A Model to Determine Residential Landscape Size Using Total Lot Size

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ABSTRACT

Assigning water allocation to residential water users is an effective tool in promoting conservation and efficient water use. Allocation can be based on four factors that are easily determined: crop coefficient, evapotranspiration, system efficiency, and indoor use. Landscape area is an additional factor that is more difficult to determine. This study details a model to determine landscape sizes for residential lots when only total lot size is available.

For this study, samples of residential lots were grouped in 1,000 square foot increments. Each sample lot was measured along with their respective landscape. The measurements were taken using aerial photography and mapping software to provide efficient and accurate measurements. An additional sample of lots was measured on site to confirm the accuracy of the software-based method of measurement. A regression curve was developed based on the landscape sizes versus the total lot sizes.

INTRODUCTION

California presents a clear example of a state that is growing in population, while its water supplies are shrinking. The Department of Interior's report, Water 2025: Preventing Crises and Conflict in the West, states that at the present time in some areas of the west, existing water supplies are or will soon be inadequate to meet the water demands of people, cities, farms and the environment even under normal water supply conditions. Solutions involving water conservation and formulas limiting scarcity that work in California may also work in other parts of the country .

California's water is supplied by a number of resources. These include existing groundwater aquifers, native mountain snow packs and rivers, rainwater stored in water tanks, and most notably, the Colorado River. In addition to the lower than average rainfall in recent years, water delivered from the Colorado River is rapidly facing reduction.

Californians must live within their 4.4 million acre-feet basic annual apportionment of Colorado River water in the absence of surplus river water and unused river water apportionments of Arizona and Nevada. Over the last three years however, the Colorado River Basin has experienced unprecedented drought and the surplus that has been provided to California is no longer available. .

Residential Water Use and Irrigation

The average Southern California family uses approximately 500 gallons of water every day (Water Facts 1). Outdoor use is approximately 50 percent of total residential demand and this water is primarily used for landscape irrigation. For this reason landscape irrigation must be looked at when considering water use and water conservation.

Efficient Irrigation and Resistance to Conservation

An incentive that is being used in many water districts is one based on customer allocation rates.

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Depending on certain factors, customers are allocated a certain amount of water per month or billing cycle. Most of the time, residential water allocation is based on meter size and elevation in relation to the water supply (City of Glendora, 2003). With the Irvine Ranch Water District (IRWD), residential water allocation is based on an allocation formula. This formula(Formula 1) combines the computed outdoor needs of each average IRWD customer with the average indoor needs of all customers, to arrive at an allocation amount for each customer district-wide. If a customer exceeds the allocation prescribed, the cost of water, for that portion over the allocation amount, is raised significantly. Water used over allocation is no longer *cheap*. This is called an increasing block-rate structure. For a number of water agencies, in areas where water supplies are becoming increasingly limited, and population has grown rapidly, this method of allocation and management has become successful at reducing wasteful consumption (Gilbert, Bishop & Weber 34-39, Featherstone 42-51). An important element in the success of an increasing block-rate structure is a clear and concise water bill for customers. It is important that customers learn the system and understand what they need to do to comply with their specific water allocation amount (Nieswiadomy & Molina 352-359).

Background

In 1991Irvine Ranch Water District adopted a tiered-rate billing system, or block-rate structure, based on a water budget allocation to encourage conservation and discourage substandard irrigation systems. The rate structure is based upon providing customers with the water they need at the lowest rates in Orange County (75 cents per CCF). Inefficient use is penalized with higher rates, ranging from $1.50 to $6.00 per CCF. Since the introduction of this rate structure, water consumption has dropped significantly, and the health of the landscape has improved (Barry, Pagano).

By 1997, inclining rates and outreach education programs had accounted for a reduction of 29.8 inches per acre of water per year (Barry, Pagano). From 1994 to 1997 a visual assessment study of the turf at 16 different sites was conducted comparing turf appearance prior to 1991. The study showed that despite the reduction in allocation due to the introduction of the new rate structure, turf quality either improved or remained unchanged. Sites that were initially *poor* prior to the introduction of the new rate structure improved the most (Chestnut, Pekelney). Since 1991, water use has dropped from an average of 4.4 acre-feet per acre to 2.2 acre-feet per acre. In the year 2000, the number of acres that were developed in IRWD's service area doubled, and water use only increased by 3 percent over water use in 1992.

Table 1. IRWD's single-family residential rate structure(Effective July 1, 2003)

Tier	Rate Per CCF	Use (As a Percent of Allocation)
Low Volume Discount	$0.59	0-40%
Conservation Base Rate	$0.75	41-100%
Inefficient	$1.50	101-150%
Excessive	$3.00	151-200%
Wasteful	$6.00	201% +

Residential Use

IRWD's residential use has dropped from 0.32 AF/yr/customer (acre feet per year per customer), in 1989-90 to 0.28 AF/yr/customer in 2002-03. This is a 12.5 percent decrease in residential use per customer. The residential water use per customer for Los Alisos (an area annexed to IRWD, but not yet on IRWD's water-budget rate structure) was 0.35 AF/yr/customer in 2002-3. This is 25 percent higher than the IRWD amount per customer.

Water Budget Allocation

In the following equation, all of the figures are readily available, including landscape size. The majority of IRWD's service area is made up of planned communities. This unique situation makes it relatively simple to calculate landscape area. IRWD uses a standard default of 1,350 sq. ft of irrigated landscape for calculating single-family residential allocations.

Single Family Allocation = $\frac{Kc \times ET \times LA(acres)}{Eff}$ + Indoor Use of 8,976 gal./month
(CCF) (4 people per home/3 CCF/person per month (billing period))

(Source: Irvine Ranch Water District Allocation Formula)

Kc - crop coefficient for Irvine Ranch Water District, it is assumed that all of the irrigatable area is covered with cool-season turf**.**

ET (reference ET) - ET is computed daily from all three of Irvine Ranch Water District's weather stations. 100 percent of ET calculated is used for allocation and is adjusted daily. (Multiply by 36.3 to convert to CCF). (Ash 33).

Indoor Use - Each customer (single family residence) is automatically allocated 3 CCF, per person, per month for 4 people or, a total of 12 CCF (12 x 748 gallons = 8,976 gallons) per month.

LA - Landscape area is calculated in acres. IRWD has established 1,350 square feet as the universal landscape area default for single family residences in IRWD's service area. The allocation is set up with 100 percent of the landscape being cool-season turf grass.

Eff Efficiency - This is the efficiency of the irrigation system.. Irvine Ranch Water District assumes 80 percent.

Applicability to Other Areas

In 1997, Irvine Ranch Water District acquired the community of Santa Ana Heights. Santa Ana Heights is very different than the rest of IRWD's service area and is mostly made up of single-family residences built in the 1950's. It is not a *cookie cutter* community like Irvine. Parcel sizes range from 4,000 square feet to 140,000 square feet, with most falling in a range between 7,000 to 10,000 square feet. IRWD needed to develop an alternative methodology for calculating irrigated area that would give Santa Ana Heights customers an equitable allocation based upon each residential site.

GOALS AND OBJECTIVES

The goal of this study is to provide standard landscape sizes based on total residential lot sizes to use in the IRWD residential water allocation formula. The objective of these findings is to use a standard landscape size based on an individual customer's total lot size to determine water allocation without the need to conduct any actual measurements.

Literature Review

Prior to developing a methodology for estimating landscape, different measurement techniques for measuring land parcels must be studied; the following are a number of ways to determine landscape area.

- Actual physical measurement using a measuring wheel.
- Electronic distance measurements (EDM).
- Aerial photographs (remote sensing) and infrared imagery to measure parcels.
- Aerial photographs and Geographic Imaging Software (GIS) to measure parcels.

All of these techniques are discussed in Evaluation of Techniques to Determine Landscape Areas, prepared by California Polytechnic State University, San Luis Obispo for the United States Bureau of Reclamation. Additional information specific to measuring landscape area using aerial photography and GIS software was found in the BMP 5 Handbook: A Guide to Implementing Large Landscape Conservation Programs as Specified in Best Management Practice 5, by Gary F. Kah, John B. Whitcomb and Warren C. Willig.

Environmental Systems Research Institute, Inc., ESRI, developed the software, ArcView, to allow the measurements of the parcels. The California Department of Transportation uses aerial photography for mapping. Land and object measurements are included in the mapping process and a background of their procedure is detailed in the June 2004 Surveys Manual.

Based on the accuracy, cost and practicality, measurements using orthogonal aerial photographs projected in ArcView GIS software, was chosen as the best method for parcel and landscape measuring.

Measuring Method

Global Imaging Software (GIS) coupled with aerial photographs of the Santa Ana Heights community were used as the method for landscape area measuring. Stewart GEO Systems of Irvine, California provided the orthogonal aerial photographs and ArcView by the software company ESRI was the GIS used to measure the areas. Lot size data was obtained from the county assessor's office and added to the GIS database.

To begin the study Stewart GEO Systems requested specifications for the aerial photographs. Orthogonal photographs were required due to the accuracy required for measurement. A resolution of 3" per pixel was chosen, however later it was discovered that 6" per pixel would probably be sufficient. Another specification required was digital track modeling which allows for accurate measurements along elevation changes. The aerial photographs were also scaled using aerial triangulation and an onboard global positioning system (GPS) aboard the aircraft. When the aerial photographs were completed, the data from the county assessor was added. The cost for the photography and setup in ArcView was approximately $24,000. The total area photographed was approximately 4 square miles.

In the case of this study, the primary interest was landscape and hardscape measurement. The data added to the photographs allows the parcels to be outlined and grouped according to the customer type. All of the residential customers were individually outlined in red, then, using the query tool provided, the residential customers were grouped according to total parcel or lot size. Once these parameters are established, a parcel can be clicked using the cursor and information specific to that parcel appears in a window next to that parcel. This allows the landscape sizes to be grouped according to their respective total lot size, and results in the median landscape sizes for each lot size category.

Figure1. Photograph with parcels outlined.

Another tool included in ArcView is a measuring device. The hardscape measurements can then be subtracted from the total individual lot area. Hardscape was traced because it provided a more solid line to trace along. In addition, total lot size was traced and compared with the database to confirm accuracy of this method. It takes roughly one minute to measure the total lot size and the hardscape. Using this method of measurement, the only question in accuracy is in identifying landscape or hardscape that is hidden underneath any sort of canopy.

RESULTS AND ANALYSIS

The following is a summary of measurements categorized by each lot size. Samples are in 1,000 square foot increments, starting with the smallest lots of 4,000 sq.ft. up to 12,000 sq.ft., at which point the square footage of the categories is increased. Out of a total population of 1,380 for all

categories, the sample size was 437. Included in the spreadsheet(Table 2, Figure 2) are the lot size groups and their respective landscape sizes and landscape sizes plus one standard deviation.

Table 2. Measurement summary grouped according to lot size

Lot Sizes (Sq.Ft.)	Total Pop.	Sample Size	Median Lot Size (Sq.Ft.)	Median Lndscp. Size (Sq.Ft.)	Median Lndscp.%	Max. Landscape Size with 1 Std.Dev. (Sq.Ft.)	1 Std.Dev. (Sq.Ft.)
4,000 - 5,000	59	40	4332	1358	31%	1,823	465
5,000 - 6,000	59	50	5750	2225	39%	2,765	540
6,000 - 7,000	160	50	6267	3015	48%	3,582	567
7,000 - 8,000	414	50	7368	3735	51%	4,330	595
8,000 - 9,000	346	50	8686	4433	51%	5,298	865
9,000 - 10,000	103	50	9506	5080	53%	5,922	842
10,000 - 11,000	56	50	10473	5532	53%	6,585	1,053
11,000 - 12,000	37	30	11597	6384	55%	7,964	1,580
12,000 - 16,000	44	30	13819	7607	55%	9,218	1,611
16,000 - 80,000	95	30	19800	12531	60%	23,506	10,975
80,000 - 140,000	7	7	114715	85229	74%	100,014	14,785

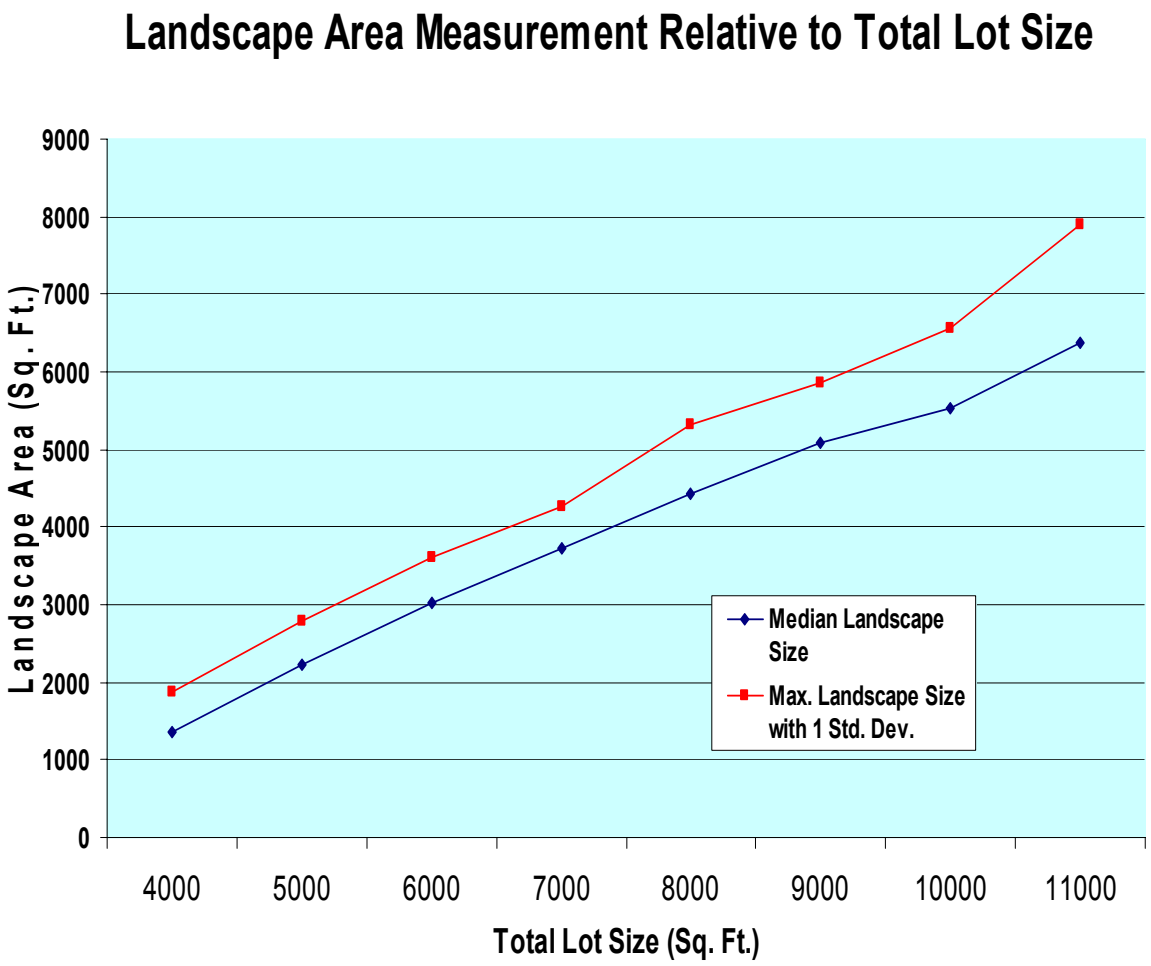

Figure 2. Landscape area measurement relative to total lot size

Regression Analysis

Figure 3 show the statistical relationship between total lot size and landscape size, using median landscape sizes plus one standard deviation for each lot size group with lot sizes over 12,000 square feet omitted. Most residential lots in Santa Ana Heights are actually less than 16,000 square feet. Although a regression line and formula was derived for lot sizes between 80,000 and 140,000 square feet, it is highly recommended that traditional surveying techniques are used to measure landscapes of lots over 43,560 square feet (1 acre).

For most months, the percentage of excessive and wasteful customers is almost the same between IRWD and SAH(Table 3). The percentages for inefficient customers are considerably different, however. This is believed to be due to IRWD's use of a 1,350 square foot default per residence which is not as accurate as the methodology prescribed in this thesis. The inefficient tier includes any water use over 100 percent and under 150 percent of the allocation. It is possible that if this methodology were used in determining Irvine's allocation, the comparison at the inefficient level would be closer. This would be a suggestion for further study. In addition, customers in Irvine that fell into the inefficient range did not receive conservation bulletins until September 2002. It is

apparent that by October 2002, inefficiency comparisons were much closer. Although an observation, this comparison shows how closely Santa Ana Heights matches the trend of overuse in Irvine, where the allocation formula is in practice, albeit using a standard default for landscape area for all residential properties.

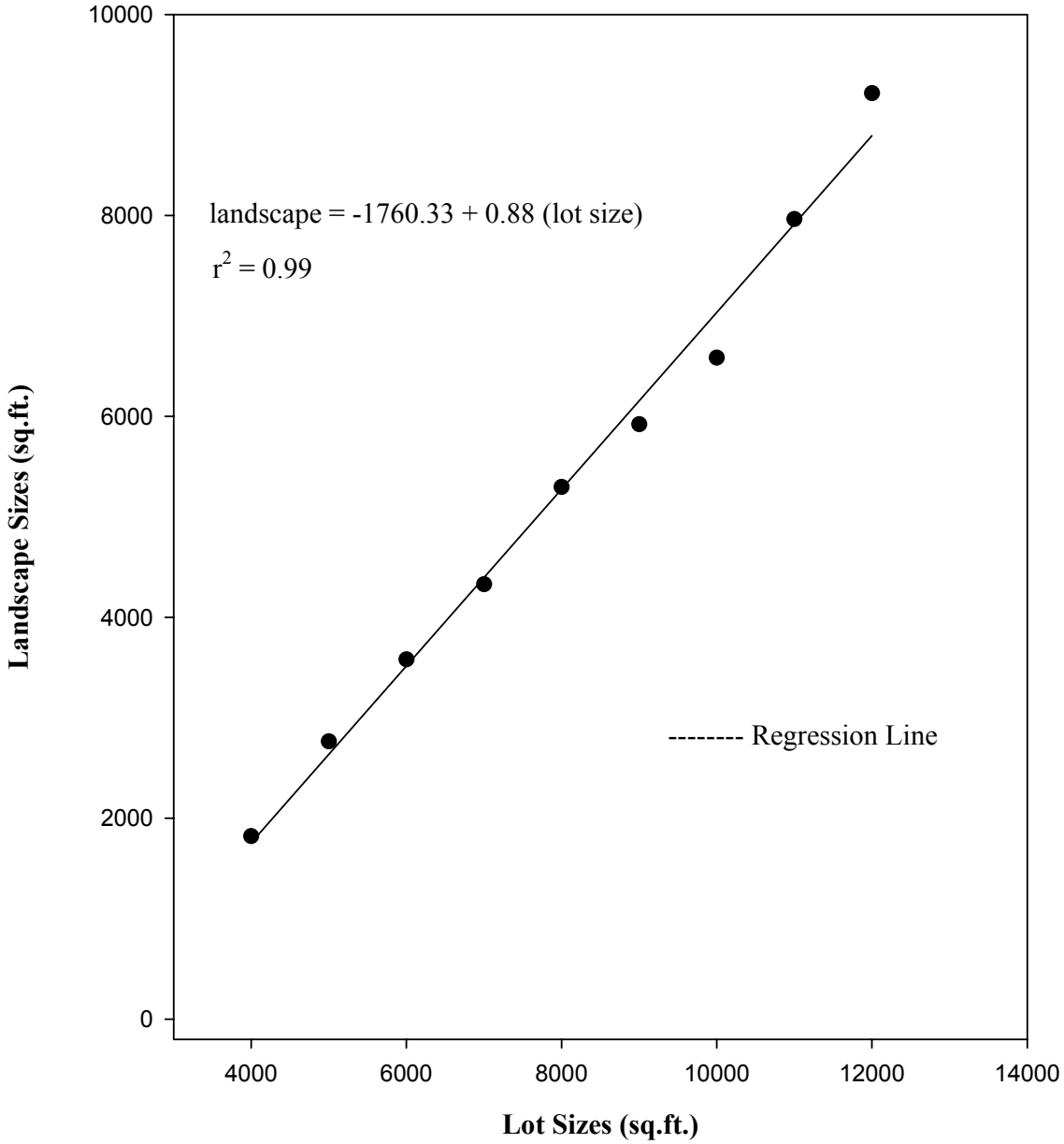

Figure 3. Regression line for lot sizes between 3,000 and 80,000 square feet

Table 3. 2002 Water over use for Irvine verses Santa Ana Heights.

Tier	Jan		Feb		Mar		Apr		May		June	
	Irvine	SAH	Irvine	SAH	Irvine	SAH	Irvine	SAH	Irvine	SAH	Irvine	SAH
% Inefficient	34	9	34	11	36	8	35	6	36	8	39	13
% Excessive	3	1	3	2	3	2	3	1	3	1	4	2
% Wasteful	1	2	1	1	1	1	1	1	1	1	1	1
	July		Aug		Sept		Oct		Nov		Dec	
	Irvine	SAH	Irvine	SAH	Irvine	SAH	Irvine	SAH	Irvine	SAH	Irvine	SAH
% Inefficient	22	12	20	14	24	17	24	24	21	18	18	18
% Excessive	5	3	6	2	6	4	6	7	6	5	4	4
% Wasteful	2	1	2	1	2	2	2	3	2	2	1	3

The Importance of Accuracy and Measuring

A total of 30 residential customers were selected at random for on-site wheel measurement verification of the ArcView measurements. The total lot and landscape areas for each of the randomly selected sites were measured and compared with ArcView measurements, drawing polygons and using infrared data. The average error rate for the 30 samples was 4.7 percent for the manual polygon tracing method. Previous studies recorded error rates under 3 percent which would fall within this study's parameters (California Polytechnic State University, San Luis Obispo 23-24). The infrared method produced an error rate of 11.6 percent.

SUMMARY

The accuracy of approximately 95 percent compared to the measuring wheel method supports the validity of using the ArcView GIS method of tracing polygons around hardscapes to determine individual landscape sizes. The practice of using a measuring wheel is too costly in time and is logistically inefficient. The use of infrared spectrometry as an added option to aerial photographs in ArcView is more time efficient, however it is not as accurate as the ArcView GIS method of tracing polygons and it is more expensive.

Since a reliable method of measurement has been established, median landscape sizes can be established. The theory of taking the median landscape size of each lot size group and adding landscape area to include one standard deviation allows for any variances in residential developments. Grouping the lot sizes in 1,000 square foot increments and assigning median landscape sizes based on sample measurements provided the data needed to derive the regression formula. The regression formula:

Landscape Size = -1760.33 + (0.88 x Lot Size)

provides a landscape size for any residential lot over 3,000 square feet. (It is recommended to measure lots over 43,560 square feet by traditional survey methods, due to more extreme variability of landscapes over 1 acre.)

CONCLUSION

The reason for setting water allocation limits is to encourage conservation and efficient irrigation practices. It is important to have an accurate and fair method for developing allocation levels in order to implement a billing rate system in which the public will be confident. Irvine Ranch Water District plans to estimate landscape area by this method for water allocation purposes.

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