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Converting turfgrass to xeriscape: Evaluating Southern Nevada water authority's "Water smart program"

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Evaluating Southern Nevada Water Authority's "Water Smart Program"

By

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ABSTRACT

Southern Nevada Water Authority:
Xeriscape

This study evaluated the use and effectiveness of the Xeriscape Conversion program, dubbed the "Water Smart Program," administered by the Southern Nevada Water Authority. The Conversion program is used by five water purveyors throughout Southern Nevada. Because of phenomenal growth in the area, water has become one of the most valuable resources. With its limited availability, conservation has become the logical solution to ever increasing demand.

Using empirical data, effectiveness of the program was evaluated in areas such as: water savings after xeriscape conversion; maintenance savings after conversion; the influence of system design on water consumption; and the long term savings potential of xeriscape versus traditional turfgrass.

Changes made to the program by SNWA were examined in this paper to determine their effectiveness in keeping pace with growing demand.

INTRODUCTION

In this study is an evaluation of the effectiveness of the Southern Nevada Water Authority's Xeriscape program. Conversion of existing turfgrass to desert-type landscape is a relatively new idea. With the explosive growth of desert communities, water as a resource has climbed to the top of the list of commodities which could hinder growth. Demands from the population well exceed the yearly rainfall and alternative sources of water must be explored. As well as alternative sources, conservation of existing sources must be explored, as it makes sense to conserve what exists currently.

With the help of many employees of the SNWA, this study covers an explanation of the need for conservation in the Las Vegas area, a brief history of xeriscape, and the impact that xeriscape conversion has had on water conservation in Las Vegas. I accompanied Hillery Leslie, an intern in the Residential department of SNWA's Conservation Division, headed by Doug Bennet, on a field visit to several participants of the 'Water Smart Program' on February 23, 2005, and Lou Reinbold, an intern with the Multi-family/Commercial department, on February 25, 2005. These were valuable sources of information because I got to witness firsthand the 'before' and 'after' of the program, for not only private residences, but apartment complexes as well. While these site visits answered some questions, they also served to add to my list of un-answered questions. These questions were more suited for Kent Sovocool, the Conservation Programs Coordinator and analytical guru of the division, whom I met with on March 11, 2005.

LITERATURE REVIEW

The Colorado River serves is the main source of water for many of the communities of the southwestern United States, permitting society to flourish, despite the harsh, arid conditions that often define it. It serves the needs of millions within the region and its yearly volume is entirely divided up by the Colorado River Compact (1922) and subsequent legislation and legal decisions, known as the "Law of the River" that specify allocations for each of the states (and Mexico) through which it flows. Among other things, the United States Bureau of Reclamation – Lower Colorado Regional Authority (USBR-LCRA) is charged with maintaining an adequate and established allocation of water for each of the states in the arid Lower Basin. Since water demand management is ultimately accomplished at local levels, USBR-LCRA actively partners with entities that divert Colorado River water to encourage conservation. In southern Nevada, the major regional organization meeting this criterion is the Southern Nevada Water Authority (SNWA) (SNWA Five-year Study).

In 1991 the SNWA was established to address water on a cooperative local basis, rather than by the five different water purveyors providing potable water to most of Clark County. The SNWA is committed to managing the region's water resources and to developing solutions that ensure adequate future water supplies for southern Nevada. The member agencies include the Big Bend Water District, providing water to the community of Laughlin; the cities of Boulder City and Henderson, providing water to their respective communities; the Las Vegas Valley Water District, providing water to the City of Las Vegas and to portions of unincorporated Clark County; the City of North Las Vegas, providing water within its boundaries and to adjacent portions of unincorporated

Clark County and the City of Las Vegas. The SNWA member agencies serve approximately 96% of the County's population. As southern Nevada has grown into a metropolitan area and a world-famous vacation destination, so too have its water needs. The SNWA was created to plan and provide for the present and future water needs of the area (SNWA.com).

Southern Nevada's climate is harsh. The Las Vegas Valley receives on average only 4.5 inches of precipitation annually (Vegas.com), has a yearly evapotranspirational (ET) water requirement of nearly 90 (SNWA Five-year study), and it is one of the fastest growing metropolitan areas in the United States (Vegas.com). Clark County, the southernmost county in Nevada, has a population in excess of 1.6 million people and has been experiencing extremely strong economic growth in recent years with correspondent annual population growth averaging in excess of five percent (Sfgate.com). The primary economic driver of Clark County's economy is the tourism and gaming industry with an annual visitor volume in excess of 30 million people per year (LVCVA.com). Today more than 7 out of every 10 Nevadans call Clark County home.

The evapotranspirational requirement of 90 inches is the amount of rainfall that the Las Vegas area would need in order to meet all requirements without any other source of water. Because an average of only 4.5 inches is provided by rainfall, additional sources must be found, such as the Colorado River. The water of the Colorado River is allocated among its bordering states and is governed by the United States Bureau of Reclamation – Lower Colorado Regional Authority (USBR-LCRA). In 1964 the Supreme Court decided in Arizona v. California (SNWA Five-year Study) the Lower Basin apportionment of 7.5

million acre feet (MAF) among Arizona, California and Nevada, including Nevada's consumptive use apportionment of 300,000 acre feet per year (AFY) of Colorado River water as specified initially in the Colorado River Compact (1922) and Boulder Canyon Project Act (1928). However, the amount withdrawn from the Colorado River may exceed 300,000AFY by the amount of treated water that is returned from the area. This credit for the returned water is termed Return Flow Credits. Return flows in Nevada consist mainly of highly treated Colorado River wastewater that is returned to Lake Mead and to the Colorado River at Laughlin, Nevada. With return flow credits, Nevada can actually divert more than 300,000 AFY, as long as the consumptive use (use where Colorado River water does not return to the Colorado River) is no more than 300,000 AFY.

Consumptive use is of paramount interest to SNWA. Since Colorado River water makes up roughly 90% of SNWA's current delivering water resource portfolio, it means that in terms of demand management, reduction of water used outdoors (i.e. water unavailable for accounting as return flow) is much more important in terms of extending water resources than reduction of indoor consumption at this point in time.

Since most of the SNWA service area contains relatively scarce local reserves (there are little surface or groundwater resources) and since, as explained above, its Colorado River apportionment is limited, the organization has an aggressive conservation program that began in the 1990's. The Authority has been committed to achieving a 25% level of conservation (versus what consumption would have been without conservation) by the year 2010. In 1995, the SNWA member agencies entered into a Memorandum of Understanding (MOU) regarding a regional water conservation plan. The MOU, updated in 1999, identifies specific management practices, timeline and criteria the member agencies agree to follow in order to implement water conservation and efficiency measures.

The programs or Best Management Practices (BMPs) listed in the MOU include water measurement and accounting systems; incentive pricing and billing; water conservation coordinators; information and education programs; distribution system audit programs; customer audit and incentive programs; commercial and industrial audit and incentive programs; landscape audit programs; landscape ordinances; landscape retrofit incentive programs; waste water management and recycling programs; fixture replacement programs; plumbing regulations and water shortage contingency plans. The BMPs provide the framework for implementing the water conservation plan and guidance as to the methods to be employed to achieve the desired savings.

As a conservation tool, Xeriscape was extremely promising, and several studies were conducted in the 1990's (Bent 1992; Testa and Newton, 1993; Nelson, 1994; and Gregg, 1994). The studies showed a range of water savings between 25% and 42% in the residential sector. The reason for the great variation in savings is due to the large number of variables ranging from the different climates of each study's locality to the methodologies employed. The SNWA is currently conducting a study into the effectiveness of the Xeriscape program funded mainly by the Bureau of Reclamation.

Although the report is not yet published (Interview, 3-11-05), Kent Sovocool, SNWA's Conservation Programs Coordinator, and one of the authors of the report, provided a majority of the collected data and analysis for inclusion in this study.

REASEARCH OBJECTIVES

The potentially large water savings attainable with the broad-scale use of xeriscaping and the fact that associated reductions are in consumptive use water makes xeriscape of paramount interest for both USBR-LCRA and SNWA. For this reason, a partnership between the Bureau and SNWA was formed to investigate the savings that could be obtained with a program to encourage converting traditional turfgrass landscape to xeriscape. Known as the SNWA Xeriscape Conversion Study (XCS) the objectives of the Study are to:

- Objective 1: Identify candidates for participation in the Study and monitor their water use.
- Objective 2: Measure the average reduction in water use among Study participants.
- Objective 3: Measure the variability of water savings over time and across seasons.
- Objective 4: Assess the variability of water use among participants and to identify what factors contribute to that variability.
- Objective 5: Measure the capital costs and maintenance costs of landscaping among participants.
- Objective 6: Estimate incentive levels necessary to induce a desired change in landscaping.

METHODOLOGY

Study Groups and Monitoring

The study team recruited participants who dwell in single-family residences within the following entities' water jurisdictions: The Las Vegas Valley Water District (77% of the participants in the entire study group), Henderson (12%), North Las Vegas (9%), and Boulder City (2%).

There are a total of three groups in the XCS, the Xeriscape Study (XS) Group, the Turf Study (TS) Group, and a non-contacted Comparison Group. The XS Group is composed of residents who converted at least 500 square feet (sqft) of traditional turfgrass to xeric landscape as well as residents who installed new xeric landscaping. To clarify, in this region, xeric landscaping is principally composed of a combination of desert-adapted shrubs, trees, some ornamental grasses, and mulch (often rock). A $0.45 per square foot incentive helped the property owner by absorbing some, but not the majority, of the cost of the conversion. Homeowners were required to plant sufficient vegetation so that the xeric landscape would at a minimum have 50% canopy coverage at maturity. This avoided the creation of unattractive "zeroscapes" composed exclusively of rocks, which could potentially act as urban heat islands. The incentive was capped for each residence at $900 for 2000 sqft; however, many residents converted much more. Indeed, the average area converted in this study group was 2162 sqft. A total of 472 properties were enrolled in the Study as XS Group participants. Aerial photographs, supported by ground measures, were used for recording areas. As a supplement to the main experimental group, 26 multi-family and commercial properties were submetered as well.

In return for the incentive, XS Group residents agreed to ongoing monitoring of their water consumption. This was accomplished two ways. First, mainmeter data was taken from standard monthly meter reading activity (this was for assessing water use at the entire single-family residence level). Second, residents agreed to installation of a submeter that monitored irrigation consumption on a portion of the xeric landscape. Submeters were typically read monthly, as with mainmeters and were used to study per unit area application of water comparatively. The area monitored by the submeter was called the Xeric Study Area. Study areas were tied to irrigation zones and stations. Virtually all study properties had in-ground irrigation systems and controllers because the presence or absence of these could affect the amount of water used for irrigation. This experimental control is important because it has been noted that the presence of automated irrigation is highly associated with increased water usage for residential properties (Mayer and DeOreo, 1999) apparently because such systems make irrigation more likely to occur regularly versus hand-watering. Having participants in both groups possess automated systems also avoids the potential bias of more heavily turf-covered properties being more likely to be fully automated, and thus having higher consumption for this reason as was the case for Bent 1992 (as identified in Gregg et. Al. 1994). All areas of each property were broken down into landscape categories. For example, a XS Group property might have monitored (via the submeter) xeric landscape and unmonitored xeric, turf, garden, and other (non-landscaped) areas. Square footages were recorded for each of these respective area types.

In addition to water consumption monitoring, residents agreed to a yearly site visit for data collection purposes. During site visits, information was collected on the xeric species present, plant canopy coverage at the site, components of the irrigation system and per station flow rates.

Staff trained in the identification of locally used landscape plants collected data on plant size and species present. Plant canopy coverage was calculated by first taking the observed plant diameters, dividing this number by two to get radius, then applying the formula for getting the area of a circle ($A=\pi r^2$). This area result was then multiplied by the quantity of those species of plants observed to be at that size. The summation of all areas of all plants of all size classes in the study area is the total canopy coverage for that area.

Data on the components of irrigation systems was collected by staff trained in the different types of irrigation emitters available (ex. drip, microsprays, bubblers, etc.). Staff then ran individual stations and watched meter movement to get the per station flow rates.

The Turf Study (TS) Group is composed of properties of more traditional landscape design where an average 2462 sqft of the landscaped area was of traditional turfgrass (most commonly fescue). Mainmeter data was collected in the same manner as for the XS Group. Due to design challenges, the submeter was more commonly hooked to monitor a mixed type of landscape rather than just turf, though many did exclusively monitor turf (only "exclusively turf" monitoring configurations were used in per unit area landscape analyses). TS participants enrolled voluntarily, without an incentive and agreed to yearly site visits as above. Other data on irrigation systems was collected in a manner similar to that for the XS Group properties. A total of 253 residences were recruited into the TS Group.

Because enrollment of participant residences into the XS and TS Groups was directly dependent on homeowners' willingness to participate in this study, sampling bias was a potential concern. To address this, a third subset of non-contacted Comparison Groups was created to evaluate potential biases. Comparison properties were properties with similar landscape footprints and of similar composition to the TS group and pre-conversion XS Group and were in the same neighborhoods as these treatment properties. This control group was also subject to the same water rates, weather, and conservation messaging as the treatment groups. This group also provided for evaluation of the combined effects of submetering and site visits on the treatment groups.

General Data Methods, Strategies, and Statistics

Several different data analysis methods were applied in the course of the SNWA study. Details of each can be found in the corresponding subsections below. Broadly, analysis methods fell into the categories of pre- vs. post-treatment evaluations, comparative analyses of different treatment groups, analyses to determine variables associated with consumption, and assorted cost-benefit analyses. Statistical methods employed include descriptive statistics (ex. means, medians, etc.), tests for differences in means assuming both normally distributed data (*t*-tests) and non-normally distributed (i.e. non-parametric) data (*Mann-Whitney U*-tests), as well as techniques employing established economic principles and multivariate regression. While it was deemed worthy of study by SNWA, variations in customers' usage (multivariate regression) will not be covered in this study, as they do not fit the objective of determining the effectiveness of the xeriscape program. In all statistical analyses, the criterion for determining statistical significance of a difference in means was an associated probability that particular result would be due entirely to chance no more than 5% (α=0.05) of the time in replication of the experiment. Types of data analyzed include mainmeter consumption data, submeter consumption data combined with area data (i.e. application per unit area data), flow rate data, cost data, survey responses, and assorted demographic and Clark County Assessor's Office data. Consumption data was gathered by the aforementioned purveyor entities and assembled by SNWA. Most other data was collected by SNWA (Aquacraft Inc. also performed some analyses on consumption and data logger collected data under contract to SNWA). In many analyses, data was scatterplotted and objective or subjective outlier removal done as deemed appropriate. Finally, in some cases, data analysis was expanded upon to include attempts at modeling.

Data Analysis Before and After Conversion

For each property and year where complete monthly consumption records were available, these were summed to provide yearly consumption. Data for each XS Group property was assembled from the five years before conversion (or as many records as were available; only properties having converted from turf to xeriscape were in this analysis sample) and as many years post-conversion as records permitted up through 2001. These data sets permitted comparison of total yearly consumption before and after the landscape conversion. The impact of submetering and site visits could also be evaluated by comparing mainmeter records for the TS Group pre- and post-installation of landscape submeters. Differences could be further confirmed by comparing the change in total household consumption following the conversion or submetering event for the XS and TS groups respectively against the change in consumption for non-contacted, non-retrofitted properties of similar landscape composition.

Recruitment of properties for the XCS spanned a couple of years. For this reason, in order to evaluate true changes over time, the first year after each conversion was designated as Y1, the second as Y2, and so forth. As such, consumption data for a property starting in, for example, 1995, was designated as belonging to Y1, but for a different property starting in 1996, 1996 was Y1. In this way, the impact of different start years was corrected for and multiyear analyses could be considered on a more common basis. This permits inferences to be made about how landscape water consumption and savings change over time as plants in the xeric areas mature. It is also the reason the sample size appears to diminish for the XS Groups from Y1 to Y5. It is not that there was heavy loss of sample sites; rather, that fewer sites were in existence for a total of 5 years owing to early enrollment. A similar effect is seen in the TS Group. There is no data for Y5 for the TS Group because enrollment for that Group started later than for the XS Group.

Savings from xeriscape may be greatest in summer when evapotranspirational demand is greatest for all plants, but so to an extreme degree in southern Nevada for turfgrasses (Cooperative Agreement). Submeter consumption data combined with measurement of the irrigated area permitted calculation of irrigation application on a per unit area basis (gallons per square foot, which can also be expressed as precipitation inches equivalents) for most study participants. In this way, exacting measures of consumption for irrigation of xeric and turf landscape types could be measured. The sample size (N_s) is the product of the number of months or years of data and the number of valid submeter records analyzed. Only records for submeters that monitored turf exclusively were included in per unit area analyses involving the TS Group so that other landscape types would not confound calculation of results. The two basic sets of analyses selected by SNWA were (i.) a comparative analysis of annual application to xeric and turf areas and (ii.) a comparative analysis of monthly application to xeric and turf areas. Secondary analyses done by SNWA comparing usage to theoretical reference ET demand projections follow the basic comparisons.

Economic Analysis

The water bill savings associated with conversion projects were calculated based on the Las Vegas Valley Water District's water rates as of spring 2004. Savings were calculated by modeling bills for a typical fifth decile (midrange in consumption) home where the average yearly consumption is 208,057 gallons and for such a home doing an average (according to data collected for the Water Smart Programs single-family sector in early 2004) 1615.8 square foot conversion from turfgrass to xeric landscape (note the difference in this average size conversion relative to that of the XS Study Group; conversion sizes, along with lot sizes, have diminished over time in this area). Bills were modeled on a monthly basis and all charges were applied that actually appear for customers. An example output (Water Bill, 3-11-05) of this model appears in Appendix 1.

The financial viability of xeriscape conversions was explored by SNWA. This necessitated looking at the economics of conversions from the homeowner and SNWA perspectives. The homeowner perspective included an estimative Net Present Value (NPV) based modeling approach to determine when return on investment (ROI) was achieved and details on this model appear in Appendix 2 (Interview, 3-11-05). This same model is used to determine the incentive level necessary to induce change, by making some assumptions about what timeframe is acceptable for owners to achieve ROI. SNWA used this information to consider alternative sources of water and use the cost associated with these to determine the maximum amount SNWA should pay to help convert grass to xeric landscape.

RESULTS AND DISCUSSION

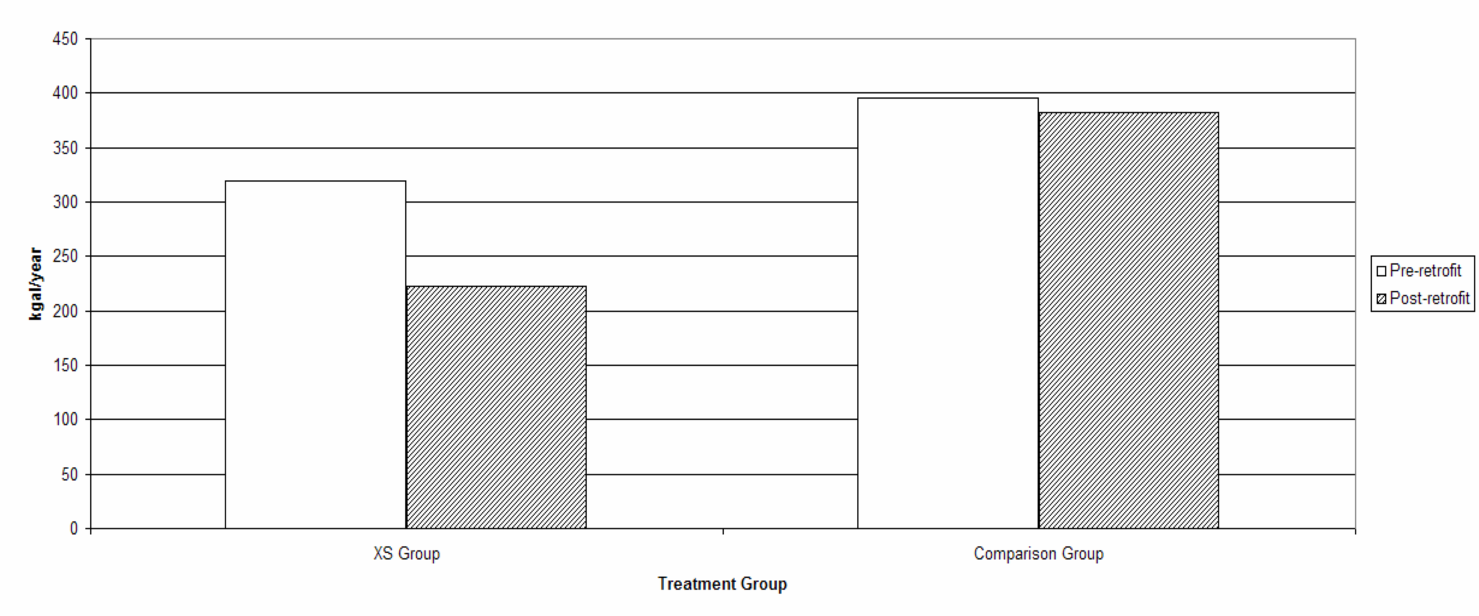
Reduction in Total Household Water Consumption Following Conversion to Xeriscape

Results for the XS Group pre/post-conversion comparisons are shown in Table 1 and Figure 1.

TABLE 1: Pre-/Post-Retrofit Analyses for XS Group

	Pre-retrofit (kgal/yr)	**Post-retrofit (kgal/yr)**	**Difference in Means (kgal/yr)**	**t-tests (* denotes significance)**
Xeriscape Treatment n=321	Mean=319 **Median=271**	Mean=223 **Median=174**	**96*** (30% reduction from pre-retrofit)	**t=16.8* p<0.01**
Comparison n=288	**Mean=395** Median=315	Mean=382 **Median=301**	**13** (3% reduction from pre-submetering)	**t=1.85 p=0.07**
Difference in Means (kgal/yr)	**76***	**159***		
t-tests (* denotes significance)	**t=4.32* p<0.01**	**t=9.69* p<0.01**		

FIGURE 1: Pre-/Post-Retrofit Consumption for XS and Comparison Groups



Mean monthly consumption for the residences dropped an average of 30% following conversion. A dependent *t*-test demonstrates that the reduction in usage is highly significant (t=16.8; p<0.01). Though individual performance may vary greatly, the overwhelming majority of homes in the study saved water following the conversion (285 out of 321 analyzed). This finding of about a third reduction in consumption is nearly identical to findings from a study of residences in Mesa, Arizona (Testa and Newton, 1993). It may be that a reduction of about this percentage may be anticipated to occur when the average single-family residence built in the late 20th century does an average size conversion in the southwestern United States. The large savings are likely in part because in this region the great majority of water consumption goes to outdoor irrigation. In this study, the average savings realized was 96,000 gallons per year per residence.

The difference in consumption of the pre-retrofit homes to the non-contacted comparison homes is shown in Table 1 and Figure 1. As demonstrated, a *t*-test of consumption between these two groups shows there was significant difference in initial consumption between the two groups (t=4.32; $p<0.01$), suggesting self-selection bias. This is not surprising since recruitment of study participants was voluntary. People who were already conserving were apparently more likely to enroll and agree to convert a portion of their respective properties. That does not, however, invalidate the results as (i.) this incentive based approach is essentially the same as the approach used for enrolling people in the actual program and, more importantly, (ii.) there is no compelling evidence that the Comparison Group experienced significant reduction over the same time period so the savings are likely attributable exclusively to the landscape conversion.

The analysis procedures suggest that the impact of submetering on outdoor irrigation may be revealed by comparing consumption at the conventionally landscaped properties with submeters (the TS Group) to that for the associated comparisons for that Group. The data appearing in Table 2 indicate this comparison.

TABLE 2: Pre-/Post-Retrofit Analyses for TS Group

	Pre-submetering (kgal/year)	Post-submetering (kgal/year)	Difference in Means (kgal/yr)	t-tests (* denotes significance)
Submetered Conventionally Landscaped Treatment n=205	Mean=352 **Median=303**	Mean=319 **Median=268**	**34*** (10% reduction from pre-retrofit)	**t=5.08*** **p<0.01**
Comparison n=179	Mean=364 **Median=314**	Mean=347 **Median=296**	**17*** (5% reduction over timeframe)	**t=2.08*** **p<0.05**
Difference in Means (kgal/yr)	**12**	**28**		
t-tests (* denotes significance)	**t=0.52** **p=0.60**	**t=1.41** **p=0.16**		

There are two potential issues with trying to consider this analysis an evaluation of the effectiveness of submetering. First, submetering is typically studied when the scenario is one where water consumption through the submeter is relayed to end-use customers and where the customers are billed for it. Without consumption data and billing, the residents in this study have received no price signal to encourage them to read the meter or reduce consumption. This theory corresponds with what staff has observed in the field with respect to the behavior of customers. Most participants apparently did not even think about the meter until it was time for their yearly site review and often they stated they had forgotten it was even there (Site visit, 2-23-05), the dynamic of submetering is rather unique and the impact most likely minimal.

The second consideration, at least as potentially significant, is the fact that participants had been exposed to annual site visits, which is likely a more important variable in terms of modifying behavior (no conservation training or formal education took place at site visits, though staff did answer questions posed to them). Indeed, the Comparison Group provides for a good gauge of the impacts on treatment groups due to site visits. Initially, results seem to suggest a reduction of possibly up to 34,000 gallons annually associated with visits and submetering (t=5.08; $p<0.01$) though as revealed in the next analyses, this impact appears to be only temporary (seen only in the first year, Table 5) and is probably in actuality much more negligible given half the "reduction" also appears to have taken place in the control group (t=2.08, $p<0.05$). The control group reduction may in fact be due to background conservation at the community level.

Assessment of Savings Potential Across Time and Seasons

For the XS Group, significant reduction in total yearly consumption took place immediately following conversion and remained relatively stable at that decreased level through subsequent years, showing no erosion with time (Table 3 and Figure 2). In every year, the XS Group consistently had lower consumption than the Comparison Groups, and this was statistically significant (Table 3). This suggests that conversions are a viable way to gain substantial water savings over at least a medium-term timeframe and quite possibly over a long term as well. It also demonstrates that xeriscape does not take more water in the first year following conversion and it suggests that, at least over the medium-term, there is no erosion of savings obtained from conversions due to residents' response to growth of plants in their xeric areas.

For the XS Group, the relative reduction in consumption became even more pronounced in the summer (Table 4) where, savings averaged 13,000 gallons per summer month (Table 4: t=18.5;p<0.01) versus an average of 8000 per month over the entire year. It should be noted that a very small, but statistically significant reduction of 1600 gallons per month appears to have also taken place in the Comparison Group during the summer (in a pre vs. post comparison of the study timeframe, Table 4: t=1.98; p<0.05). Overall, the results are consistent with the theory that xeric landscapes save the most during the summer. The comparative per unit analyses that follow reveal why this is the case.

In considering savings stability over extended time, it was found that the submetered TS group only demonstrated significantly decreased consumption for the first year following retrofit, after which savings were not significant (Table 5; statistics in table). This initial reduction might be due to resident's interest in the research and in conservation when new to the study, wearing off with time (Interview, 3-11-05). Again, it is important to recall that in no single year was the consumption statistically different from the comparison group properties. The submetered TS Group did have significantly lower consumption in the summer with a savings of 3300 gallons per month (Table 6: t=3.78;p<0.01) whereas the comparison group to the TS Group showed no such reduction (Table 6: t=1.03;p=0.31). However, there was no difference in average monthly summer consumption between the submetered properties and the controls after the retrofit (Table 6: t=1.03;p=0.31). Overall the results in Table 5 seem to reflect the finding that little enduring change in consumption was achieved by the TS Group over time despite submeter installation.

FIGURE 2: Pre-/Post-Retrofit Consumption for XS Group Across Time

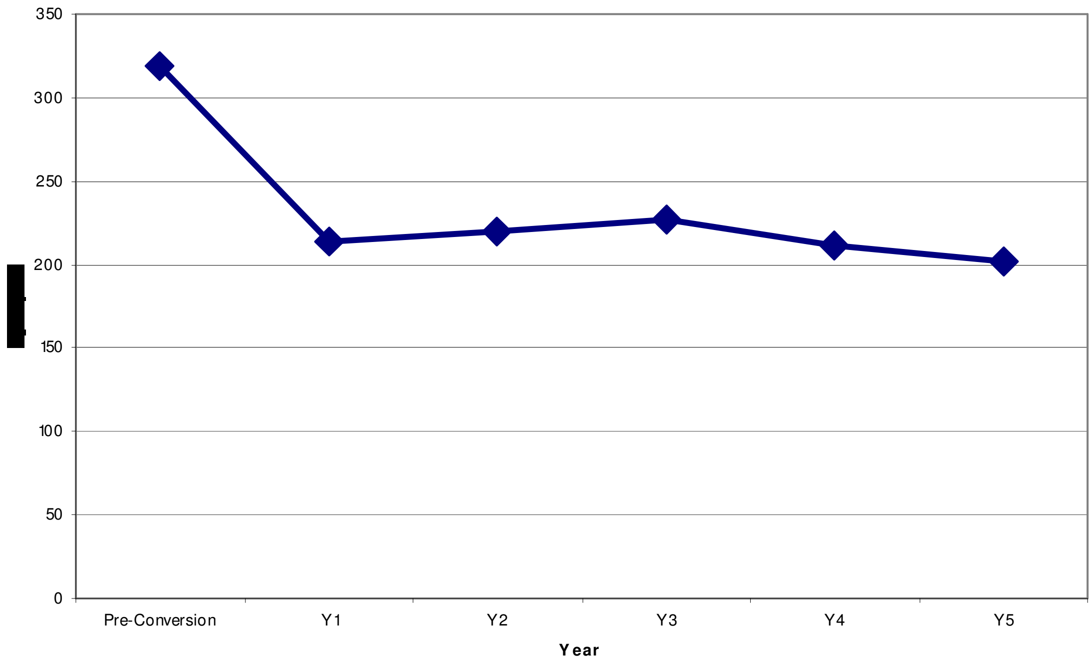


TABLE 3: Enhanced Post-Retrofit Analyses for XS Group Across Time

Post-retrofit Consumption	**First Year Post-retrofit (Y1)**	**Second Year Post-retrofit (Y2)**	**Third Year Post-retrofit (Y3)**	**Fourth Year Post-retrofit (Y4)**	**Fifth Year Post-retrofit (Y5)**
Xeriscape Treatment (kgal/year)	**214**$^{\Delta}$ (32% reduction from pre-retrofit) n=320	**220**$^{\Delta}$ (30% reduction from pre-retrofit) n=318	**227**$^{\Delta}$ (28% reduction from pre-retrofit) n=306	**211**$^{\Delta}$ (33% reduction from pre-retrofit) n=211	**202**$^{\Delta}$ (36% reduction from pre-retrofit) n=61
Comparison Group (kgal/year)	**372** n=280	**387** n=275	**383** n=260	**362** n=183	**345** n=54
Difference in Means (kgal/year)	**158**	**167**	**156**	**151**	**143**
t-tests (* denotes significance)	**t=9.98* p<0.01**	**t=9.29* p<0.01**	**t=9.08* p<0.01**	**t=8.02* p<0.01**	**t=4.85* p<0.01**

Treatment group values with a $^{\Delta}$ are significantly lower than pre-retrofit value.

TABLE 4: Summer Post-Retrofit Analyses for XS Group

	Pre-Retrofit Summer Consumption (kgal/month)	Post-Retrofit Summer Consumption (kgal/month)	Difference in Means (kgal/month)	t-tests (* denotes significance)
Xeriscape Treatment n=321	**Mean=38** Median=31	**Mean=25** Median=19	**13***	**t=18.5* p<0.01**
Comparison Group n=288	**Mean=47** Median=38	**Mean=46** Median=35	**1.6***	**t=1.98* p<0.05**
Difference in Means (kgal/month)	**9***	**21***		
t-tests (* denotes significance)	**t=4.23* p<0.01**	**t=10.1* p<0.01**		

TABLE 5: Enhanced Post-Retrofit Analyses for TS Group Across Time

Post-submetering Consumption	First Year Post-submetering (Y1)	Second Year Post-submetering (Y2)	Third Year Post-submetering (Y3)	Fourth Year Post-submetering (Y4)	Fifth Year Post-submetering (Y5)
Submetered Conventionally Landscaped Treatment (kgal/year)	**291$^{\Delta}$** (6% decrease from pre-submetering) n=228	**312** (1% increase from pre-submetering) n=229	**317** (2% increase from pre-submetering) n=228	**315** (2% increase from pre-submetering) n=146	No Data Available
Comparison Group (kgal/year)	**332** n=170	**357** n=173	**351** n=167	**351** n=108	No Data Available
Difference in Means	**41**	**45**	**34**	**36**	
t-tests (*denotes significance)	**t=2.28 p=0.02**	**t=2.39 p=0.02**	**t=1.65 p=0.10**	**t=1.40 p=0.16**	

Treatment group values with a $^{\Delta}$ are significantly lower than pre-submetering value.

TABLE 6: Summer Post-Retrofit Analyses for TS Group

	Pre-Submetering Summer Consumption (kgal/month)	Post-Submetering Summer Consumption (kgal/month)	Difference in Means (kgal/month)	t-tests (* denotes significance)
Submetered Conventionally Landscaped Treatment n= 205	**Mean=41.7** Median=34.0	**Mean=38.5** Median=31.0	**3.3***	**t=3.78* p<0.01**
Comparison Group n=179	**Mean=42.0** Median=36.0	**Mean=41.0** Median=34.7	**1.0**	**t=1.02 p=0.31**
Difference in Means (kgal/month)	**0.3**	**2.5**		
t-tests (* denotes significance)	**t=0.97 p=0.92**	**t=1.03 p=0.31**		

Comparison of Per Unit Area Water Application Between Turfgrass and Xeriscape

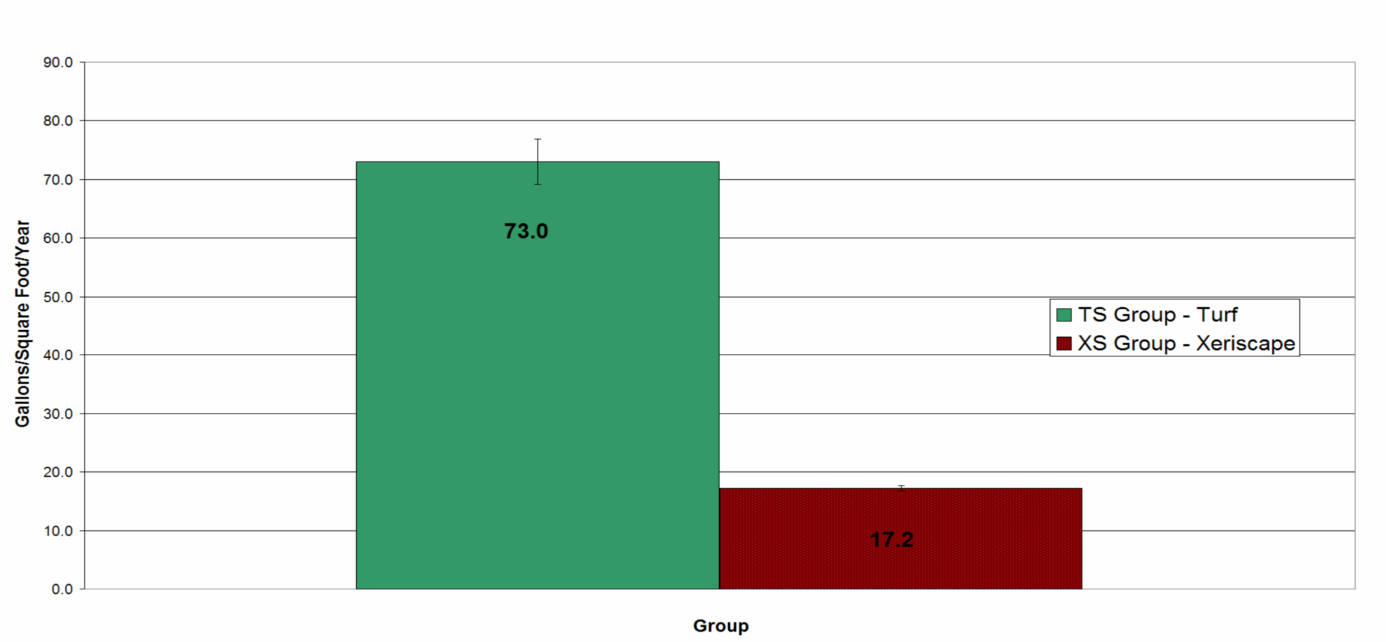
Annual application

Annual per unit area irrigation application data summaries are found in Table 7 and Figures 3 and 4. There was substantially more annual water application to turf than xeric landscape areas (Table 7 and Figure 3). Turf received an average of 73.0 gallons per square foot annually (117.2 inches), while xeriscape received on average, just 17.2 gallons (27.6 inches) each year (only 23.6% of the amount of water applied for turfgrass maintenance). The difference was thus 55.8 gallons per square foot per year (89.6 inches) and this was found to be significant assuming a normal distribution of data ($t=27.0$; $p<0.01$).

TABLE 7: Annual Per Unit Area Application to Turf and Xeriscape

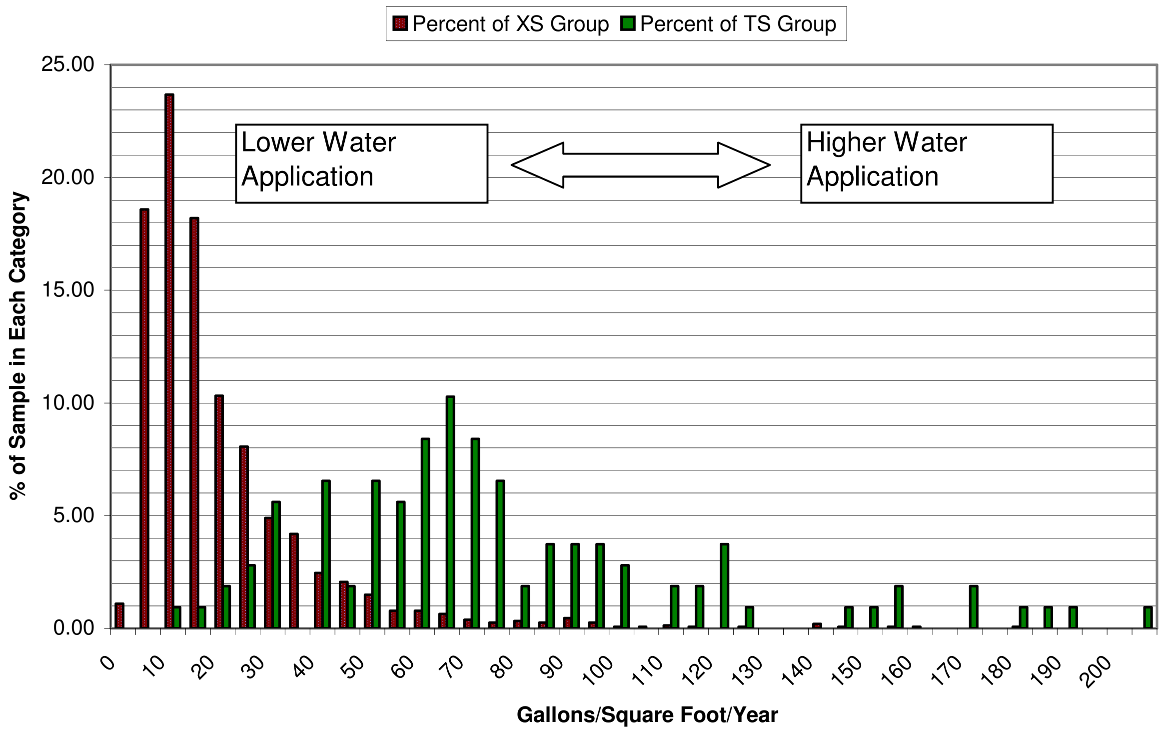
	Per Unit Area Application **(gallons/square foot/year)**	Per Unit Area Application **(inches/year)**	**Sample Distribution Statistics**
Submetered Turf (TS Group) n_s=107	**Mean=73.0** Median=64.3	**Mean=117.2** Median=103.2	**Standard Deviation=40.0 Skewness=1.17 Kurtosis=1.36**
Submetered Xeriscape (XS Group) n_s=1550	**Mean=17.2** Median=11.5	**Mean=27.6** Median=18.5	**Standard Deviation=18.6 Skewness=3.14 Kurtosis=14.9**
Difference (gallons/square foot/year)	**Mean=55.8**	**Mean=89.6**	
t-tests (* denotes significance)	**t=27.0* p<0.01**		
Levene's Test (* denotes significance)	**F(1, 1655)=130.3* p<0.01**		
Mann-Whitney U Test (* denotes significance)	**U=10177 z=15.2* p<0.01**		

FIGURE 3: Annual Per Unit Area Application to Turf and Xeriscape



Distinct differences in the sample distributions for the XS and TS irrigation data from a statistical analysis perspective caused concern. Both distributions had features strongly suggesting data was not distributed homogenously across the two groups (Table 7 and Figure 4). In particular, the XS Group data was heavily skewed with the vast majority of participants using very little water. Turf application, while indeed skewed, appears almost normal compared to xeric application, which is very heavily skewed (skewness = 3.14) and peaks sharply (kurtosis=14.9) at the lower end of the distribution. This is because the vast majority of XS participants used a very small amount of water to irrigate their xeric areas, while a small portion used greatly more volume on theirs. Because *t*-tests assume normality, the atypical and non-congruent distributions were of sufficient concern to SNWA to justify running a Levene's Test simultaneous with the *t*-tests to assess the potential need to apply non-parametric analytical techniques (though in practice the need for normality is lessened with large sample sizes due to the tendency of such a collection of data to mimic a normal distribution). Indeed, the Levene's Tests demonstrated significant differences in the distributions [Levene $F(1,1655) = 130.3$; $p<0.01$]. This suggested the need to backup the findings with non-parametric approaches. *Mann-Whitney U* (a summation and ranking based approach to the problem) was chosen as a good backup test. Associated z statistics for this test with corresponding probabilities are thus reported with the results in Table 7 as supporting evidence for statistical difference in irrigation application between the groups.

FIGURE 4: Distribution of Annual Per Unit Area Application Data for Turf and Xeriscape



Monthly Application

Monthly submeter data summaries for the XS Group and exclusively monitored turf TS Group participants appear in Table 8. It should be noted that at times the interval between reads stretched over more than one month and thus the dataset for the monthly data is slightly different than that for the above annual comparison as only consumption data deemed complete and assignable to a given month could be included (sometimes consumption across a two month gap was averaged to fill the gap). There were issues with resolution in monitoring because typically at least a thousand gallons had to pass through the meter between reads in order for the consumption figure to be advanced and registered by the reader. Sometimes this did not happen for XS Group submeters, monitoring relatively small areas due to low consumption. Both these factors likely result in slight inflation of monthly consumption values for both groups and this indeed appears to be the case if monthly averages are summed across the year (i.e. this per unit area consumption figure is slightly higher than the annual one calculated in the previous section). Still, on a monthly basis the data is generally valid and valuable in comparative analyses and in comparing water application to irrigation requirements. Per unit area application data is displayed graphically in Figure 5.

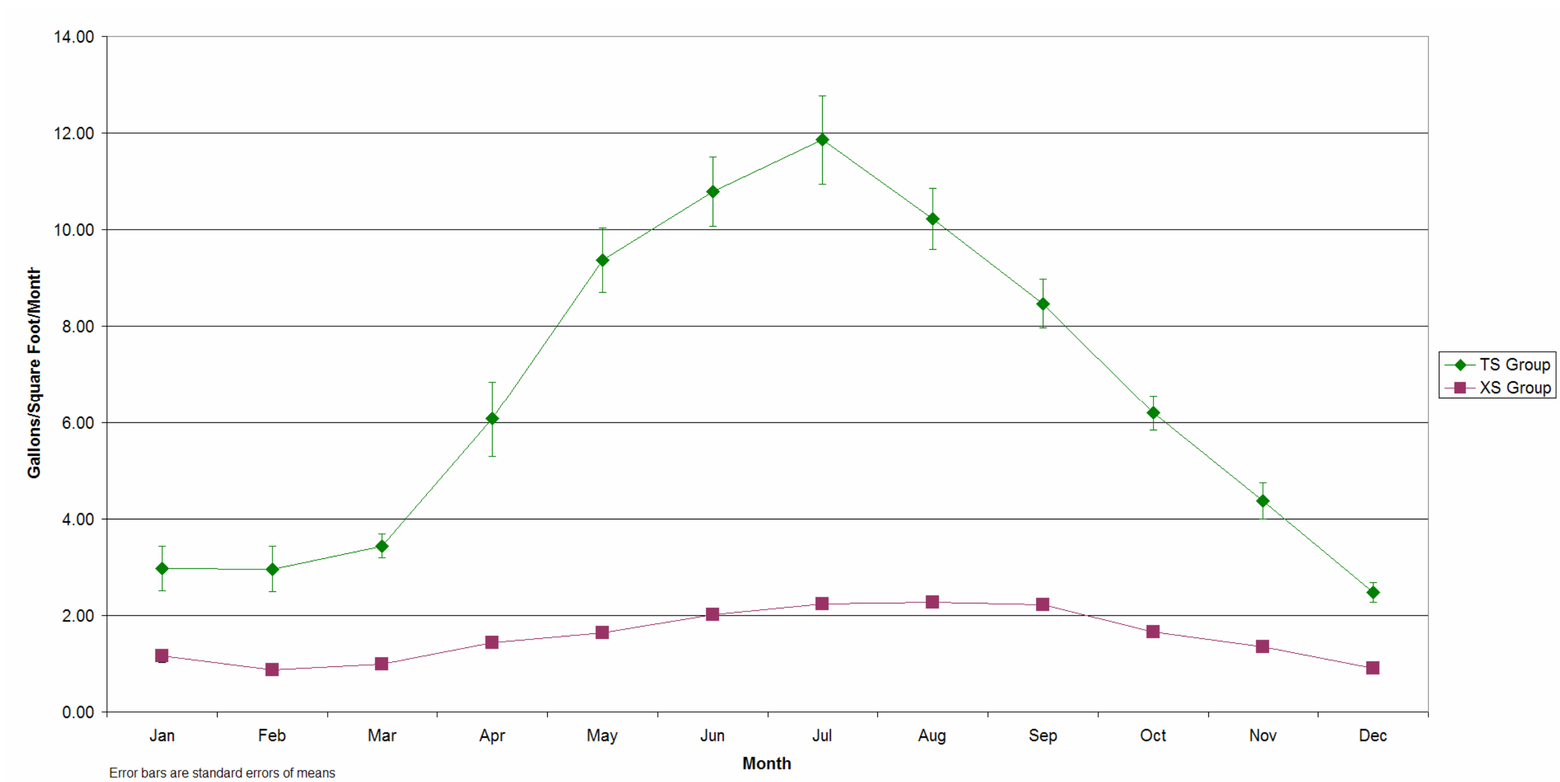
TABLE 8: Monthly Per Unit Area Application to Turf and Xeriscape

	Jan Gal/Sq Ft	**Feb Gal/Sq Ft**	**Mar Gal/Sq Ft**	**Apr Gal/Sq Ft**	**May Gal/Sq Ft**	**Jun Gal/Sq Ft**	**Jul Gal/Sq Ft**	**Aug Gal/Sq Ft**	**Sep Gal/Sq Ft**	**Oct Gal/Sq Ft**	**Nov Gal/Sq Ft**	**Dec Gal/Sq Ft**
Submetered Turf (TS Group)	**2.97** 2.11 n_s=85	**2.96** 2.06 n_s=85	**3.44** 3.29 n_s=85	**6.07** 4.85 n_s=88	**9.37** 7.86 n_s=93	**10.79** 9.38 n_s=93	**11.86** 10.50 n_s=95	**10.23** 8.71 n_s=96	**8.47** 7.15 n_s=99	**6.20** 5.29 n_s=105	**4.37** 3.50 n_s=107	**2.47** 1.96 n_s=106
Submetered Xeriscape (XS Group)	**1.16** 0.46 n_s=1291	**0.87** 0.43 n_s=1337	**0.99** 0.57 n_s=1377	**1.43** 0.83 n_s=1409	**1.64** 1.08 n_s=1412	**2.01** 1.30 n_s=1421	**2.24** 1.40 n_s=1431	**2.27** 1.39 n_s=1456	**2.22** 1.27 n_s=1496	**1.66** 1.02 n_s=1519	**1.35** 0.77 n_s=1534	**0.91** 0.48 n_s=1534
Difference (Gallons/Sqft)	**1.81**	**2.09**	**2.45**	**4.64**	**7.74**	**8.78**	**9.62**	**7.96**	**6.25**	**4.54**	**3.02**	**1.56**
t-tests (* denotes significance)	**t=73.36* p<0.01**	**t=7.52* p<0.01**	**t=13.33* p<0.01**	**t=9.92* p<0.01**	**t=29.87* p<0.01**	**t=27.7* p<0.01**	**t=26.22* p<0.01**	**t=21.96* p<0.01**	**t=13.15* p<0.01**	**t=17.59* p<0.01**	**t=13.45* p<0.01**	**t=9.39* p<0.01**
Mann-Whitney U Tests (*denotes significance)	**U=23499 z=8.84* p<0.01**	**U=18127 z=10.54* p<0.01**	**U=15959 z=11.27* p<0.01**	**U=14225 z=12.14* p<0.01**	**U=6824 z=14.49* p<0.01**	**U=4415 z=15.10* p<0.01**	**U=6062 z=14.89* p<0.01**	**U=9776 z=14.13* p<0.01**	**U=12307 z=13.91* p<0.01**	**U=14501 z=14.04* p<0.01**	**U=25290 z=11.98* p<0.01**	**U=31202 z=10.62* p<0.01**

Note: bold gal/sqft values are means; regular font gal/sqft values are medians

The first, most obvious finding from the graph below is that turf application exceeds xeric application by a large statistically significant margin in every month. Ultimately this is what constitutes the large annual savings seen at the annual landscape application and total home consumption levels.

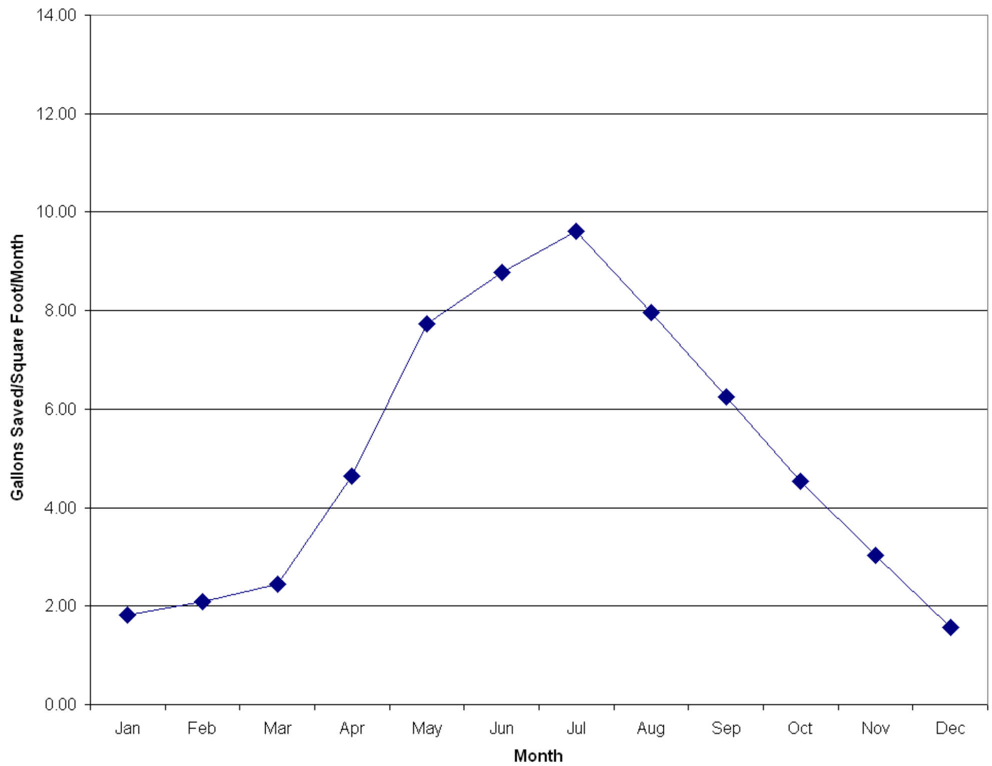
FIGURE 5: Monthly Per Unit Area Application for Turf and Xeric Areas



The data also suggests that the reason for the aforementioned enhancement of savings during the summer is because turf application peaks drastically in the summer whereas application to xeriscape does not. A graph of the difference between the groups (Figure 6) demonstrates this is the case and the observed pattern in savings obtained each month parallels the pattern observed for turfgrass application (Figure 5). It appears that the reason xeriscape saves so much water in this climate is related as much to the high demand of turfgrasses vs. plantings of most other plants as it is to any inherent aspect of xeric landscape. Furthermore, inefficiencies in spray irrigation system design, installation, and operation further contribute to the savings of having xeric landscape in place of turf because these inefficiencies drive up even further the application of water to the turfgrass to the point that it is much higher than the rate of evapotranspiration over the same timeframe (Figure 7).

Additional inferences can be made about the application of water to turfgrass areas by the participants. Specifically, on average, whereas they irrigated relatively efficiently in the spring, with the onset of summer temperatures in May, residents quickly increased their application, ultimately going way above the evapotranspirational requirement (ET). Moreover, they tended to stay well above ET through November. While it is expected that due to system inefficiencies, a high K for Fescue (Cooperative Agreement), leaching fraction considerations, and other factors, application usually would tend to exceed ET for turfgrass locally, the pattern suggests that overall people irrigate relatively efficiently in spring as the weather warms and ET rises, probably due to the immediate feedback they receive as the grass yellows in response to moisture deficits. As the landscape begins to show visible signs of stress due to deficit irrigation, the application is increased accordingly. In May, overreaction to the increasing stress causes irrigation to increase well over the requirement. In fall however, the participants do not appear to respond in a correspondent way "coming down the curve," probably because they do not have the same sort of visual feedback mechanism as they do in spring (i.e. they do not view the grass being "too green", wet, nor the occurrence of runoff as something amiss) (Interview, 3-11-05). The result is a long lag in returning to application rates more closely approximating ET in the fall and early winter (Figure 7).

FIGURE 6: Monthly Per Unit Area Savings (Turf Area Application– Xeric Area Application)



It is more difficult to make similar types of inferences with respect to xeric area application. While there is research underway on a variety of desert plants to attempt to quantify irrigation demand and there have been generalized attempts to model or approximate xeriscape need based on observations and fractions of reference ET, at this time it would be risky to make highly specific inferences (Interview, 3-11-05). The relative flatness of the xeric curve in Figure 5 does though seem to suggest that residents may irrigate xeric areas inefficiently as they seem to show little response to demands of different seasons.

FIGURE 7: Monthly Per Unit Area Application to Turf and Reference Evapotranspirational Demand

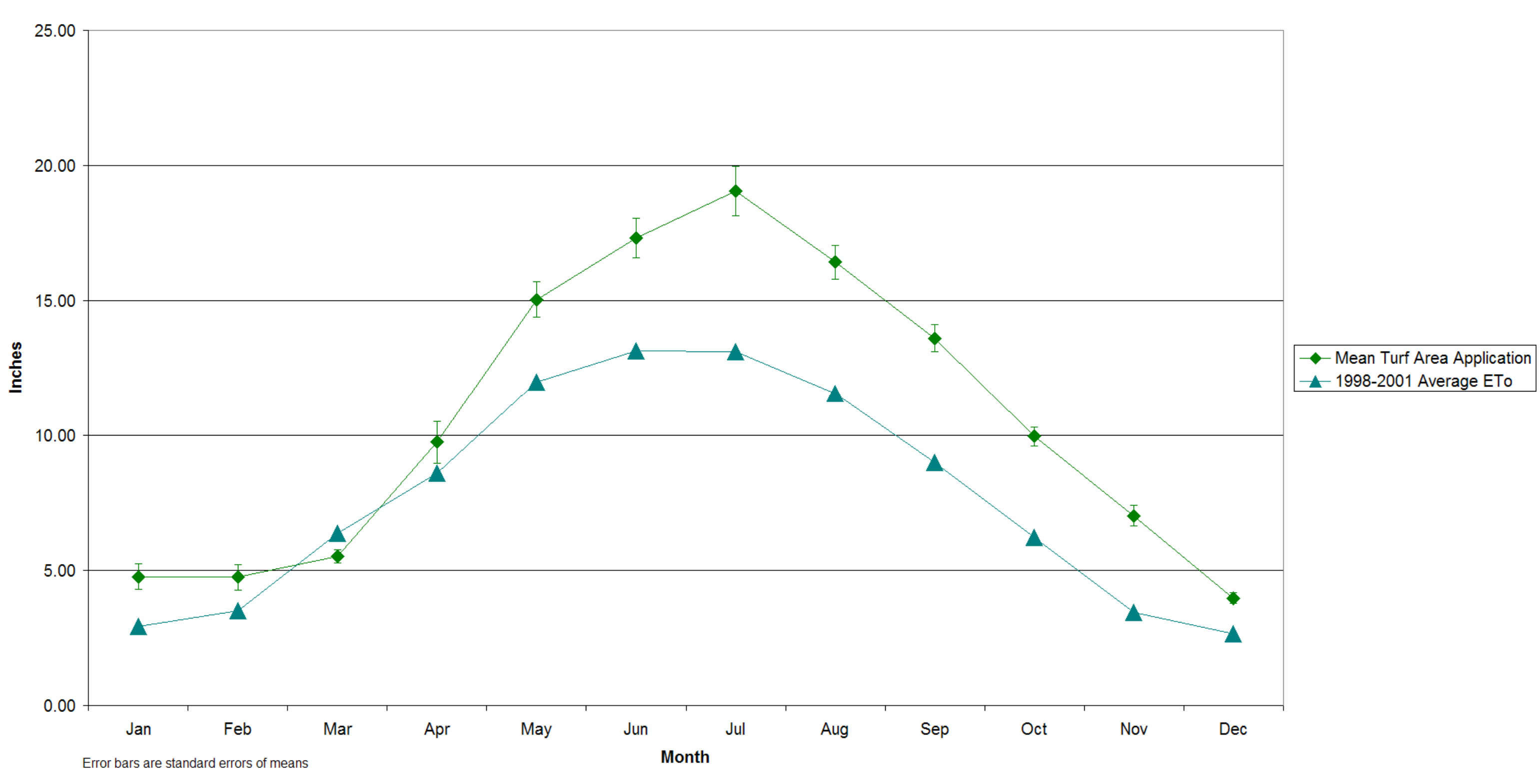
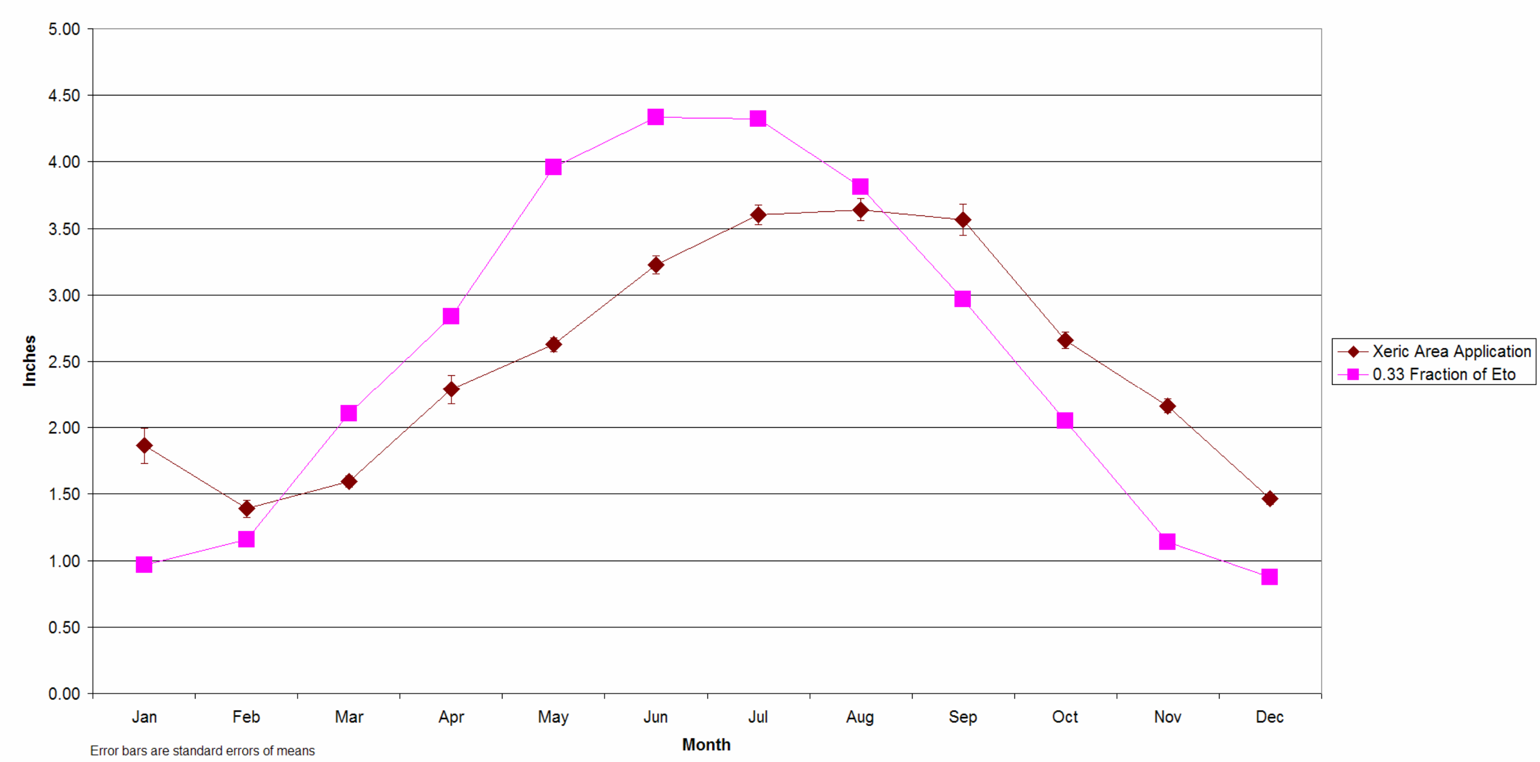


FIGURE 8: Monthly Per Unit Area Application to Xeric Areas and 1/3 of Reference Evapotranspirational Demand



Opportunities to save great volumes of water appear to exist for turf areas throughout most of the year. Significant overwatering appears to occur May through November; efficiency improvements will likely yield the most absolute benefit during this period of the year. The exploration of application per unit area vs. reference values is important for making inferences about management efficiency of water application. This however should not obscure the result that on average, per unit area, xeric landscapes in this study received much less water in totality (Figures 3 and 4) and the pattern of received irrigation showed much less tendency towards "peaking" (Figure 5) than those areas planted with turf.

Financial Savings Associated with Conversion Projects and Cost Efficiency

Savings on a water bill for a typical mid-consumption range customer were modeled as explained in Methodology and in Appendix 1. Results show that there is a large difference in the monthly bills between a modeled residence with and without the conversion throughout the majority of the year (Figure 3). The total difference in the annual cost for water between these two homes using the current (2004) rate structure is $239.92 – a significant savings attributable to the conversion (nearly $0.15 per square foot converted per annum). It should be noted that this savings of 54% in total annual water charges is greater than would initially be anticipated from consumption savings data (Figure 6). This is because the Las Vegas Valley Water District, as well as the other SNWA member agencies, uses a tiered, increasing block rate structure.

CONCLUSION

The major conclusions of this research are as follows:

1. Xeriscape conversion projects can save vast quantities of water at single-family residences. Homes in this study saved an average of 96,000 gallons annually following completion of an average size conversion project. This is a savings of 30% in total annual consumption; a finding in-line with those yielded by other research studies in this region.
2. Over the long timeframe of this study, total yearly savings have neither eroded nor improved across the years. On average, household consumption drops immediately and quickly stabilizes.
3. There is an enormous difference in application of water to locally used turfgrasses and xeric landscape by residents. On average, each year residents applied 73.0 gallons per square foot (117.2 inches) of water to grow turfgrass in this area and just 17.2 gallons per square foot (27.6 inches) to xeric landscape areas. The difference between these two figures, 55.8 gallons per square foot (89.6 inches), is the theoretical average savings yielded annually by having xeriscape in lieu of turf in this area. This is a substantial savings (76.4%) when considered in the context of the available residential water conservation measures.
4. Over the course of a year, the difference in application between turf and xeric areas varies in a predictable bell-shaped curve manner with the greatest difference

occurring in summer. This is because turf irrigation peaks to a much greater extent in summer than xeric irrigation. The difference in irrigation between these two types of landscape varies from as little as 1.56 gallons per square foot for the month of December, on up to 9.62 gallons per square foot for the month of July.

5. In comparing irrigation application to the reference evapotranspirational rate (ET), it was found that on average application to turf exceeded ET in every month except March, exceeding it the most May through November. In contrast, xeric application remained well below ET year round.

6. A model of two identical homes, one near the average for consumption (technically in the 5^{th} decile for consumption), the other having completed an average size conversion, revealed the following:

    i. The annual water bill savings yielded by landscape conversion projects can be large. For the Las Vegas Valley Water District customer modeled, the annual financial savings was $239.92 (figure includes all applicable surcharges). This equates to a savings of nearly $0.15 per square foot of turfgrass converted to xeriscape.

    ii. A large savings of 54% in total annual charges for water consumption. This level of savings is elevated over what might have been initially anticipated due to an aggressive tiered water rate structure. The effective average 5^{th} decile annual water charges with all surcharges added would be $2.13/kgal for the typical traditional home and $1.85/kgal for the one having completed the average size conversion.

iii. The savings vary by season as expected by the findings associated with the submeter data. Whereas the bill payer of the home having done the conversion saved 25% ($5.68) in charges for December vs. the typical homeowner, the same individual would realize an enormous savings of 70% ($40.84) for July. One of the great benefits of xeriscape is that it drastically mediates "peaking" in summer, making summer bills much more affordable for households, especially since power bills also peak in summer.

SUMMARY

In this paper I proposed to evaluate the effectiveness of the SNWA's Xeriscape program. The preceding information shows conclusively that participants who converted turfgrass to xeriscape enjoyed substantial savings on their water bills, and in fact helped to cut the amount of nonconsumptive water used within the Southern Nevada area. Therefore, it is concluded that the SNWA's xeriscape program is indeed highly effective in conserving one of Southern Nevada's most precious resources: water.

GLOSSARY

Acre feet: plural of acre foot: 325,851 gallons of water; enough to fill a football field one foot deep; enough to support a family of five for one year

Consumptive use: defined by SNWA as the summation of yearly diversions minus the sum of return flows to the Colorado River

Evapotranspirational rate: the amount of water, expressed in quantity/time terms, needed to sustain existing plant life

Mainmeter: water meter measuring total water usage for a property

Submeter: water meter installed to measure usage in a particular portion of property

Tiered water rate structure: pricing structure intended to encourage conservation; the more water used, the more expensive that water becomes

Turfgrass: in this paper, standardized term referring to any type of sod or grass: fescue, bermuda, etc.

Xeriscape: invented by Nancy Leavitt of Denver Water, a fusion of the Greek term "xeros" meaning dry or arid, and landscape.

5/8 inch meter: typical size of water pipes and thus water meter used in residential housing; inferring a maximum water flow as compared to a 1 inch meter

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Water Bill, 3-11-05: Example of Water Bill comparing water use before and after Xeriscape conversion, Provided by Kent Sovocool in March 11, 2005 interview.

APPENDICES

Appendix 1: Information on a Single Family Residential Water Bill

A model was used to explore the differences in water consumption charges for a typical fifth decile in consumption property (single-family home) and one doing an average size conversion. The model assumes the properties are in the Las Vegas Valley Water District's service area and subject to its regular service rules. A typical 5/8 inch meter size was assumed (meter size in large part determines rate per consumption unit). Rates for each tier and the size of the tier rate block appear below in the screen shot of the actual modeling processes for the model used in this report. As demonstrated, within a given billing cycle the rate for the first 5000 gallons is $1.05/kgal, the next 5000 gallons after the initial 5000 costs $1.75/kgal, the next 10,000 gallons after these first 10,000 gallons is $2.38/kgal and so on (for billing purposes the utility rounds to the nearest thousand gallons). In addition to the direct charges for the water, SNWA purveyor members' bills commonly include a service charge, a commodity charge and a reliability charge and these are reflected in the model below so that the outputs are indeed reflective of actual bills. A thirty-day billing cycle was assumed.

In practical terms, the calculation of outputs in the model and the savings is derived by multiplying the expected average savings per square foot per month that would be yielded by a conversion (as calculated from Table 8) by the average size conversion and then subtracting this from the 5th decile consumption level. This yielded the costs with having done the conversion (below called "Total Bill). In contrast the cost without doing the conversion (i.e. "Average 5th Decile bill without reduction") is shown under the "did conversion" scenario. The difference between these, highlighted in red, is the anticipated monthly bill savings yielded from having completed the conversion project.

Water Bill Calculator Screen Shot

Meter Size		Percent Reduction	Select Entity	Average SF WSL Conversion (n=3651)
5/8	☑ Residential	0%	LVWD Current	1615.8

		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual Totals			
		10670	9369	12255	16174	21107	23447	25084	24519	21788	18112	13738	11795	208,057	5th Decile average consumption		
		1.81	2.09	2.45	4.64	7.74	8.78	9.62	7.96	6.25	4.54	3.02	1.56		Average Gallons Per SqFt Reduction		
		2925	3377	3959	7497	12506	14187	15544	12862	10099	7336	4880	2521	97691	Avg Gal / SqFt Reduction * Avg SF WSL Conversion		
Tier Rates	Tier Blocks	8	6	8	9	9	9	10	12	12	11	9	9	110366	Avg 5th Decile Cons - (Reduction * Avg WSL Conversion)		
1.05	5	5.25	5.25	5.25	5.25	5.25	5.25	5.25	5.25	5.25	5.25	5.25	5.25	63.00			
1.75	5	4.80	1.74	5.77	6.43	6.30	7.46	7.94	8.75	8.75	8.75	6.75	7.48	80.93			
2.38	10								3.94	4.02	1.85			9.81			
3.02	20													0.00			
	Water Cost	10.05	6.99	11.02	11.68	11.55	12.71	13.19	17.94	18.02	15.85	12.00	12.73	153.74	Price Per 1000 Gal. Annual	$	1.39
3.669	Service Charge	3.67	3.67	3.67	3.67	3.67	3.67	3.67	3.67	3.67	3.67	3.67	3.67	44.03			
0.05	Commodity Charge	0.39	0.30	0.41	0.43	0.43	0.46	0.48	0.58	0.58	0.54	0.44	0.46	5.52			
0.25%	Reliability Surcharge	0.04	0.03	0.04	0.04	0.04	0.04	0.04	0.06	0.06	0.05	0.04	0.04	0.51			
	Total Bill	14.15	10.98	15.14	15.83	15.69	16.88	17.38	22.25	22.33	20.11	16.16	16.90	203.79	Price Per 1000 Gal. Annual	$	1.85
		19.85	17.08	23.71	33.25	45.98	53.18	58.22	56.48	48.08	37.98	27.32	22.59	443.72	Average 5th Decile bill without reduction	$	2.13
		5.70	6.09	8.57	17.43	30.29	36.30	40.84	34.23	25.75	17.87	11.17	5.68	$ 239.92	Total Savings with Red.		

Appendix 2: Estimate of Return of Investment After Xeriscape Conversion

	Type
Square Feet Converted	1616
Incentive level	$1.00
Conversion cost:	$1.37
conversion cost:	$2,213.92
average total bill savings for a year:	$240.00
awarded incentive:	$1,616.00
interest rate:	6.32%
average yearly rate increase	3.00%
Labor Savings	$0.20
Labor Savings	$323.20
Direct Maintenance	$0.11
Direct Maintenance	$177.76
Yearly maintenance savings	$500.96

NPV	Year
($2,070.88)	0
($636.58)	1
$751.63	2
$2,095.24	3
$3,395.67	4
$4,654.31	5