water quality standards (500 TDS – 1500 TDS) for groundwater recharge and recycled water programs. These sources of water in the MWD service area usually go through a desalinization process (mostly reverse osmosis) to reduce the amount of salinity in the water. The per acre-foot cost for treating the water to meet the regional water quality standards was used and MWD was able to identify the amount groundwater and recycled water that was treated.

Based on the revision and updating of the salinity damage model, the average benefit estimated from the model is $116 per ton salt removed in 1998 dollars in the Lower Basin. This value matches the original 1988 model (using the same baseline and area TDS levels), but with the elimination of some salinity damage categories. The real benefit (avoided cost) has fallen in the past ten years. Again, this reduction is primarily due to improving technologies as it relates to high salinity levels.

The application of the model can be used in desalinization studies to estimate the benefits of improving the water quality from an original supply (brackish water) or a new supply of water (seawater).

The data requirements to run the model are:

1. Definition of the area that will be using the water;
2. Population of the area;
3. For agricultural impacts, irrigated acreages of salt sensitive crops, crop yield, and prices for that area;
4. Estimates of commercial and industrial water use;
5. If recycling or groundwater is present, the water amounts and salinity levels;
6. Salinity levels of all water sources used in the area. With the data, the model can be run on a "with and without" project basis resulting in a total cost savings from reduced salinity by the program or on a per unit cost basis if desired.

The next section of this paper briefly explains the various spreadsheets that make up the latest version of the salinity damage model and displays the estimated damages based on projected year 2015 conditions.

COLORADO RIVER SALINITY DAMAGE MODEL

The Colorado River Salinity Damage Model consists of a number of EXCEL spreadsheets. The initial worksheet displays some overall input data and the summary dollar damages by economic sector and primary agricultural and metropolitan areas that receive Colorado River water. The remaining spreadsheets contain input data for calculating salinity damages and the actual calculation spreadsheet by economic sector. Below is a brief explanation of each spreadsheet within the model.

I. Summary salinity input/and Dollar Damage output sheet

The upper portion of this spreadsheet contains the water quality – salinity levels of the lower Colorado River that are measured at Hoover, Parker and Imperial dams. This data can come from actual sampling at these sites or projected values can be obtained from hydrologic models such as Riverware or Colorado River Simulation System (CRSS). Also, this portion of the spreadsheet contains input data for present valuing damages that may occur in the future. The present value data consists of the latest Reclamation planning interest rate, base dollar year, and the projected year the damages are to be calculated.

The remaining portion of this spreadsheet displays the salinity levels and total damages (based on a 500 TDS salinity baseline) for each primary agricultural and metropolitan area that receives Colorado River water. There are six economic sectors; agriculture, households, commercial, municipal water utilities, industrial and policy related (groundwater and recycled water requirements). The agricultural areas currently in the model are Central Arizona Project, AZ; La Paz County, AZ; Yuma County, AZ; Imperial County, CA, Riverside County (non MWD), CA, and MWD service area (covers all or portions of six southern California counties). The metropolitan areas currently in the model are: Maricopa County/Phoenix; Pima County/ Tucson; Clark County/Las Vegas; MWD service area; and lower Colorado River communities. Data is being incorporated into the model to include the Yuma, AZ metropolitan area.

II. Summary Damage Calculation Sheet

In this spreadsheet, the dollar damages from each of the sectors and areas are displayed for the baseline salinity level (500 TDS) and the current or projected salinity levels. It is a rather large spreadsheet because it is linked to all the calculation spreadsheets. For example, the household damages are listed by metropolitan area and by household item for the baseline and current or projected salinity levels. Displaying the damage estimates in this manner aids in identifying particular items or crops that are impacted by salinity damage functions differently or where salinity levels are higher in a particular area.

III. Additional Input Data Sheets

The next two spreadsheets contain input data. The first spreadsheet contains data to calculate weighted average salinity levels based on different water sources with differing salinity levels for MWD service area and recently for the Phoenix, Arizona area. Blending date for other urban areas is not available at this time. The blending of water sources has a significant impact on the overall water quality that is used by residences, commerce, and industry as well as meeting groundwater and recycled water requirements. The second spreadsheet contains population and number of households for each of the metropolitan areas. This data contains the most current and projected population estimates. The population and household data is primarily used in the calculation of household and commercial damages.

IV. Damage Calculation Spreadsheets

The next six spreadsheets are linked to the other input spreadsheets to actually calculate the salinity damages for each sector and area covered by the model. Salinity crop yield or useful life functions are contained in these spreadsheets, which tie salinity levels to crop yields or product use. Below is brief explanation of each damage spreadsheet:

A. Household Damage Spreadsheet

This spreadsheet consists of three parts. The first part (Part A) consists of the household items average costs per water appliance (e.g. water heater cost plus installation), number units per household, and the salinity- useful life functions for each household item considered in the model. There are ten household items that are included in the model - galvanized water pipe systems (older houses), water heaters, faucets, garbage disposals, clothes washers, dishwashers, bottled water, water softeners, water treatment systems, and soaps and detergents. Unit cost prices for each household item were obtained from local sources such as Sears or supermarkets in the area. The number of units per household was obtained from the latest Census data for each metropolitan area considered in the model. Salinity useful life functions were developed to estimate the average life of a household appliance based on a given salinity level. Most of the useful life functions were taken from previous salinity research and can be found in the Lohman, et.al. study. MWD had contracted for additional research of bottled water use, water softeners, and water treatment systems and found a relationship between these household items and salinity.

The second part (Part B) of this spreadsheet is the calculation of the useful life and household costs based on a given salinity level that has been calculated in the input spreadsheet for weighted average salinity values of each metropolitan area in the model and the salinity functions in Part A.

The third part (Part C) of this spreadsheet takes the information from the other sections of the spreadsheet and calculates the total annual cost per household item for each of the areas considered by the model. From the input spreadsheet on current and forecasted population and number of households, the number of households per area is multiplied by the average cost per household item and then divided by the average life of the item or percentage of household use for that item at a given salinity level. The costs are summed for each metropolitan area and are linked to the summary damage spreadsheet.

B. Commercial Damage Spreadsheet

This spreadsheet has been changed from the original "Lohman, et.al." model when commercial damages were calculated as percentage of household damages and added to total household damage estimate. MWD and their contractor Bookman and Edmonson did some research based on the relationship between salinity and water use for commercial and institutional activities in their service area. MWD was able to collect commercial water uses for particular use such as sanitary, cooling, irrigation, kitchen, and other uses. Based on the type of commercial water use, salinity cost functions were developed based on the change in costs associated with change in salinity levels. From MWD water resource management plans, projected commercial water use was used to calculate salinity damages in future years. From their research on household and commercial salinity costs, it was estimated that the percentage of commercial salinity related damages to household damages is approximately 26 percent for the MWD area. For the Phoenix area, a similar methodology was used to estimate commercial salinity damages. The advantage of the commercial water use methodology is that it ties salinity damages to actual commercial water use for a given area. Due to the lack of available data for types of commercial water use in the other metropolitan areas, the 26 percent of household damages is used as an estimate for commercial damages in those areas. On going research is attempting to better estimate the commercial related salinity damages for the Las Vegas/Clark County area.

C. Industrial Damage Spreadsheet

From research done for the MWD Salinity Management Study, salinity damages can be calculated for industrial water use. Salinity damage functions were developed based on three major types of industrial water use: process water, boiler feed water, cooling water. MWD was able to estimate the amount of water used for these industrial types of production. Related salinity costs such as higher operation, maintenance and replacement of water using equipment are on a dollar per acre-foot per mg/L basis. A change in salinity from the 500 TDS baseline would show a change in salinity costs as it relates to industrial water use. This methodology was also applied to the Phoenix and Tucson metropolitan areas to estimate industry salinity costs.

D. Water Utility Damage Spreadsheet

The MWD research estimated the per capita costs for capital investments in replacement of water production and distribution facilities. The salinity useful life functions that were developed for the "Lohman, et.al." model are used in this spreadsheet. The methodology is similar to the Household damage spreadsheet. The per capita costs for water production and distribution costs are divided by the average life of the facilities based on the given salinity level and then multiplied by the metropolitan population for relevant time period.

E. Agricultural Damage Spreadsheet

This spreadsheet estimates the change in gross revenue due to a change in crop yields of salt sensitive crops that receive Colorado River water in the Lower Basin. The agricultural areas considered by the model are irrigated lands in Central Arizona Project; La Paz County, AZ; Yuma County, AZ; Imperial County, CA; Riverside County (non MWD), CA; and MWD irrigated lands. This spreadsheet consists of three parts in calculating the salinity costs associated to crop yields.

The first part consists of the salinity-crop yield functions that were derived from a 1998 Reclamation study, *Final Report, Crop Salinity Estimation Procedures.* For the MWD, ten salinity-crop yield functions were used to estimate changes in crop yield due to changing salinity conditions of irrigation water in the service area. For the remaining irrigated areas in the Lower Basin, fourteen salinity-crop yield functions were selected due to their lower tolerances to salinity.

The next part of the spreadsheet consists of the irrigated crop acreages and crop prices. These data were updated to year 2000 prices and acreages.

The final part takes the above data and estimates the gross crop revenue based on the crop yield per acre at a given salinity level and the price per crop unit per acre times the total irrigated acres for that crop. This method is done to estimate the gross crop revenue at the 500 TDS baseline salinity level and the given salinity level to estimate the salinity damages.

Research data from the Central Arizona Salinity Study (CASS) was collected for CAP irrigated acres in the Phoenix area to identify management costs associated with flushing out salts that build up in the soil. This would reduce the impacts on yield, but would add to the costs of salinity due to the additional purchase of water. It is hoped that more research can be conducted to identify these types of costs in other agricultural areas in the Lower Basin.

F. Policy Related Spreadsheet.

This spreadsheet is based on research conducted by MWD for their *Salinity Management Study* (June, 1999). One of the purposes of the MWD study was to conduct extensive research on the costs associated to meet groundwater and recycling water quality standards within their service area. The model calculates the costs of removing salts to maintain water quality requirements for groundwater and recycled water that is used extensively in service area. MWD were able to estimate the amount of water that drains into the groundwater system and the amount that is used for recycled water purposes. MWD was able to develop salinity cost functions (costs to desalt these sources of water) that could estimate the costs at given salinity level. As of now, this methodology has not been extended to other metropolitan areas in the model.

Salinity Control Benefits Based on 2015 Conditions

Using on the latest update of the Lower Basin Salinity Damage Model, two model runs were made based on projected 2015 salinity levels that came from the *Quality of Water Colorado River Basin, Progress Report No. 19, January 1999*. From this report, two sets of projected salinity levels were obtained for Hoover, Parker, and Imperial Dams. At these dam sites, water is diverted for agricultural and M&I water uses. The first set represents 2015 salinity levels assuming only existing (as of 1999) salinity control program implementation. The second set of salinity values for the same sites and time period is based on additional salinity control projects implemented from 2000 to 2015 (see Table 1 below). All data inputs (2015 projected area population, agricultural acreages, and discount interest rate) are the same for the two model runs.

Table 1: 2015 Salinity Levels

Lower Basin Dam Sites	Salinity Levels With Existing Controls	Salinity Levels With New Controls
Hoover	790 mg/L	723 mg/L
Parker	810 mg/L	743mg/L
Imperial	928 mg/L	861 mg/L

All prices are based on 2000 dollar values and the 2015 salinity damages are present valued to the year 2000 at the current Reclamation planning interest rate of 5.875%.

Table 2 displays on the next page the salinity related damages by economic sector and impact area. It can be seen from the table that the implementation of new salinity controls can result in a reduction in salinity levels that reduces the annual damages in the agricultural and M&I areas. This reduction or avoided costs are considered the annual benefits from implementation of new salinity control projects during the 2000 to 2015 period. The model estimated approximately $75 million in annual benefits from the reduction of 67 mg/L at the three dam sites due to new salinity control projects in the program. The annual $75 million in benefits converts (assuming 10,000 tons of salt per mg/L) to approximately $112 per ton of salt removed. The average cost to implement these new salinity control projects would be $63 per ton. Based on the data and assumptions used for this analysis, the additional benefits of salinity reduction are greater than the costs of implementing new projects on a "per ton of salt" removed basis.

2015 Salinity Control Annual Benefits
(Present value @ 5.875 % to year 2000)

Economic Sectors	2015 Salinity Levels and $Damages (Existing Controls)		2015 Salinity Levels and $Damages (New Controls)		Annual Present Value Benefits from Salinity Control
Agricultural Sector Damages					
Agricultural Areas:	Levels (mg/L)	$Damages	Levels (mg/L)	$Damages	
Central Arizona	810	$6,378,003	743	$4,815,011	$1,562,991
La Paz, AZ	810	$6,387,158	743	$5,007,168	$1,379,991
Yuma, AZ	928	$66,629,279	861	$56,361,421	$10,267,859
Imperial, CA	928	$116,716,044	861	$102,073,267	$14,642,777
Riverside, CA (Non MWD)	810	$47,547,710	743	$35,525,446	$12,022,264
MWD Service Area	810	$30,979,346	743	$22,084,150	$8,895,196
TOTAL AGRICULTURAL DAMAGES		**$274,637,540**		**$225,866,463**	**$48,771,077**
Household Damages					
Metropolitan Areas:					
Maricopa County/Phoenix	810	$10,747,176	743	$8,442,326	$2,304,849
Pima County/Tucson	810	$3,167,393	743	$2,488,111	$679,282
Clark County/Las Vegas	790	$6,941,466	723	$5,344,992	$1,596,473
MWD Service Area	810	$34,225,353	743	$26,753,034	$7,472,319
Lower Colorado River Area	928	$2,392,950	861	$2,032,049	$360,901
TOTAL HOUSEHOLD DAMAGES		**$57,474,338**		**$45,060,513**	**$12,413,825**
COMMERCIAL DAMAGES					
Metropolitan Areas					
Maricopa County/Phoenix	810	$1,893,840	743	$1,502,075	$391,765
Pima County/Tucson	810	$558,150	743	$442,690	$115,460
Clark County/Las Vegas	790	$1,226,911	723	$953,473	$273,437
MWD Service Area	810	$10,244,647	743	$8,030,481	$2,214,166
Lower Colorado River Area	928	$413,048	861	$355,115	$57,932
TOTAL COMMERCIAL DAMAGES		**$14,336,595**		**$11,283,834**	**$3,052,761**
UTILITY DAMAGES					
Metropolitan Areas					
Maricopa County/Phoenix	810	$2,017,609	743	$1,593,645	$423,964
Pima County/Tucson	810	$884,003	743	$697,371	$186,632
Clark County/Las Vegas	790	$1,847,320	723	$1,433,107	$414,213
MWD Service Area	810	$8,062,813	743	$6,335,982	$1,726,830
Lower Colorado River Area	928	$477,230	861	$405,741	$71,489
TOTAL UTILITY DAMAGES		**$12,811,745**		**$10,465,847**	**$2,751,839**
INDUSTRIAL DAMAGES					
Metropolitan Areas					
Maricopa County/Phoenix	810	$5,488,991	743	$4,386,900	$1,102,090
Pima County/Tucson	810	$1,700,615	743	$1,358,883	$341,732
Clark County/Las Vegas	790	$1,154,633	723	$892,449	$262,184
MWD Service Area	810	$4,096,455	743	$3,211,092	$885,363
Lower Colorado River Area	928	$0	861	$0	$0
TOTAL INDUSTRIAL DAMAGES		**$12,440,694**		**$9,849,324**	**$2,591,370**
Policy Related Damages					
Groundwater and Recycled Damages					
Metropolitan Areas					
Maricopa County/Phoenix					
Pima County/Tucson					
Clark County/Las Vegas					
Lower Colorado River Area					
MWD Service Area	810	$23,701,720	743	$18,032,285	$5,669,435
TOTAL Policy Related DAMAGES		$23,701,720		$18,032,285	$5,669,435
Total Annual Damages		**$395,402,631**		**$320,558,265**	
Total Annual Benefits (Avoided Costs)					**$75,250,107**
Benefits per ton of salt					**$112 per ton**

SUMMARY

This guidebook presented the development of methods to estimate salinity damages that occur in agricultural and metropolitan areas in the lower Colorado River basin. As the southwestern portion of the United States became more populated and developed, there has been a greater demand for water from the Colorado River. This has created to water quality problems such as higher salinity levels that can impact agricultural production, households, businesses, and water utilities.

Since the early 1970's, there has been a need to identify the associated costs due to salinity and the benefits of salinity control. Various research studies in the 1970's and 1980's have developed methods for estimating salinity damages that have occurred in the southwestern United States. These studies have shown a range of damages from approximately $112,000 per mg/L to over $1,000,000 per mg/L.

In the development of methodologies, computer models have been constructed to allow for more flexible and accurate estimating of salinity damages in the Lower Colorado River Basin. These methodologies and models have assisted in identifying the benefits of the Colorado River Salinity Control program by showing what the avoided costs from lower salinity levels based on implementation of numerous salinity control projects in the upper basin.

Recent research has resulted in a more accurate model for estimating the damages and salinity control benefits in the lower basin area. Based on 2015 salinity levels with and without new control projects, the annual present value of benefits from new control projects are approximately $75 million which converts to about $1 million per mg/L or about $112 per ton of salt removed.

Further research is still needed to better estimate the salinity damages in the Lower Basin. Commercial damages in the Las Vegas/Clark County, Nevada area are not accurately estimated at this time. This area has a very large commercial sector that is made up primarily by the hotel/casino industry. Currently, there is little information as to the costs related to salinity management for this industry. The benefits of salinity control could be large as it relates to this industry.

Another area of research is identifying on-farm management costs that irrigators incur to maintain or reduce the salinity in the irrigation water and soils of their irrigation field.

Methods for estimating the economic impacts from salinity are evolving over time. As water demands increase in the Southwestern United States as well as other parts of the world, there will be a greater need for accurate estimates of salinity damages and the potential benefits from salinity control.

REFERENCES

Andersen, Jay, C. Alan P. Kleinman, et.al., Salinity Management Options for the Colorado River, Water Resources Planning Research Report P-78-003, Utah State University, Logan, Utah: Utah Water Research Laboratory, June 1978.

Bookman – Edmonston, Salinity Management Study, Final Report, Technical Appendix 5, Economic Impacts of Changes in Water Supply Salinity and Salinity Economic Impact Model, Metropolitan Water District of Southern California and Bureau of Reclamation, June 1999.

Kleinman, Alan, P., F. Bruce Brown, Colorado River Salinity – Economic Impacts on Agricultural, Municipal, and Industrial Users, Colorado River Water Quality Office, Bureau of Reclamation, December 1980.

Colorado River Basin Salinity Control Forum, "1996 Review – Water Quality Standards for Salinity – Colorado River System", June 1996.

Lohman, Loretta C., J. Gordon Milliken, and W. Dorn. Estimating Economic Impacts of Salinity of the Colorado River. Milliken-Chapman Research Group, Inc. Prepared for: U. S. Department of the Interior, Bureau of Reclamation. February 1988.

Ragan, Guy E., Carole J. Makala, and Robert A. Young, Improved Estimates of Economic Damages from Residential Use of Mineralized Water, Departments of Agricultural and Resource Economics and Design, Merchandising, and Consumer Sciences, Colorado State University, Research Project Technical Report, U.S. Geological Survey No. 14-08-0001G1984, Colorado Water Resources Research Institute, Colorado State University, August, 1993.

U.S. Bureau of Reclamation, Quality of Water Colorado River Basin, Progress Report 21, January 2003

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