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# Utility response to drought : business of water management practices and function in view of decreased consumption

Louis Martinez

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# **Utility Response to Drought**

## **Business of Water Management Practices and Function**

### **In View of Decreased Consumption**

by

**Louis Martinez**



**Water Resources Program**

**The University of New Mexico**

**Albuquerque, New Mexico 87131**

**June 2009**

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## **Abstract**

This paper uses parametric methods to construct 5 year, 10 year, and greater than 15 year drought scenarios to calculate potential source water reduction for the Albuquerque Bernalillo County Water Utility Authority's (Authority) service area. The drought scenarios are drawn from literature of the Southwestern region's historical precipitation patterns, the tree-ring record (TRR), and Global Climate Models (GCM). The cumulative surface water losses attributed to prolonged drought conditions are between 20,000 and 25,000 Acre-Feet per year. Converting the contracted supply, that would be unavailable for sale by the Authority, based on the commodity charge, represents a considerable financial loss, with an estimated annual revenue reduction of approximately \$14 million. The estimated cumulative cost, unrealized income, for the Authority of a 15 year drought is over \$110 million. Asset Management tools, in particular Nessi-curves, were used to graphically display the financial cost to replace aging water pipe system wide. Integrating an in-house GIS Produced Pipeline Analysis Rehabilitation Model and stacking the Nessi-curves, for the period 2005-2020, the amount needed to replace the aging pipe is around \$1 billion. Current capital programs would meet about 25% of this forecasted need. The risk exposure to a prolonged drought and the potential unmet requirements to replace critical aging pipe infrastructure over the next 15 to 20 years is around \$1 billion. Management options to address such a considerable revenue shortfall due to drought and infrastructure are limited. Continued Asset Management is recommended to prioritize project replacement work and may extend the life of the pipe asset base. This has the possibility to lessen the infrastructure cost of ownership by as much as 30%. However, it is recommended to increase monthly average rates by around \$6, and place the funds in a reserve, sinking fund. This fund is estimated to grow to over \$110 million in 15 years in order to provide protection against a severe or prolonged drought.

## Introduction

Significant water problems exist in New Mexico and other parts of the Southwestern United States, due to prolonged droughts, urban development, ground water depletion, agricultural use, and population growth. In general, this region is characterized by low precipitation, aridity and drought. Utilities must respond to the problem using planning and education. The need to manage this problem is crucial to sustainability and our future (Thebaut, 2005).

Amid day to day challenges, sustainable public and private utilities are watching the five D's below and may find it necessary to adjust the operational, financial and management strategy to coincide with these regional realities, trends and drivers. These are:

- Drinking water is scarce in the Southwest;
- Demand is outpacing water supply due to population growth;
- Drought scenarios suggest limited and vulnerable supply;
- Declining utility revenue related to effective conservation, prolonged drought and climate change;
- Deterioration of water and sanitation infrastructure.

With these realities in mind, the following sections set out the approach and framework used to satisfy the problem statement: How might prolonged drought exacerbate the consequences of the Authority's ability to replace aging infrastructure, with its high cost, yet remain financially sustainable? What are some of the feasible choices?

Utilizing the development of three plausible drought scenarios with a durations of 5 years, 10 years, and 15 years beginning with projected year of 2010 can integrate many of the current behavioral strategies, along with quantifiable physical drought conditions (intensity, duration, and frequency), past spatial / temporal patterns, as well as links to business vulnerabilities and risk to ‘test’ the ability of the utility to maintain the level of service. In order to establish a more robust drought response, utilities must include an analysis of the natural climatic and hydrologic variability pattern over the landscape encompassed by the Colorado River Basin, and climatic processes that water resources of the Rio Grande above and below the utility service area. These scenarios draw from a synthesis of both national and international drought management literature.

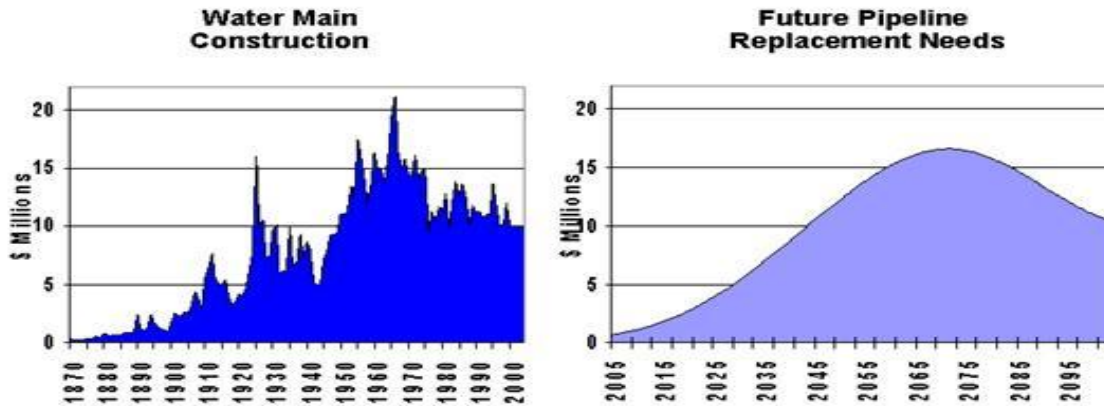
Utility risk exposure has increased through water conservation. The fiscal effect of a water conservation program means a declining base revenue stream resulting in lower per capita unit sale of water and foregone revenue in the form of rebates/ incentives. The fiscal analysis and long term impact from shrinking revenue is presented in revenue estimates. However, this financial vulnerability will be revealed with deferred maintenance, rehabilitation, and replacement of aging and critical infrastructure, and ultimately the performance and level of utility service provided.

The project develops a Nessi curve (Figure 1), an Asset Management technical/financial tool, to construct a cost estimate, to replace the backlog of aging water pipe in a service area with a capital plan to ease the financial transition over future years. A Nessi curve is a reference to the similar sinuous body shape of Scotland’s legendary Loch Ness monster, affectionately known as ‘Nessie’.



# A Nessie Curve is a demographic echo.

**Anytown – Population 250,000**



**Figure 1-Nessi Curve, a demographic echo**

A number of Southwestern water/wastewater utilities, are utilizing Asset Management Nessie-curve tools to prepare management and capital plans. “Asset management is a planning process that ensures that you get the most value from each of your assets and have the financial resources to rehabilitate and replace them when necessary. Asset management also includes developing a plan to reduce costs while increasing the efficiency and the reliability of your assets. Successful asset management depends on knowing about your system’s assets and regularly communicating with management and customers about your system’s future needs” (EPA, 2009).

Much of the asset work presented is based on the data compiled and summarized from City of Albuquerque’s (COA) Geographic Information System (GIS) Data Base (COA, 2005) and characteristics of the Albuquerque Bernalillo County Water Utility Authority’s (Authority) with some updates related to the service population, since this impacts on this paper’s forecasts and estimated future cost .

The salient data for the Authority are presented in Table 1.

<b>Authority Selected Water and Sewer System Characteristics</b>	<b>2006</b>
<b>Est. population (service area)</b>	530,600
<b>Number of meters billed</b>	171,130
<b>Est. persons per meter</b>	3.10
<b>Annual pumpage (1000 Gallons)</b>	31,384
<b>Annual water billed (1000 Gallons)</b>	27,942,376
<b>Average daily pumpage (Gallons)</b>	85,983,561
<b>Peak day pumpage (Gallons)</b>	149,940,000
<b>Average daily production per meter (Gallons)</b>	502
<b>Well pumped capacity (per 24 hour period)</b>	294,000,000
<b>Storage capacity (Gallons)</b>	211,000,000
<b>Water reclamation treatment capacity (Gallons)</b>	
<b>Number of miles of lines</b>	
<b>Water</b>	2520
<b>Sewer (wastewater)</b>	1820
<b>Wastewater Treated (millions gallons/day (MGD))</b>	55
<b>Estimated infrastructure replacement costs (Billion \$)</b>	2.5 to 3.0

**Table 1-- Authority Selected Water and Sewer Characteristics 2006**

Many of the Authority's services are resource intensive. In order to provide its services to customers, the Authority relies on a estimated \$3 billion (capital replacement value) portfolio of water wells, wastewater treatment plants, sewer lines, collection systems, distribution systems and water storage systems and other infrastructure assets (see Table 2). The top rows in Table 2 pertain to the Water System. In 2004, the Authority's estimated total cost to replace Master Plan Waterlines and Small Waterlines is shown as \$823,314,437; so waterlines (distribution) are roughly one-third the total asset portfolio value of the utility. The total pipe length is approximately 2,266 miles and the replacement cost per foot of pipe is about \$75.

Much of this infrastructure is aging, having been built since World War II. To maintain these assets and ensure reliable services to customers, the Authority routinely considers a number

of large investment project proposals and must validate decisions to finance these choices using Asset Management principles, such as a business case for a range of need, performance requirements, and efficiency alternatives and the economics for the full cost of ownership.

Historically, the Capital Program annual spending level to repair, rehabilitate, and renew assets has been about \$30 million and the most recent Water and Water Reclamation Decade Plan FY 2010-FY2019 is showing annual spending of approximately \$48 million (Authority, 2009).

Infrastructure Assets	Replacement Costs	Total Units	Cost/Unit
<b>WATER SYSTEM</b>			
MASTER PLAN WATERLINES	\$355,783,204	3,481,331 LINEAR FEET	\$102
SMALL WATERLINES	\$467,531,233	8,484,377 LINEAR FEET	\$55
WELLS	\$164,831,655	89 EACH	\$1,852,041*
PUMP/BOOSTER STATIONS	\$63,304,322	33 EACH	\$1,918,313*
STORAGE RESERVOIRS	\$147,495,612	49 EACH	\$3,010,115*
<b>SUBTOTAL</b>	<b>\$1,198,946,026</b>		
<b>*ENR UPDATED 6-17-04 JUNE 2004 INVENTORY</b>			
<b>SEWER SYSTEM (WASTEWATER)</b>			
MASTER PLAN SEWERLINES	\$215,091,187	1,724,425 LINEAR FEET	\$125
SMALL SEWERLINES	\$531,059,153	7,003,400 LINEAR FEET	\$76
LIFT STATIONS	\$49,530,911	31 EACH	\$1,597,771
ODOR CONTROL STATIONS	\$1,310,359	11 EACH	\$119,124
TREATMENT PLANT (w/SOIL AMENDMENT FAC)	\$491,967,575	76 MGD	\$6,473,258
<b>SUBTOTAL</b>	<b>\$1,288,959,185</b>		
<b>NEW SURFACE WATER PLANT &amp; ANCILLARY FACILITIES (2009 est.)</b>	<b>\$436,000,000* *\$500,000,000 estimated @ completion</b>	<b>48,200,000 ACRE/FEET</b>	<b>\$10,370</b>

**Table 2 - Authority Infrastructure Assets: Water & Sewer Inventory Replacement Cost (source: Authority)**

Figure 2 is a diagram designed to present the framework and help identify the major components of this paper. The blue boxes represent the interconnection between the effects of drought, as contraction of water supply, and the conversion of the contracted water supply (total reduction) now unavailable for sale by the Authority. As utility revenue decreases, the ability to replace aging infrastructure decreases, represented by the red box. To determine the cost to replace water pipe, the Authority first developed a spreadsheet model (See Appendix A) to understand rehabilitation/ renewal costs. The model was also used to reduce the risk between the infrastructure gap and funding requirements. Next, moving to the purple level boxes, the combined effects from drought induced reduced supply, cash requirements to replace pipe are inputted into a business case. The final components, green ovals, are three sustainable management/policy sustainable solutions.

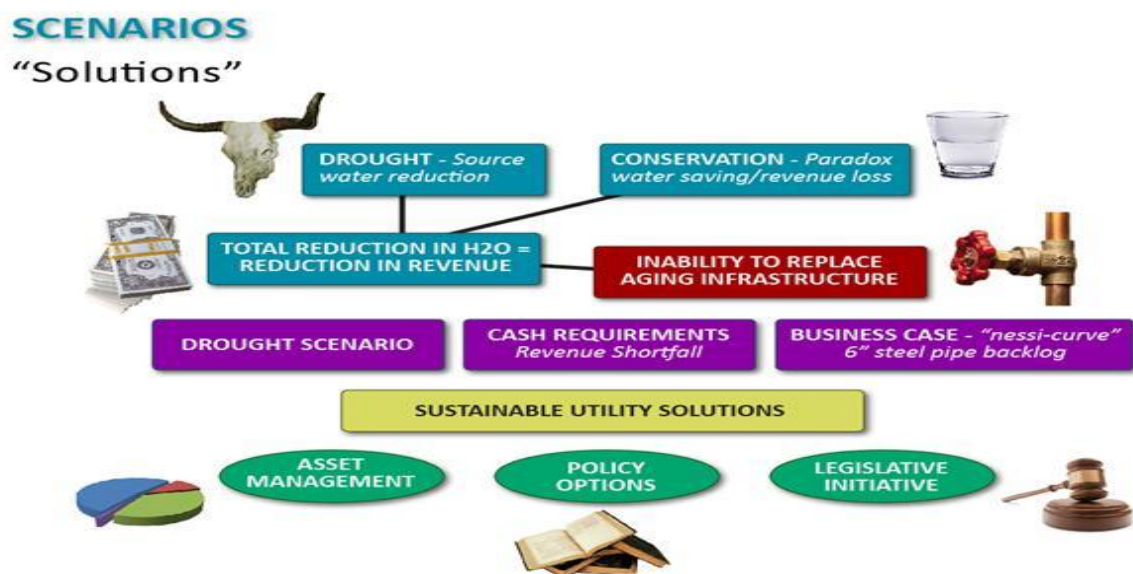


Figure 2- Scenarios/ Solutions

## **Nature, Scope and Objectives of this Research**

This paper develops a robust drought management system with rationale to include the worst case scenarios of 5 year, 10 year, and greater than 15 year drought durations. The considerable fiscal impact of drought over time is then combined with the construction of Nessi-curves for utility wide infrastructure assets to underscore the vulnerabilities and realities presented by severe drought. The Nessi-curve graphically presents the funding requirements for the Authority's aging water pipe.

Next, drought reserve projection calculations are analyzed and policy alternatives for utility requirements are discussed in the context of the Authority's choice to return to pumping ground water to avoid conflict between the local agricultural economy and environmental pressures.

The Mid Region Council of Governments (MRCOG), Middle Rio Grande Regional Water Plan 2000-2050 (MRCOG, 2001), references studies that demonstrate there is already a great imbalance between the water supply and the demand in the region. Middle Rio Grande consumers (comprised of Municipal, Industrial, Agricultural, Recreation and Riparian) share a limited quantity of renewable surface water. In times of drought the net resulting consumptive use may exceed the projected renewable supply. Extreme drought, for the region and reflected in contracted water supply, has been recorded and reconstructed from tree ring research for durations extending from about five years to over thirty years. These extreme conditions are used to establish bounds for this study to analyze the potential effects of three severe drought scenarios with durations extending 5 years, 10 years and over 15 years. When the 5 year, 10 year, and 15 year droughts might occur is unpredictable, however the certainty that they will occur is accepted from the instrument record. The data provides an opportunity for prolonged

drought analysis and the opportunity to make recommendations to alleviate the potentially devastating infrastructure related socio-economic effects of future droughts.

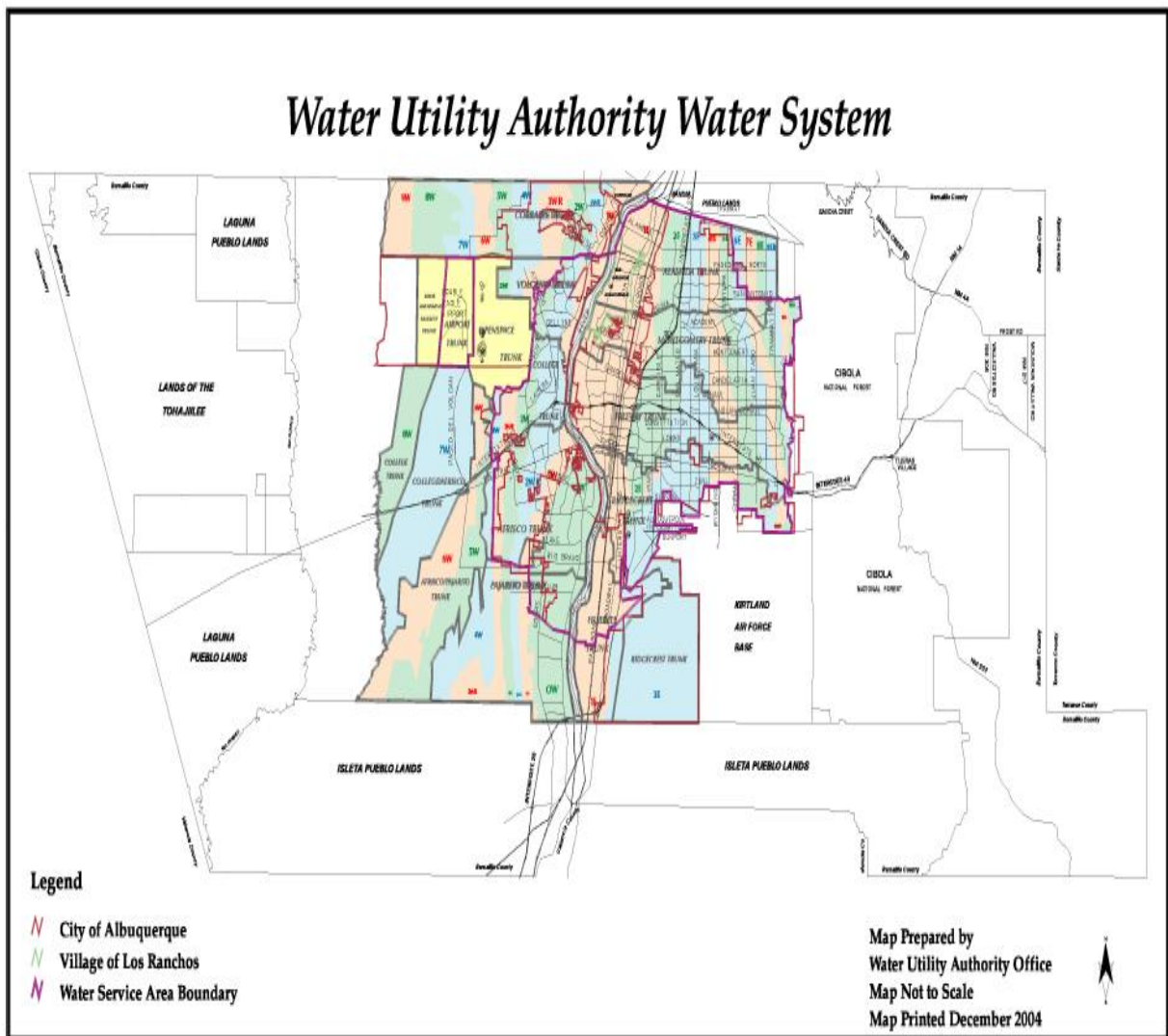
### *Nature*

Water scarcity in the Authority service area (see Figure 3) is compounded by drought. This analysis is intended to emphasize the need for the Authority to assess potential drought impacts, develop contingency plans, and a robust response to plausible, extended drought scenarios. Although, the scenarios established may not contain a precise value for water quantity, they are within the bounds of credible historic occurrence.

The premise for extending the drought scenarios is supported in the following sections with local and regional technical data such as the region's projected water budget (current, 2020 and 2060), historical precipitation/snow pack, river flow records, regional climate conditions and climate models predicting significant changes for the greater region including the Colorado River Basin and Upper Rio Grande watershed.

### *Scope*

This paper sets the stage for the drought scenarios in the context of examining the loss of drought reserve (aquifer and reservoirs), loss of surface flow, demand reduction, environmental regulation as it relates to river conditions/flow, population growth (out years 2020 and 2060), as well as loss of revenue/ increased capital cost to the Authority, and a warmer / drier climate as predicted by Global Climate Modeling, concluding with a recommendation for a more forceful Drought Management Plan for the Authority in order to maintain the utility's desired level of service.



**Figure 3- Water Authority Water Distribution System**

### *Objectives of the Research*

The objective of this research is to evaluate and analyze the economic impacts upon Utility resources for three scenarios constructed from literature to simulate severe drought. These scenarios reflect a drought of increasing duration and severity. Utility business risk exposure has increased through unintended consequences of water conservation, namely

declining revenues from lower per capita unit sale of water and foregone revenue in the form of rebates/incentives. Drought has a similar effect: when less is available to the users, less water will be sold by the utility. The fiscal analysis and long term impact from shrinking revenue is presented in revenue estimates. This financial vulnerability was achieved in part by deferred maintenance, rehabilitation, and replacement of aging and critical infrastructure, and ultimately the performance and level of utility service provided will be negatively impacted. With conservation, the Utility has already experienced a drop in the revenue stream due to voluntary and incentive-based conservation measures. Over 10 years of conservation implementation, the Utility has reduced its usage by over 100 billion gallons of water (Authority, 2008). This is a commendable achievement from a resource perspective. However, from a financial perspective this represents a loss of revenue of approximately 13 million dollars from the Utility's operating budgets. In times of severe drought, this shortfall will be compounded.

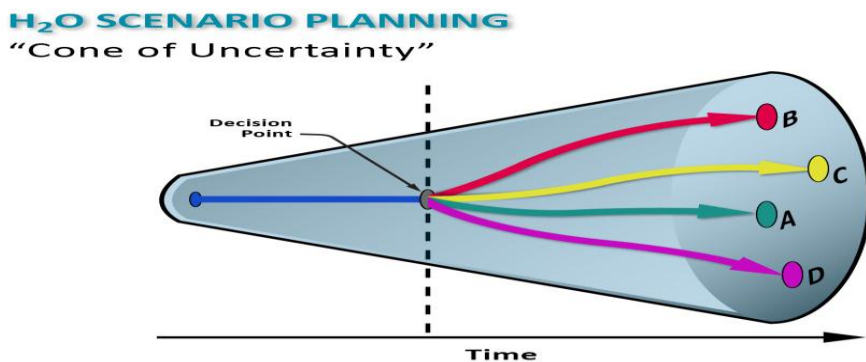
Revenue from customers is used to maintain the utility's critical infrastructure. The first step to obtain a viable revenue figure for analysis is to calculate a projected water decrease and therefore a revenue shortfall. Some of the shortfall may be made up with wastewater 'reuse,' however 'reuse' water is already accounted for by return flow credits to the Rio Grande. Return flow is, "That amount of diverted water returned to the available water supply" (New Mexico Administrative Code (NMAC, 2004)). In this case, it is ground water used by the Utility for potable supply, which is treated and returned to the Rio Grande, to compensate for the aquifer withdrawals. For the reclaimed water put back in the Rio Grande from the Southside Water Reclamation Plant, water-rights credits have been approved for the portion of water originally pumped from ABCWUA wells. In approving water rights permits for diversions of ground water, the New Mexico Office of the State Engineer, NMOSE, has found that approximately 50% of the



water delivered to households and customers is discharged back into the wastewater collection system and is the basis for the 50% Return Flow Credit to Authority.

This drought information and analysis related to shrinking available water supply, water sale revenue decrease along with the estimated cost to sustain the Utility infrastructure allows for the evaluation of future financial impact. The Utility may then use the snapshot of future requirements from constructed Nessi-curves to strategically address operational, management, financial and policy options to sustain the Utility's level of service.

The progression and data models in studies about the influence of climate change on streamflows in the Colorado River Basin and Rio Grande Watersheds, which predict the amount of water, should each be considered as having some range of value or accepted as having some uncertainty in the final values. In addition, Nessi-curve values possess some of this same uncertainty as they are averaged cost data from emergency on- call contracts, scheduled/actual and indexed cost. Figure 4 is presented to graphically capture this uncertainty concept. As this analyses moves further into the future, there is less and less certainty with each out year scenario, represented by path line and end points A, B, C and D, and a decision point also may affect the outcome of each scenario.



**Figure 4- Multiple Scenario Water Planning/Cone of Uncertainty**

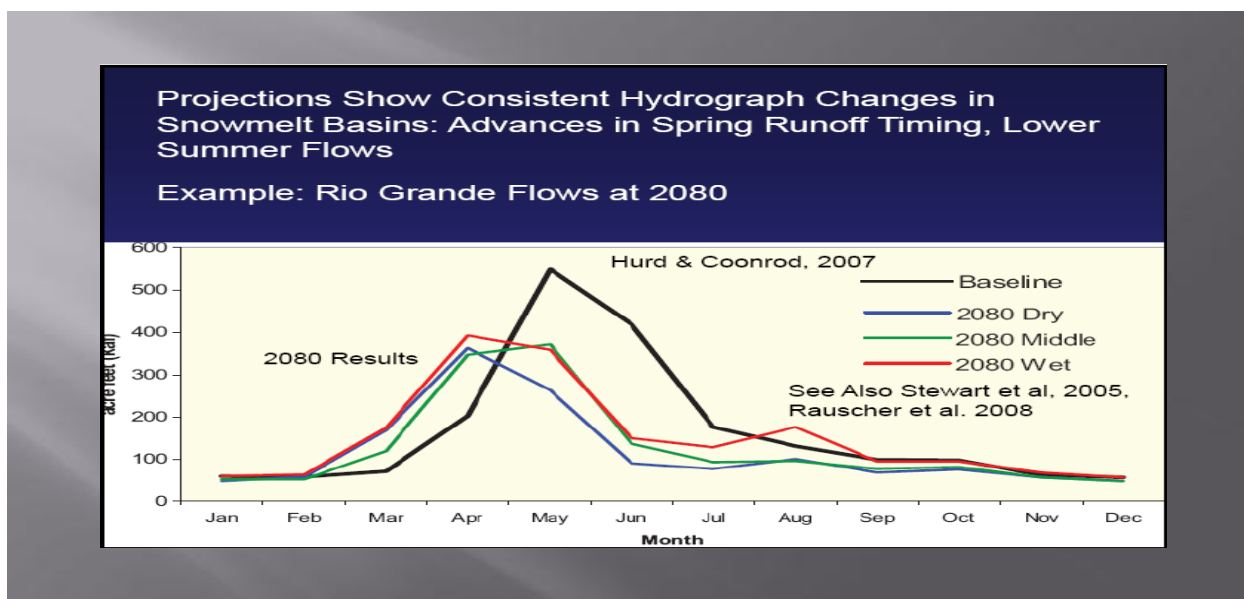
The analysis points out a number of options available to make up this revenue shortfall that may include deferred maintenance, having and/or forcing fund managers to substitute capital resources, forcing a reduction in labor costs/ materials, reducing the level of service, reducing debt, or debt refunding (refinancing of debt). However, the final recommendations focus on preparation rather than traditional mitigation solution. The selected recommendations rely on Authority Board price changes and safeguarded cash reserve protections related to markets (scarcity of water/pricing) and customer rate schedules in what proves to be a very reasonable, sustainable strategy sparing the utility from the consequences of significant water and revenue shortages. Other consequences of diminished revenue, as the result of a drought, may be an inability to meet future needs, increasing operating expenses, or impediments to meeting regulatory requirements. Each of these options, Regulation and Rate Schedules, may be considered separately, in conjunction with each other, or in total.

### *Background*

The amount of water currently available for use by the populations in the Southwest and the Authority is a combination of past conditions including reservoir storage collected from regional watersheds, imported water from the Colorado River, and regional aquifer storage. The ability to provide and deliver adequate water is a function of the combined land use sector demands by: Urban, Agricultural, Industrial, Riparian, and Evapo-Transpiration (ET). Regional population growth and population migration to the region continue to strain water supply. The Intergovernmental Panel on Climate Change (IPCC) AR4- Fourth Assessment 2007 (IPCC, 2007), which assessed the scientific, technical and socio-economic information relevant for the understanding of the risk of human-induced climate change, reports predict the Southwestern United States with less snowpack, earlier runoff, higher annual temperature, less soil moisture

and increased variability in precipitation and stream flow. All of this indicates that Southwestern reservoirs are likely to receive less water and not meet the growing demand. In the upcoming years aquifers will continue to be drawn down and watersheds will be less likely to produce the reliable and timely water supplies.

For the region encompassing the Authority's source supply, Gutzler et.al., report that the impacts to the region are a microcosm of the climate impacts expressed by the IPCC. Gutzler surmises, for the Middle Rio Grande and Southwestern NM that "warmer temperatures will lead to higher rates of consumption, reduced snowpack, less and earlier spring runoff, more evaporation from open water, and drier soil conditions." Gutzler concludes with the caution that predictions of precipitation trends carry more uncertainty, nonetheless, expects the climate to become more variable. He also adds that, "The impacts of episodic droughts would be more severe in a warmer climate, regardless of long-term trends." Hurd et.al., (see Figure 5) projections for a dry, middle and wet runoff compared against a baseline show a monthly shift and lower summer flows in Rio Grande peak flow in the year 2080.



**Figure 5- Rio Grande Flows, 2080 (projections); Dry, Middle and Wet Hydrographs**

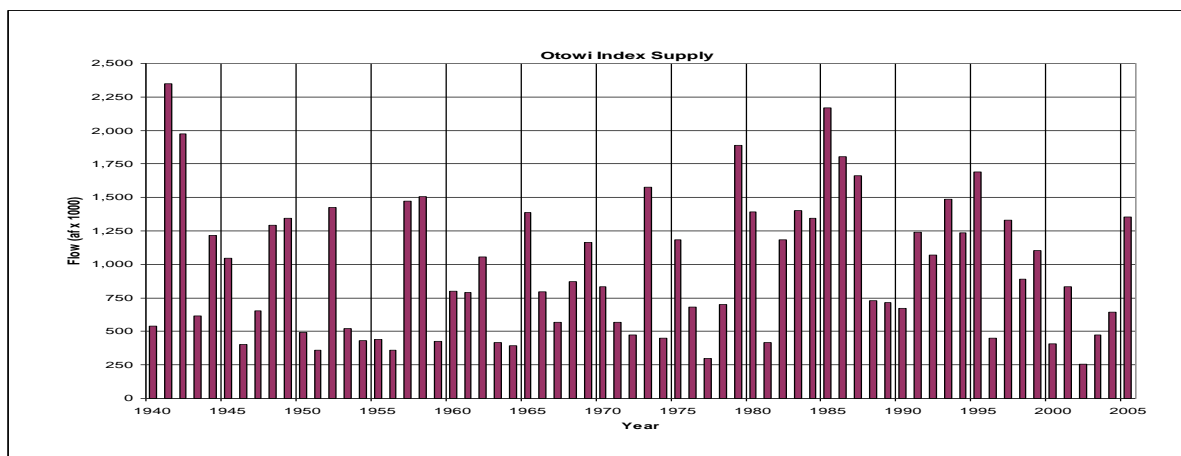
In addition, ‘Water Budgets’ prepared by the Water Assembly, a local group of citizens and water professionals, present estimated inflows and outflows to the region. The representative ‘Water Budget’ for the Middle Valley (Rio Grande/ Authority Service Area) relies heavily on non-native water, that is either imported to the region via the San Juan/ Chama diversion of the Colorado River, released from reservoir storage, and /or the ‘normal’ rainfall/ precipitation in order to meet demand (Middle Rio Grande Water Assembly, 1999 and MRCOG, 2001). Any long term interruption, or change in these numbers will lessen the ability to meet downstream Rio Grande Compact obligations that require delivery of water to Texas and Mexico. Gaume attributes the New Mexico’s Rio Grande Compact (Compact) cumulative deficits of 500,000 AF to drought periods of the 1940’s -1950’s. Gaume further states that under the Compact, New Mexico commits to pass a percentage on to stakeholders below Elephant Butte, leaving 405,000 AF as the most Rio Grande water that can be used in the Middle Rio Grande as well as tributary inflows between Otowi and Elephant Butte (Gaume, 1999).

## ***Research Methods - Construction of the Severe Drought and Business Case Development – Implications and Impacts of Drought and Aging Infrastructure to Projected Utility Revenue Shortfall***

### ***Construction of Severe Drought***

#### ***Five year Drought Scenario- based on the Historic Record***

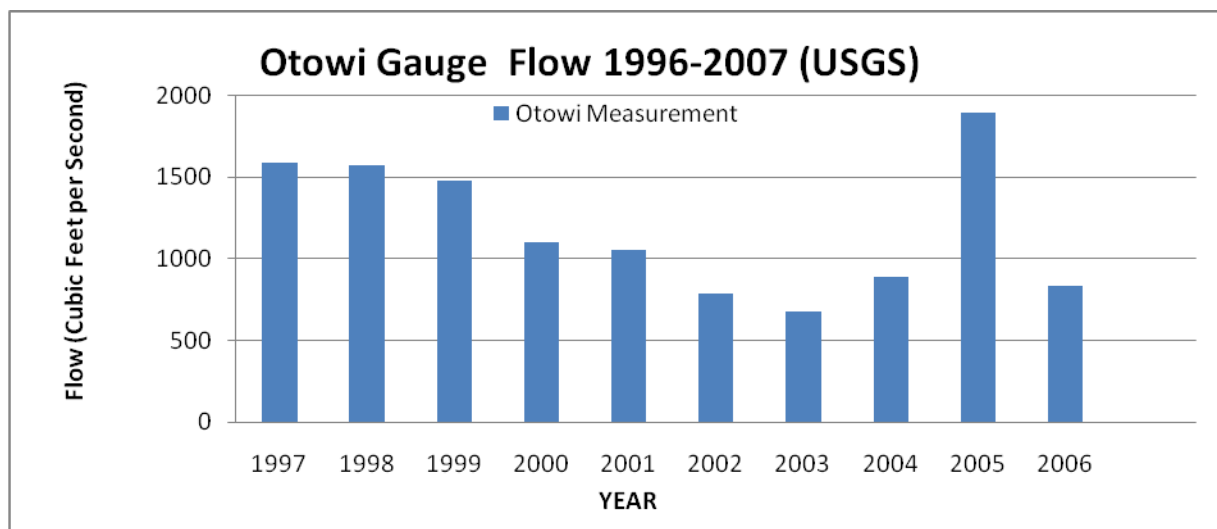
The 1895-1902, mid-1950's (see Figure 6), and 2000-2005 droughts of the Middle Rio Grande were each considered as analogs for the 5 year severe drought scenario. The 1953-1957 period was selected as an appropriate representation of the 5 year drought even though the severity of the drought was only the 4 year period 1953 – 1956 and then followed by a very wet year in 1957. In order to obtain a full 5 year period, the river flow at Otowi Gauge, was averaged and the mean was converted to an annual estimated range between 610,000 AF/ year to 620,000 AF/year. However, with reservoir storage and cooperative agency river management this appears be enough water to meet estimated demand. Figure 6 provides and the annual river flow collected for the past 65 years at the Otowi Gauge/Bridge on the Rio Grande northwest of Santa Fe and East of Los Alamos.



**Figure 6- Annual Streamflow, Otowi Bridge, NM, 1940-2005; source: Schmidt-Peterson, 2007**

### *Ten year Severe Drought Scenario- The Tree Ring Record (TRR)*

The ten year instrument record, 1997 - 2006 (see Figure 7), with the exception of a single very wet year in 2006, would suffice as it closely approximates the doubling of the 5 year drought, and very local conditions and river records. However, historical data as well as tree ring paleo-record for late 15<sup>th</sup> century also supports a more severe prolonged 10 year drought scenario. This 10 year drought scenario represents significant deficits from the water that is available from Colorado watersheds and New Mexico watersheds.



**Figure 7-Annual Streamflow, Otowi Bridge, NM, 1997-2006/ Ten Year Drought Period; source: USGS, 2009**

The ten year period in such a scenario might be likened to an extended La Nina, creating dry conditions in the Western US. Further, for consistency with longer droughts and to observe the compounding effects, the decreased water is now 22% to 30% less than the dry conditions established by the most severe drought experienced in this century. Now the cumulative water loss to the entire system begins to exceed the gains in storage and water stresses to the priority system established by delivery agreements, increased population and by nature. Reservoir

storage is purposely established to address high and low water years and to smooth out delivery to the water users/ customers. With a continued drought, the ability to manage the long term delivery to its clientele/stakeholders is affected by lower and lower reservoir elevation levels. Nonetheless, for this long term assessment water delivered to Otowi Gauge is 22 to 30 % less than the normal reference year 1,100,000 AF (Daves, 1994).

*Greater than 15 years – ‘the Perfect Drought’; Rearranged Severe Drought Scenario (combination Global Climate Model/ TRR)*

This scenario could easily be expanded to 38 years as that tree ring paleo-record supports such extended drought for the period 1550- 1588. However for this paper, research by several individuals is integrated into the termed rearranged severe drought scenario.

Current research by Niklas S. Cristensen, with the Land Surface Hydrology Research Group, Civil and Environmental Engineering, University of Washington reflects the Colorado River Basin (CRB) portion of the modeled prospective view of severe drought (resulting in degraded stream system performance and reduced storage by 27% to 50%). In addition, warmer winter temperatures projects peak flow runoff occurring earlier in the spring by nearly a month. This current research uses the US DOE/ National Center for Atmospheric Research Parallel Climate Model to assess the potential effects of climate change on the water supply for the CRB. In Cristensen’s study, three climate conditions modeled are ‘business as usual’ (BAU), and ensemble of three 105 year transient simulations global greenhouse emissions for ‘static 1995 concentrations and historic (1870- 2000) conditions.

The Grand Canyon Trust (GCT) sets up another format to evaluate Drought Scenarios for the Colorado River based on historical records (1906- 2003) and deliveries to be made under the apportionment of the Colorado River Compact (CRC), to each of the compact member states.

Annual flows at the time of the compact averaged about 18 Million Acre-Feet. The compact allocated 15 MAF and later agreements called for an additional delivery of 1.5 MAF to Mexico. However, in recent decades river production averaged between 13.5 and 15 MAF. Of significant concern is in 2000- 2003 with the river's average annual flow at only 9.85 MAF and in 2002 the river produced the 2<sup>nd</sup> lowest since 1906, when the Bureau of Reclamation (BOR) began keeping records, with a production around 6 MAF. In the GCT scenario, water available under various flow scenarios for delivery from the upper basin to the lower basin uses four average flow scenarios (GCT), A.) 16 MAF, B.) 13.5 MAF, C.) 10 MAF, and D.) 6 MAF. Each of these flow scenarios is bounded by the CRC minimum obligations, which grants 8.25 MAF to downstream lower basin users, in other words, the burden of the drought is upon the upper basin states. Of importance to this analysis is New Mexico's 11.25 % compact corresponding allocation for Colorado River flow for each of the four scenarios is: A.) 16 MAF is .84 MAF; B.) 13.5 is .59 MAF, C.) 10 MAF is .19 MAF, and D.) 6 MAF is -.25 MAF (deficit).

University of Arizona's Laboratory of Tree Ring Research, utilizing paleo-tree ring data, provides a look back at the Colorado River, near Lee's Ferry. The reconstructed records for the past 2,200 years of precipitation and a 500 –year stream flow and graphs presenting the data show severe droughts repeat every or every other century with several durations between 80-100 years and a reconstruction for the 2,000 year record for Northern New Mexico based on the tree ring record shows that some droughts have lasted 200 years.

Young (1995) models multi-year Colorado River drought events with the risk for return periods extending 22 years, 17-22 years, and 16 years for productions of 13.43 MAF, 10.47-11.05 MAF and 9.57 MAF, respectively. The period for a severe drought – rearranged severe drought, as described by Young, occurs between 2000 and 10,000 years, may appear extremely



rare or even unrealistic, however in the context of a water shortage it is certainly the most interesting, as it is useful in discovering the vulnerabilities and reliabilities of the Colorado River basin.

It is reasonable to assume a relative risk for a severe drought with an inflow into New Mexico, under the conditions of a 15+ year drought with Colorado River Basin production between the lowest annual production of 6 MAF and 10.5 MAF. Conservatively, this estimated Colorado River flow represents approximately a 40% reduction from the allocation authorizations set out in the CRC and consistent with global climate model runs performed by Christensen and others, scenario assumptions established by the Grand Canyon Trust and ‘Tree-Ring’ studies. However, Meko, 2007, using tree-ring records, characterizes the most extreme low-frequency feature of the new, covering A.D. 762-2005, is a hydrologic drought in the mid 1100’s, for annual flows of the Colorado River at Lee Ferry. Meko further states this “drought is characterized by a decrease of more than 15% in mean annual flow averaged over 25 years, and by the absence of high annual flows over a longer period of about six decades.” Lewis, 2002, in assessing paleo climate data for New Mexico’s Middle Rio Grande indexed flow for the period 1947-1976 at 78% of the 1919-1998 average. With tree ring data pointing to -15% and -22% annual river deficits over 25 years and 29 years, respectively for the Colorado River and Rio Grande. Stockton and Boggess, 1979, using temperature – precipitation relationships for changes of +2C and -10% Precipitation resulted in a roughly 33% reduction in Lee Ferry Flow. Rovellet and Waggoner, 1983, study for the Upper Colorado River Basin found the temperature-precipitation relationship that the combination of a +2C and -10% precipitation resulted in a -40% reduction in Lee Ferry Flow. However, the duration for such extremes might be conditions that could be projected over a longer period of time, in the event we continue to see an increase

of temperature, but are only used to demonstrate the large uncertainty of future flow based on current knowledge and ranges for supply are -30% to -40% over 2-7 years, however a drought of approximately 25% reduction in the average annual flow over 15 years is an intermediate, representative and plausible value for this analysis.

### ***Sustained Drought Conditions***

Table 3 presents the water supply effects of years 9-15 from the 15 year drought scenario. The demand is projected by aggregated land use categories and adjusted for population projection increases and water conservation projections.

The table shows three critical things that happen while experiencing a decade of drought. First, the water the water stored from plentiful years (reservoir storage) is discharged/ applied in water- deficit years to meet land use (urban, agricultural, riparian and upland) demand. Next, the rate of replenishment is negative, and storage levels drop. Lastly, the Authority must return to groundwater well production to augment the diminished supply. The BOR estimates land use demand at 382,000 AF, for the year 2020 and 369,740 AF for the year 1993 (Brown, 1996). However, lacking the intermediate values for years of interest 2005-2020, the higher number, 382,000 AF, was chosen to represent the period 2005-2020 for the aggregated total including Bernalillo County, Sandoval County, Valencia County and Socorro County (4 County area) which takes in the Authority service area. Most of the service area is contained in Bernalillo County. Under drought conditions this supply drops to an annual average of 282,000 AF from the modeled 15 year drought scenario, leaving an annual 100,000 AF water supply shortage. Only years 9-15 are shown here and for the full table see Appendix C.

15 yr drought ( AF x 000's)	Year 9	Year 10	Year 11	Year 12	Year 13	Year 14	Year 15	15 yr Total (AF)
2010 All Demand/ Land-Use (AF)	382	382	382	382	382	382	382	2,674
Supply during drought conditions (AF)	282	282	282	282	282	282	282	1,974
Shortage (AF x 000's)	100	100	100	100	100	100	100	700
								15 yr Total
Split Shortage (50% each of 100 AF x 000's)	year 9	year 10	year 11	year 12	year 13	year 14	year 15	(AF x 000's)
Reservoir Storage	252	102	dry	dry	dry	dry	dry	
50-100% of shortage	100	100						
Ground Water	year 9	year 10	year 11	year 12	year 13	year 14	year 15	
GW Aquifer (AF x 000's)	22,852	22,752	22,652	22,552	22,452	22,352	22,252	
50% of shortage + reservoir deficit (AF x 000's)	100	100	100	100	100	100	100	700000
	22,752	22,652	22,552	22,452	22,352	22,252	22,152	

**Table 3- 15 Year Drought; Estimated Supply contraction Year 9- Year 15**

The five year drought is certainly severe, and a 22% to 25% reduction in flow is historically based, it is manageable, as the utility is able to compensate for river flow reduction by aquifer pumping and water in reservoir storage. Certainly, the ten year duration begins to strain the supply, again, it is manageable, in part due to interannual variability that give rise to peak flow conditions that replenish the reservoirs and related conditions. The most interesting of the three scenarios is the drought in excess of 15 years, even though the average annual flows may hover at a lower percentage rates, it still proves to be the most interesting as its cumulative impact on reduction to the water supply is the most severe. The case brought forward now in the discussion is hypothetical drought with duration of 15 years and a generally consistent reduction to the annual average water supply around 25%.

If the drought is prolonged, similar to conditions experienced in the 1950's and assuming that reservoir release is used to compensate for 50% of the water demand shortage, and 50% of the water supply shortage comes at the expense of each land use category. With the drawdown due to meet continued demand during drought conditions and evaporation the reservoir storage would be dangerously depleted by the 8<sup>th</sup> year and the performance severely curtailed by the 10<sup>th</sup> year. It is easy to roughly estimate two volume estimates corresponding to the first eight year period and years 9 through 15 to represent the total loss by land use category. Continued demand would outpace supply and reservoir storage would essentially be running at a 100,000 AF annual deficit for the remaining length of the drought. It is presumed that the Authority would return to pumping groundwater out of more than 90 wells developed in the Santa Fe Group within the Albuquerque basin aquifer to offset the drought losses. Since the basin and aquifer are hydrologically connected, pumping will not only lower the water table, it will also cause river water to infiltrate, thus recharging the aquifer. In fact, the productive zone is

smaller than originally estimated and the net effects of pumping will result in subsidence and higher operating costs such as energy and infrastructure decay. The losses of water to the urban land use category have been proportionately distributed over these two periods of time and converted with the unit volume price of lost sales for the period 2010. Years 1 through 8 have a water reduction of 400,000 AF, resulting from analogous, paleo droughts, however managed reservoirs, return to aquifer pumping, under a safe yield, and contribution from reserves to meet demand. For years 9 through 15, reservoirs, practically speaking are depleted, and the aquifer has reached its safe yield. Consequently, with a 15 year drought, the region will experience annual water deficits of 100,000 AF / year, or cumulatively, 700,000 AF for the last seven years of the drought.

In the year 2005, the ratio of urban land water use (135,000 AF) to all categories of land use (382,000 AF) for the four county area encompassing Bernalillo, Sandoval, Valencia and Socorro is approximately 35% (Brown, 1996) and used to represent urban / municipal use. To calculate the contracted annual supply, the proportionate coefficient for urban use is applied to the available supply under drought the equation, which is  $100,000 \text{ AF} \times 0.35 = 35,000 \text{ AF}$ .

For the purpose of determining the revenue loss, it does not matter whether the supply reduction is attributed to conservation, drought, and/or climate change. The supply reduction is substantial and from the scenarios and the water deficit compounds in its impact. Converting this four county contracted supply available is as follows:

$$35,000 \text{ AF per year} \times 326,000 \text{ Gallons/ AF} = 11,410,000,000 \text{ Gallons/ yr.}$$

Using the Utility commodity charge for water which is approximately \$1.41/unit , a constant, and where one unit equals 748 gallons, the calculated cost is derived by:

$$11,410,000,000 \text{ Gallons/year} \times 1 \text{ unit} / 748 \text{ gallons} \times \$1.41 / \text{unit} = 152,544,010 \text{ units} \times \$1.41 / \text{unit} \\ = \$21,508,155/\text{yr}.$$

This estimate was proportionately scaled down to exclude unincorporated/ non-service 2006 population for the Authority service area to come up with an Authority service area with a population of 530,000 or about 86% of the population of Bernalillo County. The 2006 Four County area population is roughly 817, 500. The total 4 county population, and represented by the total water losses, approximated by the 35,000 AF minus the proportionate share attributed to the Authority service area roughly 65% which converts to 22,750 AF or 7,416,500,000 Gallons/yr. The Authority's commodity charge estimate is:

$$7,416,500,000 \text{ Gallons} \times 1 \text{ unit} / 748 \text{ Gallons} \times \$1.41 / \text{unit} = \$13,980,300/\text{yr}.$$

This value is now used to demonstrate the business case impact of the contracted water supply.

## ***Business Case Development – Implications and Impacts of Drought and Aging Infrastructure to Projected Utility Revenue Shortfall***

With source water reductions either through conservation efforts or drought conditions, the impact response on the utility is strikingly similar. With conservation comes the paradox. Conservation saves water for future use that allows customers and the Authority to move towards a sustainable future water supply, however, it also reduces utility revenue. This reduction occurs because water revenues are commodity based, i.e. based on water sales to customers – less water sold equals less revenue to the agency; significant conservation means significant revenue loss unless user fees are increased. Similarly, reaction to climate change that may result in less surface water entering the supply area (watershed) and/or common drought effects will force the Authority to return to reliance on groundwater withdrawal from the existing well fields. Moderate to long term drought or climate induced flow reductions, puts the utility on a path which impacts both sustainability factors and revenue. When the system reaches a critical withdrawal, customers will be asked or required to curtail water use. The reduced sale of water, with respect to drought and conservation, leaves the Authority with less water revenue. This reduction in Authority revenue is compounded by the length and severity of the drought and/or drier climate, with reduced surface flows. Currently, no significant ‘fee’ is recovered to offset this loss, and it should be noted that the ‘conservation’ charge on the Utility water bill is not related to Authority (customer) conservation efforts and would be more correctly named State - mandated water testing fee.

### *Current Drought Management Strategy (2003)-Voluntary/Mandatory Conservation/Rationing*

The City of Albuquerque (COA), Public Works Department (PWD), prepared the Drought Management Strategy (February 2003), as directed under legislation, City Council Bill Number R-137, Enactment Number 4-2001. This mandated called for the PWD to first prepare three drafts and then through a citizen/ government task force develop the strategy and present it to City Council for approval. The task force developed a four stage drought warning system and enforcement system comprised of the following drought response measures to achieve target demand reductions (COA, 2001):

- Drought Advisory: 10,000 acre-feet/year; equivalent to 9 % of current production (voluntary conservation)
- Drought Warning - Stage I: 20,000 acre-feet/ year; equivalent to 17% of current production (Mandatory Conservation)
- Drought Warning - Stage II: 30,000 acre-feet/year; equivalent to 26% of current production (Mandatory Conservation)
- Drought Warning - Stage III: 40,000 acre-feet for one year, or 30,000 acre-feet;/year for more than one year; equivalent to 26% of current production. (Water Rationing)

The Drought Warning –Stage III level of 40,000 acre-ft/ year has a predicted frequency of occurring in any given year of 2%. The document states this amount of excess demand is expected to occur in consecutive years about once every 50 years. Some fee and surcharge assessments are associated with Drought Emergency – Stage III; water rationing would be used to alter economic behavior to achieve this demand reduction. Revenues may be generated from



some ratepayers/ customers paying a ‘Triple Surcharge’ or, “Doubling the water waste fees’ (COA, 2001), however, would have little financial impact. In fact, the data from this demand reduction option supports the effect of drought impact on sales and corresponding revenue shortfalls as mandatory water rationing/ curtailment would exceed 26% or 40,000 acre/ft /year. In essence, this four stage drought response is not focused on the financial concerns and revenue shortfall it is intended, primarily, to achieve the demand reduction appropriate for the amount of supply available. The existing Drought Management Strategy does not discuss what will happen in the event of a drought beyond immediate attempts to address the water shortage.

The immediate financial consequence of the long term severe drought conditions is reduced annual revenue of approximately \$14 million a year. Authority management will be faced with a shortfall, under current drought conditions, to pay expenses or related bond debt service. Adding in the conservation losses, could add another \$1 million/year. In general, the customary administrative response to reduced revenue includes: a cutback in activity (reduced customer service), labor reductions, defer capital project work to a future time, operation changes or increase revenue, such as rate increases to customers.

This paper now projects the revenue lost/shortfall by modeling the costs to repair/replace/ renew pipe (infrastructure), in order to develop policy options such as a rate increase or decrease in the level of service provided to customers.

To evaluate the impact on level of service provided by the Authority with respect to infrastructure and the capital spending necessary to sustain the utility, the study was limited to horizontal assets or pipe in the distribution system. The data utilized in the model was retrieved from the Authority’s GIS database and integrated into a customized model.

### *Model Development---Integrating GIS Produced Pipeline Analysis into an Economic Rehabilitation Model*

An essential part of our Asset Management planning is a pipeline rehabilitation program. The Water Engineering and Planning (WEP) Division has been working on creating decision support tools to help with the long term renewal and replacement of aging infrastructure, and in particular, underground pipe. This effort has led to the development of a model aimed to estimate and graphically represent funding required to meet pipeline rehabilitation. The model inputs are horizontal assets (pipe) and their attributes stored in the GIS database, as well as, Unit Replacement Costs (estimates) and Asset Economic Life Expectancy by Material Type. The management approach utilized to address this aspect related to the revenue shortfall is Asset Management and a Nessi-curve model that has been customized and applied to the asset category of pipes (ABCWUA, 2006).

The model allows the investigator to observe historical patterns of past expansions to the collection and distribution system by providing numerical results of interactions between certain variables. Currently, the utility industry is also working on new analysis presentations such as ‘dashboards’, ‘sensitivity dials’, and dynamic graphs. A new program developed by the Environmental Finance Center, Boise State University (EFC-BSU) is called “Financial Dashboard” (EFC-BSU, 2008) which gives utilities a view of the current and future financial status of their system using asset management and financial planning tools. Another EFC-BSU software program called “Rate Checkup” has been designed to do rate-setting and a three year financial planning and budgeting for small utilities. EPA Officials and State Agencies got a preview of these new tools at a Region 6 through 10 Capacity Development Workshop held in Albuquerque on November 5, 2008.

From the GIS database, water distribution pipeline segments were extracted, by length, size, material pipe type, and installation date for the entire system. These variables were then placed in Excel spreadsheet arrays. Simply stated, the data in the arrays were then inputted into replacement cost equations.

Certain assumptions were made to represent the asset condition, and more specifically the remaining useful life, for each pipe type based on experience and industry standards. For example, steel water pipe that was installed under normal field conditions is assumed to last for up to 50 years, and if older, would have deteriorated to the point of replacement.

The data is extracted from a partial model run (<1931 -1935) and is presented in a filtered form only showing attributes for 6-inch pipe (diameter), install date (year), pipe age, steel (material type), pipe length (feet), and the summation of pipe segment (feet) by age (see Table 4). This attribute data begins with 6-inch steel pipe segments having no identified install date (presumed to be before we have accurate records) followed by the years 1931 – 1935. However, the category showing “Cumulative Replacement Value” (see Table 4) in the partial table reflects the total value from the complete table for 6-inch diameter steel pipe found in Appendix A.

pipe type	2	STL (Steel)
pipe size	6	
Evaluation yr=	2005	
Life cycle yrs=	35	
Replaced Pipe Length =	103,839	
Unit Replacement Cost =	\$ 75.00	
<b>Cumulative Replacement Value</b>	=	\$ 7,787,925.00

Pipeline Inventory Data

Type	Date New	Material Type	Diameter Size (inches)	Length	Pipe Age	Replace
(Truncate)				450,975		103,839
2	1931	STEEL	12	1259	74	0
2	1932	STEEL	6	77	73	77
2	1934	STEEL	6	2294	71	2294
2	1935	STEEL	6	85	70	0
2	1935	STEEL	6	6569	70	6569

Table 4 -Cost to Replace Aging Infrastructure (sample model run data for 6-inch steel pipe)

Next is a portion of the data contained in the “look up” tables (see Table 5) showing cost per diameter form 4 inches to 24 inches and per foot to replace the pipe by the material type,

		Diameter (inches)	Diameter (inches)	Diameter (inches)	Diameter (inches)	Diameter (inches)	Diameter (inches)	Diameter (inches)	Diameter (inches)	Diameter (inches)	Diameter (inches)
0	Material Type (abbrev.)	4	6	8	10	12	15	16	18	21	24
1	RCP	\$0.00	\$0.00	\$80.00	\$90.00	\$94.00	\$100.00	\$110.00	\$110.00	\$116.00	\$124.00
2	STL	\$72.00	\$75.00	\$80.00	\$84.00	\$88.00	\$92.00	\$108.00	\$108.00	\$112.00	\$124.00
3	AC	\$0.00	\$75.00	\$80.00	\$84.00	\$88.00	\$92.00	\$106.00	\$106.00	\$112.00	\$124.00
4	CIP	\$74.00	\$76.00	\$82.00	\$88.00	\$92.00	\$98.00	\$112.00	\$112.00	\$116.00	\$126.00
5	DIP	\$74.00	\$76.00	\$82.00	\$88.00	\$92.00	\$98.00	\$112.00	\$112.00	\$116.00	\$126.00
6	PVC	\$70.00	\$74.00	\$78.00	\$84.00	\$88.00	\$92.00	\$106.00	\$106.00	\$112.00	\$122.00
7	CCYL	\$0.00	\$80.00	\$80.00	\$90.00	\$94.00	\$100.00	\$110.00	\$110.00	\$116.00	\$124.00
8	CMP	\$74.00	\$76.00	\$82.00	\$88.00	\$92.00	\$98.00	\$112.00	\$112.00	\$116.00	\$126.00
9	GSP	\$74.00	\$76.00	\$82.00	\$88.00	\$92.00	\$98.00	\$112.00	\$112.00	\$116.00	\$126.00
10	LWS	\$74.00	\$76.00	\$82.00	\$88.00	\$92.00	\$98.00	\$112.00	\$112.00	\$116.00	\$126.00
11	CPRLN	\$74.00	\$76.00	\$82.00	\$88.00	\$92.00	\$98.00	\$112.00	\$112.00	\$116.00	\$126.00

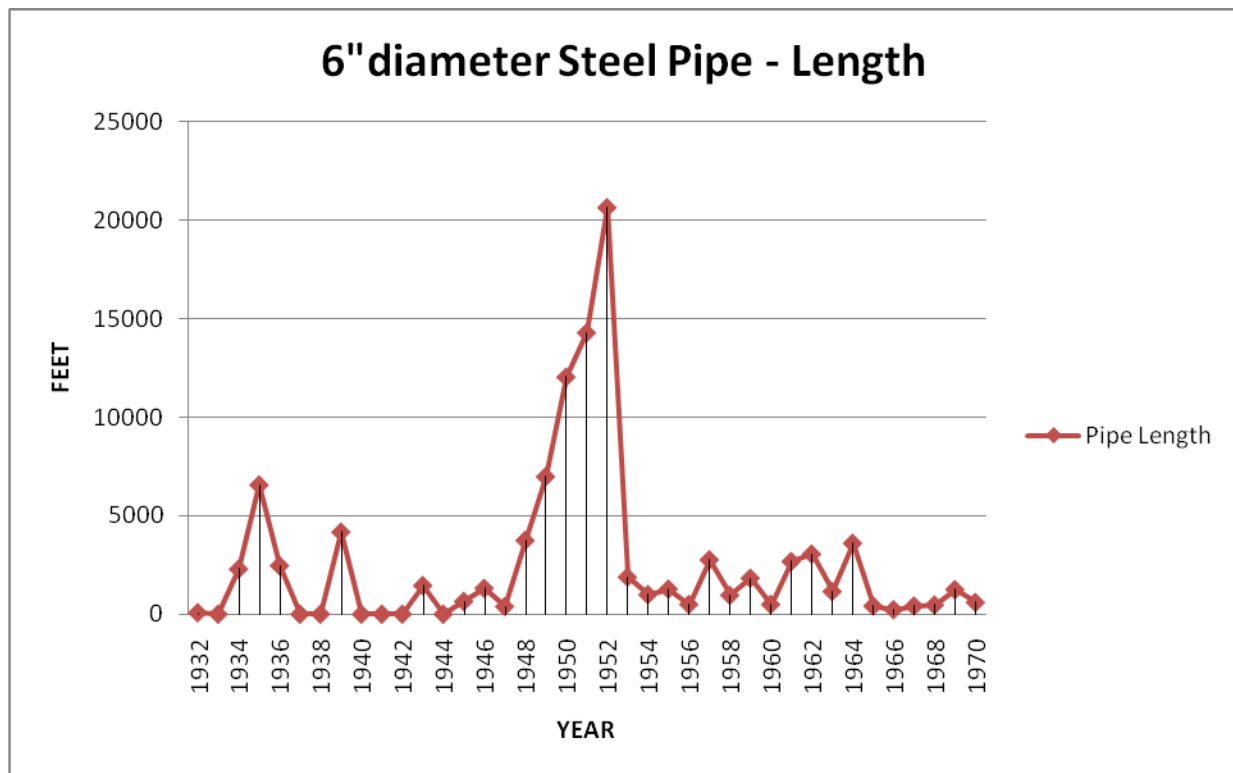
**Table 5- Look Up Table for Pipe by Diameter Size (x-axis) & Material Type (y-axis)**

Table 6 presents the life cycle, time in number of years, the material is expected to perform to its designed purpose. The life cycle value is used to subtract from the installation date to calculate the remaining life. The example is to formulate a replacement plan totaled through the next 15 years. Each same year segment is totaled and multiplied by the cost corresponding to the diameter of pipe.

Life Cycle			
Type No.		Pipe Material	Life Cycle- Years
1	RCP	Concrete or RCP	35
2	STL	Steel Pipe or STL	35
3	AC	Asbestos Cement or AC	40
4	CI	Cast Iron Pipe or CI	50
5	DIP	Ductile Iron Pipe or DIP	60
6	PVC	Polyvinyl Chloride or PVC	75
7	CCYL	Concrete Cylinder	40
8	CMP	Corrugated Metal Pipe	35
9	GSP	Galvanized Steel Pipe	35
10	LWS	Linear Wrapped Steel	35
11	CPRLN	Copper Line	35

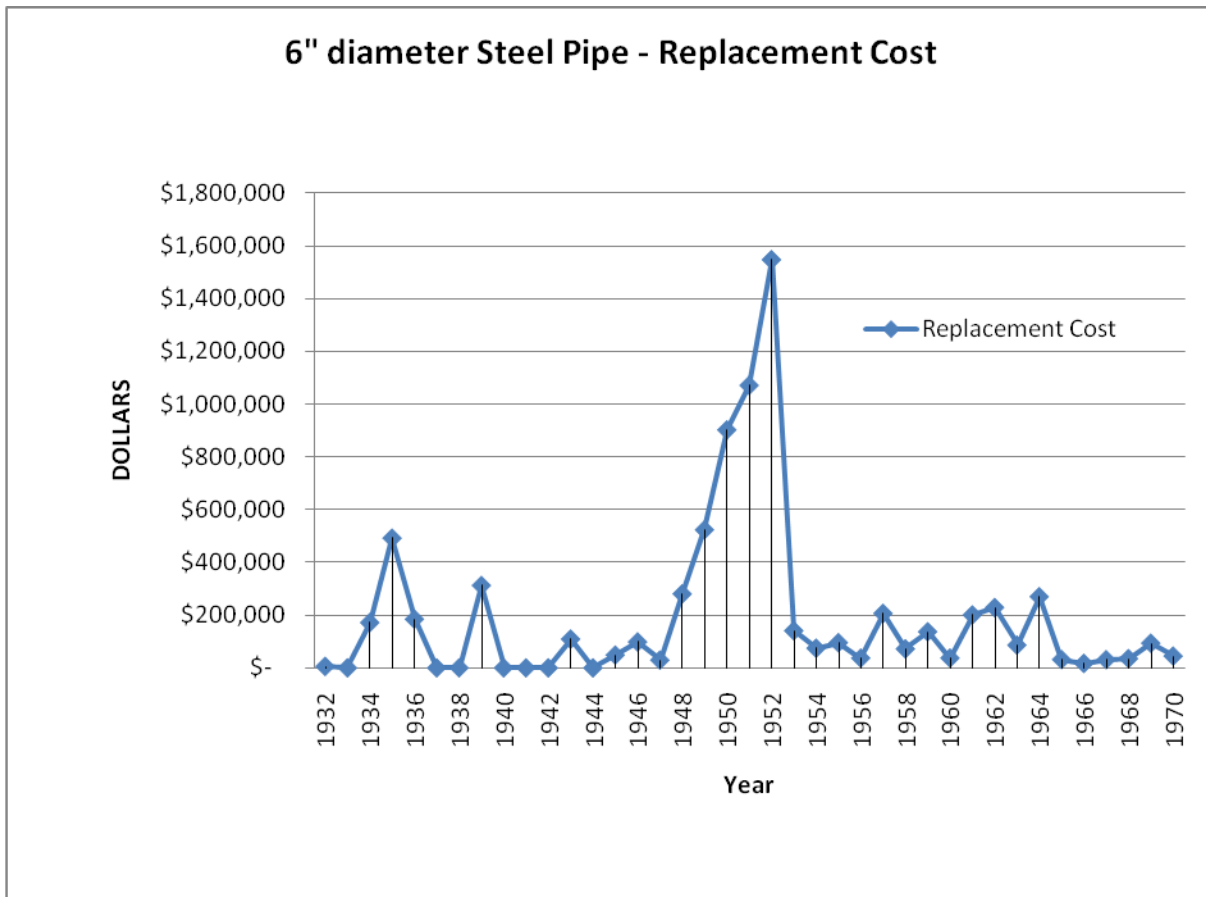
**Table 6- Look Up Table for Life Cycle: Material Type & Life Cycle**

Figure 8 presents the current in-ground, 6-inch diameter steel pipe segment length in a time series, which represents a 50+year history from 2005 back to the 1930's when the pipe was first installed. Of note is the amount of 6-inch steel pipe installed in the 1950's and 1960's.



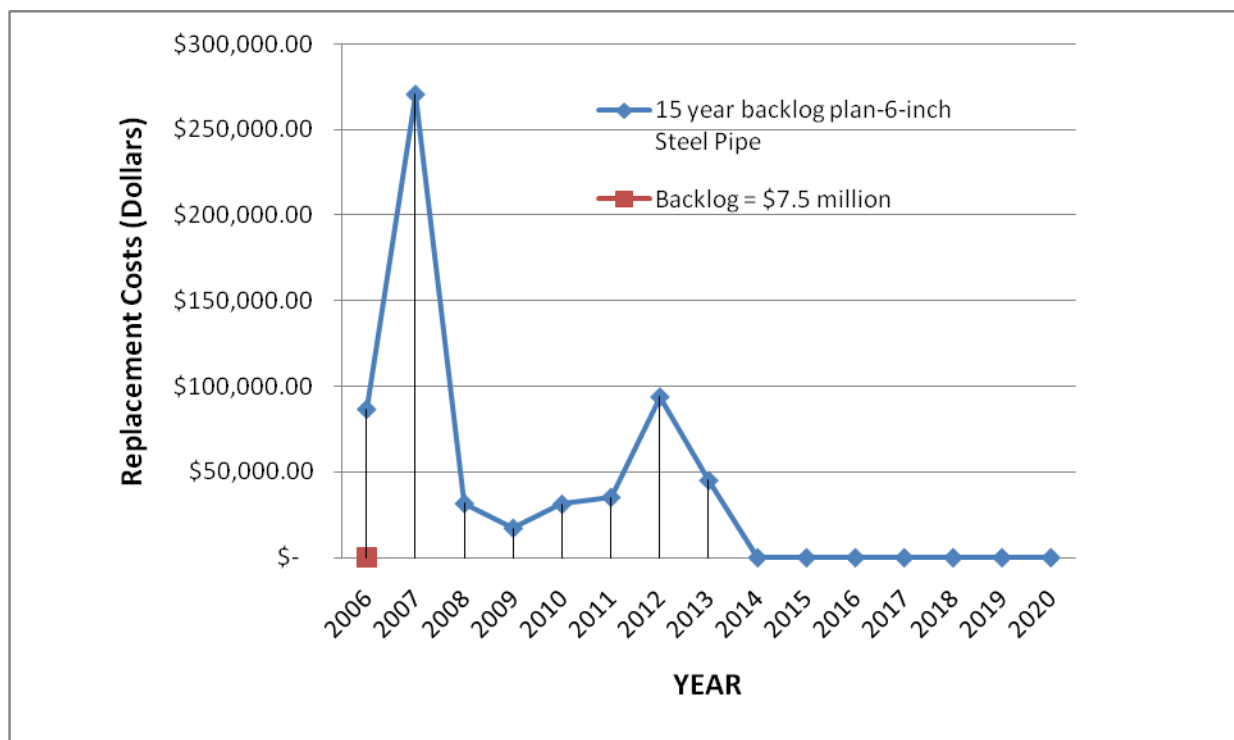
**Figure 8- Total Length of 6-inch Steel Pipe by Years in Ground, <1932-1970; source: Authority, 2005**

Figure 9 presents the cost, by year, estimated to replace deteriorated 6-inch steel water pipe. To calculate the cost to replace deteriorated pipe, the pipe segment length is multiplied by the corresponding 6-inch steel pipe cost (\$75/foot) found in the model's look-up tables (Life Cycle).



**Figure 9-Backlog Replacement Costs for 6-inch Steel Pipe, 1932-1970; source: Authority, 2005**

Figure 10, is a 15 year replacement plan, for 2005 through 2020, assuming that all 6-inch diameter steel pipe that has been in the ground more than 35 years is fully consumed and/or deteriorated to the point of replacement. The backlog cost to replace all pipe of greater age than the 35 year expected pipe life-cycle, 1931 through the year 2005 (the last year of full data), is approximately \$7 million and approximately \$600 thousand for pipe that will be consumed in each subsequent year until all pipe is replaced. The complete set of the model's tables can be found in Appendix A, and the cumulative sum of each year through the life cycle of every material type.



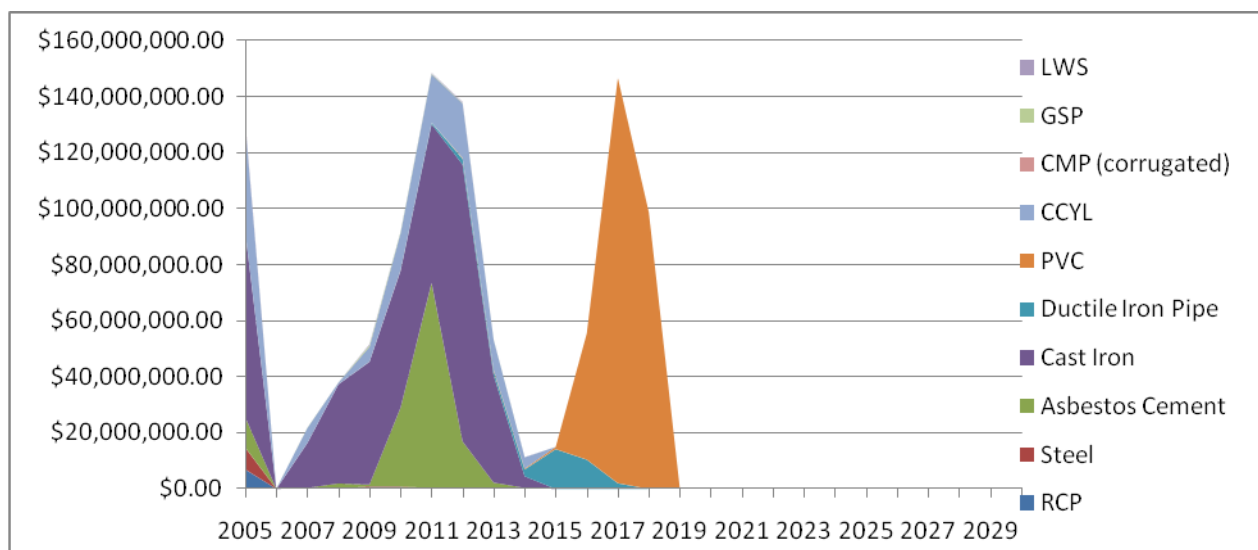
**Figure 10- Fifteen Year Plan...Backlog Replacement Costs for 6-inch Steel Pipe, 2005-2020**

In the following section, the data and model runs, extracted from Appendix A, are graphically presented by 'stacking' the graphs/curves for each and every material pipe type, into one graph, a view of total future replacement costs of these horizontal assets can be generated by using the complete GIS Data base and presented in the same model graphics.

### *Infrastructure Planning with Nessi-curve*

The Nessi-curve presented in this analysis for 6-inch steel pipe represents the deteriorating infrastructure for just one pipe type (steel) and size (diameter in inches). However, stacked Nessi-curves can also be employed to combine the total estimated pipe rehabilitation and replacement requirements for all water pipe. Planning for these requirements is documented and budgeted in the Authority's 2 year Capital Improvement Projects and the Decade Plan. In

summary, initial model runs demonstrate the need to continually replace deteriorated pipe installed prior to the 1960's and 1970's. Figure 11 is a modified stacked Nessi-curve. The curve, for our purposes, has been modified to show the total pipe replacement backlog, accumulated replacement cost, because much of authority's water pipe infrastructure has already exceeded its life cycle. Consequently, this customization of the curve alters the regular echo shape especially for the replacement backlog. The estimated replacement backlog is the \$120 million peak at the year 2005. Future replacement needs approaching \$900 million are shown in years 2006-2020. The rehabilitation cost is enormous to keep up which will reach \$1 billion over through the year 2020 (see Figure 8). The model is intended to both examine the backlog, consumed pipe, and pipe from 2005 forward. For this reason the model, reflects the methodology and calculates all pipe consumed before 2005 and then is reset to the zero, 2005, then future cash requirements are calculated 2005 forward. Another low point in the graph around years 2013 and 2014 reflects the life cycle of the material type and installation dates as well as a 15 year replacement plan.



**Figure 11- Stacked Nessi-Curves for all Material Pipe Types over 15 Years, 2005-2020**

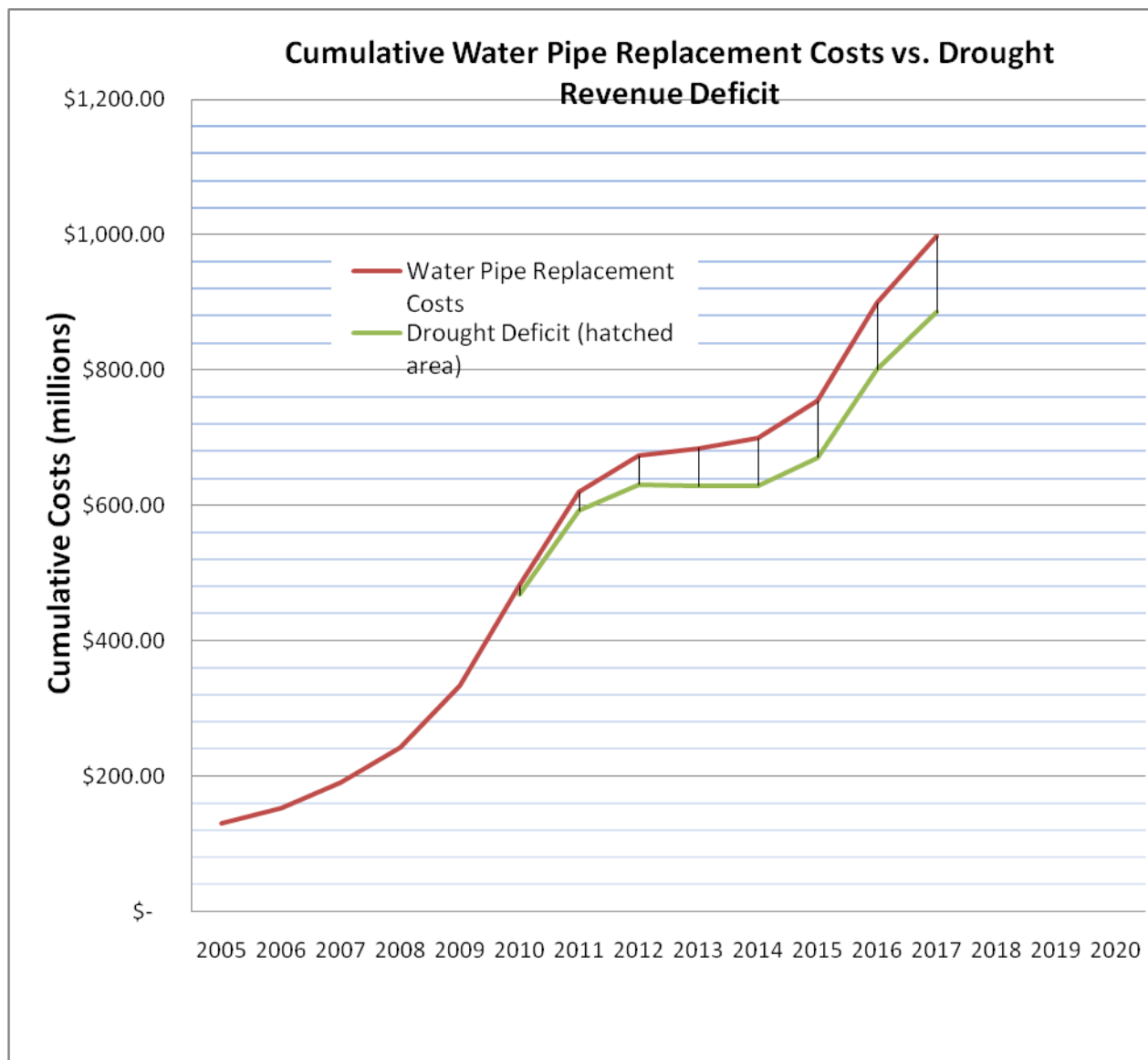


### *Cash Requirements for the Future*

To determine how much money the utility will need, the methodology utilized generalized predictive models or Nessi-curves, incorporating consumption of existing assets (pipelines), asset renewal needs and cash requirements. These were compiled into a stacked graph estimating a number of relevant cost categories.

At this point, each infrastructure category or program can be reviewed to determine the possible financial options, such as: reduce cost (if necessary) by reducing the level of service, debt/ future debt comparison, dispose of under-utilized and under-performing assets, manage demand for service (pricing, regulation), alter maintenance or operations, increase other income sources (grant funds), accept higher residual risk, rationalize/ prioritize project work in order of risk.

Figure 12, presents financial projections for the cumulative water pipe replacement costs and the projected dollar equivalent to a drought induced 25% reduction in water supply as discussed in previous sections above. The cumulative revenue effects (deficit) of a 15 year drought estimated at over \$100 million are plotted against the \$1 billion projected cash flow needed for pipe replacement. The combined effect is significant. Even if infrastructure is maintained well and greatly exceeds the expected life the replacement costs are large the revenue deficits brought about by the projected drought and mitigation and planning measures beyond those now in place are needed.



**Figure 12-Cumulative Water Pipe Replacement Costs vs. Drought Revenue Deficit, 2005-2020**

## **Critical Policy Issues and Recommendations**

So much more is possible, with respect to a long term view, with Nessi-curves, as is the case here, with the potential drought revenue deficits, because future financial need can be measured against other factors/circumstances. This research strongly suggests the need for the Authority to prepare for the financial effects and impacts from a prolonged drought and its ability to maintain sustainable asset infrastructure of the utility. In the event of a 25% shortfall of water availability through its ownership share of water rights, it would be necessary to consider both the current option to conserve more water and to resort to ‘Stage Four’- a regulated level of water use by all customers. This may be all that is needed to supply the most basic need- drinking water for customers but little else for outside use and growth. The \$110 million shortfall related to the 15 year drought unless made up in some form would be devastating to the operations of the Authority.

Perhaps, the easiest place to see the effect of this revenue drop is in the current annual funding level of Capital Improvement Program varies between \$30 and \$50 million a year. With a reduction in revenue, much of the required work would be deferred and much of the infrastructure would fail prior to replacement. Critical infrastructure, if it failed, could cause significant consequences, such as 6-inch inch steel pipe, which is needed for fire protection and also customer water delivery. Generally, replacing or repairing critical infrastructure after it has failed is more costly.

In addition, a very uncertain future is created due to spiraling costs for the Authority, as other infrastructure continues to be strained and moves toward a condition of failure. The cost to repair failed infrastructure is often higher than intervening before it wears out. Intervention at

the optimal point in time can substantially lower the full cost of ownership of assets and would be a normal response if adequate funding is available.

New water rights are continually being purchased or leased by the Authority from sellers in the area, however, this option also becomes more difficult as it is expected that the cost of water rises in response to demand. But in reality, little water has been purchased over the past 20 years and it appears that water transfers are becoming more difficult as water concerns grow. Water purchases from other sectors, such as agriculture, will drive demand further, and cost will increase. It is already established that the transfer to urban use from agricultural use has not been favorably accepted from certain segments of the valley population such as farmers, environmental groups, and Native Americans. It is unclear as to the impact the Authority would have if it attempts to make up water shortfall by major new purchases in the region, and it will have to deal with the issue of less money for acquisition. Adverse impact on agricultural production in the region and ecological imbalance has been cited by Water Assembly Workshops and Surveys. With dwindling revenue and cash reserves, it does not appear feasible to make up the shortfall with water purchases and leases even if water was available from other sectors. The cost to purchase a perfected water right (one acre-foot of water) varies from \$7,000 to \$25,000 per acre-foot. Consequently, the annual cost to fully make up the 23,000 AF drought loss would be about \$230 million using a conservative price of \$10,000 / AF.

Strategies to utilize wastewater and low quality industrial reuse water are already implemented and there are plans to fully expand to capture this category of water. It is difficult to calculate any of the net gains in order to compensate for drought as much of this water is already credited to the water system through 'return flow credits' when the treated wastewater is discharged to the river.

### ***What are the options? To prepare / plan for impact due to drought***

Steve Reynolds, former NM State Engineer is often quoted for his axiom that ‘water runs uphill to money.’ The truth and simplicity in his words are that much can be done to overcome the natural, economic, and financial obstacles to obtain legal rights to water with a ‘fat wallet’. This statement also challenges the concept that water should be analyzed as though it is a finite resource, but rather suggests the importance of analysis to place the economy of the area/cost of water in its relative importance to water supply and concludes that water suitable for any purpose can be obtained (renewable supplies) and is only a function of cost. The premise that water can always be obtained and this is only a function of the person’s ability to pay for water should seriously be considered as a desirable management and a policy option to combat drought. The other factor that should also be remembered, in the cultural context, for this region’s water economy, is that it is dominated by a utility which operates as a monopoly and not in a ‘free market’ setting.

### ***Secure and Sustainable Water Supply and Water Resource Infrastructure in an Uncertain Future***

The San Juan /Chama project in conjunction with ground water wells in the Albuquerque Basin in the short term may be adequate to provide water to meet the projected demand. For a short term drought event with the weak financial outlook presented, herein, limit the real options available to respond to a contracted water supply. This situation only adds to the urgency to prepare in advance for this adverse situation. Perhaps for 5 to 7 years following the implementation of San Juan Chama water treatment plant and the return to ground water exploitation, the impact of drought will become manageable. However, greater uncertainty hinges when the severity of the compound effect of a release of water from storage reservoirs,

ground water withdrawal from the aquifer is strained beyond replenishment, land subsidence impacts development and conservation reaches saturation effect due to prolonged drought.

### ***Management Options-Asset Management and Legislation (Rate Structure Changes)***

The response options are combinations of aggressive and less aggressive options. The main categories that require our attention are management, specifically, asset management, financial and policy, followed by technical/operational elements. This list of options examined for this paper is meant to be exclusive of programs and strategies already implemented and in progress by the Authority such as Conservation and Aquifer Storage and Recovery. Efforts that may include related but less developed programs, such as Water Banking, are incorporated to the future options to respond to drought.

### ***Costs and Rate Implications***

The drought and pipe replacement scenarios outlined above imply a total cost of about \$110 million and \$1 billion, respectively. Practically speaking, project phasing and the time required to gain public support and political will mean that not all capital and funding needs will or can be obtained immediately. This also makes it possible to gradually approach or phase in rate increases. The rate increases proposed to make up for the drought deficits are minimal when planned and applied across the entire customer base. This proposal calls for increasing rates by approximately by \$5.30/month for each of the 190,000 customers, over a period of ten years . This is equivalent of increasing the typical monthly charge to that of two gallons of gasoline for your car each month. Even with this new monthly charge the utility rates will remain competitive with utilities in the neighboring areas and region. To meet the need to replace aging infrastructure is discussed following sections.

A rate structure to service the debt, for the estimated \$110 million (Table 7), over a 10 year time period, at very conservative 1 % interest rate, would mean an annual sinking fund payment of just under \$8 million per year. To the approximately 190,000 existing customers (includes estimate for recent acquisition of New Mexico Utility customers), this is a rate increase of about \$63 per year or a monthly increase to the base charge for water of around \$5.25. Using the average residential class usage of 7 units, customer monthly billing water/wastewater charge is around \$37.39 (Oral Communication, Gerald Chavez, Division Manager, Customer Services, ABCWUA, 6/2009,). This price change would require an Authority Board increase to the rate structure of less than 15 % and would bring the monthly water bill to about \$42.70.

Fund Schedule								
Initial Yr Payment (Y/N) =			N	P =	\$110,000,000			
				i =	0.01	(single or		
	Trial Initial Paymnt =		\$11,614,028	n =	10.0	variable)		
	A = (Beg Yr)		11,485,614	A = (End Yr)	11,614,028.4			
Pay No.	Principal Remaining	i Rate %	Interest Paid	Principal Paid	Payment Due	Principal Balance	Principal To-Date	Interest To-Date
1	\$110,000,000	1	\$1,100,000	\$10,514,028	\$11,614,028	\$99,485,972	\$10,514,028	\$1,100,000
2	\$99,485,972	1	\$994,860	\$10,619,169	\$11,614,028	\$88,866,803	\$21,133,197	\$2,094,860
3	\$88,866,803	1	\$888,668	\$10,725,360	\$11,614,028	\$78,141,442	\$31,858,558	\$2,983,528
4	\$78,141,442	1	\$781,414	\$10,832,614	\$11,614,028	\$67,308,828	\$42,691,172	\$3,764,942
5	\$67,308,828	1	\$673,088	\$10,940,940	\$11,614,028	\$56,367,888	\$53,632,112	\$4,438,030
6	\$56,367,888	1	\$563,679	\$11,050,350	\$11,614,028	\$45,317,539	\$64,682,461	\$5,001,709
7	\$45,317,539	1	\$453,175	\$11,160,853	\$11,614,028	\$34,156,686	\$75,843,314	\$5,454,885
8	\$34,156,686	1	\$341,567	\$11,272,462	\$11,614,028	\$22,884,224	\$87,115,776	\$5,796,452
9	\$22,884,224	1	\$228,842	\$11,385,186	\$11,614,028	\$11,499,038	\$98,500,962	\$6,025,294
10	\$11,499,038	1	\$114,990	\$11,499,038	\$11,614,028	\$0	\$110,000,000	\$6,140,284

Table 7- Sinking Fund Schedule to Recover 'Unrealized Income' Due to Drought

With cost to replace aging water pipe approaching \$1 billion, the Authority is relying on implementing to Asset Management best practices to lower the cost of ownership and capital replacement in hopes of achieving 30-35 % savings. In addition, past operations have also used various finance strategies to fund capital replacement programs such as reducing the debt service, grants and loans as well as utility expansion charges/fees (UEC's) and general revenue. The annual current capital spending level is around \$48 million, but generally annual program spending has averaged about \$30 million for all capital including water, wastewater, IT and customer services. For the Decade Plan (ABCWUA, 2009) the total for the next ten years is around \$480 million. The plan has programmed about \$10 million a year to replace water lines or about 10-20% of the backlog. It appears that a more detailed study is needed to identify all funding sources in order to keep pace with the rate of decay of water pipe. At first glance, the total programmed capital budget would meet less than 50% of the future cash requirement for even water pipe. However, it is unclear as to any general revenue forecasted capital shortfall and ability to acquire capital funds due to the number of funding sources available to the ABCWUA Board and their authority to control spending levels. Asset Management is one of primary steps the Authority is taking to address this problem. The other is to raise the annual level of capital spending to pay for the backlog of aging pipe, which is the end result from the years of underinvestment.

At the direction of the Authority, the Engineering and Planning Section, developed Goal 4- Objective 1, in accordance with the 2005 Business Objectives for the Comprehensive Development Plan (see Appendix B) which was adopted by the ABCWUA. The plan, in part, is set out below. The development of the plan is in various stages of implementation (and appended to this report). The main recommendations for Asset Management:



- Manage Critical Assets for sustainability – Construct and Expand Nessi-Curves for all critical Assets to predict financial needs minus shortfall needs.
- Identify Critical Assets to provided the desired level of service
- Collect data and evaluate remaining life of desired assets
- Determine Customer desired ‘level of service’ and willingness to pay for services
- Evaluate and determine the Risk of the critical assets expressed as the intersection of Probability of Failure and Consequence of Failure
- Prepare a strategy to finance the critical assets required to deliver water/sanitary/wastewater/ reuse services. This is the culmination of Nessi – curves developed for the critical assets stacked on the time series graphs for the long term.

### ***Recommendations***

The region’s population has increased which creates increased water demand. Historical and tree- ring findings based reconstructions foreshadow more severe droughts and climate models predict increased temperature. Conservation practices will extend water supplies, but with limitation and paradoxical fiscal consequences, and the Authority’s infrastructure is in need of costly replacement. This paper has demonstrated that under severe drought conditions and the aging infrastructure suggests considerable fiscal constraints and vulnerability - ranging from just over \$1 billion, to keep pace with critical infrastructure replacement costs, and another estimated \$110 million to cope with severe drought in coming years.

The Authority has established the Capital Planning process to address the annual infrastructure need. However, with population increases, and the rate of decay of this infrastructure, it remains a substantial challenge to keep up with the fiscal needs. Adding the unpredictability, yet certainty, of a drought, with substantial cost implications appears to require not only stronger commitment to fiscal capital planning, but additions to cash reserves in order to withstand the impact of a significant contraction of the water supply.

As outlined here, it is evident that several activities in accordance with the Authority's adopted Water Resources Strategy (Mayors Review Draft, 1997), must be continually be updated, such as to define performance measures and guidelines for the establishment and maintenance of the drought reserve. This paper proposes the further development of this concept to include the financial equivalent of the physical reserve to include building a cash reserve. Another activity must be to spare the ratepayer from the vulnerability to drought, as was also stated in the Water Resources Management Strategy (WRMS), is "Conduct rate studies and adopt new rate structure that fairly distributes the cost of providing a sustainable water supply" (COA, 1997). It has become clear with the rate and cost analysis that a rate structure change should be enacted to increase the average customer monthly rates by less than \$6, which appears to satisfy the fiscal need and the money is placed in a reserve fund. It is simple, doable and, in accordance, with many of the community values of water and the cost of other basic needs.

The plan, as with capital planning, requires understanding of the consequences of drought and cost to replace aging infrastructure, sensible planning, political desire and impetus to enable legislative changes to the rate structure and a 15 year commitment to save and earmark the money for this purpose.

Along with the rate increase option, there must be requirements such as legislation and rules and regulations to protect the corpus of the sinking fund for its specific establishment and use to alleviate the potential disastrous impact and vulnerability to prolonged drought conditions. To insure the success of the long term savings and prohibit this money's use for other 'emergencies'. The following measures are suggested:

- Create Enabling Legislation to establish a \$110 million Permanent Drought Fund (FUND)/'Rainless Day' Act that will permanently 'lock' expenditures from Corpus of Fund and establish conservative investment criteria.
- Distribution/ withdrawals from FUND only from interest earned and only for times / durations beyond 7 years and / or reservoir storage levels below 20% 'dry' indexing
- Permanent Fund distribution and withdrawal exceptions permitted with 2/3 rd approval of rate payers and Governing Body
- New supply purchases and infrastructure (desalination plants foreign and domestic, storage, pipeline, water right acquisition) to bring supply to the Utility
- Match to acquire federal, state funds for purchase of new supply
- Prohibit withdrawals from FUND for purchases related to eminent domain and utility mergers and acquisition
- Enhance stability of FUND with one time appropriation injection from State of NM.  
Earmark the cash reserve and trigger the opening of the account utilizing federal or state drought monitoring agencies and index severity such as Palmer Index

- Allow Third Party transfer of water to facilitate more efficient use; but do not do away with impairment rules and protest hearings that are in place to protect small communities and farmers. Continue to limit eminent domain actions outside service areas.
- Continue to develop Aquifer Storage Opportunities in times of plentiful water supply

## ***Conclusion***

Under drought conditions a more robust drought management strategy is necessary to ensure future water supply, and to meet the forecasted water demands and infrastructure needed to deliver water. Southwestern drinking water supplies are scarce, growing populations are fueling demand for water. The looming prolonged drought coupled with climate change has the potential for a pronounced impact on the business side of utilities to generate revenue from the sale of water service. Revenue loss limits management options to obtain quality water, provide adequate infrastructure to deliver water, and rehabilitate and replace infrastructure to sustain the desired level of service for a growing population. The expected revenue loss attributed to a prolonged drought and cost to replace the Authority's aging infrastructure is estimated to be \$110 million and \$1 billion, respectively. It is recommended that the option to address the fiscal impacts of drought is creation of reserve fund. A rate increase of less than \$6 to the monthly average customer water bill, if saved, would amass more than \$110 over a 15 year period, or enough to match the revenue loss due to a prolonged drought. Nessi-curve construction for pipe used in the delivery of water has revealed the considerable cost of the utility to replace the aging pipe infrastructure. This infrastructure will also require substantial financial commitment and Asset Management. Nonetheless, the Authority must show increased attention to the possibilities of drought and account in the rate pricing structure to fully recover the cost of the

Utility's required levels of service to the customer and address the realities of the region's limitations to reliably supply water.

## **Glossary of Terms / Acronyms**

ABCWUA- Albuquerque Bernalillo County Water Utility Authority (Authority)

BAU- Business As Usual

COA- City of Albuquerque

CRB- Colorado River Basin

GCM- Global Climate Mode

GCT- Grand Canyon Trust

GIS- Geographic Information System

IPCC- Intergovernmental Panel on Climate Change

MRCOG- Mid Region Council of Governments

NMAC- New Mexico Administrative Code

NMOSE- New Mexico Office of the State Engineer

USBOR- United States Bureau of Reclamation

USDOE-United States Department of Energy

USDOI- United States Department of the Interior

USEPA- United States Environmental Protection Agency

USGS- United States Geological Survey

## **Acronyms**

AF	acre-feet
CFS	cubic feet per second
G	gallons
GPCD (gpcd)	gallons per capita per day
GW	ground water
MAF	million acre-feet
MGD	million gallons per day

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**Appendix A (see disc / back cover)**

**Appendix B (see disc / back cover)**