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Baselining water consumption in the Las Vegas Valley single family residence

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BASELINING WATER CONSUMPTION

IN THE LAS VEGAS VALLEY

SINGLE FAMILY RESIDENCE

by

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ABSTRACT

Baselining Water Consumption in the Las Vegas Valley Single Family Residence

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This thesis baselines the monthly water consumption in the LVMA[1] and analyzes the patterns of water-use with respect to physical and environmental aspects present in single family residences. The physical aspects included within the scope of this study are the built-up area, the un-built area and the pool area, provided by the Clark County Assessor Office at Las Vegas for the single family residences of LVVWD. The environmental aspects include outdoor ambient temperature, cooling degree day data and heating degree day data, monitored at the Mc Carran International Airport. The results from this research also provide historical monthly and annual water use per acre of built-up area and per acre of un-built area for the years 1990, 1995, 2000, 2005 and 2006. Based on the historical and the recent data year analysis, the water use limits for the future can be predicted.

This thesis also illustrates through a series of maps, the zip-code and street level water consumption for the years 1990, 1995, 2000, 2005 and 2006. These maps help to identify water consumptive hot spots. For each of these years, both annual and monthly correlation of water use with built-up area, un-built area and pool area are calculated. These factors are fitted in a linear equation through regression analysis, so that the total water used in a SFR can be devised as a function of built-up, un-built and pool areas. For example, for the recent data year 2006, it is

[1] For the purpose of this thesis, Las Vegas Metropolitan Area is composed by a total of 55 zip-codes which includes, incorporated Clark County (19 zip-codes), City of Las Vegas (19 zip-codes), City of Henderson (8 zip-codes) and City of North Las Vegas (9 zip-codes).

derived that for 'B' sq. ft of total built-up area, 'UB' sq. ft of total un-built area and 'P' sq. ft of total swimming pool area, the kilo gallons of water used can be calculated from the equation:

Y = 0.043268 B + 0.010871 UB + 0.287903 P - 24.0163.

This study compares the monthly water use trends with the outdoor ambient temperature, cooling degree day data and heating degree day data. Thereby the impact of temperature and degree days on the usage of water for the single family residences are investigated and quantified. Lastly, the ratios between the built-up area, un-buiit area, pool area and water use are calculated. It is found that, during the year 1990, the average un-built and built area ratio was 3.8 and it was declined to 3 during the year 2006, whereas the average un-built and pool area ratio was 80 during the year 1990 and it was declined to 70 during the year 2006. From these values, the annual and monthly water uses for an addition of every acre of built-up and un-built area are calculated.

By identifying hotspots of water consumption, understanding the impact of the physical aspects of SFR on water use and projecting the water use limits for an addition of every acre of built-up and un-built area, this thesis becomes an important reference for planners and designers in the LVMA and the US Southwest. The analysis could be used from the design perspective to reduce direct (onsite) water, thereby reducing the indirect use of both water and energy (offsite – water used for energy generation and energy used to pump heat and distribute water). Thus this research forms a useful tool in water conservation management especially for the single family residences of the LVVWD.

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DEFINITION OF TERMS AND ABBREVIATIONS USED

Definition of Terms

1. Assessor- Clark County Assessor's Office.
2. Average water use or average water consumption refers to the water use per single family residence
3. Built-up area refers to the total constructed square footage of single family residences including the area of all floor levels. The built-up area doesn't include the garage area or car-park area.
4. City of Henderson- refers to the Incorporated City of Henderson as defined by the City Government of Henderson.
5. City of Las Vegas- refers to the incorporated area of the City of Las Vegas as defined by the City Government of Las Vegas.
6. City of North Las Vegas- refers to the Incorporated City of North Las Vegas as defined by the City Government of North Las Vegas.
7. Clark County- refers to the area of Clark County which is within the Las Vegas Metropolitan Area and is otherwise identified as Incorporated Clark County by the City Government.
8. Cooling Degree Day- refers to the number of degrees in the days on which the temperature is more than 65 degree F.
9. Heating Degree Day- refers to the number of degrees in the days on which the temperature is less than 65 degree F.
10. Las Vegas Metropolitan Area- refers to the 54 zip codes considered in this study, which lie in the City of Las Vegas, City of North Las Vegas, incorporated Clark County and City of Henderson. It does not include Laughlin, Mesquite and Boulder City.

11. Nevada Power- refers to Nevada Power and Sierra Pacific Power Company, the two main providers of electricity in Nevada. These two are sister companies and share a common data pool for delivered electricity. For this research, they are considered as a single enterprise/ data provider and referred to as Nevada Power.
12. Parcel- refers to the numbered plot of land on which the single family residences are constructed. Each Parcel contains one single family residence.
13. Pool area refers to the total area of swimming poois in a single family residence. The five different pool sizes found in Las Vegas metropolitan Area are, 300 sq. ft, 450 sq. ft, 512 sq. ft, 648 sq. ft and 800 sq. ft.
14. Single Family Residence- refers to the detached single family home that doesn't include the attached single family residence or twin townhome.
15. Total water use or total water consumption refers to the overall water used by all the single family residences
16. Tree area refers to the totai square footage of trees and shrubs area present in a single family residence.
17. Turf area refers to the total square footage of turf area present in a singie family residence.
18. Un-built area refers to the total square footage of un-constructed area around the built-up area within the single family residential parcel. The un-built area doesn't include the garage area or car-park area.

Abbreviations

- SFR- Single Family Residence
- WC- Water Consumption in Kilo Gals
- EC- Electricity Consumption in Kilo Watt Hours
- CDD- Cooling Degree Day.
- HTDD- Heating Degree Day
- DD- Degree Days in degree F
- LVMA- Las Vegas Metropolitan Area

- LVVWD- Las Vegas Valley Water District
- CC- Clark County
- CLV- City of Las Vegas
- CH- City of Henderson
- CNLV- City of North Las Vegas
- SNWA- Southern Nevada Water Authority
- GISMO- Geographical Information System and Management Office.
- NCDC- National Climatic Data Center.

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I like to thank the Lord Almighty for giving me the courage and strength to take over every obstacle I faced during the course of this study and change them into stepping stones that led me throughout this journey. This thesis is the result of many wonderful and dedicated souls who constantly helped me with their valuable critics and encouragement. I wholeheartedly thank my family – especially my husband for the sacrifices and compromises he made for the successful completion of my thesis, my parents for their love and affection and most importantly, my advisor and committee chair, Prof. Alfredo Fernandez-Gonzalez for guiding me with all his enthusiasm and support. He always believed in my capabilities and words cannot express the gratitude I feel for him. Without them there are no doubts that I wouldn't have done this study from start to finish. As this thesis is a follow-up research that parallels a previous study done by another student, Ms. Abhilasha Wadhwa, I am greatly thankful to her for she has set up the path clear that helped me to get a smooth ride. She has never failed to lend me her shoulders both as a good friend and as an intellectual support.

Altogether, this thesis made me to realize that this world is surrounded by marvelous and wonderful people who are there to help me when I am in need. Besides the numerous lessons I learnt from doing this thesis, as mentioned in the Bible – "Ask and you shall receive, knock and the door will be opened", through all the good souls I met during the course of my thesis I learnt that, anything is possible and everything has a solution when I really seek for it.

I wholeheartedly thank my committee members Dr. Michael Kroelinger, Dr. Zouheir Hashem and Prof. Daniel Ortega from Architecture department and Dr. Lambis Papelis from Desert Research Institute for lending me their helpful hands and for giving me their valuable support to make the thesis successful.

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CHAPTER 1

INTRODUCTION

Water is one of our most precious resources – the source and nurturer of life. It has been the reason for the development of many great civilizations and the cause for the extinction of many others. In 2000, the United States National Intelligence Council projected that, "By 2015 nearly half the world's population—more than 3 billion people—will have less than 1,700 cubic meters[1] of water per capita per year. Water has been a source of contention historically and by 2015, the possibilities of conflict will increase" (20-21). Especially, the South West United States is mired in drought of unprecedented severity. According to the Southern Nevada Water Authority (SNWA), the Las Vegas valley is in the eighth year of a continuous drought. Water scarcity is sensed all around the world and a former Interior Secretary of United States states that, it is "The era of limits" both in terms of available water supplies and federal financial resources to deal with the issue (Norton 2-3).

Southern Nevada is characterized by a hot-dry desert climate and is, at the same time, one of the fastest growing states in U.S, with a growth rate more than triple the National Average (Bernstein). Besides the global increase in temperature, the ever-increasing water demands of the burgeoning population of Nevada are beefing up against the supply. As said by the Governor of Nevada in the State of the State Address to the 74th session of the Nevada Legislature on January 2007, "No natural resource in the State of Nevada is as critical or as controversial as water. We have the driest state in the nation and one of the highest rates of growth - a combination that places tremendous stress on our precious water resources" (Gibbons 5). Therefore water conservation is essential to sustain Nevada. Nevadans are faced with the

[1] 450,000 gallons (1 cubic meter = 264.17 gallons). Water used for Industrial purposes and Energy production are included in the value.

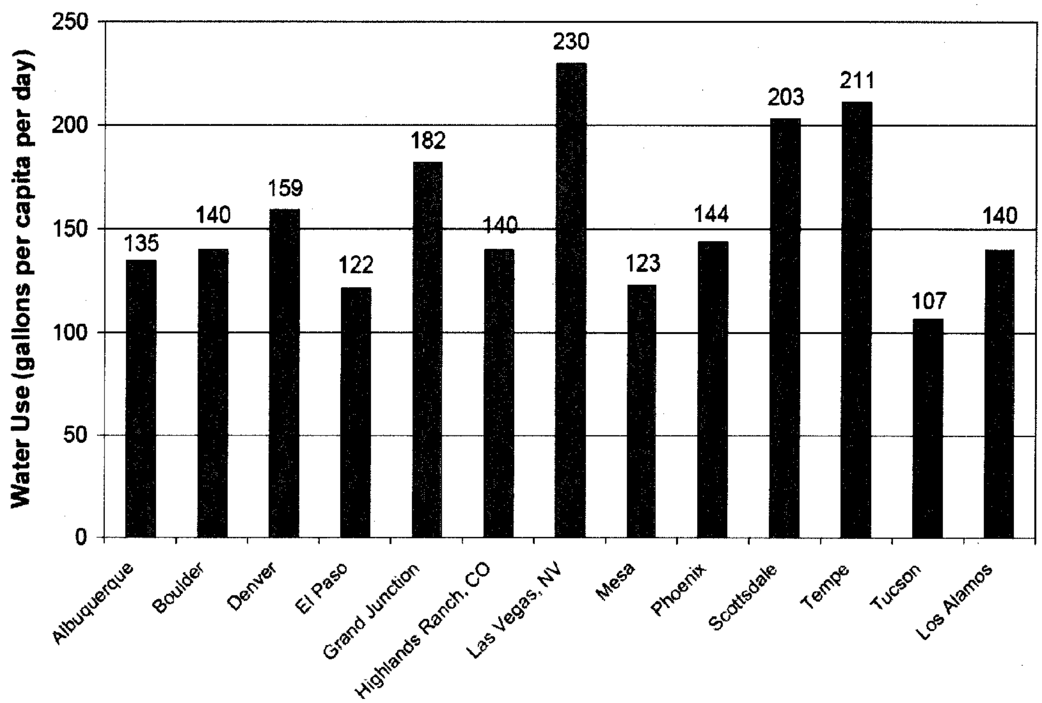
challenge to reduce water use and still protect the thriving economy coupled with the harshness of desert climate. This situation demands an urgent study in the subject of water use.

Purpose of Research

Why Should the Research Focus on Single-Family Units of LVMA?

Since the Las Vegas Metropolitan Area has experienced exceptional growth in population, and given the fact that single family residence is the highest consumer of water over the other southwestern cities (qtd. in "Long Range Water Supply Plan", 30), there is an inevitable need that focuses on the water use of single family residences of LVMA.

Fig.1.1: 2001 Single Family Residential Per Capita Water Use (qtd in "Long Range Water Supply Plan", 30).



According to 2006 U.S. Census Bureau, Clark County of Nevada ranks second out of 3141 counties in U.S for highest percentage increase in housing units from 2000 to 2006, with 29.2% increase. While Las Vegas, Henderson and North Las Vegas are among the fast growing cities in

U.S. with remarkable increase rate in population from 2000 to 2006 as 14%, 34% and 67.5% respectively[2] (U.S. Census Bureau). As rapid increase in population and housing units are directly proportional to the increase in overall annual water consumption, the focus of this research is on the residential sector. In 2004, based on Southern Nevada Water Authority's municipal metered service area potable and non-potable water records, single-family residential sector consumes the highest percentage of water when compared to the other sectors. Out of 57.9% of potable water used in the residential sector, 74.1% of potable water is used in the single family units. Thus targeting the single-family units of the residential sector of the Las Vegas Metropolitan area would reap more benefits.

Why Should Water Conservation Measures Focus on Outdoor Water Use?

The 1922 Colorado River Compact provided Nevada, 300,000 acre feet per year (AFY) of water from Colorado River as Nevada's consumptive use apportionment. According to the compact, with the return flow credits (from indoor use), Nevada can draw more than 300,000 AFY, till the consumptive use is maintained less than the apportionment. It is importunate that more focus be thrown on conserving the outdoor water use as opposed to the indoor water use, as all of the indoor water flows back to Lake Mead and earns return flow credit.

Why Should Outdoor Ambient Temperature and Vegetation be considered?

This research focuses on analyzing the factors that increase the outdoor water use. Among all the factors that affect the outdoor water use, outdoor environmental temperatures and existing vegetation play important roles. Outdoor temperature and vegetation have a direct relationship to water consumption, as hot conditions increase evaporative loss and larger areas of vegetation demand more water. Trees present a different picture - though they take in more water for survival than other types of vegetation, they transpire most of the water they absorb and thereby help to reduce the outdoor temperature. A 2007 report on 'Heat Island Effect' from the U.S. Environment Protection Agency says that, "a mature tree with a 30-foot crown transpires approximately 40 gallons of water per day" (1). According to the book - Introductory Horticulture, "only about 1 percent of the water absorbed is actually used by the plant; the other 99 percent is

[2] Release June 28, 2007.

lost through the leaves and stems as water vapor in a process called transpiration" (Reiley 40). These evidences prove that though water makes up 90 percent of the weight of plants (Reiley 40), they spend almost all of it to keep the ambient temperature down.

It is further proved that trees reduce energy consumption significantly by reducing the outdoor temperature. According to one of the researches done by Lawrence Berkeley National Laboratory on heat island effect, trees offer significant benefits by shading the building and lowering the air temperature and thus can offset or reverse the heat island effect (Akbari 295-310). The research states that, "Typically, electricity demand in cities increases by 2 to 4 percentage points for each 1 degree Celsius increase in temperature" (Akbari 295-310). Inspired by the findings of Akbari, this research attempts to identify the effects of temperature change and the nature of vegetation within parcels at Las Vegas Metropolitan Area and establish a direct relationship between water consumption and energy use with respect to change in temperature and vegetation.

Research Questions

This Research aims to answer the following questions,

1. What was the city level and zip code level historic annual water consumption trend in the single family residence of LVMA from the year 1990 to 2005? Similarly what was the water consumption trend for the recent data year 2006?
2. What was the zip code level and street level relationship between water consumption and built-up area, un-built area and pool area in the single family residence of LVMA from the year 1990 to 2005? Similarly what was the relationship between water consumption and built-up area, turf area, tree & shrub area and pool area for the recent data year 2006?
3. What was the relationship between water use and built-up area, un-built area and pool area, for the extreme summer and winter months, during the years 1990 to 2006.
4. How do the cooling and heating degree days affect the monthly water consumption in the single family residences of LVMA from 1990 to 2006? Similarly how do the degree days affect the monthly electricity use in the single family residences of LVMA from 2002 to 2006?

What are the effects of outdoor ambient temperature on water and electricity use for the single family residences of LVMA from the year 2002 to 2006?

5. How can water use be projected for an addition of every acre of built-up area and un-built area of single family residences in LVMA?

The findings of this study will help individuals to learn the consumption trends of the past and the present of the single family homes of LVMA. As mappings are done in three scales – street level, zip code level and city level, one can compare his/her contribution in different levels and learn from the low consumptive streets, zips and cities. These maps can also bring water consumptive hotspots to light.

Water conservation is no more an option - it is a compelling need for people to sustain their lives. As outdoor water conservation has been in practice throughout LVMA for more than a decade, before proceeding with the conservation measures, it is imperative to understand the effects of certain forces that play against it. One such force is the climate – the hot and dry desert air coupled with very low precipitation. Another factor is the vegetation – turf, trees and shrubs. Though tree gives shade and cools the place around it, heavy, dense shrubs and turf consumes as much as 73 gallons of water per sq. ft per year (Sovocool, 31). As water consumption is compared against climatic factors such as outdoor ambient temperature and cooling-heating degree days, and existing vegetation which influence the climatic factors, a thorough understanding of the effects they cast on the outdoor water consumption is attained.

Most importantly, in light of analyzing the effects of microclimatic aspects on water consumption, energy usage patterns are analyzed. It is obvious that water is used to produce electricity and electricity is used to pump, distribute and heat water. Water has an indisputable offsite relationship with energy and this research attempts to seek if there is any direct (onsite) relationship between water and energy with respect to change in outdoor temperature and vegetation. Ultimately, it is believed that by outlining the local conditions of Las Vegas Metropolitan Area, a thorough understanding of water use at the demand-side is obtained which helps the common public, home owners and policy makers to set a target and do their best in terms of water conservation.

CHAPTER 2

LITERATURE REVIEW

In the miraculous evolution of our planet, nature has developed into an interdependent eco-system. Human needs are woven together with the resources and life cycles of nature that sustains the earth. Our civilization is continuously faced by the challenge of finding shelter and nourishment from the earth. This quest is followed by exhaustion and depletion of resources which in-turn disturbs the life cycle and ultimately endangers the human species itself. This situation demands a study that deals with one of the precious resources of the planet, water. Before one can take the necessary measures to start conserving water, it is imperative to first understand the current situation. For the convenience of documentation, the analysis of current status in terms of water consumption and availability of resources is divided as global level, state level and city level analysis. This part of the research brings together all the relevant facts that substantiate the need for this study. Besides, this study envelopes, other similar investigations and ongoing initiatives that seeded this research.

Part 1: Global Water Use

Of all the factors that increase the demand for water, population growth and global warming are prominent. According to Roman Kupchinsky, in 2005, "The U.S. government has predicted that by 2015 almost half of the world's population will be "stressed" for water. Water -- rather than oil -- could become the world's next biggest catalyst for conflict". Impacts of water conflicts followed by the water crunch would be more on the areas which are highly populated and experiences overall high temperatures coupled with low precipitation and humidity.

Abel Wolman introduced the concept of 'urban metabolism' in 1965 and according to him water is the largest component of urban metabolism in an American city (179-88). He states that no other resource could be compared with water for the extent of consumption in urban areas. Urban Metabolism varies from place to place and it is the measure that signifies the degree to which a place has circular as opposed to linear metabolism levels. In other words it is the quantification of the overall distribution and transfer of water and other resources and their waste, in and out of an urban area. As understanding the urban metabolism of a place provides knowledge about the health of that place, it is important to understand the water-cycle which is part of the urban metabolism. It is true that, though the chief factor that drives water-cycle – the sun is one and the same, the impact and effectiveness could be altered due to factors such as climate, vegetation, etc....

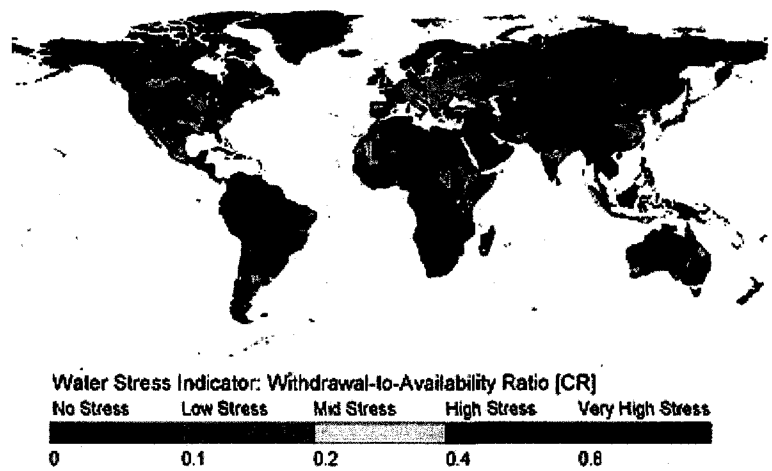
According to Rodney White, water use is not the same in urban and suburban areas. He says that there is lot of differences between the amount of water used in an urban area and the amount of water used in a rural area. An individual in water scarce regions might survive with 30 liters[1] of water per day. A city dweller can survive with 200 liters[2] of water, whereas an urban consumer might use 600 liters[3], where water rates are fixed as a lump sum and physicai availability of water is easy (White). According to White, high water consumption is not based on need, but on habit. In global level, it is a stark reality that consumption of water doesn't have a direct relation to the resource available, but increases with the growth of the living standard as well as the population. This condition results in exorbitant consumption of water in densely populated urban areas. To help people understand this and to relate individual behavior to large scale resource availability, the difference between needs and wants of water should be analyzed and monitored.

It is a known fact that currently 1.1 billion People live without clean drinking water ("Water Crisis: Facts and Figures"). When it is hard for some people to satisfy even their basis water needs, some cannot live without the lushness around their house. Wolman says that, "While New Yorkers were watching empty reservoirs, Californians were building aqueducts. Thanks to foresight people in California were watering lawns and filling their swimming pools, while in New

[1] 7.8 U.S. gallons, as1 liter is 0.26 U.S. gallons.
[2] 52 gallons.
[3] 156 gallons.

York lawns were dying and pools were empty" (Wolman, 179-88). It is necessary to establish a connection between the individual and the global i.e. per capita water use and availability of resources. To do this, people should first understand the current water situation.

Fig. 2.1: Water Stress Indicator: Withdrawal-to-Availability Ratio (CR) (Alcamo et al. 22).



Water stress occurs in regions where there is no relation between water use and water resources. A measure that calculates the level of water scarcity in different river basins is the criticality ratio (CR) which is the ratio between the annual mean water withdrawals to the availability of water (Alcamo et al. 22). According to the calculations by Alcamo and others, high criticality ratio indicates the high amount of water use stress placed on water resources and it signifies high intensity water use by all and low quality water use by rear end users. They also state that the higher the CR, the greater the chance of absolute water shortages during low flow periods. As per the above map, most of the states in America are marked as high or very high stress regions with the criticality ratio from 0.4 to 0.8. While over-exploitation of aquifer and dry rivers are some of the problems caused by water stress in terms of quantity, saline intrusion, organic matter pollution and eutrophication are some of the problems caused by water stress in terms of quality. Besides, these aspects elevating water tension among people, they also intensify water tension in both national and international levels.

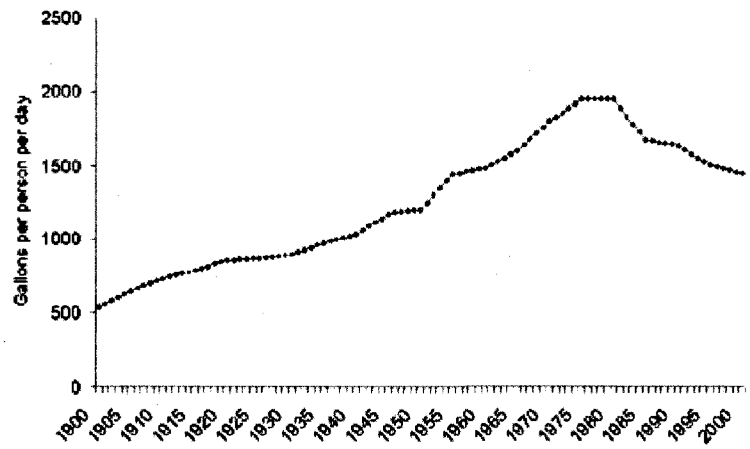
Comparative Analysis of Water Use across Nations

According to 2006 Living Planet Report, the annual water withdrawal per person for United States including domestic, industrial and agricultural uses is 440 Kilo Gals. But in similarly developed countries like Japan and Germany the annual water withdrawal per person is 190 kilo gallons and 150 kilo gallons respectively. Meanwhile in highly populated countries like India and China the annual water withdrawal per person is only 158 Kilo gallons and 135 kilo gallons respectively. The annual water withdrawal per person ranges from 1365 kilo gallons – in Turkmenistan to 105 kilo gallons in Philippines ("Living Planet Report"). From these values, it is obvious that water consumption doesn't depend on behavior of an individual alone, but it is likely to be based on the cumulative set of practices and constraints of that region. Especially in developed countries, water is consumed not just to satisfy their needs. In the National level, water consumption patterns are rooted deeply in a region as a culture, more than a habit.

The annual domestic water withdrawal per person in U.S., Japan and India are 53 kilo gallons, 40 kilo gallons and 13 kilo gallons respectively. Whereas in Countries like Syria, Sudan, Bulgaria, Pakistan, Afghanistan, Sri Lanka, Bangladesh, Netherlands, China, Nepal, Indonesia, Madagascar and Uruguay it is less than 13 kilo gallons ("Living Planet Report"). Also it is evident through the report that in some countries, the annual domestic water withdrawal per person is even less than 4 kilo gallons. In most cases this difference is associated with the technological development of that place, which in turn is related to the physical availability of water. As the ease of water availability increases, it is hard to curb the amount of water spent.

When the total water use in United States has increased over the period of years, per capita water consumption has been reduced considerably (qtd. in "Pacific Institute Analysis"). According to Pacific Institute, as per USGS data, from 1995 to 2000 the total water use has increased 1.7 percent; meanwhile the per capita water use has reduced 4 percent. The overall increase is due to growth and raising demands of the country and the per capita reduction is due to efficiency programs and conservations measures that instigated awareness throughout the country. The following graph published by Pacific Institute in 2005 shows that in United States, between the years 1970 to 1980, the annual per capita water use was 712 kilo gallons, but it started declining after 1980 and during 2000, it was 530 kilo gallons, which is around 25 percent decrease within the next couple of decades.

Fig. 2.2: Per Capita Water Withdrawals in US ("Pacific Institute Analysis").



Though the decline in per capita water consumption is encouraging, climate change and population growth are inevitable, which increases the overall water use. Besides the macro level analysis, as water availability and consumption patterns are specific to a region, it is imperative to analyze water use in micro levels.

Part 2: State Level and City Level Water Use

In Southern Nevada, it is surprisingly true that the region is well guarded with almost all the forces – both natural and manmade that sky rocket water use. Nevada ranks first as the fastest grown state of the nation, with more than five times increase in population from 1910 to 2004 ("Centennial: Vegas by the numbers").

Southern Nevada experiences hot-dry desert climate with only 4.5 inches of average annual precipitation. Moreover the average annual temperature of Nevada is drastically increasing in the past thirty years. In the City of Las Vegas, it is reported that the summer mean monthly temperature of the year 2006 was 3.5 degrees higher than the thirty years average from 1970 to

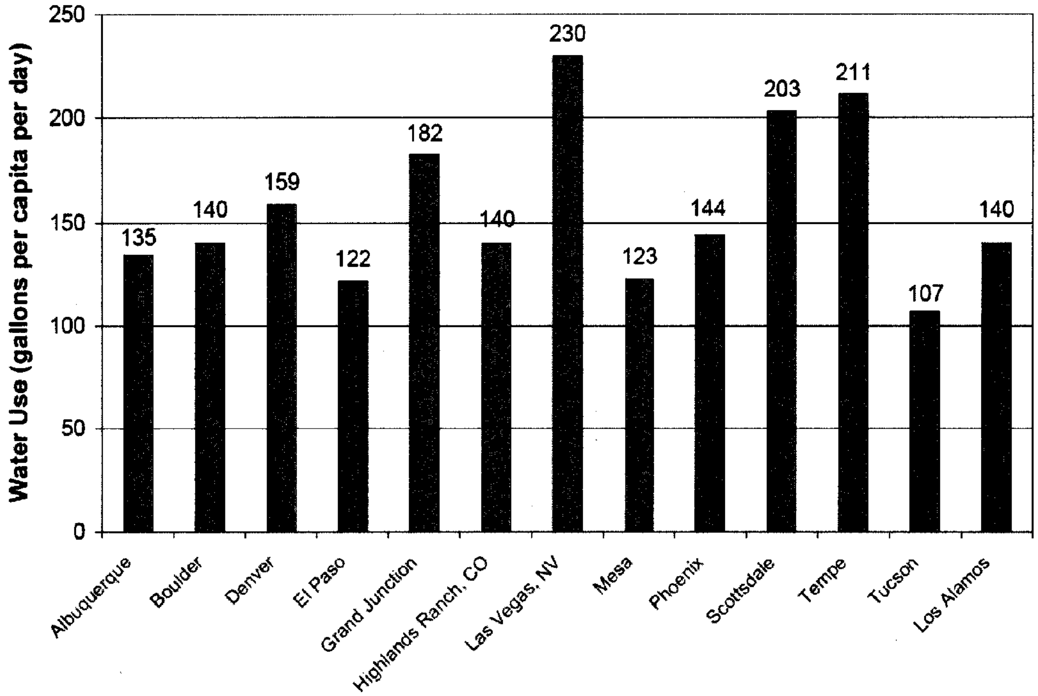
2000. It is also evident that the evapotranspirational[4] demand of Las Vegas Valley is around 90 inches (Sovocool, 8), which is believed to be high compared to other areas due to very high evaporation and remarkably less humidity in the Valley. As the chief economic driver of Vegas is tourism and gaming industry, the Valley housed 37.4 million visitors in the year 2004 ("Centennial: Vegas by the numbers"). In addition to all these factors, "Outdoor consumption averages 70 percent of total residential water use, rising to 90 percent in summer months" ("One Goal", 2). These factors aggravate water crunch in Nevada and demand meticulous planning and appropriate allocation of resources within the state.

Comparative Analysis of Water Use across South-Western Cities

Among the thirteen south western states shown in the fig. 2.3, for single family residential water use, Las Vegas topped the graph with 230 gallons per capita water use per day (qtd in "Long Range Water Supply", 30). Las Vegas also leads the other cities in outdoor water consumption. When the average outdoor water consumption is only 55 percent of the overall water consumption in the single family residences throughout the 13 south western cities, the average outdoor water use in the single family homes of Las Vegas is 70 percent of the total consumption. According to Western Resource Advocates, the per capita water use per day in single family Units of Las Vegas Valley is 294 gallons in 2003, 274 gallons in 2004 and 276 in 2005, where the average outdoor consumption is 61 percent. The outdoor water use in cities such as Tucson, Mesa, El Paso, Albuquerque, Highlands Ranch and Phoenix are well below the average. It is interesting to notice that the outdoor water consumption is only 35.5 percent in Tucson, where the water rate structure is noticeably high (Cooley et al. sec2:22). It could be implied that water rate structure plays an important role in snipping the waste out of the overall water use.

[4] Evapotranspiration is the summation of evaporation of water into water vapor from the earth surface and transpiration of plants through stomata of their leaves. It is an important part of the water-cycle. The rate of Evapotranspiration differs between different species of plants and trees. For example, a woody plant with deep tap root transpires more compared to an herbaceous plant. Similarly, a coniferous tree transpires more compared to a deciduous tree. Evapotranspiration (ET) could be derived for a specific condition using the factors such as precipitation (p), steam flow (q), ground water recharge (d) and change in storage (s). It is calculated as the difference between precipitation and the summation of steam flow, ground water recharge and change in storage – $ET = p - (q + d + s)$.

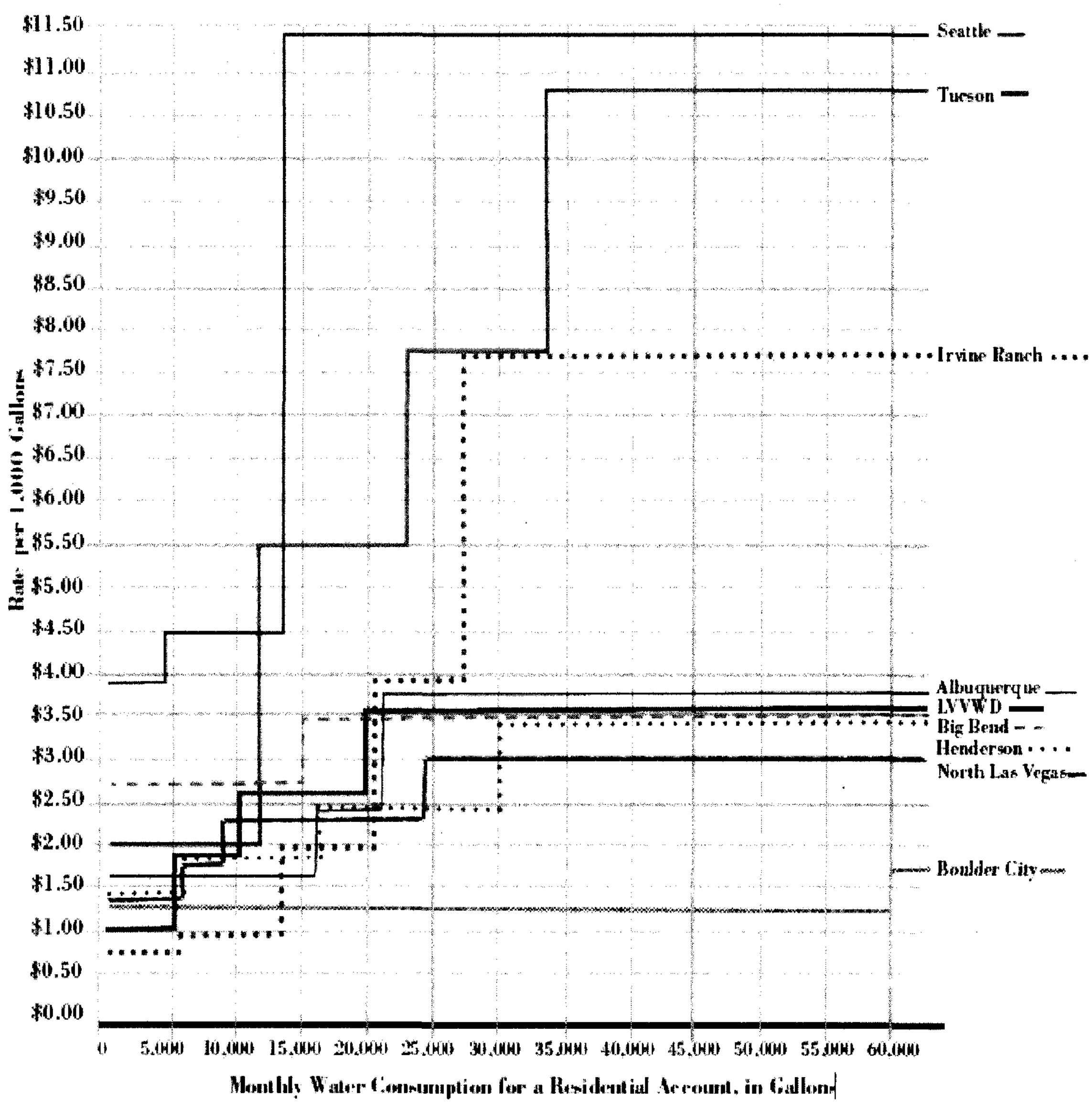
Fig.2.3: 2001 Single Family Residential Per Capita Water Use (qtd in "Long Range Water Supply Plan", 30).



<u>Water Rate Structure and Expenditures on Water Conservation</u>

"An effective rate structure can be an important tool for promoting efficient use" (Cooley et al. sec2:21-24). A comparison of water rate structures between the nine south western states such as Seattle, Tucson, Irvine Ranch, Albuquerque, Las Vegas Valley Water District, Big Bend, Henderson, North Las Vegas, and Boulder City reveals that the per capita water demand of the most conservation oriented water rate structure agencies – Seattle, Tucson and Irvine Ranch is lower than that of the per capita water consumption of the other agencies (Cooley et al. sec2:21-24). When there is increase in the per-unit cost of water from block to block, there would be noticeable water savings ("Water in the Urban Southwest"). But it is obvious from the graph that water rates of Las Vegas Valley fail to send a signal to the consumers to conserve water. However, Southern Nevada Water Authority, an agency that provides Southern Nevada with its regional water needs, offer various conservative measures and some of them are proved to be the most successful ones in the Nation.

Fig.2.4: Residential Water Rate Structures - South Western Cities (Cooley et al. sec2:23).



On the other hand, it is reported by the Western Resource Advocates that compared to Albuquerque and Tucson, Las Vegas Valley spends more money on both conservation and supply development. From the year 2000 to 2005, when the annual per capita expenditure on conservation for Albuquerque and Tucson were $5.94 and $0.85 respectively, Las Vegas Valley spent $19.47 on conservation, which is around 8 times more than that of the average expenditure of Albuquerque and Tucson on conservation ("Water in the Urban Southwest"). Similarly, when the average annual per capita expenditure on supply development for Albuquerque and Tucson were $2.61 and $21.02 respectively, Las Vegas Valley spent $103.69 on conservation, which is more than 8 times of the average expenditure of Albuquerque and Tucson on supply development ("Water in the Urban Southwest").

There could be two main reasons for the high expenditure on conservation in Las Vegas Valley. Las Vegas Valley has 1,747,536 residents population during the year 2005, when the population of Albuquerque and Tucson were only 488,133 and 507,362 respectively ("2005 American community Survey Data"). Also, the average evapotranspiration rate for each year between 2003 and 2005 in Las Vegas Valley was 74.8 inches, when the evapotranspiration rate in Albuquerque and Tucson was only 38.1 inches and 67.56 inches respectively ("Water in the Urban Southwest"). It is evident that Southern Nevada Water Authority (SNWA) spends enormous amount of money in implementing conservation measures to snip the outdoor water consumption.

Part 3: Consumptive Water Use of Southern Nevada

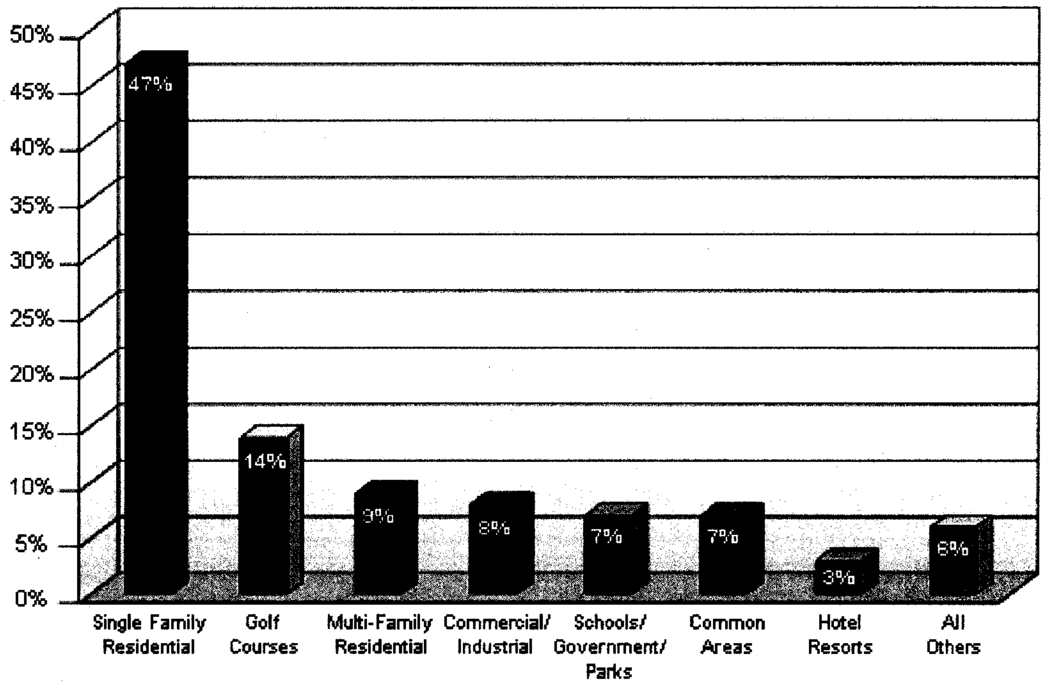
SNWA gets return flow credit for the water that is spent indoor, as the water is collected, treated and then sent back to Lake Mead. This credit is added over the 300,000 acre feet per year of consumptive use. Hence according to SNWA, concentrating on indoor water savings may not be beneficial compared to outdoor water savings. But, in the year 2005, if only the Valley concentrated on indoor water savings, it could have saved 46,966 acre feet per year of water[5] ("Water in the Urban Southwest"). SNWA says that, "Consumptive use is the water that is actually consumed and not returned to Lake Mead. The way to really make a difference is to save water where it counts the most – outside" ("Water Use Facts: Consumptive Use").

Fig. 2.5 shows that the first two highest contributors to the consumptive water use are the single family residences and the golf courses of the Las Vegas Metropolitan Area. It is obvious that if more light is thrown on these highest contributors, more benefits could be reaped. When the

[5] According to Western Research Advocates, for every 1,000,000 residents, the savings potential is 8,760 Millions of gallons per year which is 26,883 acre-feet per year.

outdoor consumptive water use reductions remains the main focus on the single family residences, the nature of turf and kind of irrigation remains the foci on the golf courses of LVMA.

Fig.2.5: Consumptive Water Use in Southern Nevada[6] ("Water Use Facts: Consumptive Use").



Water Conservation - Golf Courses of Southern Nevada

SNWA has continuously tried to keep the water use in the golf courses low. According to SNWA, "since 2001, Las Vegas area courses have converted more than 18.5 million square feet of grass—about 425 acres—to water-smart landscaped, target-style courses resulting in a 1 billion gallon per year water savings" ("Vegas Golf Courses"). SNWA is proud to state that currently seven golf courses have so far participated in water smart programs. According to SNWA, some of the steps taken by the golf courses of southern Nevada are summed up as follows.

[6] The values are based on 2004's municipal metered potable and non-potable water consumption, in SNWA's metered service area.

- Every golf course is encouraged to have an on-site weather monitoring equipment which is connected to the irrigation system through computers that allows the golf courses to irrigate their turf based on the conditions of daily weather.
- Most of the courses use valve-in-head technology where every sprinkler head has a valve to control water running time and coverage.
- Water uses in the golf courses are strictly budgeted with high financial penalties for water use beyond the budgeted amount.
- The golf courses of Las Vegas Metro Area are encouraged to use the right type of turf that needs almost no water during the winter months and only two third of the water needed by other types of turf during the summer months.

Water Conservation – Outdoor water use at the Single Family Residence

Besides the golf courses of the Las Vegas Metropolitan area, SNWA targets the outdoor consumptive water use of residences around southern Nevada. After setting outdoor consumptive water use reduction as the chief target, the Southern Nevada Water Authority started water smart programs in the year 2002 focusing on reducing outdoor water exorbitantly spent on the landscape. This program includes water smart landscaping, partnership on landscape with private sectors, rebate programs for irrigation controllers and a trade fair that supports water efficient practices and products. SNWA reports that these efforts have so far reaped 20 billion gallons of water per year. Fig.2.6 shows that more conversions are noticed in the Las Vegas Valley – more than 20 million square feet of landscaped areas have been converted into water smart landscapes. These figures prove that active participation is noticed between the southern Nevada residents indicating the extent of awareness prevalent among them. It is also evident through fig.2.7 that there was gradual increase in the area of landscape converted from 1996 to 2004. Fig.2.7 shows that the conversions peaked during the year 2004 and has gradually started to decline from the year 2005.

Fig. 2.6: Landscape Converted in Las Vegas Metro Area (Sovocool, "Data Delivery").

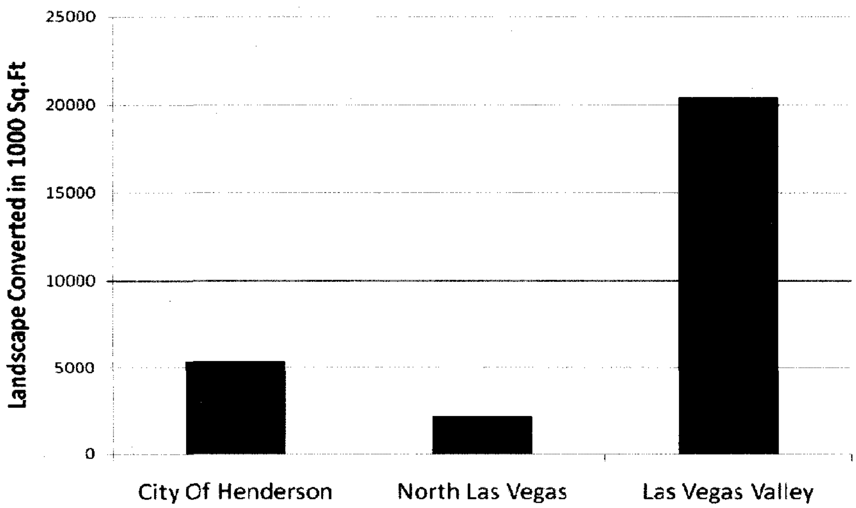
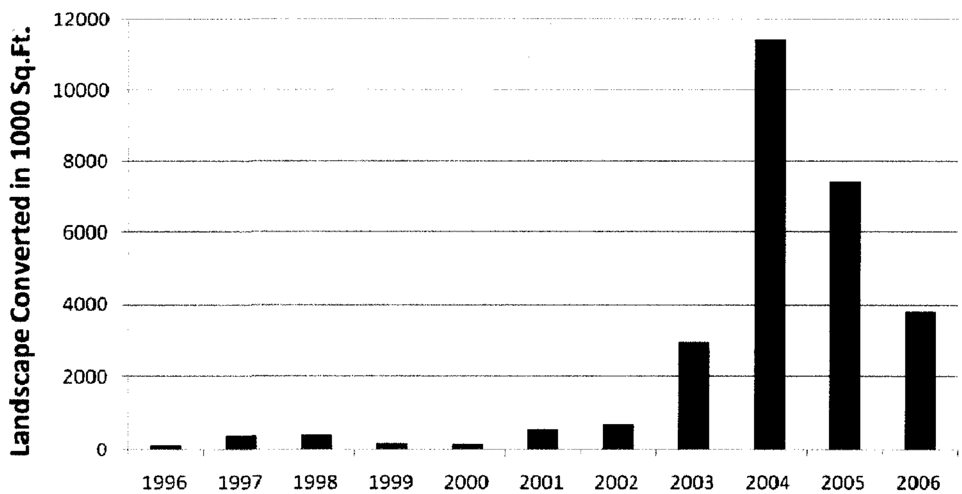


Fig. 2.7: 1996-2006 Landscape Conversion in Las Vegas Metro Area (Sovocool, "Data Delivery").



A recent research done by the Southern Nevada Water Authority on the effects of landscape conversion program during the year 2005 implies that there are some behavioral aspects influenced by the type of vegetation, contributes to high outdoor water use in the residences of Las Vegas Metropolitan Area. The research says that though the average outdoor water application is generally efficient during the spring, during the month of May, when the weather warms up and increases the evapotranspiration, people start to increase the irrigation well over the evapotranspiration and they keep the outdoor water use high through November, though the evapotranspiration requires lower than the irrigated quantity (Sovocool, 34-5). The study states that this might be because of the fact that, during the month of May, the grass turns yellow due to moisture deficits, giving a faise signai to the people to increase the irrigation. Aiso in the fail there is a long lag noticed in returning to application rates much closer to the required level dictated by the evapotranspiration value. The study describes that this is also due to the poor visual feedback obtained from the turf as they fail to turn green; thereby they fail to indicate the people to reduce the rate of irrigation.

These inferences prove that some of turf varieties in the Las Vegas Metropolitan area are fed more than what they require. Also it could be inferred from the analysis of the study that the evapotranspiration values corresponding to that place are better indicators of the rate of irrigation than the visual feedback from the vegetation. It would be ideal if the residents irrigate their landscapes based on their evapotranspiration values. Though it is not practical to install a monitor that checks the evapotranspiration at every house, it is definitely possible to have a common meter in the areas which are rich in vegetation.

The above mentioned study aiso compares the outdoor water use of residences that has recently converted their landscape to Xeriscape, with the outdoor water use of residences that has the regular type of turf and other vegetation. The results prove that with water smart vegetation nearly 30% of the total annual water use of a residence could be saved (Sovocool, 4).

Turf Limits of Las Vegas Metropolitan Area

Apart from the water smart landscaping and other landscape conversion programs, SNWA has devised turf codes specific to each of the cities of Las Vegas Metropolitan Area. They recommend people installing landscape at their new home or business to make sure whether they meet the turf limits code appropriate to their city. In other words, the turf limit restricts the total square footage area of grass – otherwise called as the turf cover, which can be planted at new properties. Besides, the turf codes also prohibit the type of grass that can be planted during summer and winter months. The restrictions are divided into three categories such as no drought, drought watch and drought alert. So that the restrictions depend upon the drought stage in effect at the time a building permit is issued. Based on the type of housing, the turf limit varies. I.e. the turf limits are unique for single family residence, multi-family dwellings such as condos and apartment complexes, non-residential developments and golf courses.

The following tables list the turf codes applicable to Clark County, City of Henderson, City of Las Vegas and City of North Las Vegas.

Table.2.1: Clark County Turf Limits of Single Family Residents ("Turf Limits", SNWA)

No Drought	Drought Watch	Drought Alert
50 percent of a front yard can be grass. This does NOT include a driveway or parking area.	Same as No Drought. New turf prohibited in common areas of neighborhoods, except for privately-owned parks with an area greater than 10 feet.	No new turf allowed in front yards. On side and rear yard, new turf shall not exceed 50 percent of the gross area or 100 sq. feet, whichever is greater, provided no turf area dimension is less than 10 feet. Maximum of 5,000 sq. feet turf.

The turf limit of Clark County also specifies the type of grass recommended and prohibited during a particular season – "Planting cooi-season grasses such as tali fescue and ryegrass prohibited from May through August. Planting of warm season grasses (i.e. bermuda and zoysia) is permitted" ("Turf Limits", SNWA).

Table.2.2: City of Las Vegas Turf Limits of Single Family Residents ("Turf Limits", SNWA)

No Drought	Drought Watch	Drought Alert
50 percent of a front yard, including a driveway or parking area, can be grass.	Same as No Drought. New turf prohibited in common areas of neighborhood, except for privately-owned parks with an area greater than 10 feet.	No new turf allowed in front yards. 50 percent of turf in side and rear yard or 100 square feet, whichever is greater, may be grass (max. 5,000 square feet).

Table 2.3: City of Henderson Turf Limits of Single Family Residents ("Turf Limits", SNWA)

No Drought	Drought Watch	Drought Alert
50 percent of a front yard can be grass. This includes a driveway or parking area.	New turf prohibited in common areas, except for public and privately-owned parks as long as turf area is not less than 10 feet.	No new turf allowed in front yards. Side and rear yards may not exceed 50 percent. Maximum of 5,000 square feet allowed.

Table 2.4: City of North Las Vegas Turf Limits of Single Family Residents ("Turf Limits", SNWA)

No Drought	Drought Watch	Drought Alert
50 percent of a front yard can be grass. This includes a driveway or parking area.	Turf prohibited in common areas of residential properties.	Prohibited in residential front yards and restricted to 50 percent of side and back yards. Maximum of 5,000 square feet turf allowed.

Besides the turf codes, the Southern Nevada Water Authority encourages people to use pool covers to avoid unnecessary evaporation of water by providing rebate coupons for pool covers. It is their claim that a typical pool cover can save from 10,000 to 15,000 gallons of water in a year from evaporation. In the same way they encourage people by various rebate programs to buy rain sensors and water smart irrigation controllers. While the numerous opportunities to save water are deployed in all possible ways around us, it is the duty of the people to participate in them to reap benefits not only for themselves but for the region as a whole, thereby helping the people to sustain their lives in arid Southern Nevada.

Part 4: Conclusions

This literature review gives profound understanding about the current water consumption status of Las Vegas Metropolitan area, the factors that influence water consumption and the various ongoing measures that have been under-taken by the water authorities towards water conservation. This study proves that there are strong relationships between the amount of water consumed in a house and the physical, environmental and social – behavioral aspects of the single family residence. Besides the research pin-pointing the most crucial sectors that needs to be focused to improve the current water use conditions of the overall Las Vegas Metropolitan Area, it also lime lights the susceptibilities and root causes of such conditions in those areas. Analyzing the results of various studies documented in this chapter, the focus of the following research is well established. Keeping the literature review as the base, the following research narrows down to the physical aspects, such as size of the built-up area, turf area, trees area, shrubs area and pool area and some of the environmental aspects, such as monthly cooling degree days, heating degree days and the variation in temperature over the period of years.

CHAPTER 3

RESEARCH METHODOLOGY

This chapter summarizes the methods used to investigate the five research questions presented in the first chapter. While the other chapters document the intended or final output of this research, this chapter takes a step further and documents the fine details of the background works carried out throughout this research. Based on the five research questions, the study can be broadly classified into two parts. The first part analyses the physical aspects that addresses the first two research questions and the second part analyses the environmental aspects that addresses the last three research questions. When the first part analyses the annual water use, the second part analyses the monthly water use and compares them with the monthly electricity use of the Las Vegas Metropolitan Area.

Physical aspects correspond to the built-up area, un-built area and pool area of the single family residences of the Las Vegas Metropolitan Area. But for the 2006 analysis, the un-built area is replaced by the turf, tree and shrub area, as vegetation data is available for that year.

Environmental aspects correspond to the cooling degree days, heating degree days and outdoor ambient temperature measured at the Mc Carran airport of Las Vegas. For the convenience of documentation, the methodology of study is divided into four parts:

1. Data Collection
2. Data Processing
3. Statistical Analysis
4. Limitations

The physical and environmental factor together forms the integral part of all the three stages of this research.

Part 1: Data Collection

The nature of this thesis demands seven types of databases, from various resources. As shown in the figure 3.1, the data set includes three databases that contain the dependent variables and four databases that contain the independent variables. The dependent variables are the water and electricity data from the utilities departments such as Southern Nevada Water Authority and Nevada Power respectively. The utilities are categorized as the dependent variables because of the fact that both water and electricity consumption changes from year to year and from parcel to parcel and the high and low usage depends on the influence of the independent variables on them. The independent variables are the residential data from the assessor office, the vegetation data from the Southern Nevada water Authority and the climate data from the National Climatic Data Center, monitored at the Mc Carran airport of Las Vegas. In general the independent variables of this research are the square footage values of built-up, un-built, turf, tree and pool areas and the degree Fahrenheit values of cooling degree days, heating degree days and outdoor ambient temperature.

Table 3.1: List of Data with Timeline, Scale, Precision and Units

		Scale			Precision		
Data Set	Timeline	Region	City	Parcel	Monthly	Annual	Units
Assessor Data	2007	LVMA	CC, CLV,CH & NLV	yes	n/a	n/a	Sq. Ft
Water Data	1990-2006	LVVWD	CC & CLV	yes	yes	yes	Kilo Gallons
Water Data	2006	LVMA	CH	yes	yes	yes	Kilo Gallons
Water Data	2006	LVMA	NLV	yes	yes	yes	Kilo Gallons
Electricity Data	2002-2006	LVMA	CC, CLV,CH & NLV	no	yes	yes	kWh
Vegetation Data	2006	LVMA	CC, CLV,CH & NLV	yes	n/a	n/a	Sq. Ft
Degree Days	1990-2006	LVMA	n/a	n/a	yes	yes	Degree F
Temperature Data	1990-2006	LVMA	n/a	n/a	yes	yes	Degree F
Turf Conversion Data	1996-2006	LVMA	CC, CLV,CH & NLV	yes	yes	yes	Sq. Ft

Table 3.2: Distribution of Zip Codes across the Las Vegas Valley Water District

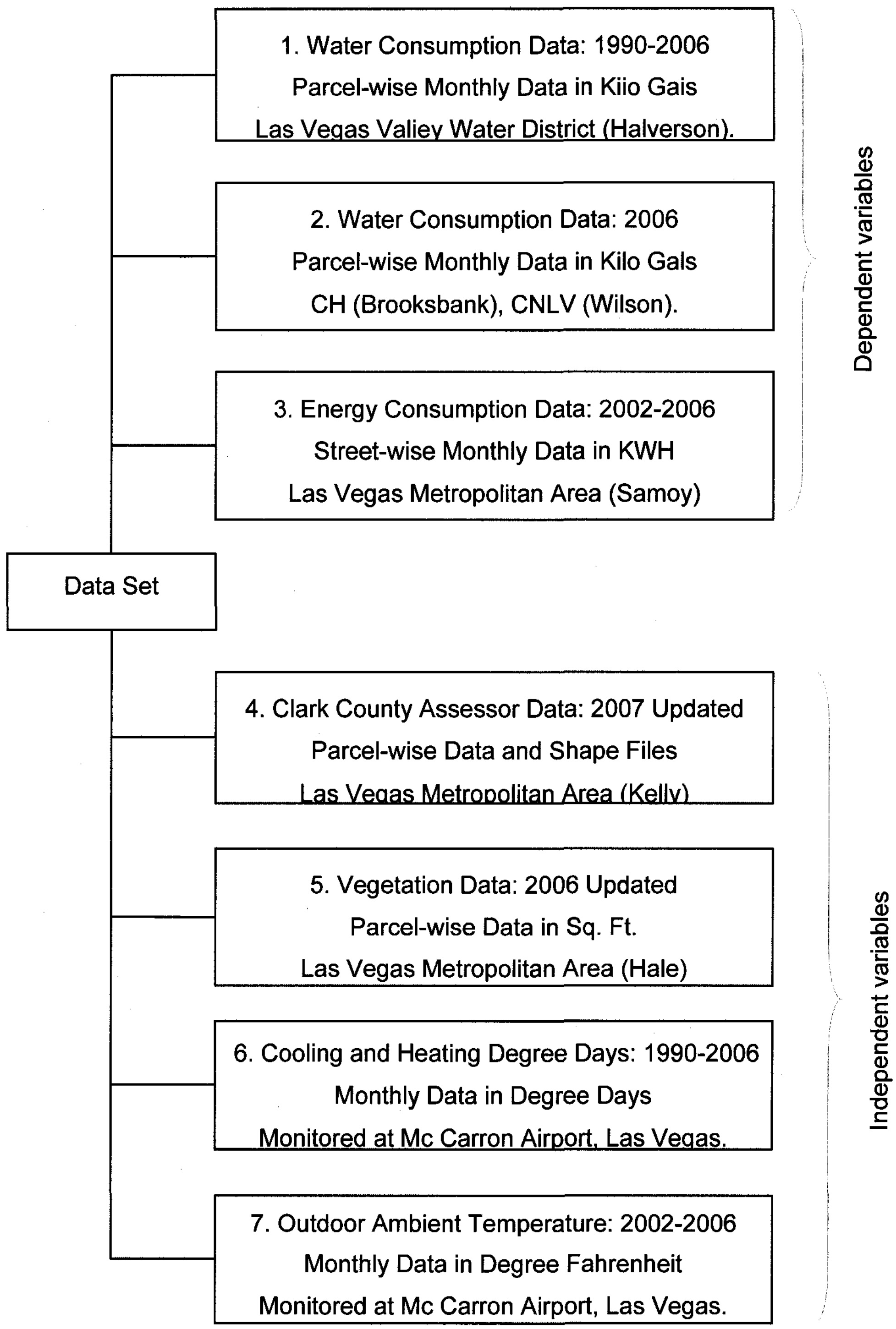
incorporated Clark County		City of Las Vegas	
89103	89123	89101	89131
89109	89135	89102	89134
89110	89139	89104	89143
89113	89142	89106	89144
89118	89147	89107	89145
89119	89148	89108	89146
89120	89156	89117	89149
89121	89074	89128	89032
89122		89129	89115
		89130	

Table 3.3: Distribution of Zip Codes across the Las Vegas Metropolitan Area

Incorporated Clark County		City of Las Vegas		North Las Vegas	City of Henderson
89103	89135	89101	89131	89030	89002
89109	89139	89102	89134	89031	89011
89110	89141	89104	89138	89032	89012
89113	89142	89106	89143	89081	89014
89118	89147	89107	89144	89084	89015
89119	89148	89108	89145	89085	89044
89120	89156	89117	89146	89086	89052
89121	89178	89128	89149	89087	89074
89122	89179	89129	89166	89115	
89123		89130			

The above tables show the list of zip codes that come under each of the cities of Las Vegas Valley Water District and Las Vegas Metropolitan Area, as considered in this study. This list is based on the zip shape files given by the Clark County Assessor Office.

Fig. 3.1: List of Data Categorized as Dependent and Independent Variables.



In table 3.1, the data sets are listed with their timeline, scale, precision and units. The coiumn- timeline is the period of years for which the data is obtained. It is evident here that some databases are from 1990 to 2006, some are from 2002 to 2006 and some are only for the year 2006. The column, scale is divided into three further divisions such as region, city and parcel. This explains for which regions[1] and cities[2] the data is obtained. Meanwhile the column, parcel states whether the data is giving for each parcei number[3]. The coiumn, precision is divided into two columns: monthly and annual. In this study, when the data is given for all the twelve months of the year, the data is referred as the monthly data; similarly when the data is given for the year, it is referred as the annual data. The three main units used throughout the thesis are Kilo Gals, Sq. Ft and kWh for water use, area of independent variabies and electricity use respectively.

1. Water Consumption Data

The water agencies gave two types of water use data: one is the parcel-wise monthly water use data from the year 1990 to 2006 for the City of Las Vegas and the Clark County and the other one is the parcei-wise monthiy water use data for the year 2006 for the City of Henderson and the City of North Las Vegas. The first one for seventeen years was from Mr. Phillip Halverson of the Las Vegas Valley Water District and the other one for one year was from the respective authorities of the individual city agencies. The data from the LVVWD is used to analyze the water use trend from 1990 to 2005 and it forms the main bulk in terms of focus, of all the databases obtained for this thesis. The water use data obtained from the City of Henderson (Brooksbank) and the City of North Las Vegas (Wilson) are used together with the LVVWD data for 2006 for the City of Las Vegas and Clark County to analyze the Las Vegas Metropolitan Area's water use for 2006. A sampie of the water use database is shown as obtained in the table 3.2(a).

[1] Las Vegas Valley Water District and Las Vegas Metropolitan Area are the two regions considered in this thesis.
[2] City of Las Vegas, City of Henderson, City of North Las Vegas and Incorporated Clark County are the four zones commonly mentioned as cities in this thesis.
[3] Parcel number is a 11 digit number that is unique throughout the region. As this study considers oniy the single family residences, each parcel corresponds to one single family residence.

Table 3.4(a): A Sample of the Water Consumption Data in Kilo Gallons (Halverson).

Parcel	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
16211312016	30	11	10	11	12	22	31	33	29	14	4	5
16205215005	7	8	12	14	19	32	30	31	26	14	11	7
13816513074	10	7	9	13	13	16	27	31	36	20	19	10
13826313028	4	4	5	6	6	13	8	9	16	6	2	2
16313611007	40	37	19	20	63	54	65	81	75	66	58	60
14031610026	4	3	5	7	10	13	12	9	7	4	4	3
16318612020	3	3	3	9	8	6	10	9	9	6	9	5
16303701008	19	18	39	53	57	58	95	66	65	48	60	59

As shown in the above table, water use data is given separately for all the seventeen years from 1990 to 2006 for all the twelve months. Table 3.2(b) lists the number of parcels for which the data is given.

Table 3.4(b): Number of Parcels in the Water Consumption Data by City: LVVWD.

Year	CC - Parcel Count	CLV - Parcel Count	Year	CC - Parcel Count	CLV - Parcel Count
1990	26475	43748	1999	70774	103431
1991	27779	46011	2000	76109	109049
1992	28653	48677	2001	83979	113926
1993	30595	52929	2002	92821	117894
1994	50037	74303	2003	101389	122448
1995	53268	80328	2004	110653	129120
1996	56787	87092	2005	121348	134724
1997	61098	92503	2006	132471	139572
1998	66198	97975	Average/Yr	70026	93749

2. Electricity Usage Data

The monthly electricity data given by the Nevada Power for Las Vegas Metropolitan Area is street wise, given for five years from 2002. Through Mr. Ramon Samoy, the Nevada Power was requested to give electricity usage data only for the single family residences of Las Vegas Metropolitan Area. Also they were requested to give monthly electricity data exclusively for the four cities: CC, CLV, CH and CNLV, generally considered as Las Vegas Metropolitan Area in this study. A sample of the electricity usage database as obtained from NP is shown below.

Table 3.5(a): A Sample of the Electricity Usage Data in kWh (Samoy). (Continued below)

YEAR	ZIP	STREET	JAN	FEB	MAR	APR	MAY
2005	89183	ARKELL	18310	14744	13821	15199	15750
2003	89147	HORSESHOE M	16523	13816	12970	12363	13777
2003	89147	HUTCHINSON	8281	7627	6855	6781	7000
2002	89130	RYMER	8350	6801	6479	6911	10419
2002	89130	SADLER	18808	15341	13553	16941	24810
2004	89183	SWEEPING VINE	44861	34638	32269	34617	45791
2004	89183	SWIMMING HOLE	24157	18341	17941	21511	31014
2004	89183	TALL TIMBER	18068	13235	11295	12814	18237
2006	89147	VISTA ROYALE	9175	9313	8037	8094	11385
2006	89147	WAINSCOT	16433	13257	12832	11676	18157

STREET	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANNUAL
ARKELL	35219	51239	55758	46396	27485	14730	17620	326271
HORSESHOE M	34191	36407	45310	31830	21084	15020	15267	268558
HUTCHINSON	22789	22282	25563	23641	14961	8475	8757	163012
RYMER	15681	22395	17428	12776	7633	6347	8137	129357
SADLER	37786	54700	47266	35786	19456	15754	18768	318969
SWEEPING VINE	68659	89030	121004	90948	62549	39475	41125	704966
SWIMMING HOLE	43611	55169	66411	56748	39174	20902	21315	416294
TALL TIMBER	29003	38264	48006	37642	24882	14450	15653	281549
VISTA ROYALE	17161	25860	27422	23735	11405	9776	10517	171880
WAINSCOT	26677	37671	40572	35617	18988	15899	15855	263634

Table 3.5(b): Number of Streets in the Electricity Usage Data: LVMA.

Year	No. of Streets	No. of Single Family Residences[4]
2002	18423	203250
2003	19749	215049
2004	21264	228450
2005	22943	242892
2006	23811	257207

3. Clark County Assessor Data

The Clark County Assessor office provided two kinds of database,

- LVMA Residential Parcel Data: Parcel Records and Building records
- LVMA Residential Parcel Shape Files

The LVMA residential parcel database is given as two tables: one providing the necessary information about the parcels of LVMA and the other providing the building records for the parcels listed in the first table. Samples of part of the tables provided by the Assessor are given below.

Table 3.6(a): A Sample of the Residential Parcel Data with Parcel Records (Kelly).

Parcel Number	Street Name	Street Type	Landuse	Calc. Acres
00108510025	Ruby	Drive	110000	0.16
00108510026	Turquoise	Circle	140000	0.15
00108511005	Copper Springs	Drive	110000	0.11
00108511031	Diamond	Circle	110000	0.2

[4] The number of SFR for the corresponding streets for which the electricity usage data was given is derived by joining these streets with the streets from the Assessor's residential data.

Table 3.6(b): A Sample of the Residential Parcel Data with Building Records (Kelly).

Pcl Number	Year Built	Pool Code	Garage Area	Car Area	Floor 1 Area	Tot.SqFt
00108510025	2005	3	850	0	2037	2901
00108510026	1994	1	502	0	2920	3714
00108511005	1999	2	504	0	1774	1774
00108511031	1999	0	610	0	1824	1824
00108511032	2002	5	506	0	1597	2413

The land use codes listed in the table 3.4(a) is helpful to segregate the single family residences from the other type of land uses. Also the calculated acres are used as the parcel shape areas of the SFR. As the electricity database is given by street, when joined with the streets of the assessor table, the other parcel records and building records for the streets of the electricity consumption data are derived. The building records of the residential data are as useful as the parcel records and it is given by parcel number. The column, pool code ranges from 0 to 5 and their interpretations (Schofield, "Appraisal Key Codes") are as follows,

Pool Code- 0: refers to, no swimming pool in the parcel

Pool Code- 1: refers to, parcel with pool size- 12 x 25 = 300 Sq. Ft.

Pool Code- 2: refers to, parcel with pool size- 15 x 30 = 450 Sq. Ft.

Pool Code- 3: refers to, parcel with pool size- 16 x 32 = 512 Sq. Ft.

Pool Code- 4: refers to, parcel with pool size- 18 x 36 = 648 Sq. Ft.

Pool Code- 5: refers to, parcel with pool size- 20 x 40 = 800 Sq. Ft.

Besides the pool codes, the garage area, car-park area and first floor are the columns jointly used along with the next column, total sq. ft., to compute the un-built area of the parcels. Total sq. ft. is the total square footage area of total built-up area of the parcel. The total sq. ft values don't include the garage area or car-park area.

4. Vegetation Data

There are two types of vegetation data given by the Southern Nevada Water Authority. One is the total vegetation data that comprises of trees, shrubs and turf areas of the SFR and the other one is the landscape conversion data that lists the SFR that has undertaken any of the water smart landscaping programs. These data are requested by parcel within all the four zones of the study area, CC, CLV, CH and CNLV of the Las Vegas Metropolitan Area. A sample of the total vegetation data given by the SNWA is shown in the table 3.5(a). Similarly, a sample of the conversion data given by the SNWA is shown in the table 3.5(b).

Table 3.7(a): A Sample of Vegetation Data for LVMA in Sq. Ft. (Hale).

Parcel Number	Area of Trees and Shrubs	Area of Turf
12326799001	68.2881291	0.58538518
12326201002	176.363222	0
12327601010	0	7.70567784
12327101033	13795.7316	5238.57949
17820597003	0	0

Table 3.7(b): A Sample of Landscape Conversion Data for LVMA (Sovocool).

Parcel Number	Type of Program	Area Converted in Sq. Ft	Date of Enrollment
16212811032	XS	2233	02-Dec-96
16310705007	XS	3235	26-Jul-98
17930819014	XS	3528	01-Mar-99
17715310052	SNX	1340	22-Aug-01
17707301007	SNX	2805	23-Oct-02
13801214002	WSL	4719	13-May-04
13801213025	WSL	1774.7	06-Jun-05

As the database referring to the table 3.5(a) is given for the entire LVMA, using assessor's land use codes, SFR are exclusively filtered out from the vegetation data. But the landscape conversion data is given for only the single family residence. As shown in the table 3.5(b), the conversion data includes landscape conversion programs such as the Xeriscape Study- XS, Southern Nevada Xeriscapes – SN and Water Smart Landscaping- WSL. As per the given database, the date of enrollment ranges from May 1996 to Dec 2006 and the size of converted landscape ranges from 1 sq. ft. to 29,461 sq. ft.

5. Climate Data

The climate data included in this study are the monthly cooling degree days, heating degree days and outdoor ambient temperature. The outdoor ambient temperature data is downloaded as text files, obtained by hourly basis for seventeen years from 1990 to 2006, from the National Climatic Data Center website, monitored at the Mc Carran International Airport of Las Vegas. The hourly data is processed into monthly data and it is not within the scope of the study to analyze the weekly, daily or hourly climate data. This study considers the monthly mean, monthly mean maximum and monthly mean minimum temperatures in degree Fahrenheit as the chief parameters of study.

Part 2: Data Processing

As this stage is the intermediate stage between data collection and statistical analysis, the procedures involved in this stage are primarily the ground works for statistical analysis. The databases given by various agencies have to be processed to suit the requirements of this study. As this study requires handling multiple databases, joints and relationships between two distinct databases having one common field are established through Microsoft Access. It is followed throughout this thesis that data processing is exclusively done using MS Access, whereas statistical analysis is done using MS Excel.

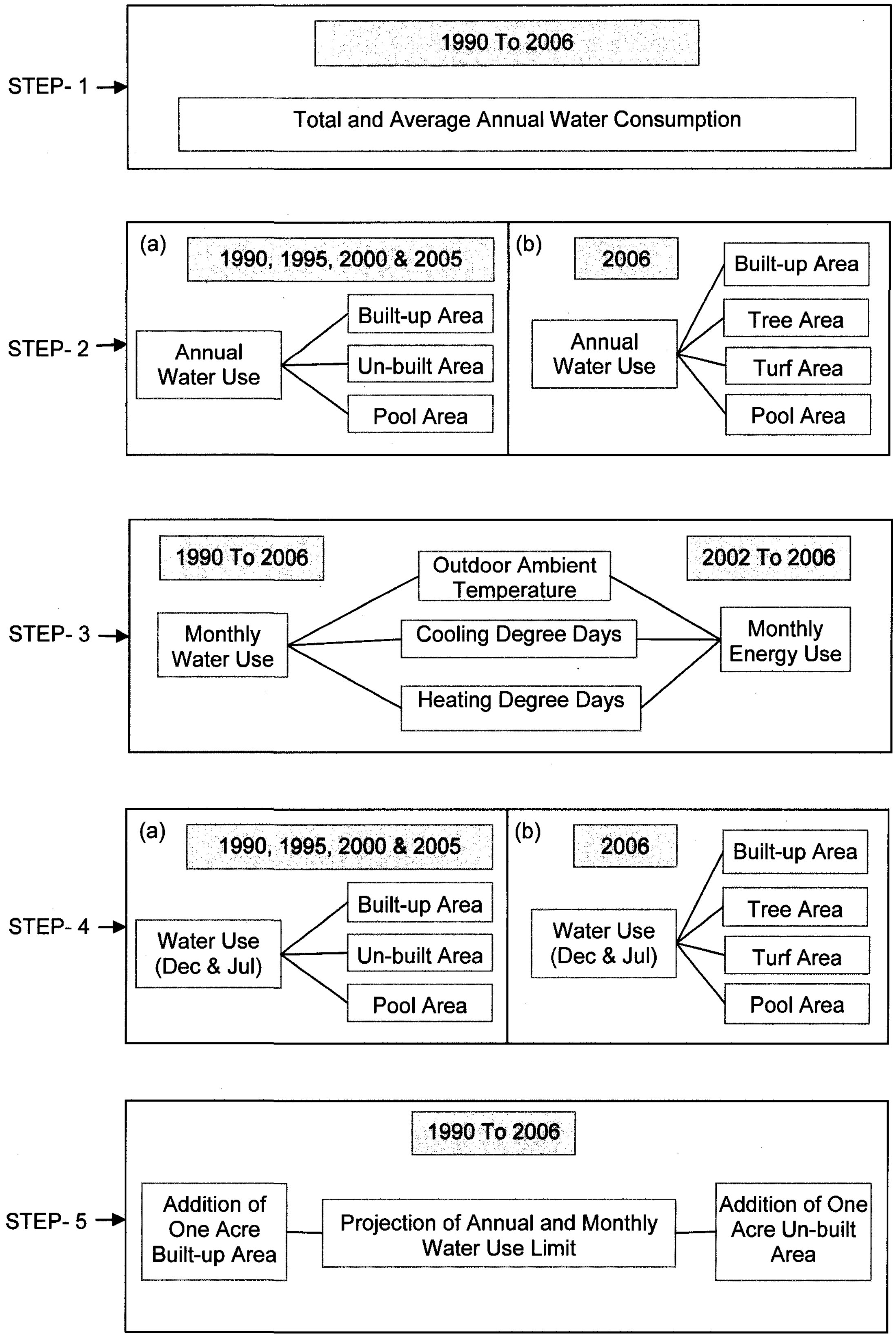
While some databases have unwanted information, some databases have very little information. For instance, the water use data is given for the entire Las Vegas Valley that includes Single family residents, duplex, triplex, fourplex, multiple homes, town homes, residential condo and residential manufactured homes. As the thesis includes only the single family residences, based on the land use codes provided by the assessor office, the single famiiy residences are solely filtered from the list. The residential data has a column, land use, which is a six digit number. According to the iand use codes of the Clark County Assessor Office, the first digit is the source code and the next two digits are the use code (Schofield, "Land use Codes"). The source code – 1 refers to the residential sector. Table 3.6 shows the list of use codes and their appropriate interpretations.

Table 3.8: Use Codes from the Clark County Assessor Office. (Schofield, "Land use Codes")

Use Code	Category
10	Residential Single Family
20	Duplex
30	Triplex
40	Fourplex
50	Multiple Homes
60	Town Homes
70	Residential Condo
80	Residential Manufactured Homes

As dictated by the use codes of the Assessor office, this research exclusively considers the parcels with use code 10, which refers to the single family residences. Table 3.4(a) of the previous section shows a sample of the residential parcel data given by the assessor with parcel records. In table 3.4(a), by following the use code chart above, it is evident that the parcels with street names- Ruby Drive, Copper Springs Drive and Diamond Circle are single family residences; but the parcels with street names- Turquoise Circle and Opal Street are fourplex and residential manufactured homes respectively.

Fig. 3.2: Framework of Research



Total and Average Water Use

Total water use is the summation of water used both indoor and outdoor in all the single family residence in one year and it is measured in Kilo Gallons. Average water use is the quantity of water consumed both indoor and outdoor by one single family residence in one year and it is measured in Kilo Gallons/SFR. These values are obtained in MS access by dividing the total number of SFR parcels with the total water use.

When the first two steps in the above figure analyses the annual water use, the remaining steps analyses the monthly water use. In this study, the zip wise, total and average water uses are calculated separately for 1990, 1995, 2000, 2005 and 2006. For the convenience, water use analysis is divided into two parts: historic analysis and recent year analysis. Historic analysis includes 1990, 1995, 2000 and 2005, whereas the recent year analysis is done for the recent data year 2006.

Built-up, Un-built, Pool, Tree and Turf Area

Built-up area is the total constructed square footage of single family residences including the area of all floor levels. The built-up area doesn't include the garage area or car-park area. The built-up area data is directly available from the assessor's residential database in the name- Tot. Sq. Ft.

Un-built area is the total square footage of un-constructed area around the built-up area within the single family residential parcel. In general the un-built area includes the garage area and car-park area. But as the un-built area in this study indirectly represents the total square footage area of vegetation present in the parcel, the garage area and car-park area are excluded under the un-built area. The assessor's residential database includes a column- 'Floor 1 Area', which is the total built-up area of the first floor in a SFR. The un-built area is obtained by subtracting the summation of floor 1 area, garage area and car-park area from the shape area[5] of the single family residential parcel.

[5] Shape area is the total lot size of the single family residential parcel. This data is extracted from the GIS database of residential parcel shape files given by the GISMO of the Clark County Assessor office.

Pool area for every SFR is derived as explained in the previous section under the secondary heading- 'Clark County Assessor Data'. Trees and shrubs areas are together mentioned in this study as tree area and it is directly used as given by the SNWA, except for the fact that, as part of data processing, the turf and tree areas of the parcels with land uses other than SFR should be filtered out as explained in the beginning of this section. Similarly the turf areas are processed to have only the vegetation information for required parcels.

Comparing Water and Electricity Usage Data

Comparing water use with electricity use will never be accurate until the same entries are used in the comparison. As water and electricity data are given by two different companies, it is not surprising to see lots of discrepancies. When the water use data is given by parcel, the electricity use data is given by street names. This forces the study to take a step down and deal with street level entries. Also the number of streets of the water data in a specific zip code doesn't match the number of streets of the electricity data in the same zip code. This demands data processing which involves joining the streets of specific zip codes in electricity use data with the streets of the same zip codes in water use data. So that the streets that are common between water and electricity data in all the 54 zip codes of LVMA are exclusively considered.

As water and electricity are compared against tree, turf, built-up and un-built areas in the fourth stage of the study, the vegetation and building records for the number of streets that are common between water and electricity use are queried using MS access and made as a separate table in excel for the statistical analysis.

Part 3: Statistical Analysis

This is the most crucial part of the study that consummates the thesis. Each one of the five stages shown in fig. 3.2, is approached uniquely as each demands a different kind of analysis. For the convenience of documenting the methodology of the statistical analysis carried out in each stage of the study, this section is structured based on the five stages of the framework of study.

Step- 1: Finding the Total and Annual Water Use

The first step is to find the total and annual water use by city and by zip codes. The city wise comparison is done for all the seventeen years and the zip code wise comparison is done separately for 1990, 1995, 2000, 2005 and 2006. This stage doesn't include month wise analysis.

Step- 2(a): Comparing the Water Use with Built-up,
Un-built and Pool Area

As part of the historic analysis, this stage analyses the water use trend of the Las Vegas Valley Water District for a total of four years with five year intervals, starting from 1990, up to the year 2005. For every year of the study, the study compares the total water use for that particular year with the totals of built-up area, un-built area and pool area. This annual comparison is done in the street level. The statistical analysis of this study is done in three steps as following,

1. Finding the Correlation Coefficients between water use and the physical & Climatic factors that affect water consumption of that region.
2. Finding the Regression equations for total water consumption as a function of the physical aspects that affect the water use such as, built-up area, un-built area, turf area, tree area and pool area of the street.
3. Finding the Rankings for zip codes based on water use and the physical aspects that affect the water use in that zip code.

The first two steps, finding the correlation coefficients and regression equations are done in the street level and the third step- assigning ranks for every zip code is done in zip code level.

Step- 2(b): Comparing the Water Use with Built-up,
Turf, Tree, Shrub and Pool Area

As part of the recent year analysis, this stage analyses the water use trend of the Las Vegas Metropolitan Area for the most recent data year, 2006. The statistical analysis of this stage is done in a similar manner to the previous stage. Just as mentioned in the previous stage, this stage also includes the three parts of the statistical analysis such as finding the correlation coefficients, regression equations and rankings. But in this stage, instead of considering the total un-built area of the streets, the total turf area and the total of trees & shrubs area are considered. This is because of the availability of vegetation data for the year 2006.

Step- 3: Comparing the Water Use with CDD and HTDD

This is the first stage where water consumption is analyzed in the monthly basis. Comparison of water consumption with the cooling and heating degree days are done from the year 1990 to the year 2006 in two steps: as a first step, average monthly water consumption for a single family residence for one cooling and heating degree day is calculated and as the second step, average monthly water consumption for a square footage lot area of a single family residence for one cooling and heating degree day is calculated. Here average monthly water consumption is different for summer and winter months. The average water consumption of summer months is calculated by finding the average of water consumption for the five summer months: May, June, July, August and September. Whereas the average water consumption of winter months is calculated by finding the average of water consumption for the four winter months: January, February, November and December.

Step- 4: Comparing WC and EC with Built-up,
Un-built, Pool Area & Temperature

Here the outdoor ambient temperature plays as a variant just as the water usage and electricity usage values that change both monthly and yearly from 2002 to 2006, when the physical aspects of the study such as built-up area, un-built area and pool area acts as constants throughout the five years. To eliminate the growth factor as a contributor of increasing water and electricity consumption, the streets with no growth in the number of parcels from 2002 to 2006 are considered. Here the statistical analyses are done in a similar manner to the step- 2 of this study.

Step- 5: Projecting Annual and Monthly
Water Use Limits

In this stage, the years 1990, 1995, 2000, 2005 and 2006 are studied separately to calculate the water used per acre increase in built-up area and un-built area of the single family residences in LVVWD. This projection is done as a result of the correlation factors and regression equations derived from the built-up area, un-built area and pool area to find the water use of single family residences.

For example, in the zip code 89146, for the year 2000, the ratio of un-built area vs. built-up area is 5.5 and the ratio of un-built area vs. pool area is 44.3. For one acre increase in built-up area, the proportional increase in the un-built area is found by multiplying 43,560 sq. ft. with 5.5. Thus the new un-built area is 237,634. The proportional increase in pool area is derived by multiplying the new un-built area with 44.3, so that the new pool area is 5,367 sq. ft for one acre increase in built-up area. To find the amount of water used for one acre increase in built-up area, the equation **Y = 0.062674 * B + 0.015105 * UB + 0.248101 * P - 32.7662** is used, where Y is the Kilo Gallons of water used per one acre increase in built-up area, B is one acre which is 43,560 sq. ft., UB is the new un-built area, which is 237,634 sq. ft. and P is the new pool area which is 5,367 sq. ft. Thereby the amount of water used per acre increase in built-up area is calculated as 7,618 Kilo Gals. Similar calculations are done for all the zip codes for the years 1990, 1995, 2000, 2005 and 2006 using the respective regression equations. Also, similarly, the water used per acre increase in un-built area is found for all the five years. As July and December are the peak months where water use is the most and the least respectively, the amount of water used in July and December for an addition of one acre of built-up and un-built area is calculated.

From these calculations, water use limits for the future are determined for every acre increase in built-up and un-built area of single family residences.

Part 4: Limitations

Though this study aims to present a wholesome thesis with absolutely no shortfalls, there are some faint ineluctable facts. The following are some of the limitations of this study:

1. There are several factors that affect the consumption of water in a single family residence. As it is not feasible to study all the factors, this thesis concentrates only on the three main aspects such as the size of the built-up area, the area of vegetation and the size of swimming pools in the SFR. Also, as far as the landscaping is concerned, the nature and type of turf, trees and shrubs are not included within the scope of the study.
2. The projections made in this study can be used only for the near future; as while projecting the annual and monthly water use for one acre increase in built-up and un-built area of SFR, any drastic change in climate that could affect the slope of the trend-line for future years is not taken into consideration.

CHAPTER 4

FINDINGS OF THE STUDY

Summary

There are numerous factors that affect the water consumption of single family residence in the Las Vegas Valley Water District. Some of the factors that are considered in this study are the size of the built-up area, size of the un-built area which includes the area of trees, shrubs and turfs and the size of the swimming pools. Though the first part of the study analysis the overall water use trend of LVVWD from the year 1990 to 2006, the second part of the study divides the analysis into two: the years - 1990, 1995, 2000 and 2005 are studied individually under the historic analysis and the year 2006 is studied under the recent data-year analysis. These analyses are carried-out both in annual and monthly basis. Monthly analysis includes the extreme winter and summer months, December and July respectively. In the first part, for the convenience of analysis, LVVWD is considered as two different zones - Clark County and City of Las Vegas and in the second part, LVVWD is considered in zip-code wise and street wise scales, for each of the above mentioned years. The city wise analysis includes graphing the raise in the total water use and the number of SFR and the decline of the average water use and the water use per square footage of SFR in LVVWD.

For each of the five years mentioned above, the zip code wise analysis includes mapping the following:

1. Total annual water consumption
2. Average annual water consumption
3. Density of SFR
4. Total built-up area
5. Total un-built area that includes the area of trees, shrubs and turfs

6. Total pool area
7. Average water use ranking, compared with the averages of built-up area, un-built area and pool area of SFR
8. Total water use ranking, compared with the totals of built-up area, un-built area and pool area of SFR.

The street wise analysis studies the correlation between built-up area, un-built area and pool area with the total water use, for each of the five years, both annually and monthly, and derives a linear equation that fits in all the above mentioned factors. Thereby, for the year 1990, the linear equation from the regression analysis is, **Y = 0.083415B+0.01843UB+0.198063P+61.35414**, where the street level total water use in 'Y' Kilo Gallons is calculated with the built-up area as 'B' sq. ft, un-built area as 'UB' sq. ft and pool area as 'P' sq. ft. Depending on the availability of vegetation data for the year 2006, the linear equation from the regression analysis is, **Y = 0.05623B+0.017556TR+0.10707TU+0.165483P+2737**, where the un-built area is considered as 'TR' sq. ft for the trees and shrubs area and as 'TU' sq. ft for the turfs area. Thereby, to keep the value of the total water use in a street constant, using the above equation, the values of total built- up area, trees & shrubs area, turfs area and pool area in a street could be fixed by norms.

The next stage of the thesis analysis the outdoor ambient temperature, cooling degree day and heating degree days, based on the data monitored at Mc Carran International Airport, Las Vegas. It is evident that water use has high correlation, 0.98 to the outdoor ambient temperature, especially during the peak summer and winter months. This stage also analysis water use normalized with the CDD and HTDD for the Las Vegas Valley Water District from 1990 to 2006. Here, the total water used in a SFR per CDD during summer months is almost the same as the total water used in a SFR per HTDD during winter months. Moreover, in a SFR, the water used per sq- ft of lot area per CDD during summer months is lesser than that of the water used per sq. ft of lot area per HTDD during winter months. Similarly, the electricity usage from 2002 to 2006 is climatically analyzed along with the water usage during that period for the LVVWD. In LVVWD, when the overall water use per CDD during the summer months is declining, the overall electricity use per CDD during the summer months is constantly increasing. Whereas the overall water and electricity use trend line per HTDD during the winter months points high from 2002 to 2006.

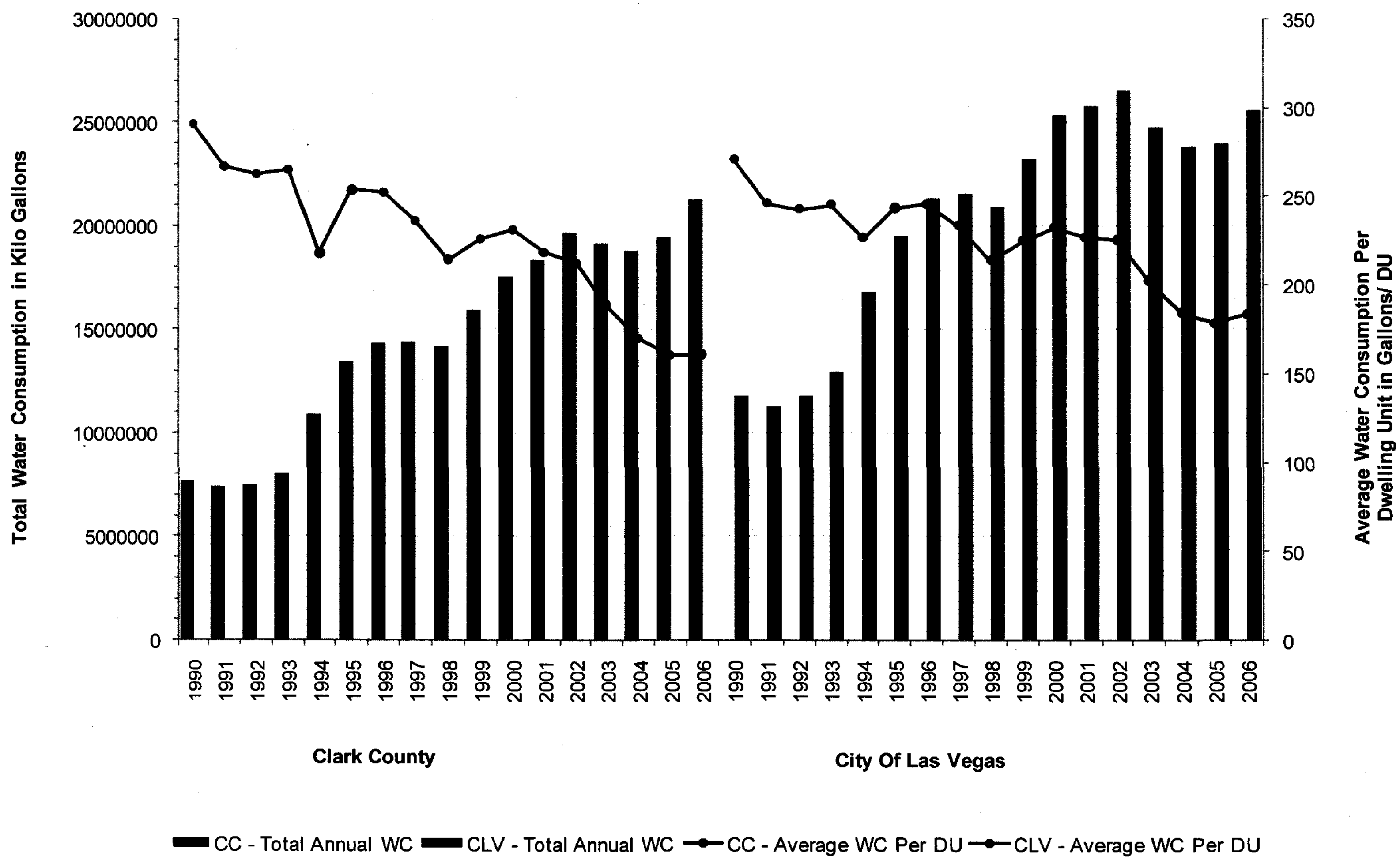
Part 1: Total and Average Water Use in LVVWD from 1990 to 2006

This thesis starts with analyzing the trend in water consumption for seventeen years from 1990 to 2006 for the Las Vegas Valley Water District. The total water used in single family residence depends on various aspects. Sometimes one factor acts independently and sometimes multiple factors act together or counter act against each other favoring high water use. For example, places with high concentration of vegetation and lots with big square footage are expected to have high water use. Also, places with higher temperature are expected to have higher water use compared to the places that have low temperature. Meanwhile, it is proved that high concentration of vegetation reduces the temperature, thereby reducing the overall water use (Akbari 295-310). According to Akbari, though the existing vegetation in a SFR consumes water for their survival, they indirectly contribute to lowering the total water use. Thus there are numerous factors that are intertwined which causes high and low water use. This research concentrates on the built-up area, the area of vegetation as a component of the un-built area and the pool area of the SFR. Thus this research attempts to answer the reasons for the surges and drops in the water consumption trend of LVVWD that lies within the scope of the research.

City Level Analysis

The figure 4.1.1 shows the total water used in the SFR of Clark County and Las Vegas from the year 1990 to 2006 in bars, whereas the average water used in a SFR is plotted in the secondary axis for seventeen years. The Valley experiences rapid growth in population and it is obvious through the graph that the overall water use in the SFR of LVVWD are increasing from the year 1990 to 2006 due to increase in the number of SFR in both Clark County and City of Las Vegas. But the trend line showing the average water used in a SFR from the year 1990 to 2006 is declining. Though there are various factors that contribute to this change, it is important to notice that the awareness towards water conservation amidst the people of LVVWD is steadily growing.

Fig. 4.1.1: Total Water Consumption Vs Average Water Consumption per SFR: LVVWD.



It is obvious from fig. 4.1.1 that during the year 1994, the water use surge was comparatively higher than the other years - more than 30 percent higher than the previous year. Also during the same year, there was an obvious drop in the per SFR water consumption i.e. more than 12 percent, which is the highest drop reported in 17 years period[1]. It is interesting to notice that there was a surge in population[2] during the same year ("Clark County and Nevada Populations"). Moreover, fig. 4.1.2 suggests that the surge in water use could be because of the sudden change in the total number of single family residence in LVVWD. There could be many reasons that have contributed to the sky-rocketing total number of dwellings in the Valley[3].

Figure 4.1.2 shows that the change in total number of SFR is more than 48 percent for the year 1994, which is the highest change ever recorded in 17 years. Also this figure shows that the annual water used for one square feet lot area of a SFR is gradually declining from 1990 to 2006 in both the cities. The decline in the lot area of SFR along with the decrease in the size of un-built area[4] and average water use of a SFR compliments to the decline in water use per sq. ft of a SFR.

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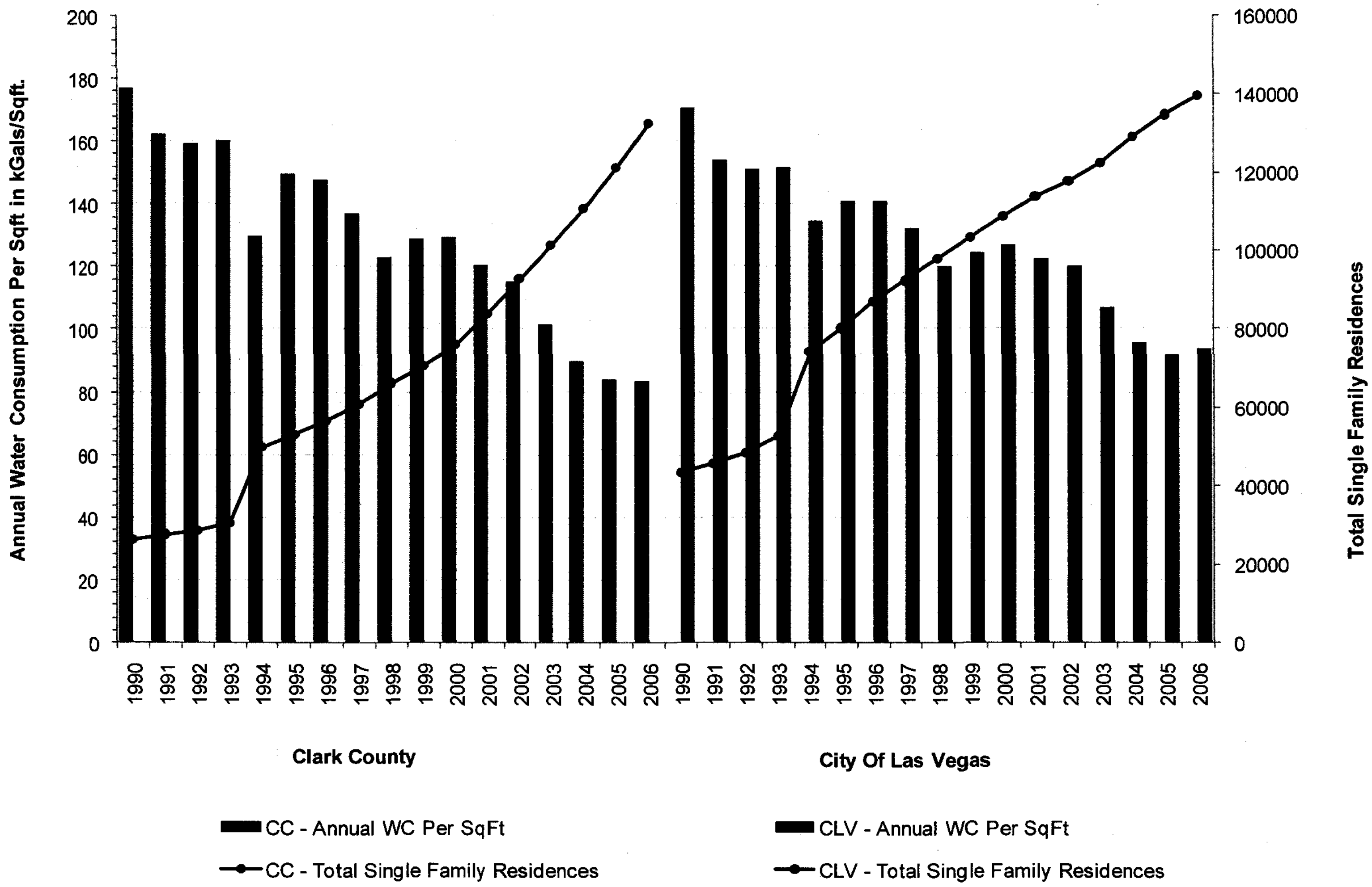
[1] This might be due to the fact that though there was a sudden increase in the total number of SFR, not all the newly constructed houses of the year 1994 were occupied. There might be some new house that were occupied which contributes to the overall high water use, whereas there might be some unoccupied SFR, which together with the occupied SFR contributes to the sudden drop in the average SFR water use.

[2] When the average increase in population per year was less than 6 percent, during the year 1994, population increase was more than 8 percent - highest in seventeen years from 1990 to 2006 ("Clark County and Nevada Populations").

[3] According to Los Angeles Times published in June 1994, "Transplants from throughout the nation have flooded Nevada in the last 10 years, drawn by plentiful jobs and cheap housing, the lack of a state income tax and a perception that anything is possible out here on the cultural frontier. A record 6,292 people turned in out-of-state driver's licenses in March to live in Las Vegas, which is home to three-quarters of the state's population. Nevada as a whole created 48,300 jobs, a 7.4% gain, in the year ending in March" (La Ganga, Part: A; Metro Desk – pg 1).

[4] It is evident from the literature review that more than 70% of the total water used in a SFR is consumed outdoor by the existing vegetation of the SFR. As vegetation data is not available except for the year 2006, the un-built area that excludes the built-up area, garage area and car park area from the total lot area of a single family residence, is considered in place of vegetation.

Fig. 4.1.2: Annual Water Consumption per Sq Ft. Vs Total SFR: LVVWD.



The average annual water use in Clark County from 1990 to 2006 is less compared to the average annual water use in Las Vegas. It is obvious from the fig. 4.1.3 that the total number of single family residences in Las Vegas is overall higher than that of Clark County[5].

Fig. 4.1.3: Comparison between Clark County & Las Vegas: Number of SFR and their Size.

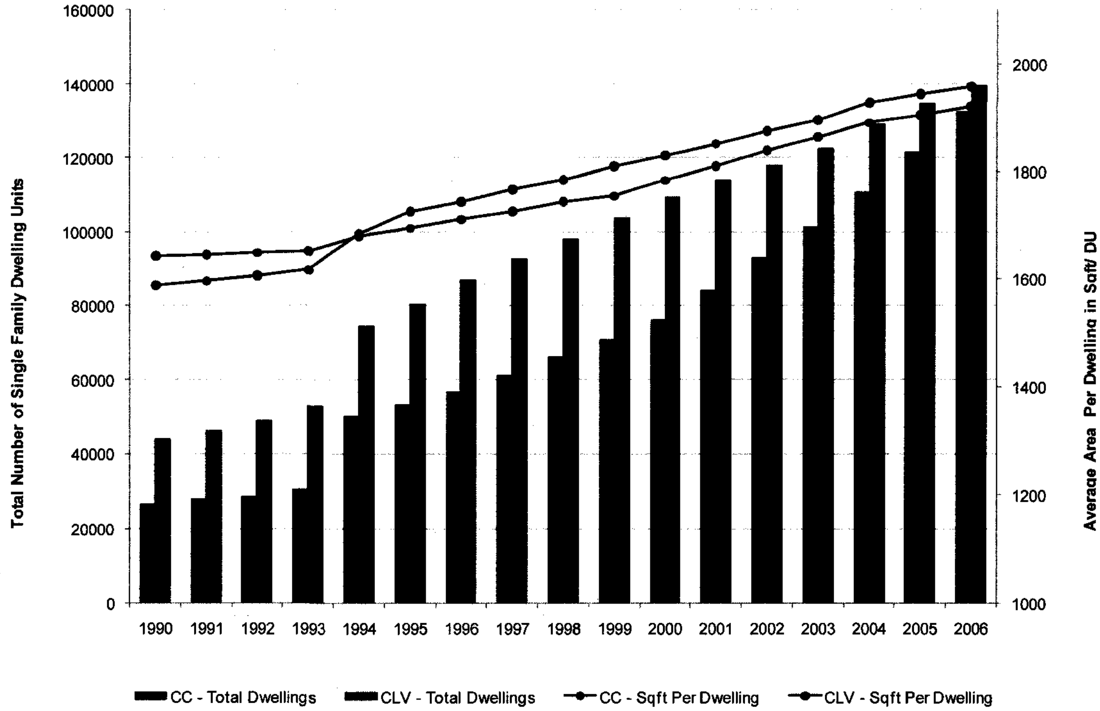


Fig. 4.1.3 shows that the average area per single family dwelling is higher in Las Vegas compared to Clark County. The different in average area per single family dwelling is almost 20 Sq. Ft. for seventeen years and it is almost 40 Sq. Ft in 2006. Hence, the higher number of single family residences together with the higher average area per dwelling contributes to the overall

[5] The average difference between the two cities is 23723 dwelling units for seventeen years and it is 7100 during the year 2006. The difference in number of single family homes from the year 1990 to 2005, between Clark county and Las Vegas has never dropped below 13,000 and in fact in 2000, the difference was as high as 32,940. Fig. 4.1.3 shows that 2006 was the first year where the difference in single family dwelling units between Clark county and Las Vegas was as low as 7100. This is because of the fact that there was constant increase in the difference in number of dwelling units between the two zones till 2000. But after 2000 the difference in single family dwelling units started to decline, which implies that the rate of single family residence growth in Las Vegas was taken over by the growth rate of Clark County from 2000.

higher water consumption in Las Vegas compared to Clark County. As a result of this, the water consumption per single family residence is overall higher in Las Vegas.

Though the average annual water use per dwelling from the year 1990 to 2006 is the same – 225 Kilo Gallons per dwelling for both the cities, the average annual water use per dwelling in Clark County and Las Vegas are 165 and 180 Kilo gallons per SFR respectively for the recent three years. These conditions presents Las Vegas to have comparatively higher threat in terms of water scarcity as the water demand, both overall and per capita are high.

After 1994's surge in total number of single family dwellings in both Clark County and Las Vegas, the curves showing increase in the number of residences from 1994 to 2006 grew distinct for each of the zones. When the water use curve at the Las Vegas follows the beginning of a downward curve, Clark County's water use curve grows upward. In other words, the growth rate of SFR in Las Vegas is gradually declining when the growth rate of SFR in Clark County is shooting up. This could be because of the reason that when Las Vegas is reaching its saturation level in terms of increase in SFR, Clark County is yet to find its limiting horizon.

Zip Level Analysis

The next step is zip-code wise analysis of water use in the Las Vegas Valley Water District from the year 1990 to 2006. This study includes all the 36 zip codes of the LVVWD, which has been assigned under the zones- incorporated Clark County and city of Las Vegas by the Clark County Assessor. In fig. 4.1.4 the annual water use per single family residence from the year 1990 to 2006 are stacked one above the other for every zip code, to show the cumulative annual water use per SFR for all the seventeen years. Besides, the graph also shows the average of the annual water consumption per single family residence for seventeen years in the secondary axis with markers and lines. This graph enables comparison of annual water use per SFR across the zip codes and across the years. Also the graph helps to spot the highest and lowest water consumptive zips for each year. The fig. 4.1.5 shows the average lot size of SFR and the total number of SFR in each of the zip codes of the LVVWD. Similarly, the fig. 4.1.6 shows the average built-up area of SFR in all the zip codes from the year 1990 to 2006 and the cumulative un-built area percentages of each of the zip codes for seventeen years.

Fig. 4.1.4: Annual Water Consumption per SFR Vs. Average Water Consumption per SFR from 1990 to 2006: LVVWD.

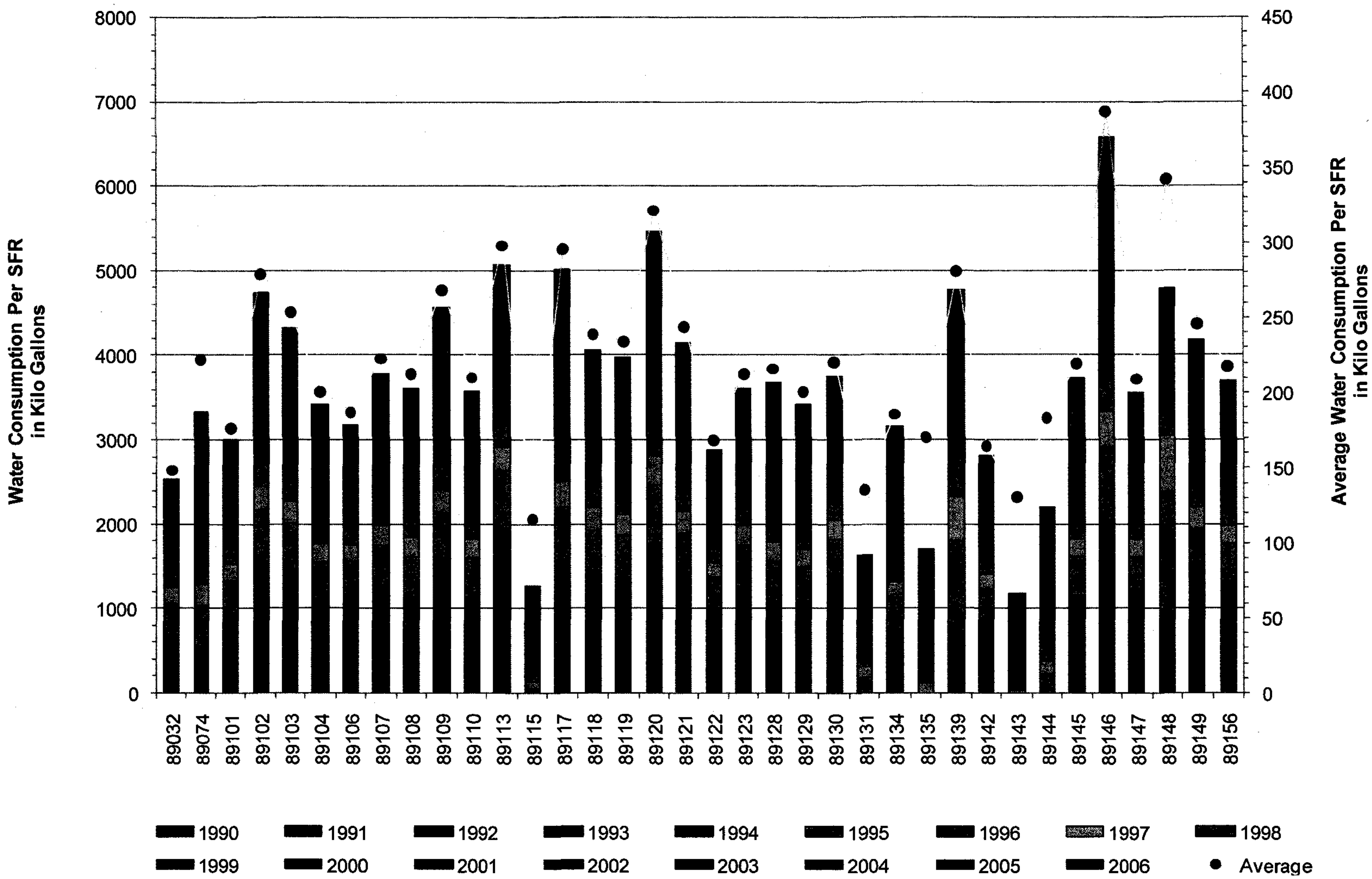


Fig. 4.1.5: Average Lot Size of SFR Vs. Total Number of SFR from 1990 to 2006: Las Vegas Valley Water District.

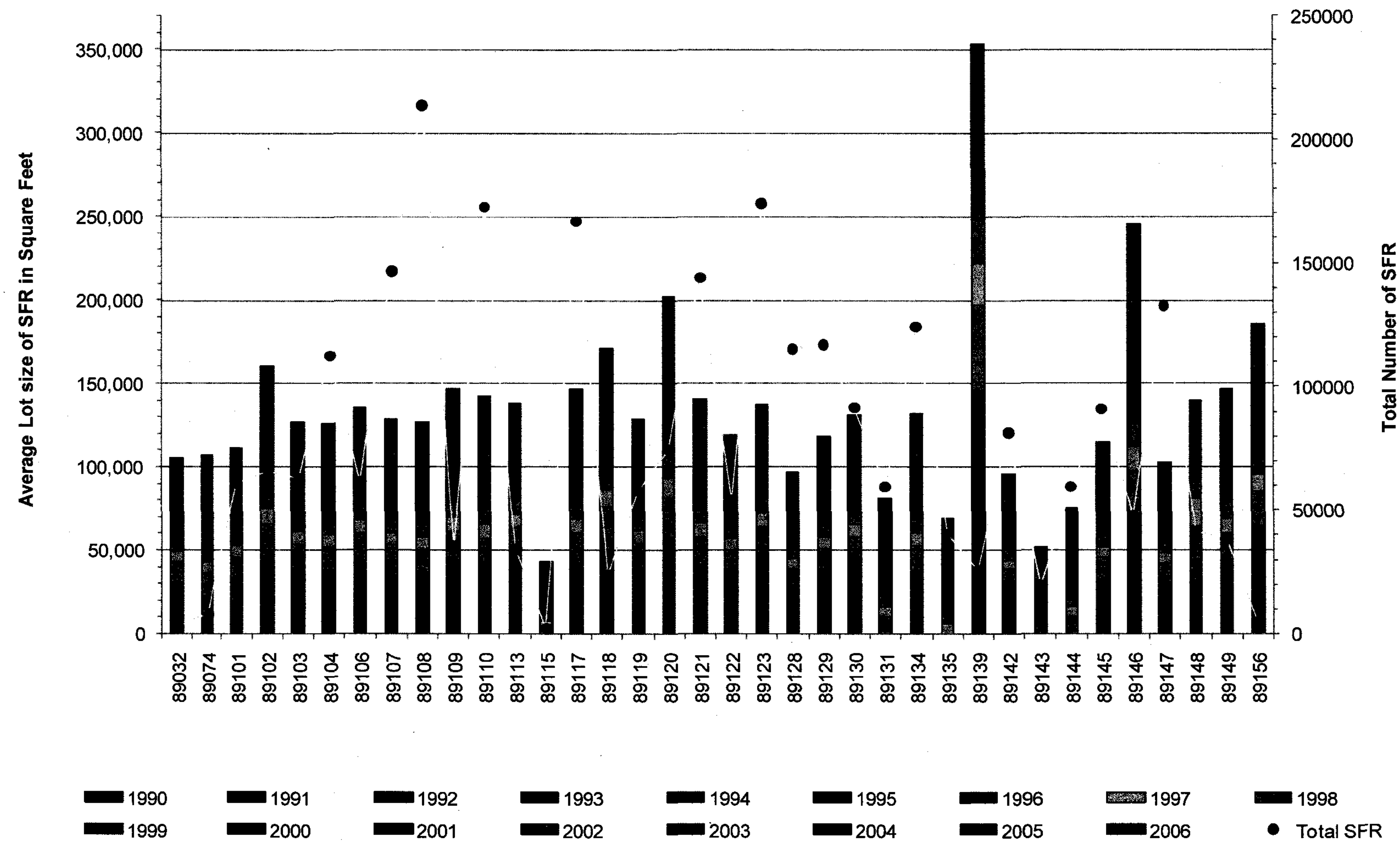
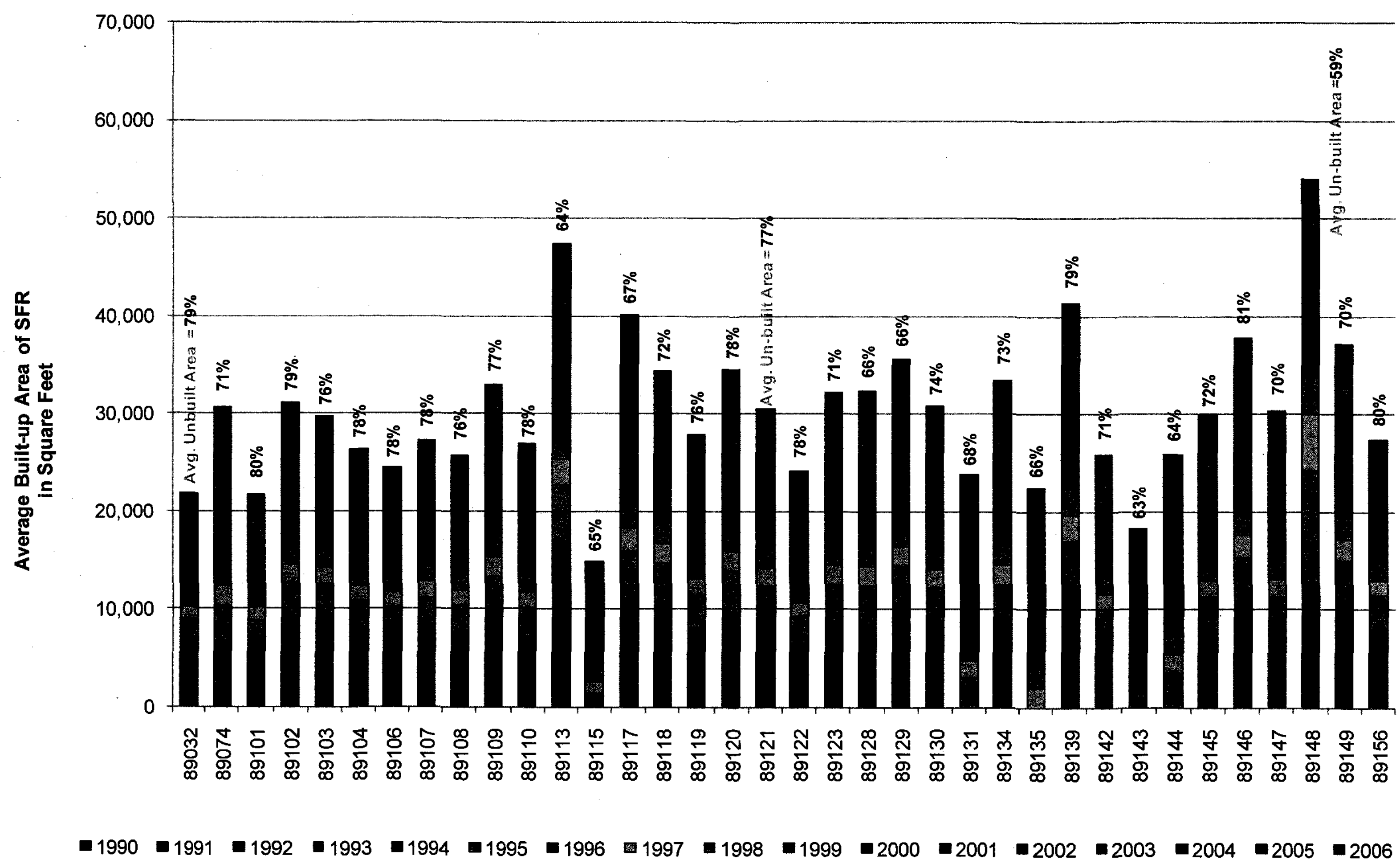


Fig. 4.1.6: Average Built-up and Un-built Area of SFR from 1990 to 2006: Las Vegas Valley Water District.



Some of the key findings from the above charts are summed up as follows,

1. The average water use has no relevance to the age of the zip codes: 89148 and 89074 are comparatively newer zip codes; but their average water uses are higher than some of the old zip codes.
2. (a) The above graphs help to determine the obvious reasons for high average water use in zips codes. It is seen from figure 4.1.4 that the zip code- 89146 ranks first in average water use. This is because of the fact that the zip code- 89146 has high lot area and high un-built area percentage as seen in figure 4.1.5 and figure 4.1.6.

   (b) Also, the zip code- 89139 has high average water use; because it has the highest lot area among all the other zip codes and high un-built area percentage. It is interesting to notice that 89139 is one of the zips that have the least number of SFR. This also shows that the density of the zip cannot alone determine the amount of damage a zip can cast on the city.
3. (a) The average size of built-up area and un-built area percentages of zips are independent to each other: Though in zip codes like 89148 and 89113 the cumulative average built-up areas of the lots are the highest among the other zips, they have comparatively lower average un-built area percentages. Similarly in zip codes like 89101, 89156 and 89106 the cumulative average built-up areas of the SFR are low, whereas their average un-built area percentages are high.

   (b) It can also be said from the above analysis that, the size of the built-up area or the size of the un-built area could not be determined as the reasons for the high and low average water use of a zip code.

These charts are the ready reference graphs for each of the zip codes, as they help to compare where each zip code stands when compared to the other zip codes in LVVWD in terms of average water use, total number of SFR, lot size, built-up area and un-built area.

Part 2: Historic Water Use in LVVWD from 1990 to 2005

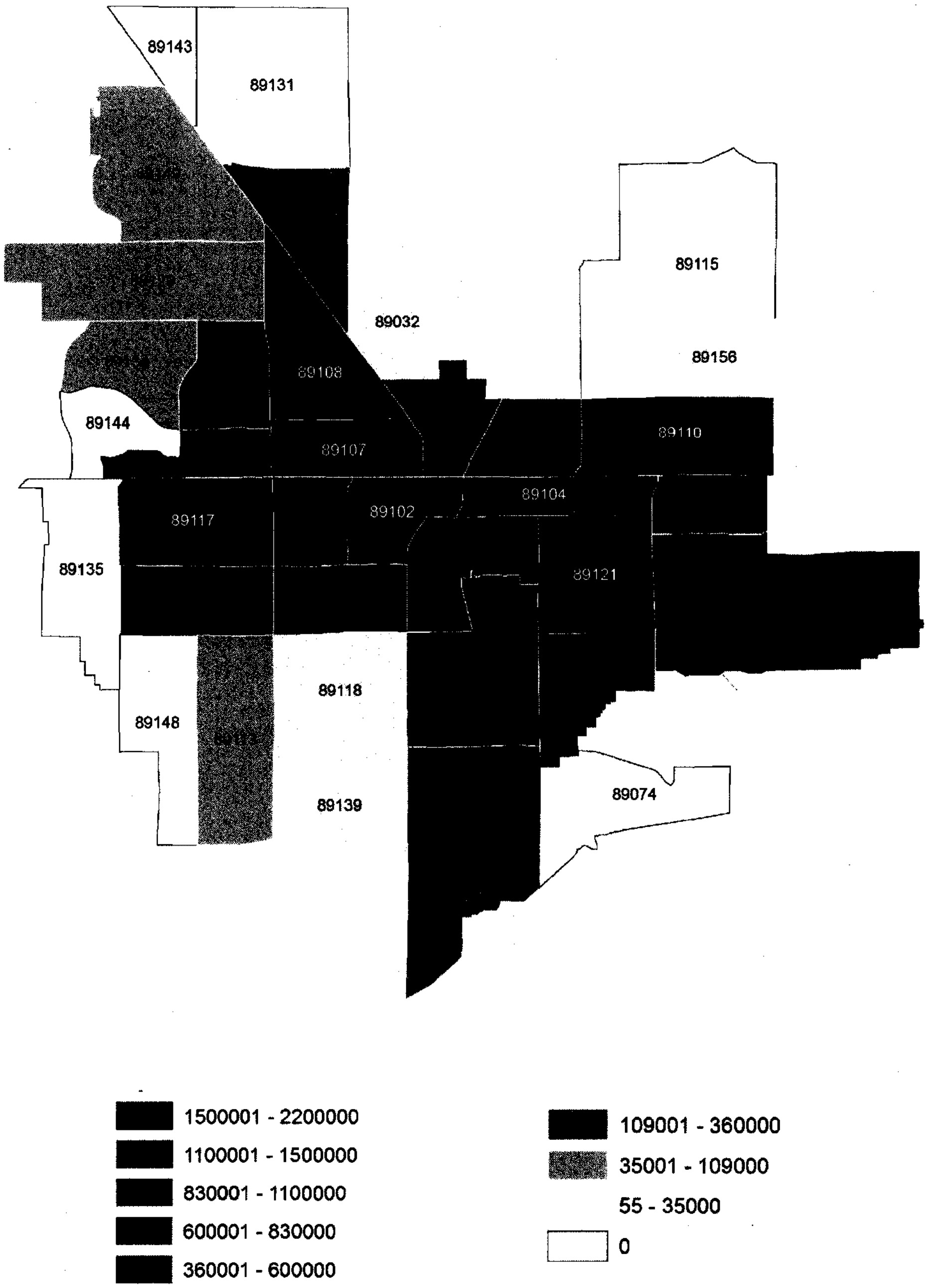
Historic Analysis- 1990

As explained in the summary of this chapter, the historic analysis is done individually for the years 1990, 1995, 2000 and 2005. For each one of the year's total and average water uses are analyzed in both the zip code level and the street level. The zip level analysis includes mapping the total & average water use, the total built-up area, un-built area & swimming pool area and listing their rankings with respect to the total and average water use of the SFR. Whereas the street level analysis includes plotting the street level water use with the total built-up area, un-built area and pool area separately. The last part of the street level analysis includes the statistical analysis that involves finding the correlation coefficients and regression equations for each one of the factor that affects the water use such as the built-up area, un-built area and pool area of the single family residences.

For the year 1990, the zip level analysis includes all the 36 zip codes of the LVVWD for which the built-up, un-built and pool data are obtained from the Clark County Assessor office. But out of the 36 zip codes, only 29 zip codes have the water use data for the year 1990. The remaining 7 zip codes - 89143, 89131, 89115, 89144, 89135, 89148 and 89074 are marked in the figure 4.2.1 and 4.2.2 in white color. Whereas the zip level rankings and street level analysis includes only the 29 zip codes for which both the water use data and the assessor data are obtained from SNWA and Clark County Assessor office respectively.

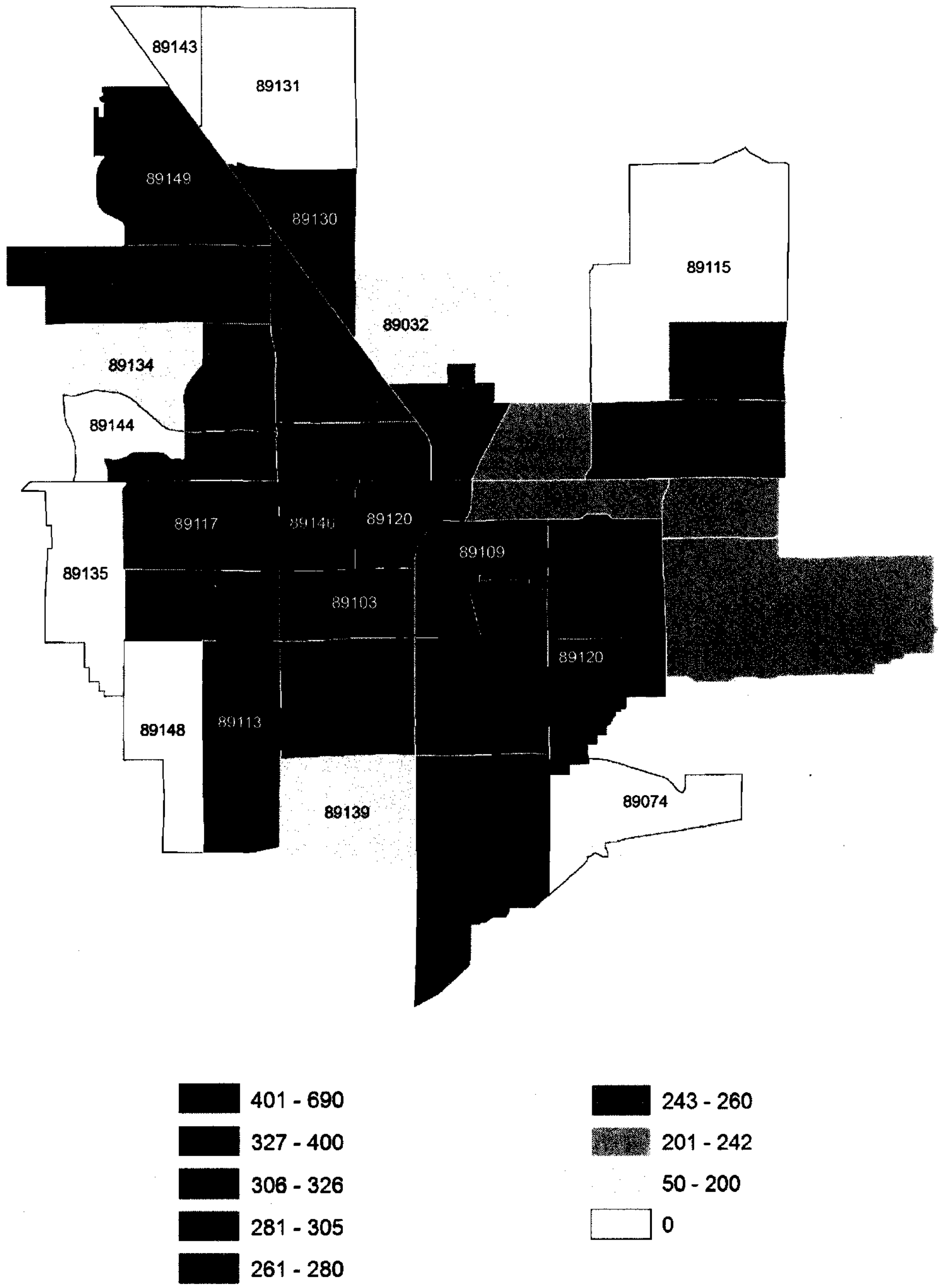
The zip level mappings and rankings are intended to be studied side by side to understand the real cause of high and low water use in each one of the zip code. When the maps below shows the range within which each zip code lies, the rankings table shows the respective cause and position of each zip code with respect to the other zips. For the uniformity and simplicity of the zip code maps and the street level charts, the water use is colored blue-green-yellow, the density is colored brown, the built-up area is colored maroon, the un-built area is colored green and the swimming pool area is colored blue throughout this section.

Fig. 4.2.1: 1990- Total Water Use in Kilo Gallons: Las Vegas Valley Water District.



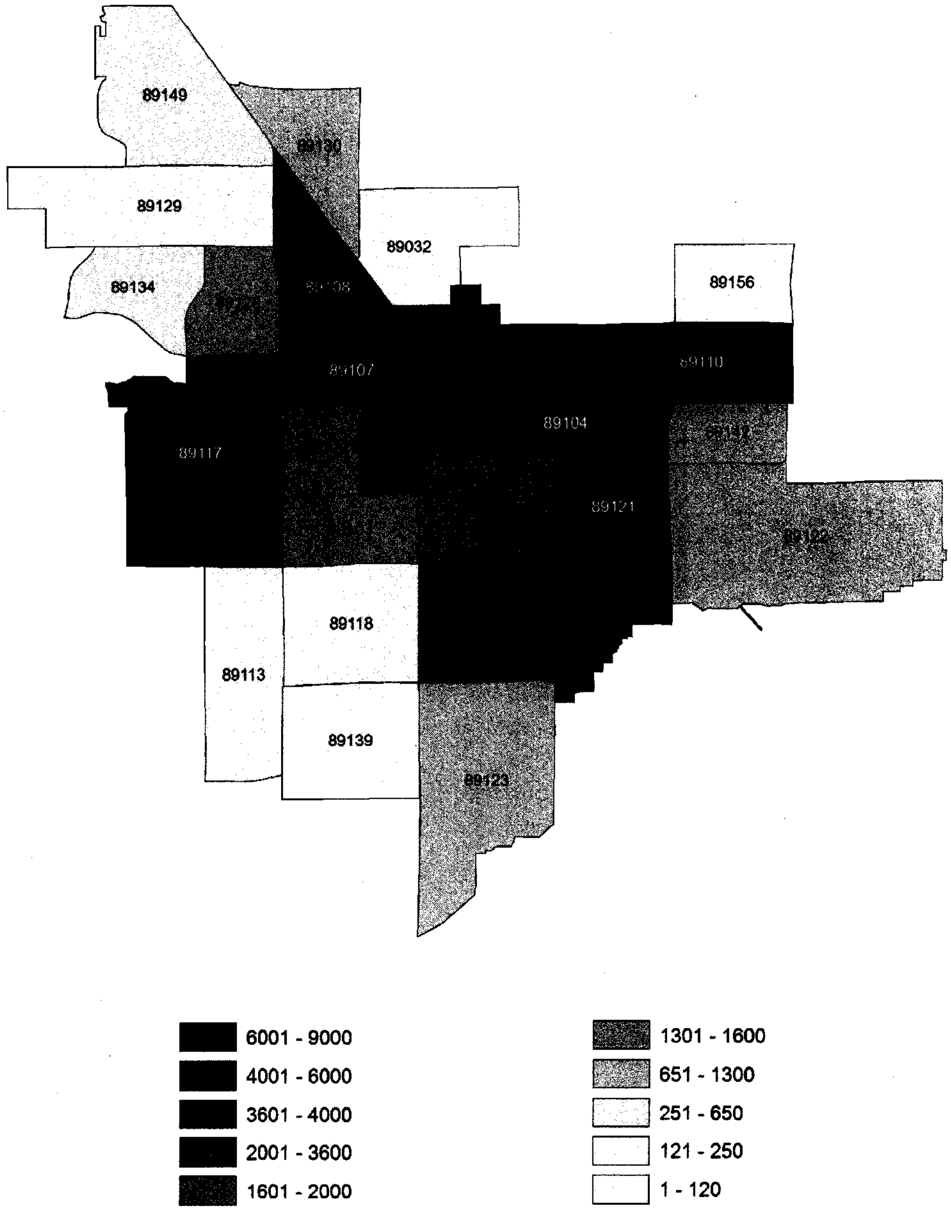
Zip codes 89107, 89108, 89110, 89121, 89117, 89102 and 89104 are the highest consumers of total annual water in the LVVWD. Whereas, the zip codes 89032, 89156, 89118 and 89139 consumes less than 5% of the total water consumed by the highest consumers.

Fig. 4.2.2: 1990- Average Water Use in Kilo Gallons: Las Vegas Valley Water District.



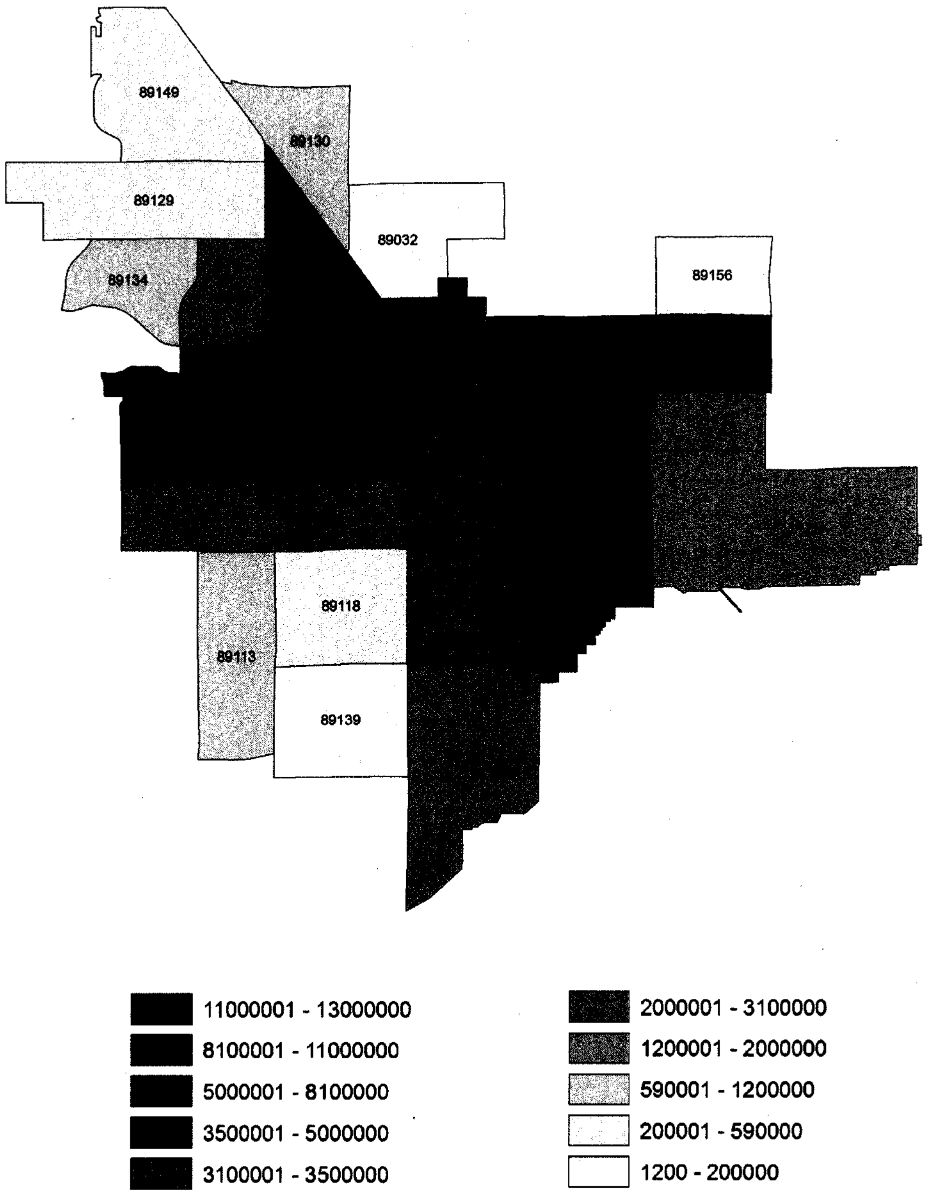
Zip codes 89149, 89130, 89146, 89113, 89117, 89120, 89102, 89103 and 89109 are the highest consumers of average annual water in the LVVWD. Whereas, the zip codes 89032, 89134 and 89139 consumes less than 50% of the total water consumed by the highest consumers.

Fig. 4.2.3: 1990- Total Number of Single Family Residence: Las Vegas Valley Water District.



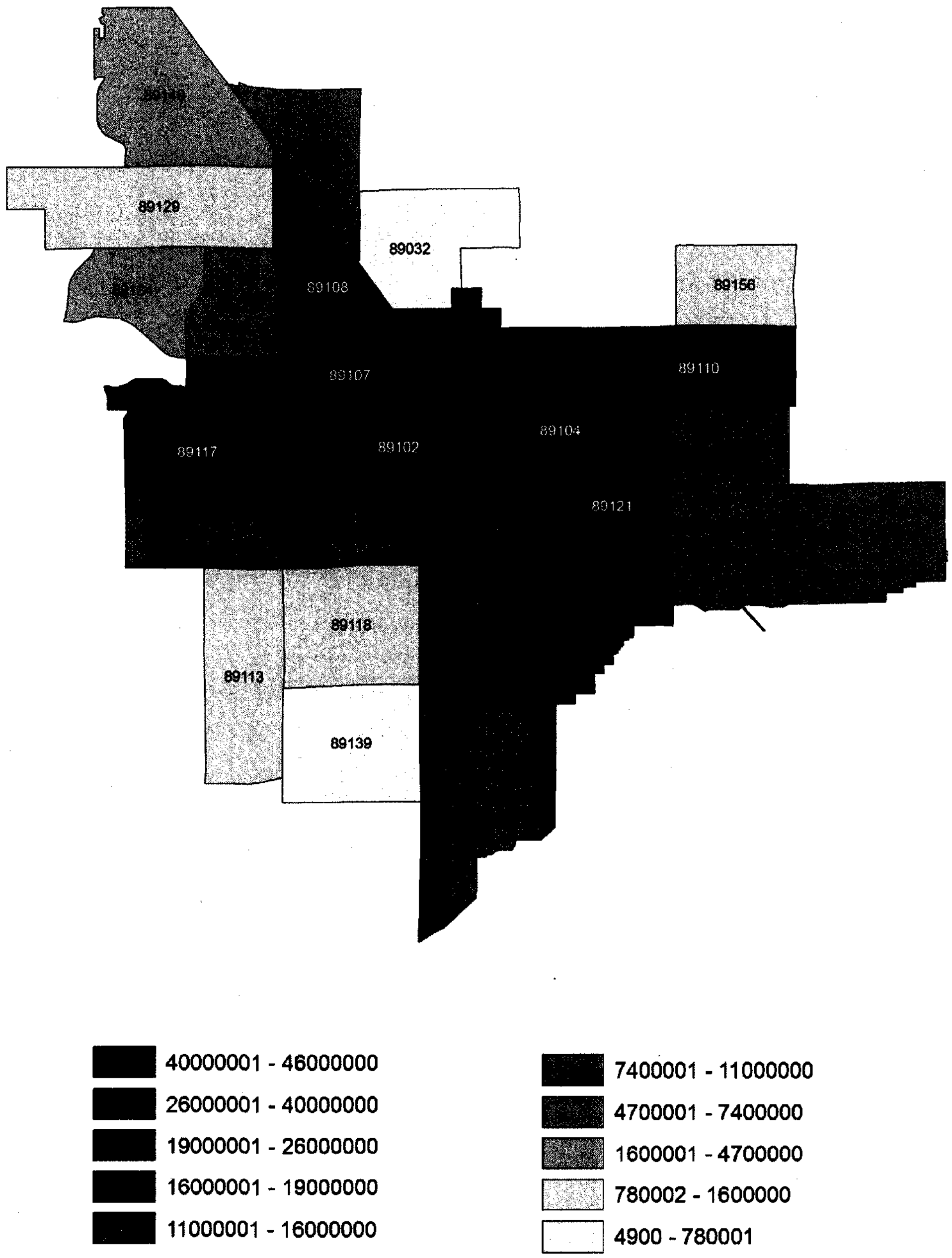
When the fig. 4.2.3 is overlapped with the above figure, it is obvious that the zip codes where the total number of single family residence is high are the highest consumers of total annual water. Also, the zip codes with less number of SFR are the lowest consumers. In other words, the denser the SFR in a zip code, the higher the total water use.

Fig. 4.2.4: 1990- Total Built-up area in Square Feet: Las Vegas Valley Water District.



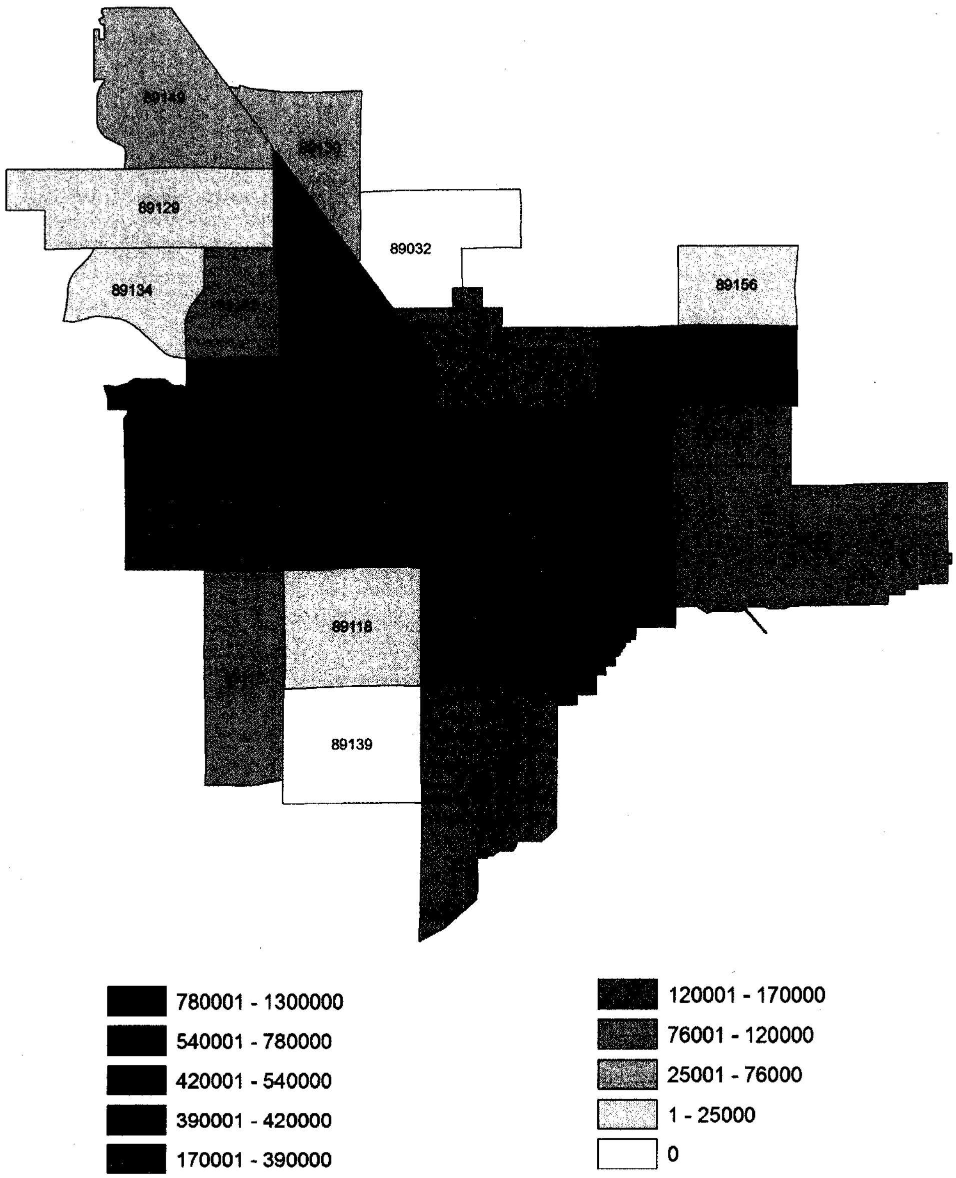
When the fig. 4.2.3 is overlapped with the above figure, it is evident that the zip codes where the total built-up area is high are the highest consumers of total annual water. Also, the zip codes with less total built-up area are the lowest consumers. In other words, the higher the built-up area, the higher the total water use and vice versa. This proves that the size of the built-up area has strong correlation to the total quantity of water used in that region.

Fig. 4.2.5: 1990- Total Un-built area in Square Feet: Las Vegas Valley Water District.



When fig. 4.2.3 is overlapped with the above figure, it is evident that the zip codes where the total un-built area is high are the highest consumers of total annual water. Also, the zip codes with less total built-up area are the lowest consumers. In other words, the higher the un-built area, the higher the total water use and vice versa. This proves that the size of the un-built area has strong correlation to the total quantity of water used in that region.

Fig. 4.2.6: 1990- Total Pool Area in Square Feet: Las Vegas Valley Water District.



When the fig. 4.2.3 is overlapped with the above figure, it is evident that the zip codes where the total pool area is high are the highest consumers of total annual water. Also, the zip codes with less total pool area are the lowest consumers. In other words, the higher the pool area, the higher the total water use and vice versa. This proves that the total area of the pool has strong correlation to the total quantity of water used in that region.

Table 4.2.1: Rankings: 1990- Zip-wise Totals of, Water Use, Built-up Area, Un-built Area and Pool Area of the LVVWD.

Zip	Water Use in Kilo Gals	Rank (WC)	Built-up Area in Sq. Ft	Rank (B)	Un-built Area in Sq. Ft	Rank (UB)	Pool Area in Sq. Ft	Rank (P)
89108	2191554	1	12736841	1	43845781	2	662004	5
89107	2103390	2	12470665	2	45692564	1	868640	2
89121	1784554	3	10719721	3	38673877	4	1292818	1
89110	1491914	4	8597807	5	39179443	3	431884	8
89117	1324566	5	8768532	4	26090474	7	776238	3
89104	1269143	6	8096663	6	29952767	5	487888	7
89102	1181955	7	6530172	7	26214298	6	738184	4
89120	1014063	8	4979326	9	24078836	8	541904	6
89145	931818	9	5828681	8	17898131	10	403740	11
89101	748418	10	4712607	10	18830893	9	169450	15
89146	684553	11	3281080	14	16281326	12	415312	9
89119	646240	12	3470181	12	13412010	13	386788	13
89106	599526	13	3527005	11	17321855	11	143084	17
89109	585138	14	3363813	13	12336137	14	413068	10
89147	558334	15	3080178	15	9317443	17	262666	14
89103	539354	16	2983163	16	9413530	16	388658	12
89128	371796	17	2305132	17	5519034	20	118648	18
89123	352273	18	2015421	18	10294326	15	159686	16
89122	279263	19	1696613	20	7341627	18	81434	20
89142	277345	20	1815328	19	5610131	19	99966	19
89130	228826	21	1170301	21	4734383	21	59746	23
89113	108240	22	851511	22	1544301	24	76258	21
89149	85656	23	587214	24	1618847	23	60898	22
89134	71319	24	704187	23	2662015	22	3724	27
89129	66133	25	451676	25	1180789	26	24344	24
89118	34409	26	239545	26	783865	27	24192	25
89156	32956	27	190369	27	1338054	25	12456	26
89032	163	28	1269	29	4903	29	0	28
89139	55	29	2283	28	34544	28	0	28

Table 4.2.2: Rankings: 1990- Zip-wise Average of, Water Use, Built-up Area, Un-built Area and Pool Area of the LVVWD.

Zip	Water Use in Kilo Gallons	Rank (WC)	Built-up Area in Sq. Ft	Rank (B)	Un-built Area in Sq. Ft	Rank (UB)	Pool Area in Sq. Ft	Rank (P)
89146	451	1	2160	5	10718	3	273	2
89113	444	2	3490	1	6329	15	313	1
89120	396	3	1945	7	9406	4	212	7
89130	341	4	1744	13	7056	8	89	19
89103	338	5	1867	9	5891	18	243	3
89102	329	6	1816	10	7292	7	205	8
89149	328	7	2250	3	6202	16	233	4
89117	328	8	2171	4	6460	12	192	10
89109	327	9	1882	8	6903	9	231	5
89119	308	10	1656	15	6402	13	185	11
89123	297	11	1699	14	8680	5	135	12
89121	293	12	1759	12	6347	14	212	6
89118	284	13	1980	6	6478	11	200	9
89156	282	14	1627	17	11436	2	106	16
89147	271	15	1495	22	4523	27	128	13
89107	269	16	1593	19	5836	19	111	15
89128	267	17	1654	16	3959	29	85	20
89129	266	18	1814	11	4742	26	98	17
89145	257	19	1605	18	4928	24	111	14
89106	253	20	1486	23	7296	6	60	25
89108	250	21	1451	24	4996	23	75	22
89110	248	22	1427	25	6505	10	72	23
89104	241	23	1539	21	5694	20	93	18
89122	216	24	1310	27	5669	21	63	24
89142	214	25	1402	26	4332	28	77	21
89101	202	26	1273	28	5085	22	46	26
89032	163	27	1269	29	4903	25	0	28
89134	161	28	1586	20	5996	17	8	27
89139	55	29	2283	2	34544	1	0	28

Table 4.2.1 and 4.2.2 lists the total and average water use rankings of all the 29 zip codes of the year 1990 in the LVVWD. This ranking is compared with the individual rank of every zip code for the built-up area, un-built area and pool area of SFR. It is obvious from the table 4.2.1 that the total annual water use rank of the zip codes correlates very closely with the total square feet values of built-up area, un-built area and pool area of SFR. In other words the zip codes that rank high, medium and low in the total water use are the same zip codes that rank high, medium and low in the total square feet of built-up area, un-built area and pool area of SFR. But in the table 4.2.2 this is not true. This is because of the difference in the density of SFR in each of the zip codes. For instance, the zip code 89139 ranks low in the terms of average water use; but due to the very less density, this zip code ranks high in terms of the average size of built-up area and un-built area of SFR.

The next step is the street wise analysis. In this stage, 3,340 streets from the LVVWD are considered and their total annual water uses are plotted against the total built-up area. This is shown in the figure 4.2.7. Similarly, for the same number of streets, the total annual water uses are plotted against the total un-built area, as shown in the figure 4.2.8. In both the cases the correlation between water use and the built-up is as high as the correlation between water use and the un-built area. It is also evident through the charts that due to high correlation, the plots could be easily fit into a linear equation.

In the year 1990, only 2,780 streets out of 3,340 streets have swimming pools. Hence, the total annual water uses of the streets with swimming pools are plotted against the total square feet area of the pools. Figure 4.2.9 shows that though swimming pool is one of the contributing factors of high water use, SFR with similar size swimming pools varies greatly in their water uses due to the influence of other factors.

In table 4.2.3, through regression analysis, the equations with water use and each one of the factor that affects the water use are derived. At the same time, a combined equation is derived through regression analysis with water use and all the factors that affects the water use. Thus for a given year, the total annual water used in kilo gallons can be determined by plugging in the square feet values of built-up area, un-built area and swimming pool area of SFR.

Fig. 4.2.7: 1990- Street-wise Total Built-up area of SFR: Las Vegas Valley Water District.

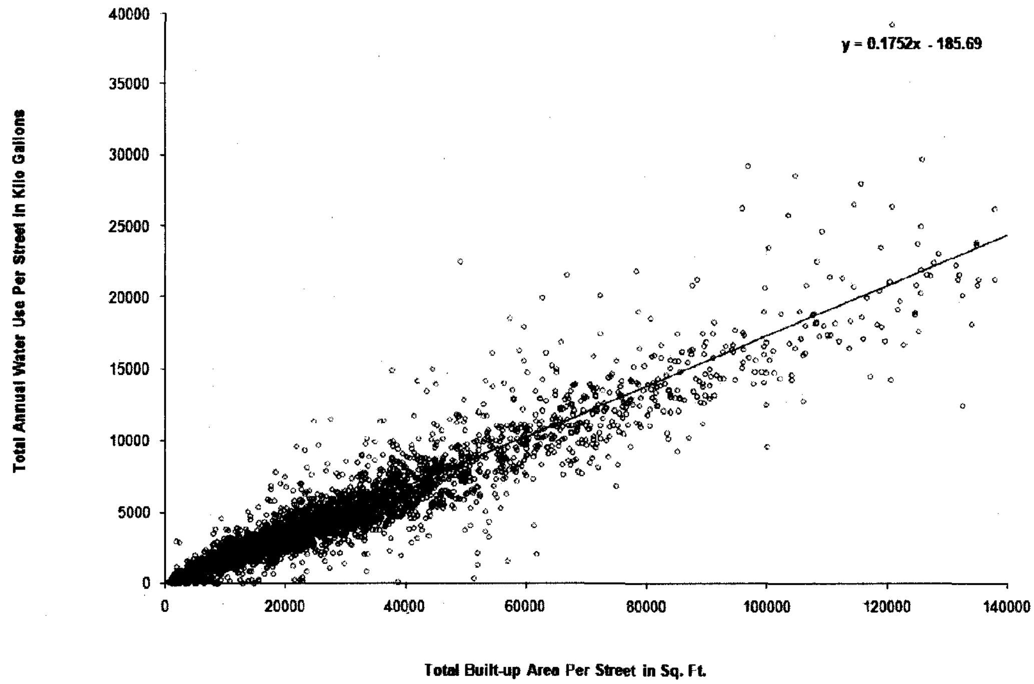
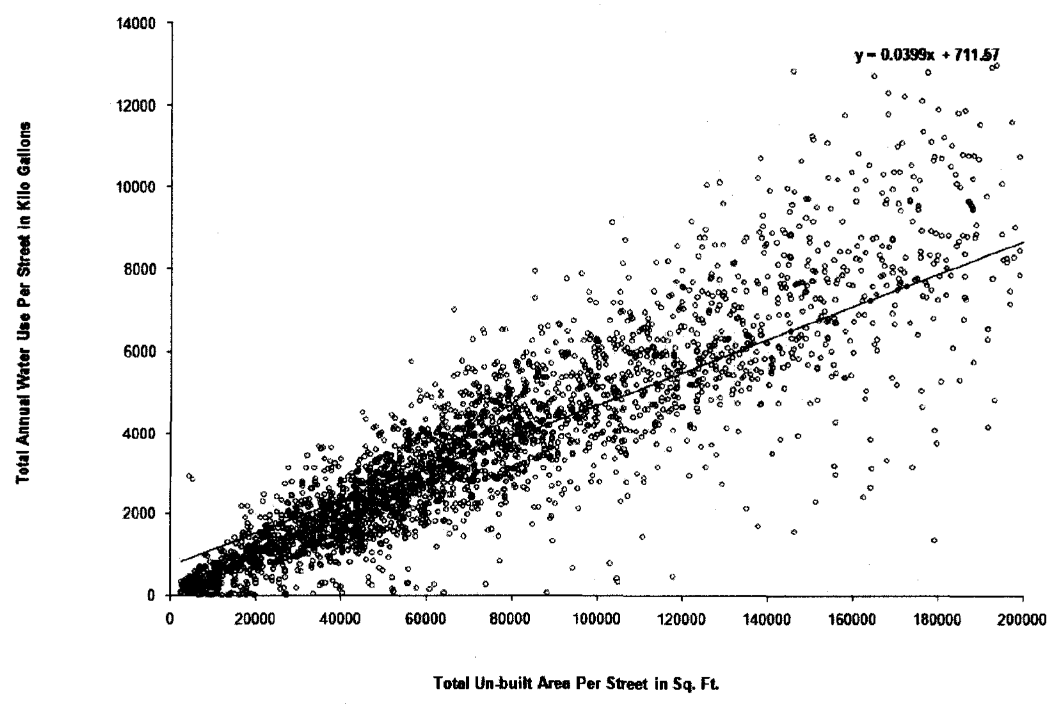


Fig. 4.2.8: 1990- Street-wise Total Un-built Area of SFR: Las Vegas Valley Water District.



Flg. 4.2.9: 1990- Street-wise Total Pool Area of SFR: Las Vegas Valley Water Dlstrict

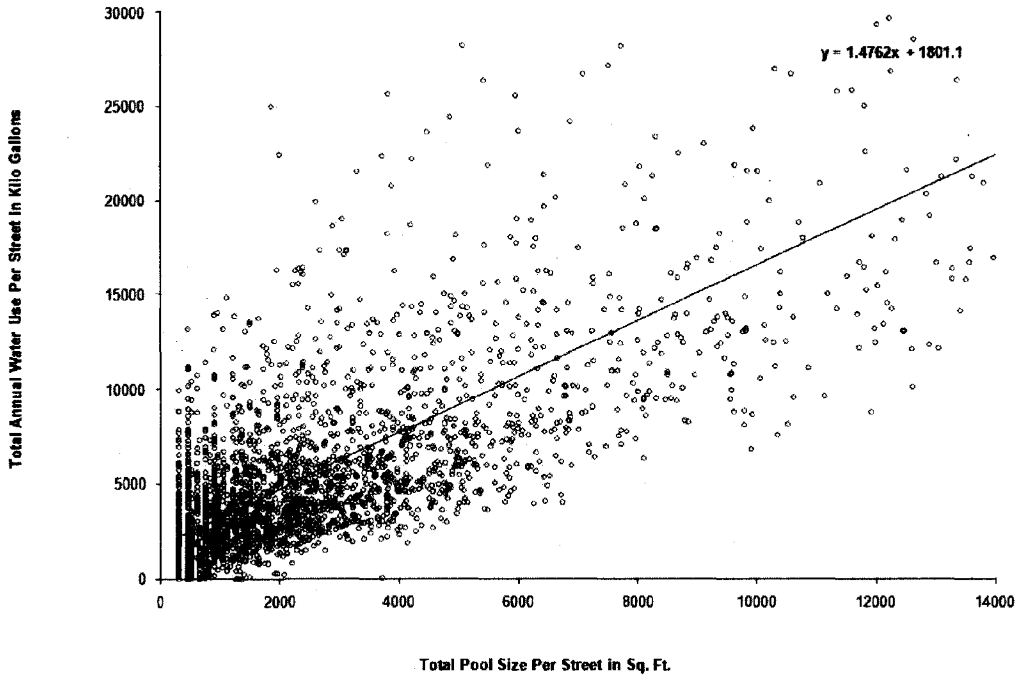


Table 4.2.3: Regression Statistics - with Water Use and Buiit-up/Un-built/Pool Areas: LVVWD

Year - 1990	Coefficient	Linear Equation
B	0.967908	Y = 0.175239B-185.998
UB	0.965508	Y = 0.039856UB+711.8931
P	0.849734	Y = 1.47122P+1847.458
B, UB	0.984922	Y = 0.093804B+0.020034UB+35.9017
B, P	0.973382	Y = 0.148852B+0.309109P-118.553
UB, P	0.973289	Y = 0.032987UB+0.358089P+622.5517
B, UB, P	0.987027	Y = 0.083415B+0.01843UB+0.198063P+61.35414

Where, Y = Total Water Consumption of SFR in a street (Kilo Gals), B = Total Built-up Area of SFR in a street (Square Feet), UB = Total Un-built Area of SFR in a street (Square Feet), P = Total Pool Area of SFR in a street (Square Feet).

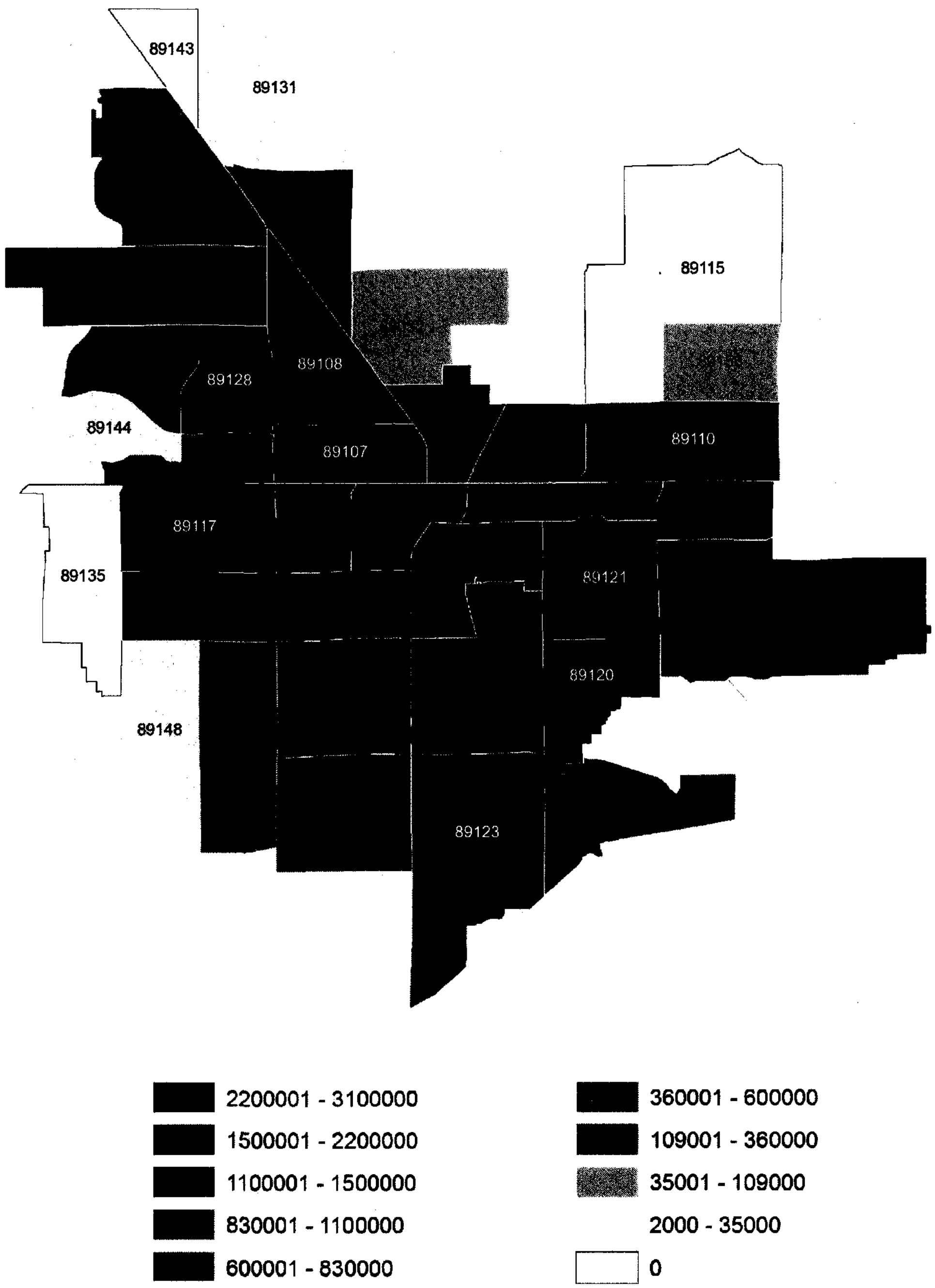
Historic Analysis – 1995

For the year 1995, the zip level analysis includes all the 36 zip codes of the LVVWD for which the built-up, un-built and pool data are obtained from the Clark County Assessor office. But out of the 36 zip codes, only 33 zip codes have the water use data for the year 1995. The remaining 3 zip codes - 89143, 89115, and 89135 are marked in the figure 4.2.10 and 4.2.11 in white color. Whereas the zip level rankings and street level analysis includes only the 33 zip codes for which both the water use data and the assessor data are obtained from SNWA and Clark County Assessor office respectively. This is because of the fact that both the zip level rankings and street level analysis involves comparing the total and average water use derived from the water use data from SNWA with the total built-up area, un-built area and pool area derived from the residential data from the Clark County Assessor office.

For the uniformity and simplicity of the zip code maps and the street level charts, the water use is colored blue-green-yellow, the density is colored brown, the built-up area is colored maroon, the un-built area is colored green and the swimming pool area is colored blue throughout this section.

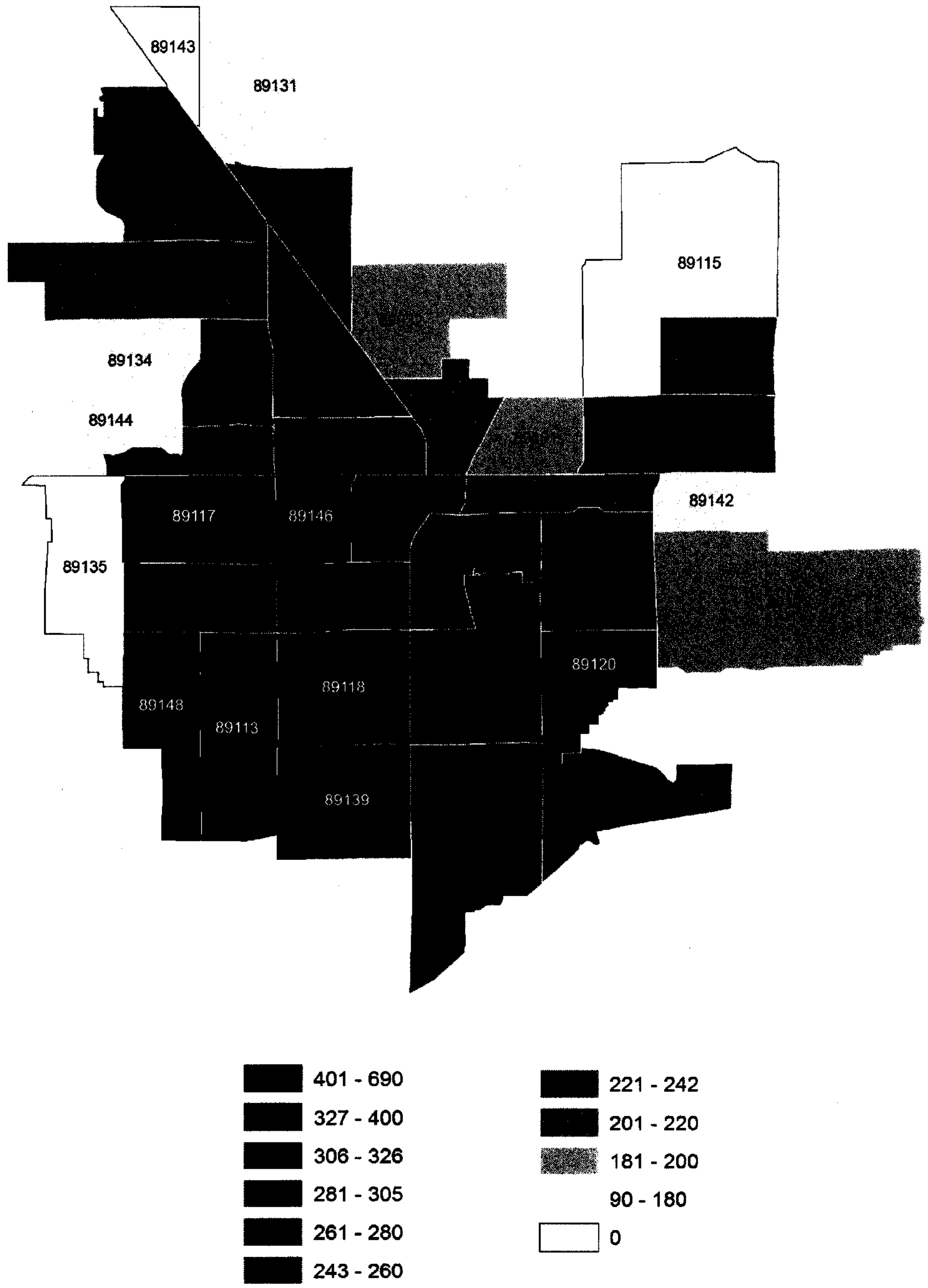
Besides finding the cause for high and low water use and finding the position of each zip with respect to the other zips, the goal of this analyzing is to find the correlation between water use and each one of the factor that affects the water use, so that an equation that fits in all the factors of study and water use could be derived.

Fig. 4.2.10: 1995- Total Water Use In Kiio Gallons: Las Vegas Valley Water District.



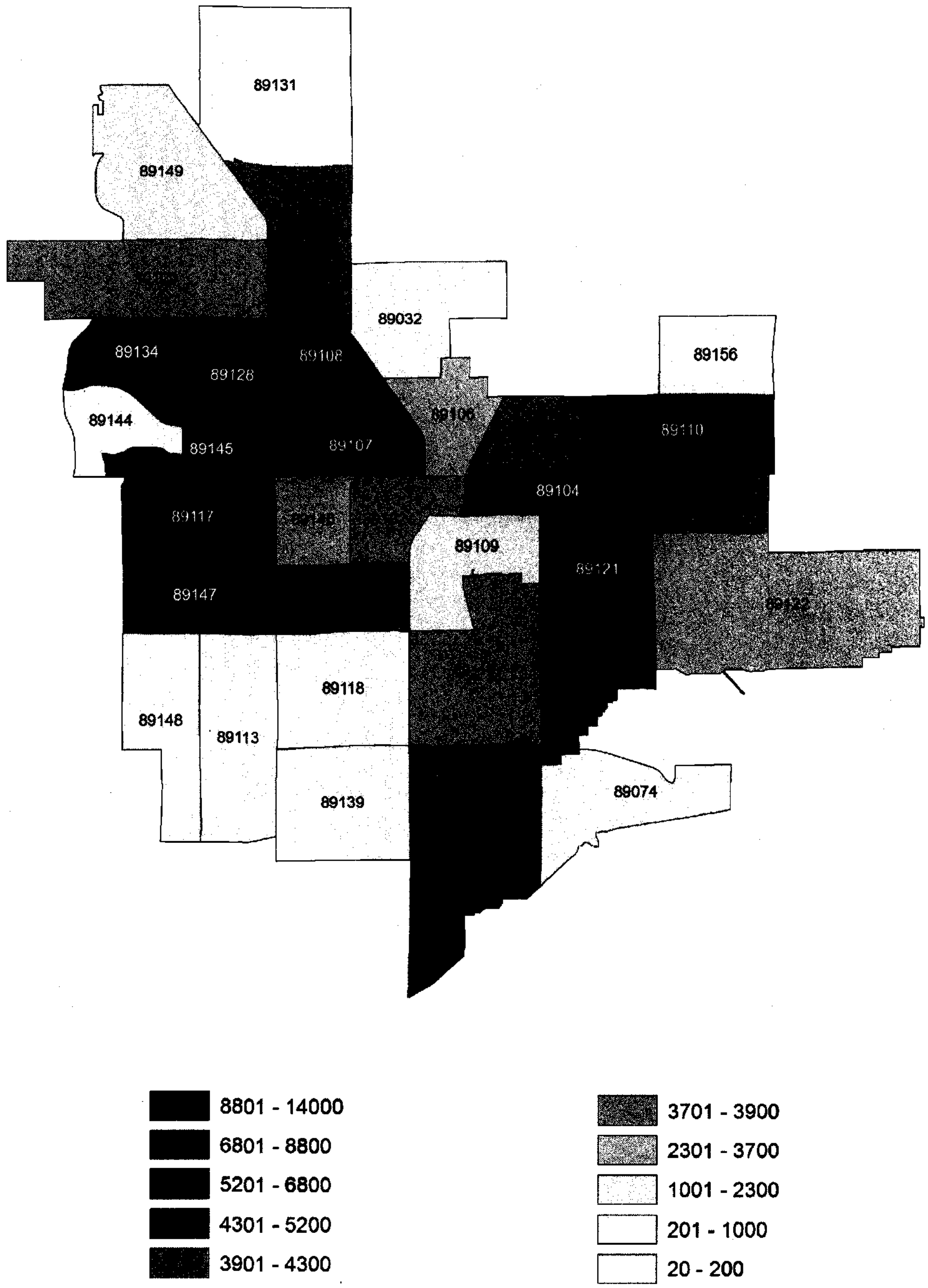
Zip codes 89108, 89117, 89121, 89128, 89110, 89107 and 89120 are the highest consumers of total annual water in the LVVWD. Whereas, the zip codes 89131, 89144, and 89148 consume less than 1.5% of the total water consumed by the highest consumers.

Fig. 4.2.11: 1995- Average Water Use in Kilo Gallons: Las Vegas Valley Water District.



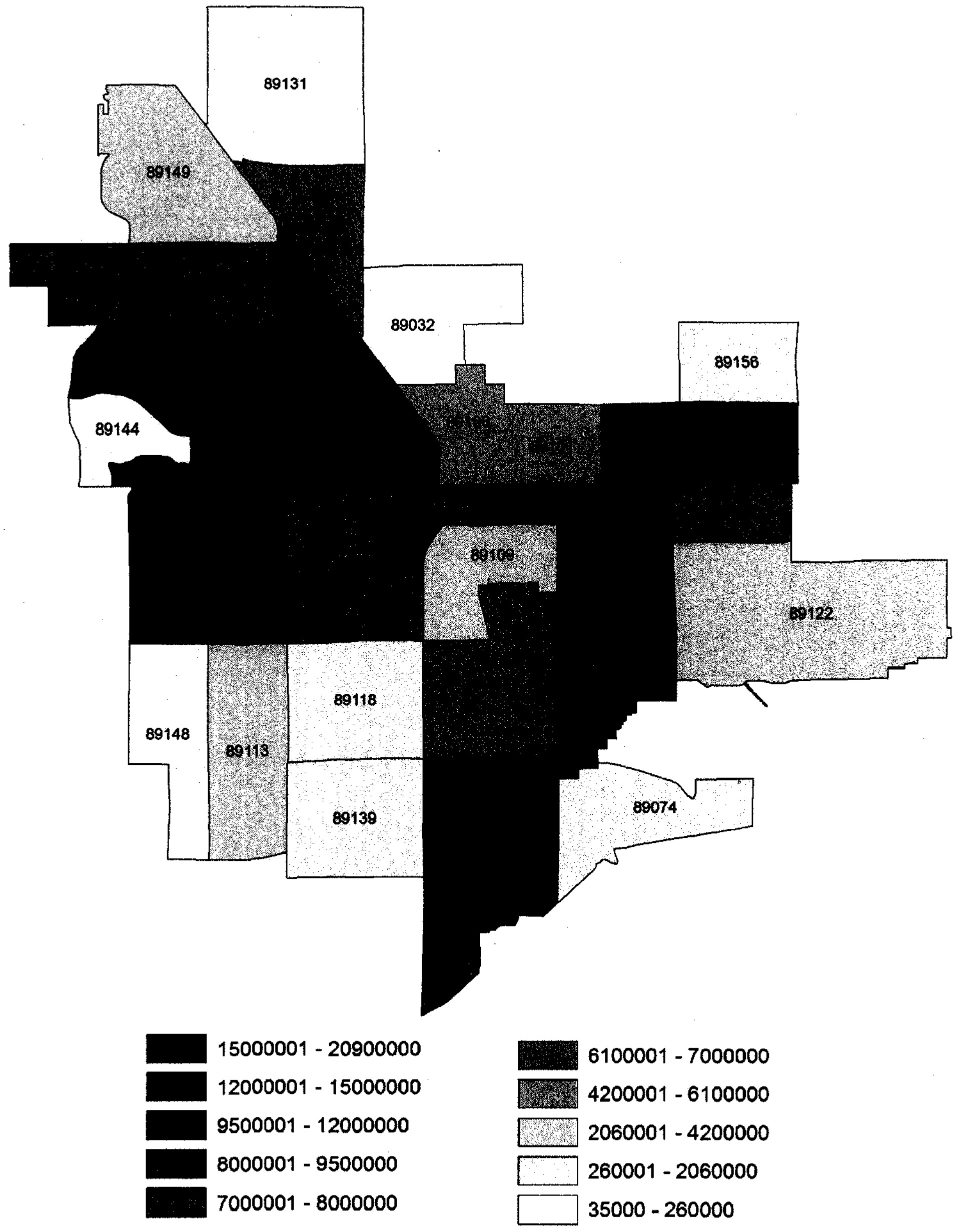
Zip codes 89146, 89148, 89139, 89120, 89113, 89118 and 89117 are the highest consumers of average annual water in the LVVWD. Whereas, the zip codes 89131, 89134, 89144 and 89142 consume less than 48% of the total water consumed by the highest consumers.

Fig. 4.2.12: 1995- Total Number of Single Family Residence: Las Vegas Valley Water District.



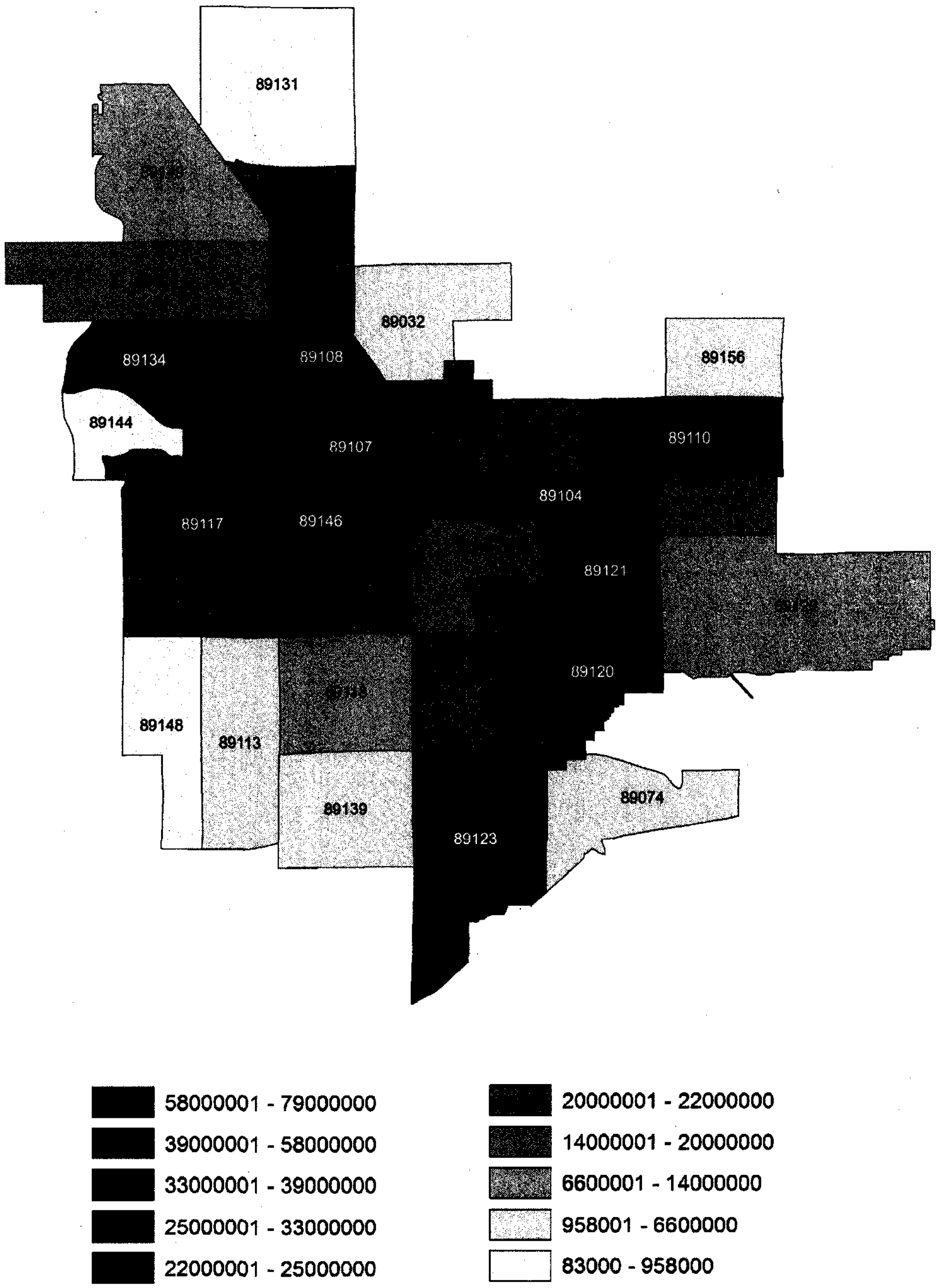
When the fig. 4.2.10 is overlapped with the above figure, it is obvious that the zip codes where the total number of single family residence is high are the highest consumers of total annual water. Also, the zip codes with less number of SFR are the lowest consumers. In other words, the denser the SFR in a zip code, the higher the total water use.

Fig. 4.2.13: 1995- Total Built-up Area in Square Feet: Las Vegas Valley Water District.



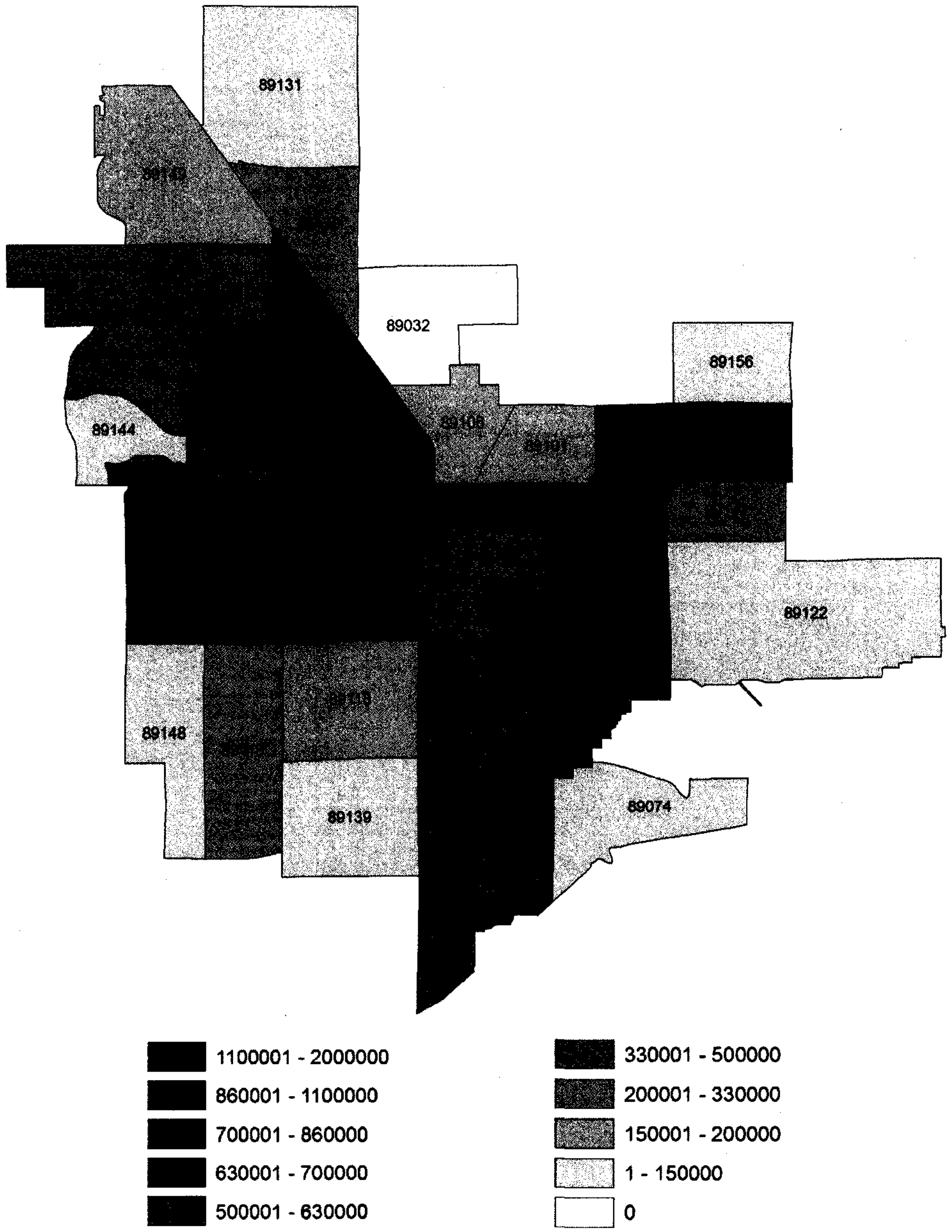
When the fig. 4.2.10 is overlapped with the above figure, it is evident that the zip codes where the total built-up area is high are the highest consumers of total annual water. Also, the zip codes with less total built-up area are the lowest consumers. In other words, the higher the built-up area, the higher the total water use and vice versa. This proves that the size of the built-up area has strong correlation to the total quantity of water used in that region.

Fig. 4.2.14: 1995- Total Un-built Area in Square Feet: Las Vegas Valley Water District.



When the fig. 4.2.10 is overlapped with the above figure, it is evident that the zip codes where the total un-built area is high are the highest consumers of total annual water. Also, the zip codes with less total built-up area are the lowest consumers. In other words, the higher the un-built area, the higher the total water use and vice versa. This proves that the size of the un-built area has strong correlation to the total quantity of water used in that region.

Fig. 4.2.15: 1995- Total Pool Area in Square Feet: Las Vegas Valley Water District.



When the fig. 4.2.10 is overlapped with the above figure, it is evident that the zip codes where the total pool area is high are the highest consumers of total annual water. Also, the zip codes with less total pool area are the lowest consumers. In other words, the higher the pool area, the higher the total water use and vice versa. This proves that the total area of the pool has strong correlation to the total quantity of water used in that region.

Table 4.2.4: Rankings: 1995- Zip-wise Totals of, Water Use, Built-up Area, Un-built Area and Pool Area of the LVVWD.

Zip	Water Use in Kilo Gals	Rank (WC)	Built-up Area in Sq. Ft	Rank (B)	Un-built Area in Sq. Ft	Rank (UB)	Pool Area in Sq. Ft	Rank (P)
89108	3084110	1	20063638	2	78472323	1	1074364	4
89117	2863741	2	20850170	1	58848366	3	1697452	2
89121	2458170	3	16366674	3	57321278	4	1905032	1
89107	2145777	4	14161439	5	51280791	5	964174	5
89110	2141325	5	14025242	6	60947380	2	705432	10
89128	1745975	6	15192159	4	30567608	11	796700	8
89120	1671773	7	9511818	10	43878372	6	1089256	3
89104	1491999	8	10620349	8	38829704	7	633106	12
89146	1321828	9	6890242	17	37921706	8	859160	7
89147	1249662	10	10085245	9	24839540	13	639844	11
89123	1190465	11	8941683	11	32657908	10	625896	13
89102	1166244	12	7068312	15	28741881	12	792616	9
89103	1164831	13	7411579	14	23486731	15	884128	6
89145	1151642	14	8570264	12	24333378	14	526952	15
89134	1067830	15	11682886	7	33331319	9	388402	18
89119	944894.8	16	6147284	19	20832479	19	556066	14
89130	924100.8	17	6980619	16	22102467	17	329934	19
89101	783698	18	5211202	20	20943622	18	179960	23
89129	765297.8	19	7942671	13	19077707	20	499632	16
89142	731717.1	20	6293225	18	16451108	21	227656	21
89106	698647.2	21	4813486	21	22106602	16	175746	25
89109	636508.8	22	4175908	22	14045190	22	496990	17
89122	439990	23	3083410	23	12616575	23	148170	26
89149	345557.2	24	2803988	25	7774243	25	191992	22
89113	344550.1	25	2984773	24	5840714	27	239164	20
89118	324433	26	2054510	26	10319187	24	178604	24
89139	164076.9	27	787800	28	6584024	26	107540	27
89074	128558.5	28	1119394	27	2911506	28	87436	28
89156	62251.01	29	402844	29	2154113	29	25700	29
89032	36679.39	30	258975	30	958033.2	30	0	33
89148	13699.5	31	125138	31	212562.7	31	9714	30
89144	3373.206	32	59046	32	124295.6	32	2974	31
89131	2578.58	33	35242	33	83208.71	33	1200	32

Table 4.2.5: Rankings: 1995- Zip-wise Average of, Water Use, Built-up Area, Un-built Area and Pool Area of the LVVWD.

Zip	Water Use in Kilo Gals	Rank (WC)	Built Area in Sq. Ft	Rank (B)	Un-built Area in Sq. Ft	Rank (UB)	Pool Area in Sq. Ft	Rank (P)
89148	684.975	1	6256.9	1	10628.14	3	485.7	1
89139	554.314	2	2661.486	3	22243.32	1	363.3108	2
89146	427.776	3	2229.852	5	12272.4	2	278.0453	3
89120	354.7153	4	2018.209	9	9310.072	5	231.1173	5
89113	348.0304	5	3014.922	2	5899.711	15	241.5798	4
89118	332.7518	6	2107.19	6	10583.78	4	183.1836	11
89117	325.3882	7	2369.068	4	6686.554	9	192.8704	10
89102	301.6669	8	1828.327	16	7434.527	7	205.0222	8
89109	295.7755	9	1940.478	12	6526.575	11	230.9433	6
89121	269.2999	10	1793.019	17	6279.719	13	208.702	7
89103	268.8898	11	1710.891	20	5421.683	23	204.0923	9
89119	252.0392	12	1639.713	22	5556.81	20	148.3238	13
89156	252.0284	13	1630.947	23	8721.104	6	104.0486	19
89149	249.3198	14	2023.079	8	5609.122	18	138.5224	14
89123	248.8431	15	1869.081	15	6826.486	8	130.8311	16
89107	242.9273	16	1603.242	24	5805.592	16	109.1559	17
89108	234.1591	17	1523.319	26	5957.962	14	81.57042	25
89130	232.771	18	1758.342	18	5567.372	19	83.1068	24
89074	229.5688	19	1998.918	10	5199.117	24	156.1357	12
89110	228.0674	20	1493.795	27	6491.36	12	75.13388	26
89128	224.3319	21	1951.967	11	3927.484	31	102.3641	20
89145	220.3677	22	1639.928	21	4656.215	28	100.8328	21
89104	217.556	23	1548.607	25	5661.957	17	92.31642	23
89147	212.0588	24	1711.394	19	4215.092	29	108.577	18
89106	211.1354	25	1454.665	29	6680.75	10	53.11151	29
89129	201.6064	26	2092.379	7	5025.739	26	131.6207	15
89101	191.2858	27	1271.956	33	5111.941	25	43.92482	32
89122	191.0508	28	1338.867	31	5478.322	21	64.33782	27
89032	182.4845	29	1288.433	32	4766.334	27	0	33
89134	175.4855	30	1919.948	13	5477.62	22	63.82942	28
89142	170.2856	31	1464.562	28	3828.51	32	52.98022	30
89144	108.8131	32	1904.71	14	4009.537	30	95.93548	22
89131	103.1432	33	1409.68	30	3328.348	33	48	31

Table 4.2.4 and 4.2.5 lists the total and average water use rankings of all the 33 zip codes of the year 1995 in the LVVWD. This ranking is compared with the individual rank of every zip code for the built-up area, un-built area and pool area of SFR. it is obvious from the table 4.2.4 and the table 4.2.5 that the total annual water use and the average annual water use rankings of the zip codes correlates very closely with the total square feet values of built-up area, un-built area and pool area of SFR. In other words the zip codes that ranks high, medium and low in the total water use are the same zip codes that ranks high, medium and low in the total square feet of built-up area, un-built area and pool area of SFR. For instance, the zip codes 89108, 89117 and 89121 ranks high in terms of total water use, total built-up area, total un-built area and total pool area of SFR. Whereas the zip codes 89142, 89131, 89132 ranks low both in water use and built-up, un-built & pool areas.

The next step is the street wise analysis. In this stage, 6,379 streets from the LVVWD are considered and their total annual water uses are plotted against the total built-up area. This is shown in the figure 4.2.16. Similarly, for the same number of streets, the total annual water uses are plotted against the total un-built area, as shown in the figure 4.2.17. In both the cases the correlation between water use and the built-up area is as high as the correlation between water use and the un-built area. It is also evident through the charts that due to high correlation, the plots could easily fit in a linear equation.

In the year 1995, only 5,384 streets out of 6,379 streets have swimming pools. Hence, the total annual water uses of the streets with swimming pools are plotted against the total square feet area of the pools. Figure 4.2.18 shows that though swimming pool is one of the contributing factors of high water use, SFR with similar size swimming pools varies greatly in their water uses due to the influence of other factors.

In table 4.2.6, through regression analysis, the equations with water use and each one of the factor that affects the water use are derived. At the same time, a combined equation is derived through regression analysis with water use and all the factors that affects the water use. Thus for a given year, the total annual water used in kilo gallons can be determined by plugging in the square feet values of built-up area, un-built area and swimming pool area of SFR.

Fig. 4.2.16: 1995- Street-wise Total Built-up Area of SFR: Las Vegas Valley Water District.

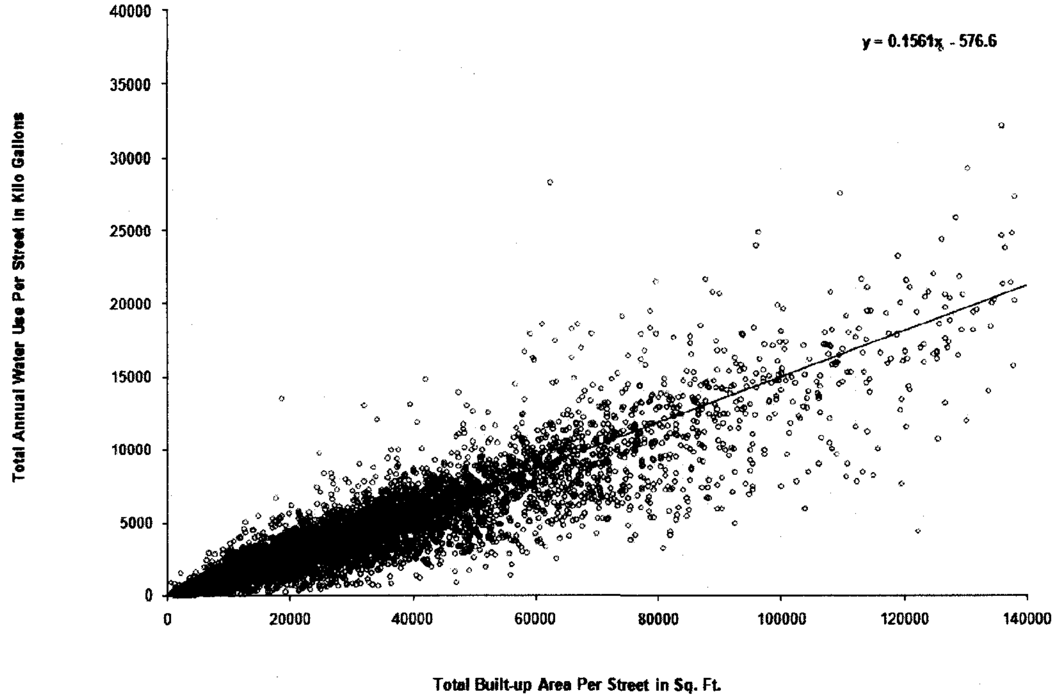


Fig. 4.2.17: 1995- Street-wise Total Un-built Area of SFR: Las Vegas Valley Water District.

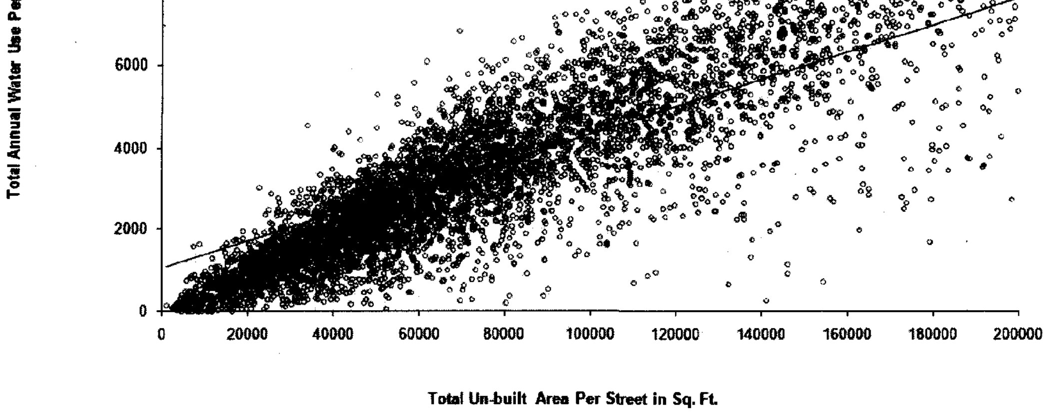


Fig. 4.2.18: 1995- Street-wise Total Un-built Area of SFR: Las Vegas Valley Water District.

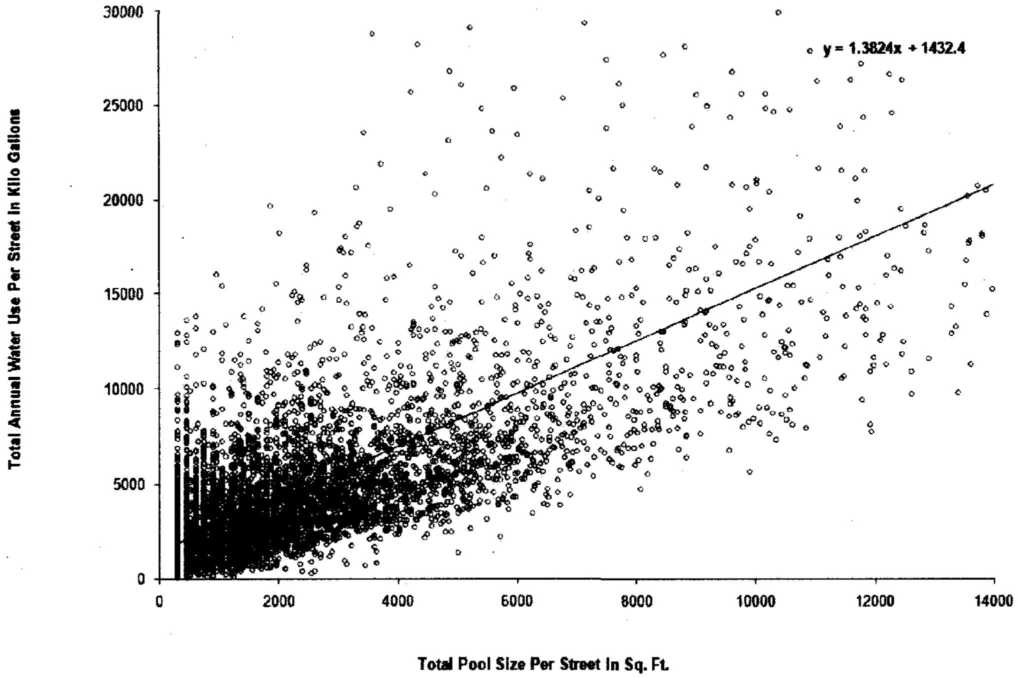


Table 4.2.6: Regression Statistics - With Water Use and Built-up/Un-built/Pool Areas: LVVWD

Year - 1995	Correlation	Linear Equation
B	0.95096	Y = 0.156065B-576.947
UB	0.946679	Y = 0.0329UB+1034.422
P	0.862377	Y = 1.368698P+1558.518
B, UB	0.976694	Y = 0.085616B+0.016807UB-98.0258
B, P	0.962279	Y = 0.121753B+0.405763P-387.532
UB, P	0.959058	Y = 0.025324UB+0.423193P+866.4949
B, UB, P	0.987027	Y = 0.075748B+0.014728UB+0.219717P-54.6807

Where, Y = Total water consumption of SFR in a street (Kilo Gals), B = Total built-up area of SFR in a street (Square Feet), UB = Total Un-built Area of SFR in a street (Square Feet) and P = Total pool area of SFR in a street (Square Feet).

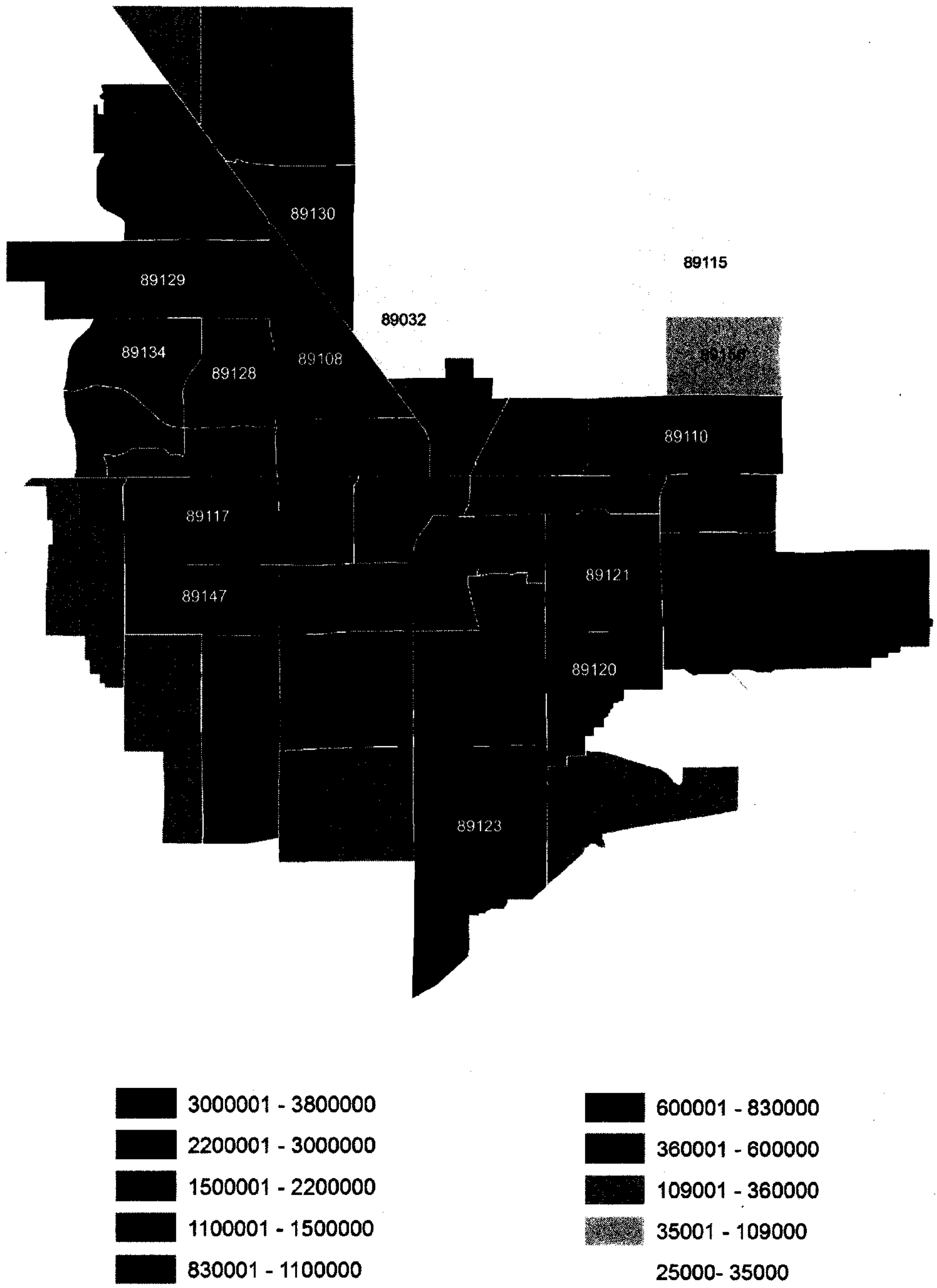
Historic Analysis – 2000

For the year 2000, both the zip level and the street level analysis includes all the 36 zip codes of the LVVWD for which the water use data and the built-up, un-built & pool data obtained from the SNWA and the Clark County Assessor office respectively. This analysis involves comparing the total and average water use derived from the water use data with the total built-up area, un-built area and pool area derived from the residential data.

For the uniformity and simplicity of the zip code maps and the street level charts, the water use is colored blue-green-yellow, the density is colored brown, the built-up area is colored maroon, the un-built area is colored green and the swimming pool area is colored blue throughout this section.

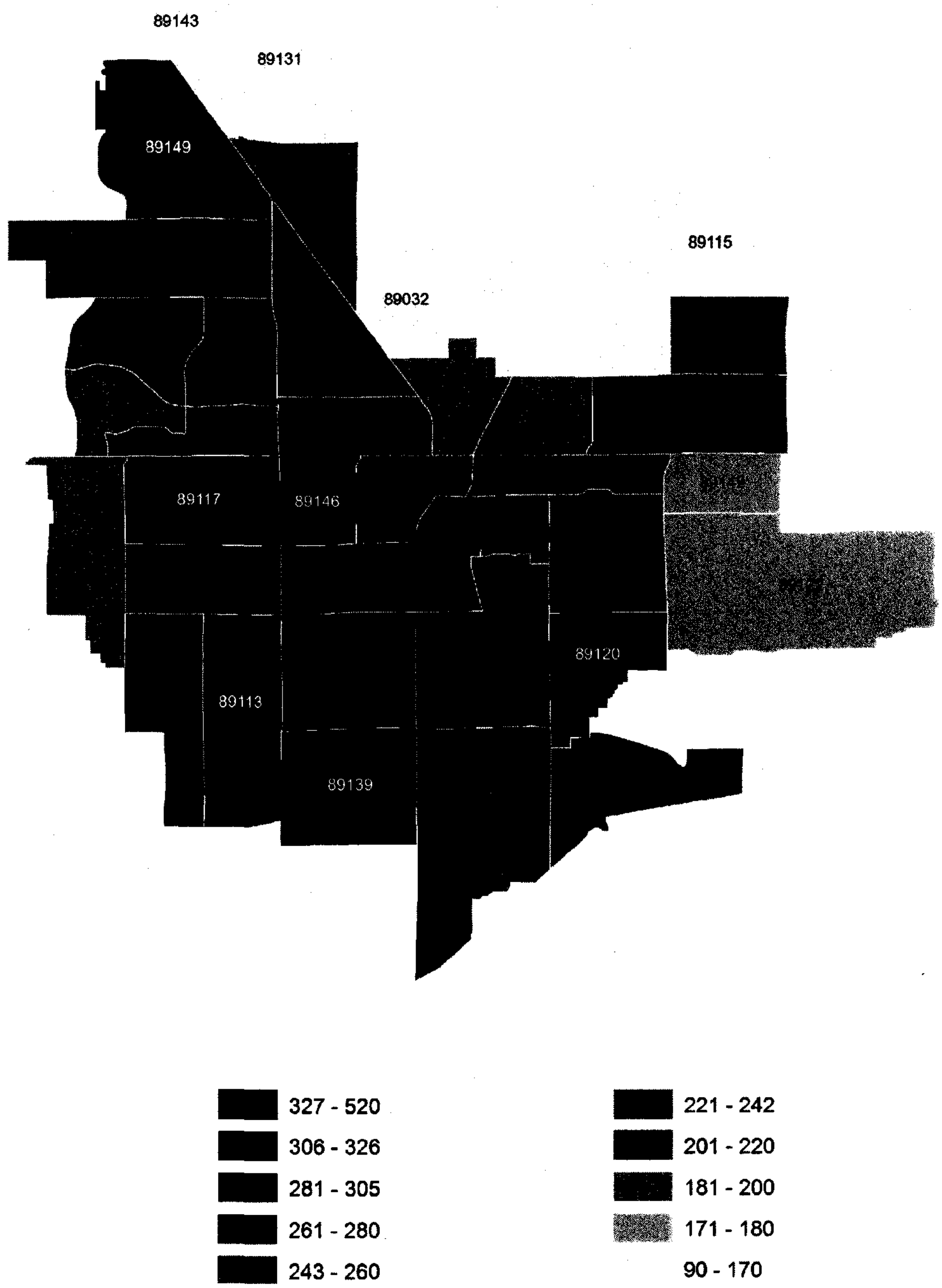
Besides finding the cause for high and low water use and finding the position of each zip with respect to the other zips, the goal of this analyzing is to find the correlation between water use and each one of the factor considered in this study that affects the water use, so that an equation that fits in all the factors of study and water use could be derived.

Fig. 4.2.19: 2000- Total Water Use in Kilo Gallons: Las Vegas Valley Water District.



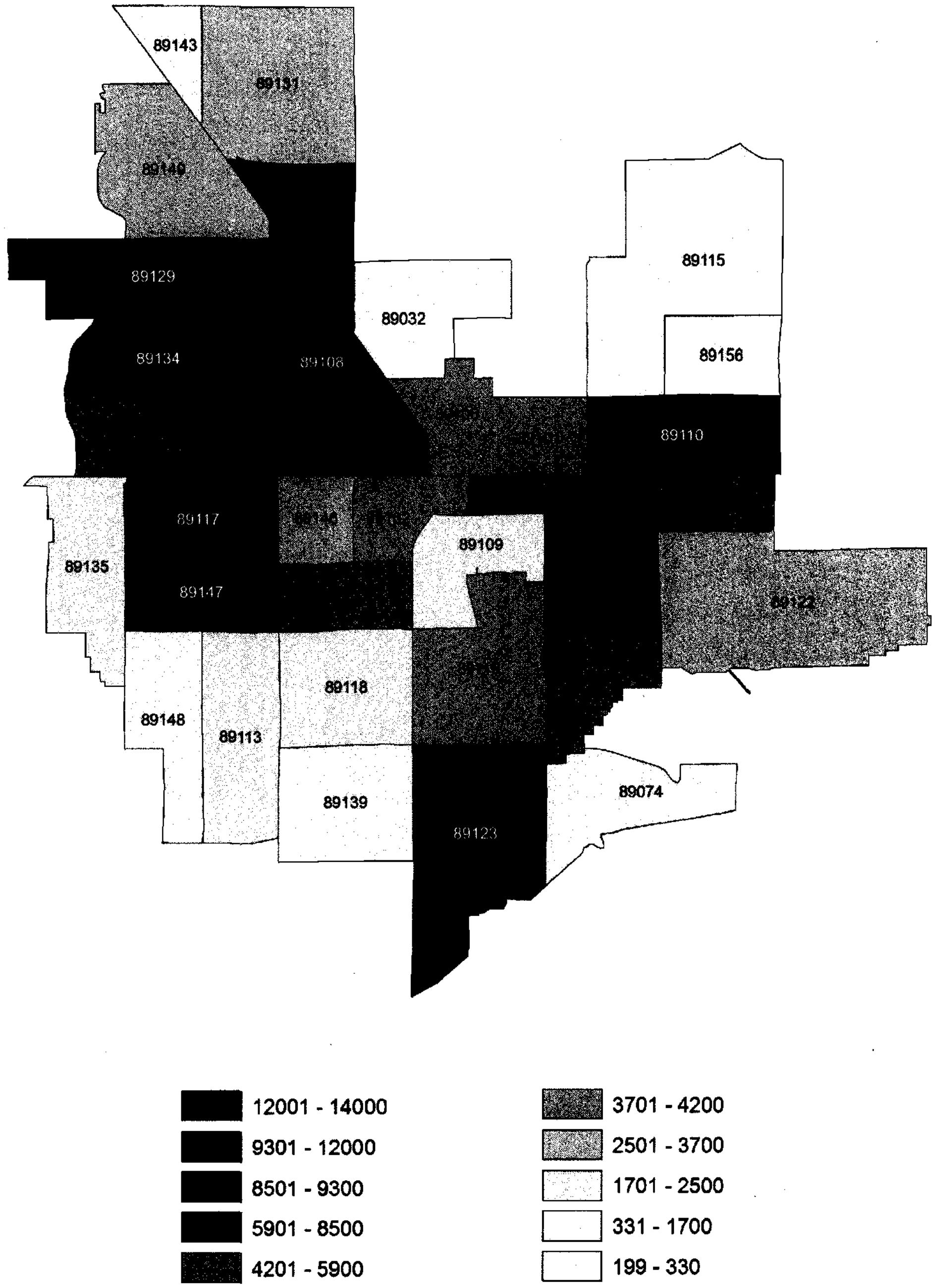
Zip codes 89108, 89117, 89110, 89121, 89123 and 89147 are the highest consumers of total annual water in the LVVWD. Whereas, the zip codes 89032 and 89115 consumes less than 1.16% of the total water consumed by the highest consumers.

Fig. 4.2.20: 2000- Average Water Use in Kilo Gallons: Las Vegas Valley Water District.



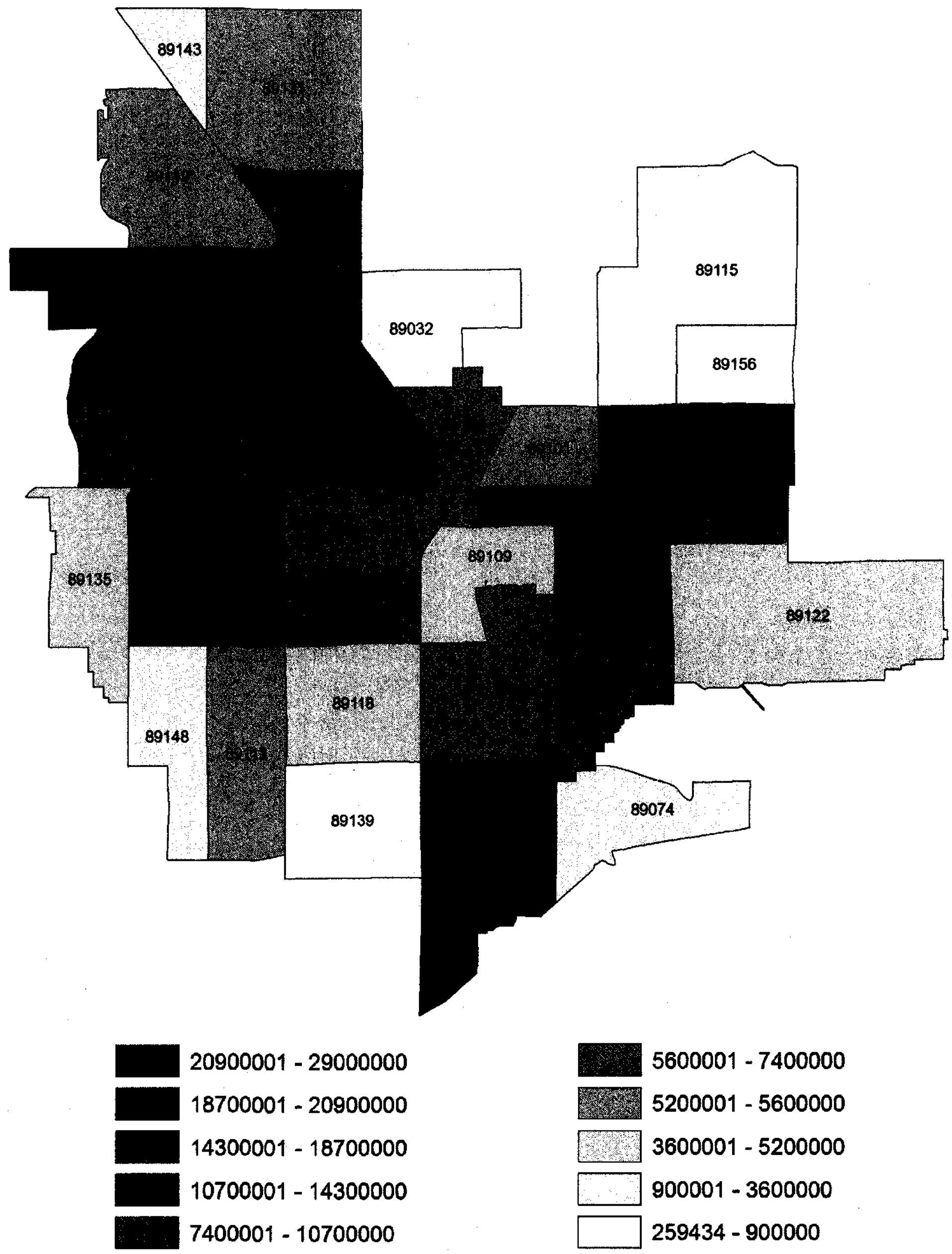
Zip codes 89146, 89120, 89139, 89117, 89102, 89113, 89109 and 89148 are the highest consumers of average annual water in the LVVWD. Whereas, the zip codes 89143, 89131, 89032, 89115, 89142 and 89122 consumes less than 45% of the total water consumed by the highest consumers.

Fig. 4.2.21: 2000- Total Number of Single Family Residence: Las Vegas Valley Water District.



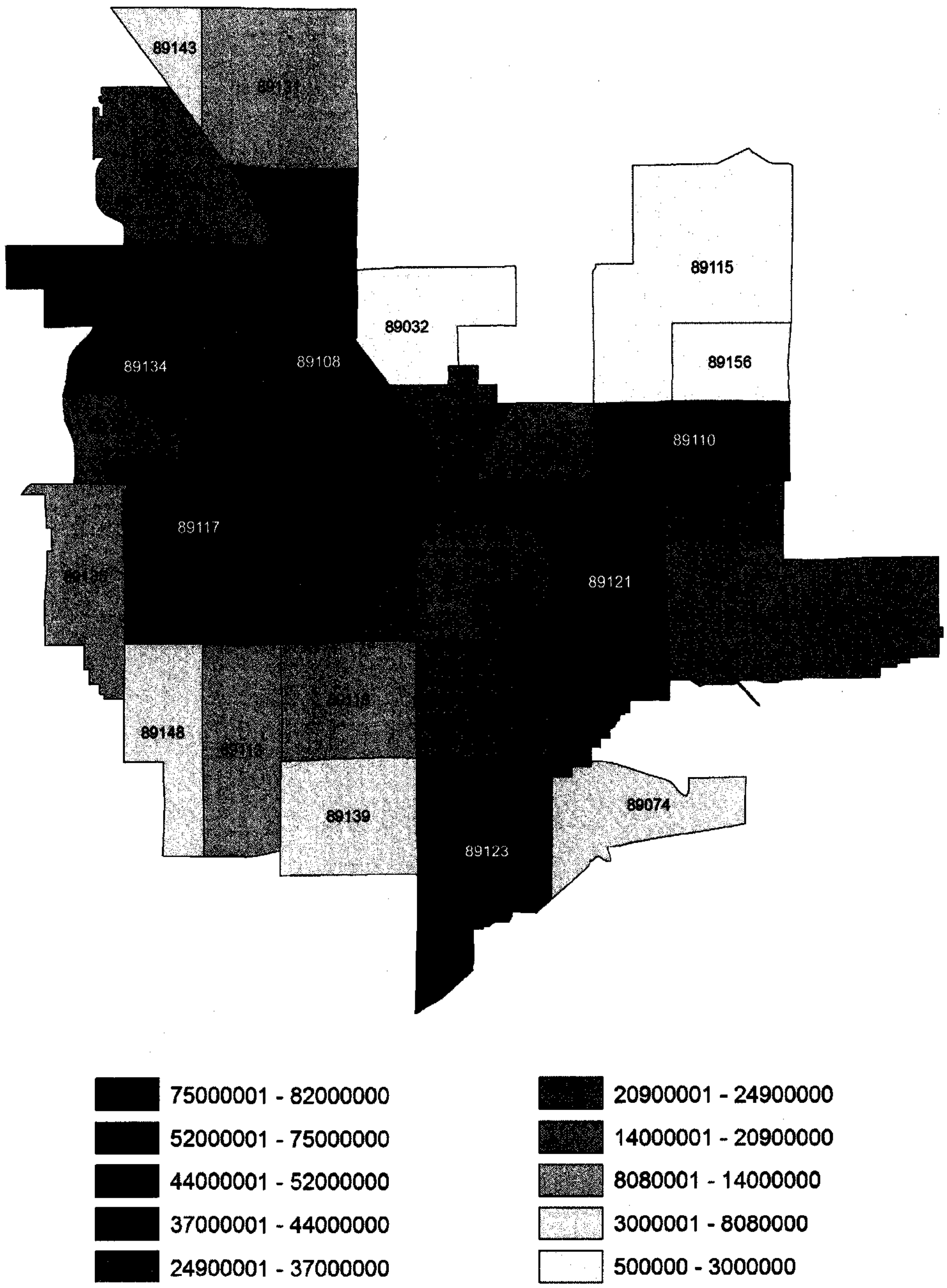
When the fig. 4.2.19 is overlapped with the above figure, it is obvious that the zip codes where the total number of single family residence is high are the highest consumers of total annual water. Also, the zip codes with less number of SFR are the lowest consumers. In other words, the denser the SFR in a zip code, the higher the total water use.

Fig. 4.2.22: 2000- Total Built-up Area in Square Feet: Las Vegas Valley Water District.



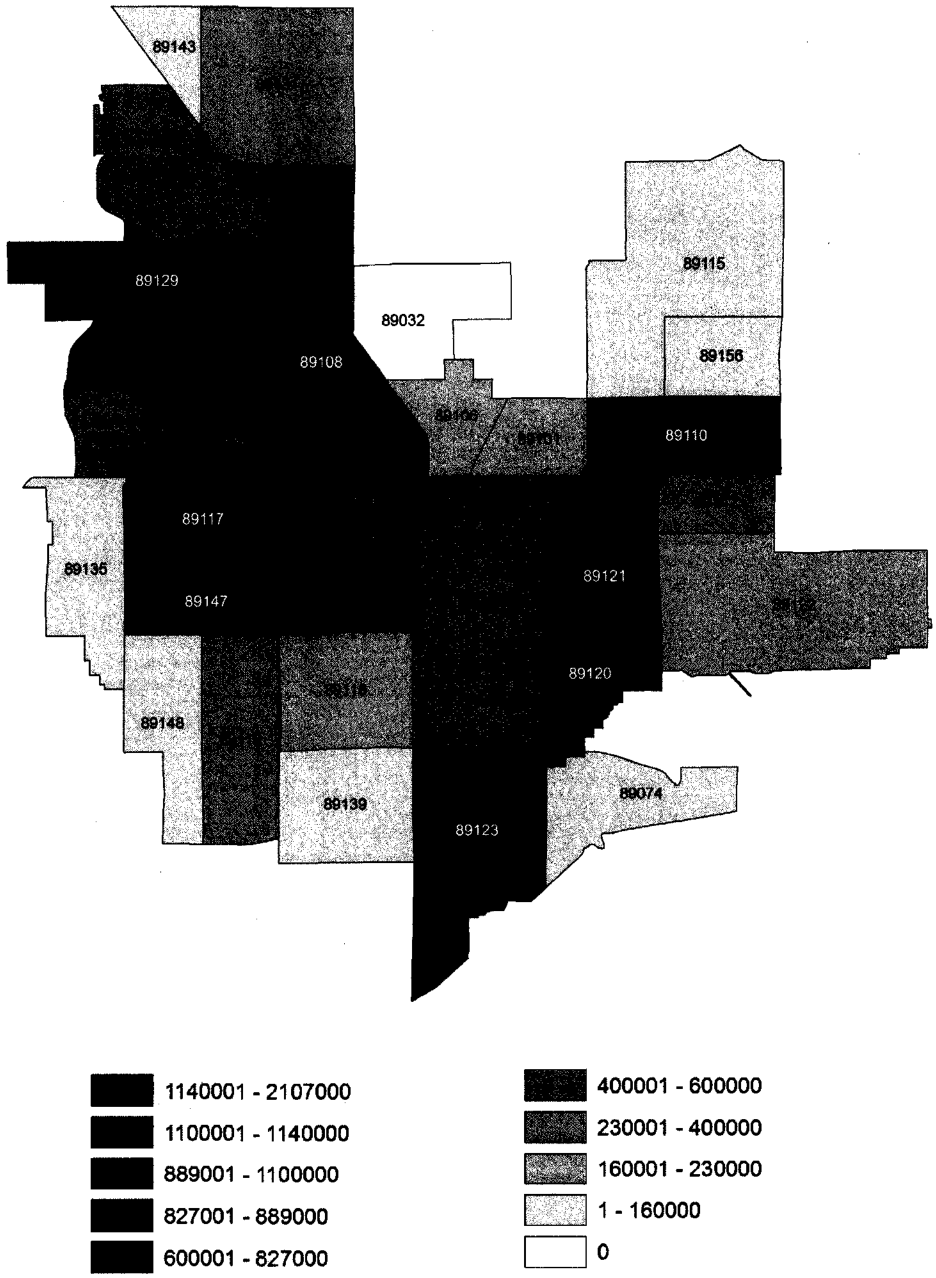
When the fig. 4.2.19 is overlapped with the above figure, it is evident that the zip codes where the total built-up area is high are the highest consumers of total annual water. Also, the zip codes with less total built-up area are the lowest consumers. In other words, the higher the built-up area, the higher the total water use and vice versa. This proves that the size of the built-up area has strong correlation to the total quantity of water used in that region.

Fig. 4.2.23: 2000- Total Un-built Area in Square Feet: Las Vegas Valley Water District.



When the fig. 4.2.19 is overlapped with the above figure, it is evident that the zip codes where the total un-built area is high are the highest consumers of total annual water. Also, the zip codes with iess total built-up area are the lowest consumers. In other words, the higher the un-buiit area, the higher the total water use and vice versa. This proves that the size of the un-built area has strong correlation to the total quantity of water used in that region.

Fig. 4.2.24: 2000- Totai Pool Area: Las Vegas Valley Water District.



When the fig. 4.2.19 is overlapped with the above figure, it is evident that the zip codes where the total pool area is high are the highest consumers of total annual water. Also, the zip codes with less total pool area are the lowest consumers. In other words, the higher the pool area, the higher the total water use and vice versa. This proves that the total area of the pool has strong correlation to the total quantity of water used in that region.

Table 4.2.7: Rankings: 2000- Zip-wise Totals of, Water Use, Built-up Area, Un-built Area and Pool Area of the LVVWD.

Zip	Water Use in Kilo Gals	Rank (WC)	Built Area in Sq. Ft	Rank (B)	Un-built Area in Sq. Ft	Rank (UB)	Pool Area in Sq. Ft	Rank (P)
89117	3720464	1	28982343	1	76024510	3	2106598	1
89108	3072665	2	20932417	4	81401565	1	1106596	6
89123	2816623	3	26486410	2	74990545	4	1542516	3
89110	2511804	4	18753240	7	76693466	2	942512	9
89121	2323955	5	16576461	9	57890414	5	1908548	2
89147	2259128	6	20061114	5	44696124	9	1102986	7
89134	2196833	7	21270607	3	57020763	6	827218	13
89107	2031164	8	14283920	10	51607508	7	965660	8
89129	1978274	9	19679108	6	43701873	10	1142500	4
89128	1975426	10	16729600	8	33375599	14	889300	10
89120	1636601	11	9977899	14	47290839	8	1118270	5
89130	1511594	12	13045961	11	37245383	13	606072	17
89104	1458072	13	10944663	12	39546342	11	634858	16
89145	1357809	14	10688360	13	29135242	15	649460	15
89146	1325217	15	7183439	19	39187921	12	885118	11
89102	1141721	16	7255507	18	29133650	16	799184	14
89103	1118330	17	7433748	17	23489464	19	882326	12
89142	1046830	18	9418209	16	24844438	17	356964	22
89119	900123.4	19	6167470	20	20921346	20	555902	18
89144	831247.3	20	9464311	15	18625191	23	513850	19
89101	756789.7	21	5202178	25	20897470	21	180710	27
89106	735329.7	22	5622229	21	24333494	18	176210	28
89149	663873.2	23	5512959	23	16071496	24	400374	21
89113	605472.6	24	5247567	24	11449017	28	336480	23
89122	603872.6	25	4940928	26	18979499	22	215736	26
89109	586167.3	26	4205604	27	14012655	25	495778	20
89131	458267.3	27	5525089	22	13162415	27	255744	24
89118	434991.3	28	3646730	29	13710649	26	224484	25
89135	337547.4	29	3792665	28	8089807	29	159290	29
89148	181889.4	30	2114162	31	3424017	32	114912	32
89139	169755.4	31	890414	33	7581570	30	118352	31
89143	159853.5	32	2649670	30	5264348	31	123140	30
89074	150896.3	33	1183663	32	3033583	33	90436	33
89156	64457.17	34	463749	34	2354310	34	28408	34
89032	32191.56	35	259434	36	957411.2	35	0	36
89115	27094.55	36	269533	35	514128	36	1050	35

Table 4.2.8: Rankings: 2000- Zip-wise Averages of, Water Use, Built-up Area, Un-built Area and Pool Area of the LVVWD.

Zip	Water Use in Kilo Gals	Rank (WC)	Built Area in Sq. Ft	Rank (B)	Un-built Area in Sq. Ft	Rank (UB)	Pool Area in Sq. Ft	Rank (P)
89139	506.7325	1	2657.95	2	22631.55	1	353.2896	1
89146	414.6485	2	2247.63	5	12261.55	2	276.9456	2
89120	337.4436	3	2057.3	11	9750.688	3	230.5711	3
89117	307.4002	4	2394.64	4	6281.46	11	174.0559	8
89113	288.3203	5	2498.84	3	5451.913	20	160.2286	10
89102	288.0225	6	1830.35	20	7349.559	6	201.6105	7
89109	272.5092	7	1955.19	17	6514.484	8	230.4872	4
89148	262.8459	8	3055.15	1	4948.001	25	166.0578	9
89149	262.5042	9	2179.9	7	6354.882	9	158.3132	11
89074	259.272	10	2033.79	12	5212.342	22	155.3883	12
89103	257.7985	11	1713.63	24	5414.814	21	203.3947	6
89121	252.8512	12	1803.55	23	6298.598	10	207.654	5
89119	239.5219	13	1641.16	25	5567.149	18	147.925	13
89128	234.7784	14	1988.31	13	3966.675	34	105.6929	20
89118	234.2441	15	1963.77	15	7383.225	5	120.8853	15
89145	230.098	16	1811.28	21	4937.34	26	110.0593	18
89107	228.3746	17	1606.02	29	5802.508	14	108.5743	19
89156	225.3747	18	1621.5	27	8231.852	4	99.32867	22
89108	225.1366	19	1533.74	31	5964.359	13	81.08118	30
89110	219.161	20	1636.27	26	6691.691	7	82.23645	28
89134	215.5025	21	2086.58	10	5593.561	16	81.14754	29
89147	214.4199	22	1904.05	18	4242.229	32	104.6874	21
89129	212.4435	23	2113.31	9	4693.071	28	122.6912	14
89130	209.3911	24	1807.17	22	5159.355	23	83.95512	27
89123	208.2839	25	1958.62	16	5545.407	19	114.0661	17
89104	207.2597	26	1555.74	30	5621.371	15	90.24279	24
89144	194.8084	27	2218.02	6	4364.938	31	120.4242	16
89135	190.4895	28	2140.33	8	4565.354	29	89.89278	25
89101	185.0342	29	1271.93	36	5109.406	24	44.18337	34
89106	184.6634	30	1411.91	33	6110.872	12	44.25163	33
89142	178.6705	31	1607.48	28	4240.389	33	60.92576	32
89122	177.6618	32	1453.64	32	5583.848	17	63.47043	31
89032	160.157	33	1290.72	35	4763.24	27	0	36
89131	155.187	34	1871.01	19	4457.303	30	86.60481	26
89115	136.1535	35	1354.44	34	2583.558	36	5.276382	35
89143	118.6737	36	1967.09	14	3908.202	35	91.41797	23

Table 4.2.7 and 4.2.8 lists the total and average water use rankings of all the 36 zip codes of the year 2000 in the LVVWD. This ranking is compared with the individual rank of every zip code for the built-up area, un-built area and pool area of SFR. It is obvious from the table 4.2.7 and the table 4.2.8 that the total annual water use and the average annual water use rankings of the zip codes correlates very closely with the total square feet values of built-up area, un-built area and pool area of SFR. In other words the zip codes that rank high, medium and low in the total water use are the same zip codes that rank high, medium and low in the total square feet of built-up area, un-built area and pool area of SFR. For instance, the zip codes 89108, 89123, 89117, 89110 and 89121 rank high in terms of total water use, total built-up area, total un-built area and total pool area of SFR. Whereas the zip codes 89142, 89131, 89132 rank low both in water use and built-up, un-built & pool areas.

The next step is the street wise analysis. In this stage, 9,185 streets from the LVVWD are considered and their total annual water uses are plotted against the total built-up area. This is shown in the figure 4.2.25. Similarly, for the same number of streets, the total annual water uses are plotted against the total un-built area, as shown in the figure 4.2.26. In both the cases the correlation between water use and the built-up area is as high as the correlation between water use and the un-built area. It is also evident through the charts that due to high correlation, the plots could easily fit in a linear equation.

In the year 2000, only 7,813 streets out of 9,185 streets have swimming pools. Hence, the total annual water uses of the streets with swimming pools are plotted against the total square feet area of the pools. Figure 4.2.27 shows that though swimming pool is one of the contributing factors of high water use, SFR with similar size swimming pools varies greatly in their water uses due to the influence of other factors.

In table 4.2.9, through regression analysis, the equations with water use and each one of the factor that affects the water use are derived. At the same time, a combined equation is derived through regression analysis with water use and all the factors that affects the water use. Thus for a given year, the total annual water used in kilo gallons can be determined by plugging in the square feet values of built-up area, un-built area and swimming pool area of SFR.

Fig. 4.2.25: 2000- Street-wise Total Built-up Area of SFR: Las Vegas Valley Water District.

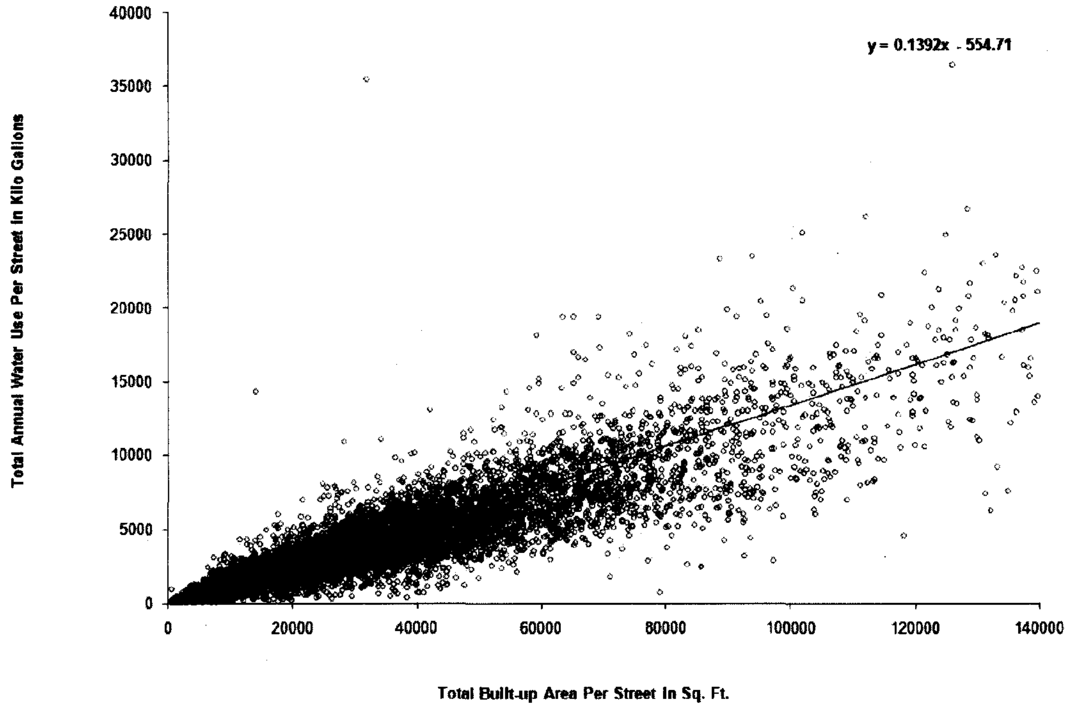


Fig. 4.2.26: 2000- Street-wise Total Un-built Area of SFR: Las Vegas Valley Water District.

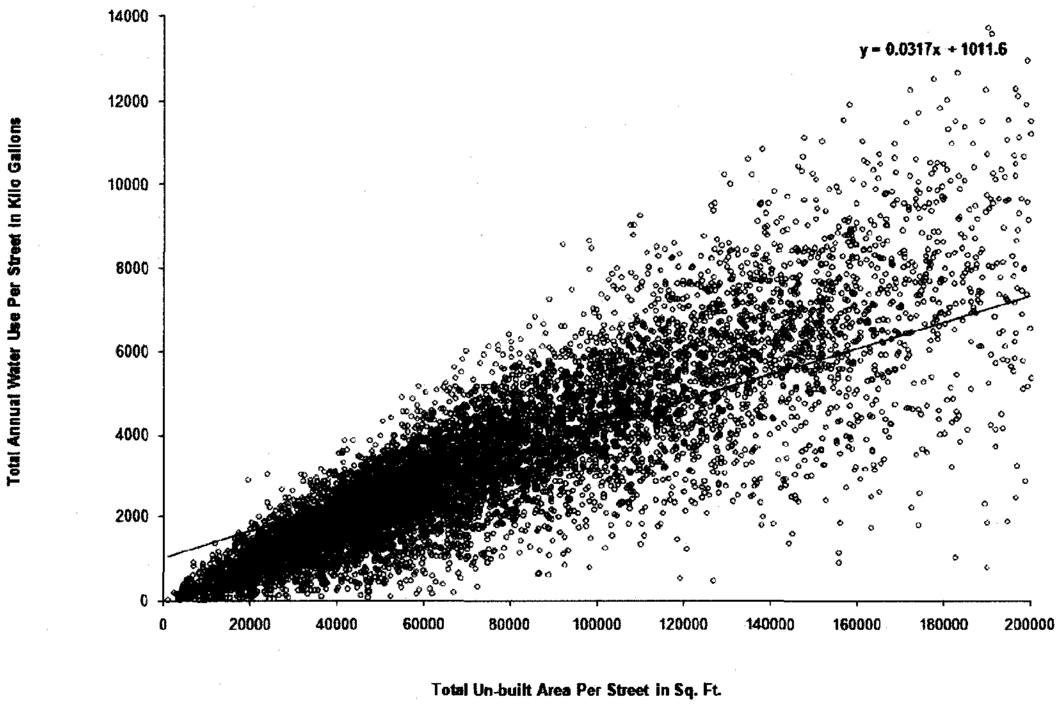


Fig. 4.2.27: 2000- Street-wise Total Pool Area of SFR: Las Vegas Valley Water District.

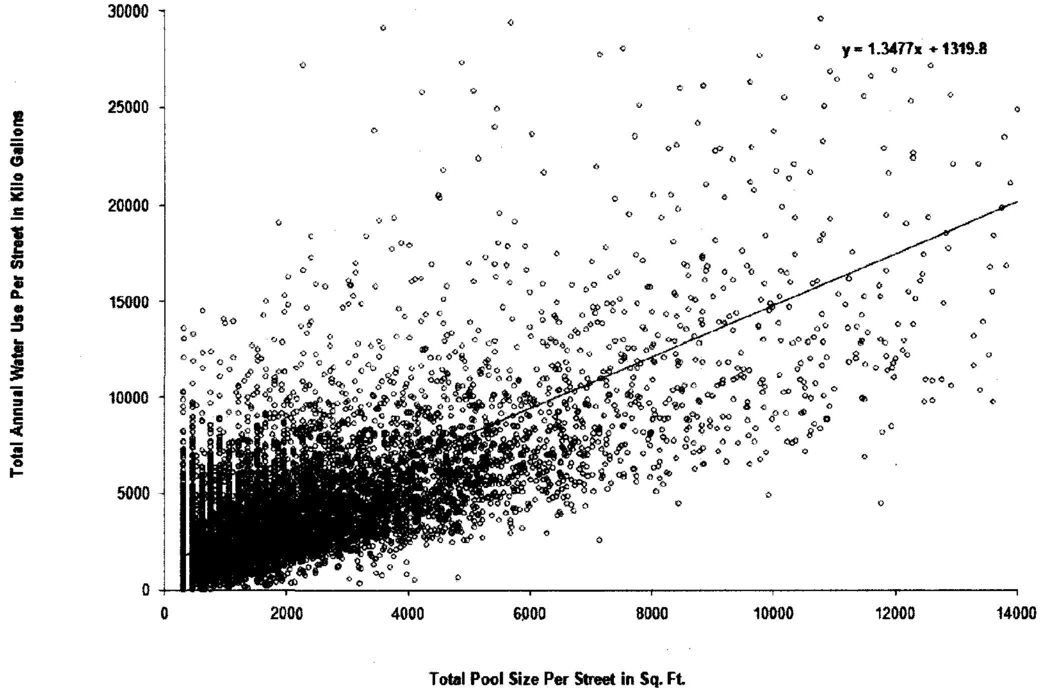


Table 4.2.9: Regression Statistics - With Water Use and Built-up/Un-built/Pool Areas: LVVWD

Year - 2000	Correlation	Linear Equation
B	0.933105	Y = 0.139183B-554.895
UB	0.938121	Y = 0.031655UB+1011.803
P	0.862595	Y = 1.333091P+1442.06
B, UB	0.971035	Y = 0.072535B+0.017594UB-88.6117
B, P	0.951722	Y = 0.101209B+0.48847P-315.109
UB, P	0.953849	Y = 0.023552UB+0.456906P+839.1281
B, UB, P	0.974945	Y=0.062674B+0.015105UB+0.248101P-32.7662

Where, Y = Total water consumption of SFR in a street (Kilo Gals), B = Total built-up area of SFR in a street (Square Feet), UB = Total Un-built Area of SFR in a street (Square Feet) and P = Total pool area of SFR in a street (Square Feet).

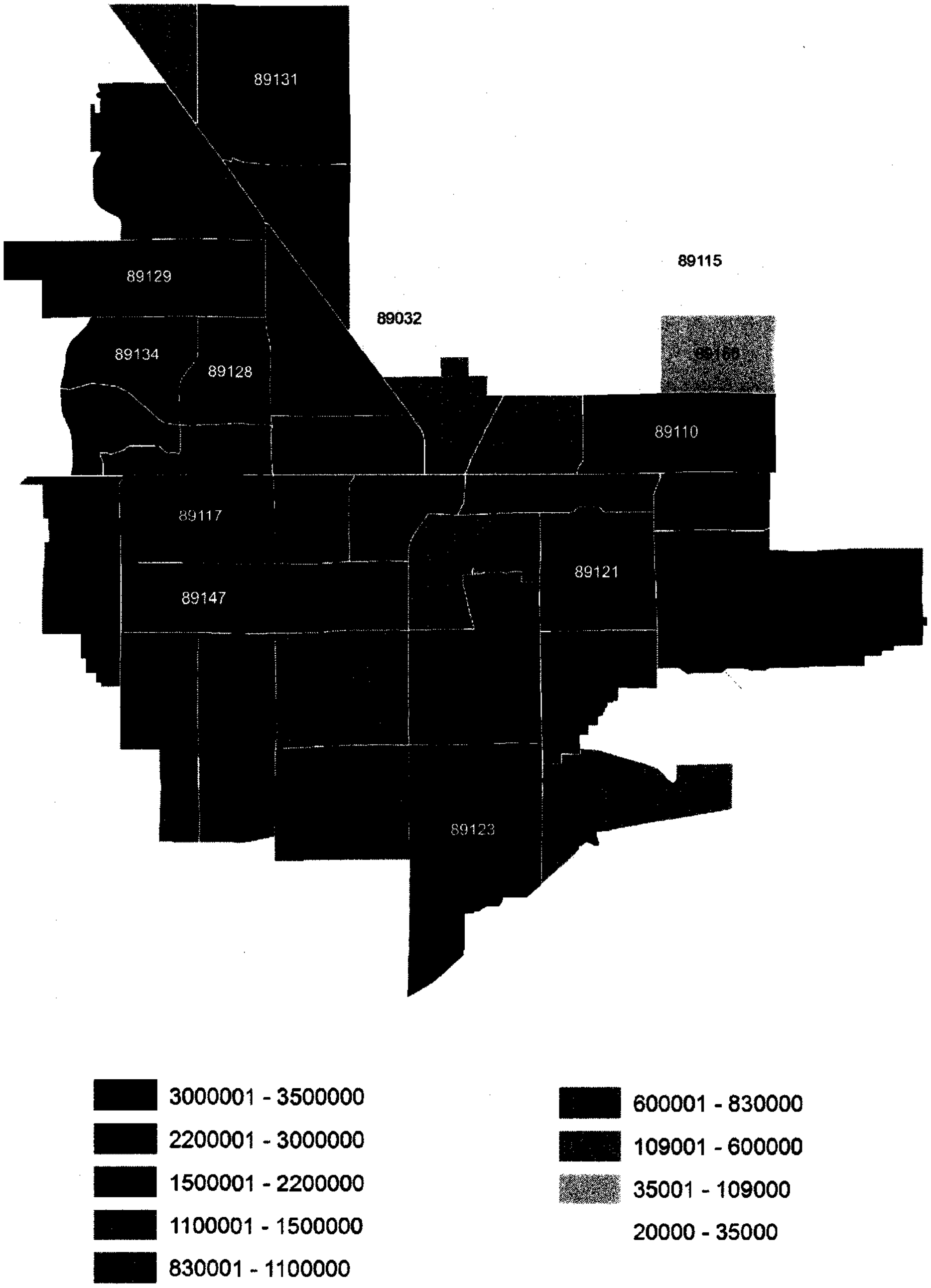
Historic Analysis – 2005

For the year 2005, both the zip level and the street level analysis includes all the 36 zip codes of the LVVWD for which the water use data and the built-up, un-built & pool data obtained from the SNWA and the Clark County Assessor office respectively. This analysis involves comparing the total and average water use derived from the water use data with the total built-up area, un-built area and pool area derived from the residential data.

For the uniformity and simplicity of the zip code maps and the street level charts, the water use is colored blue-green-yellow, the density is colored brown, the built-up area is colored maroon, the un-built area is colored green and the swimming pool area is colored blue throughout this section.

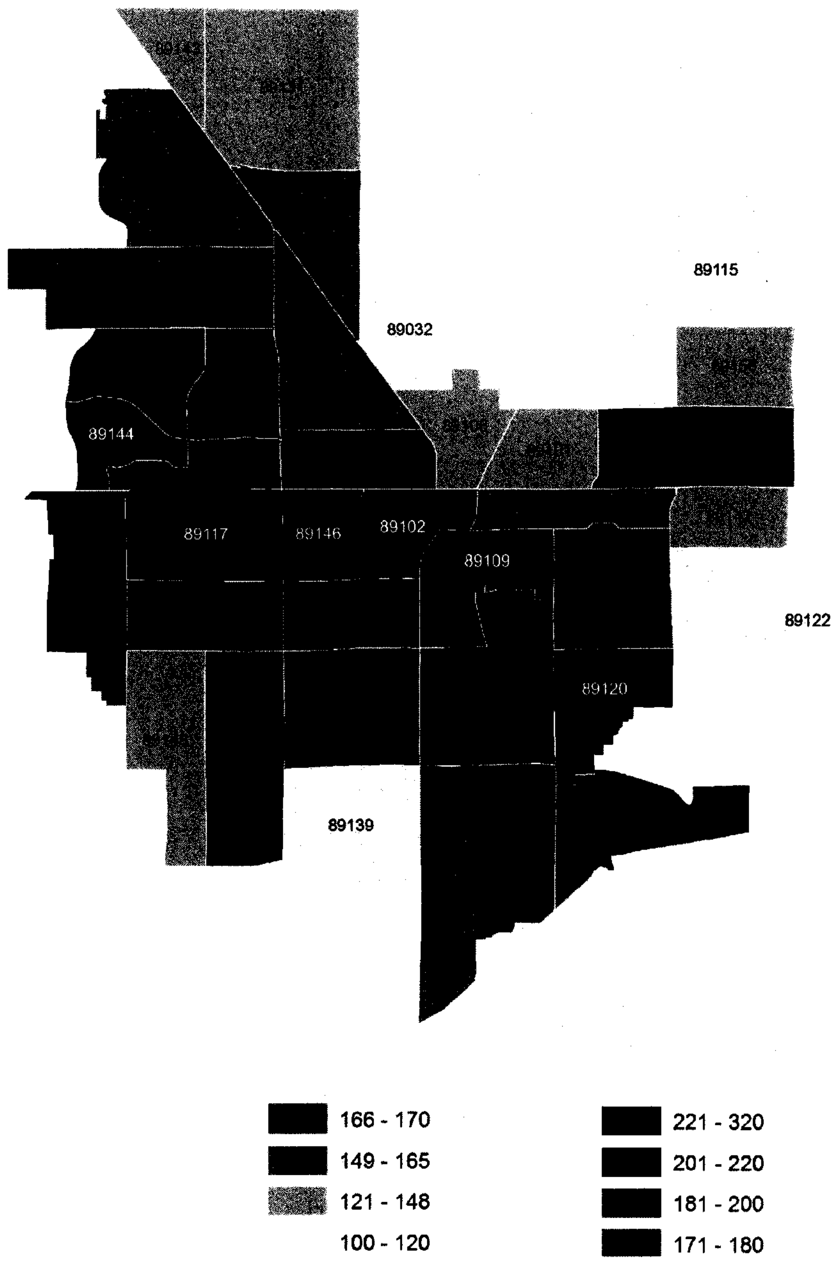
Besides finding the cause for high and low water use and finding the position of each zip with respect to the other zips, the goal of this analyzing is to find the correlation between water use and each one of the factor considered in this study that affects the water use, so that an equation that fits in all the factors of study and water use could be derived.

Fig. 4.2.28: 2005- Total Water Use in Kilo Gallons: Las Vegas Valley Water District.



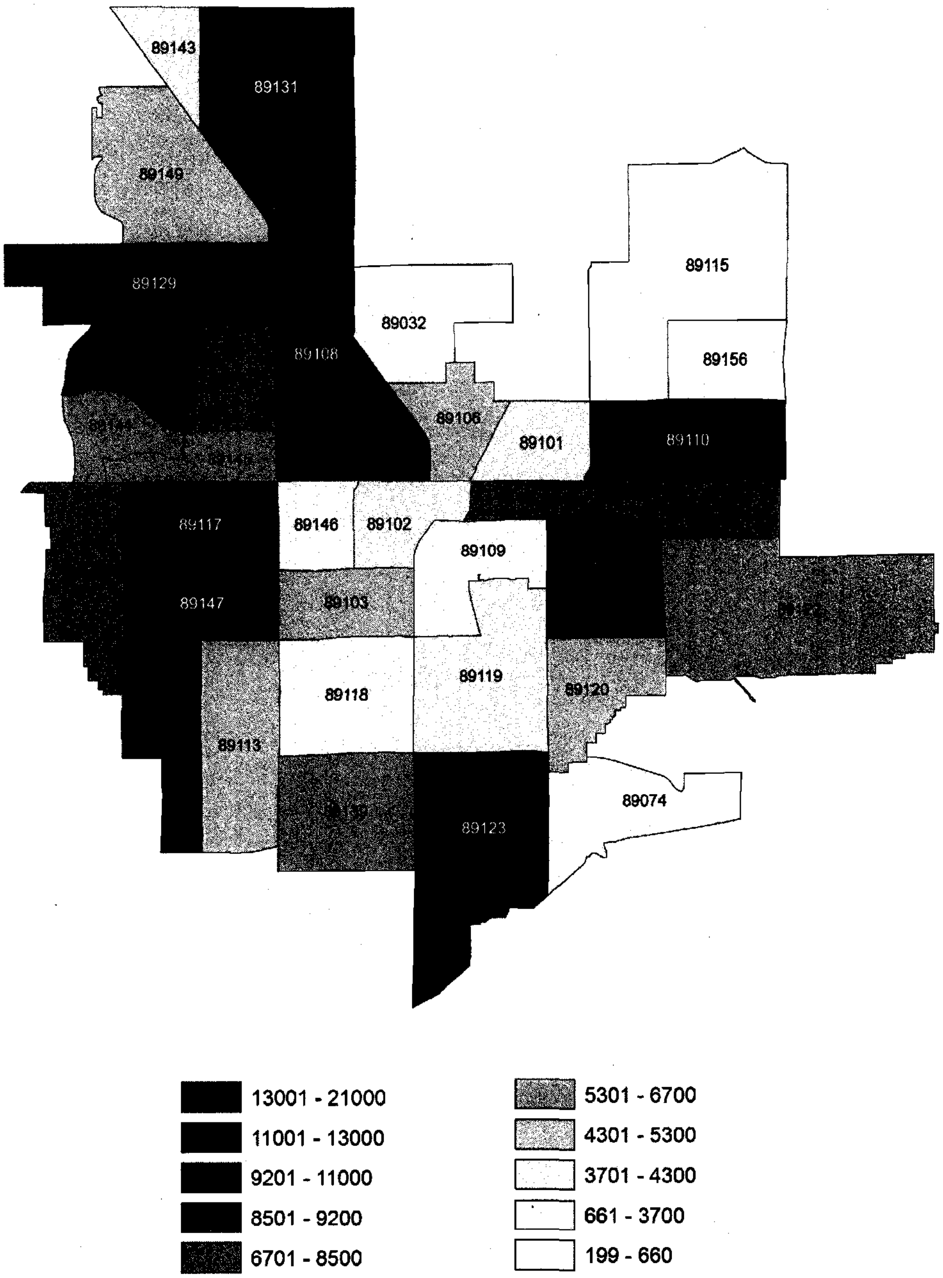
Zip codes 89108, 89110, 89117, and 89123 are the highest consumers of total annual water in the LVVWD. Whereas, the zip codes 89032, 89115 and 89156 consumes less than 1.16% of the total water consumed by the highest consumers.

Fig. 4.2.29: 2005- Average Water Use in Kilo Gallons: Las Vegas Valley Water District.



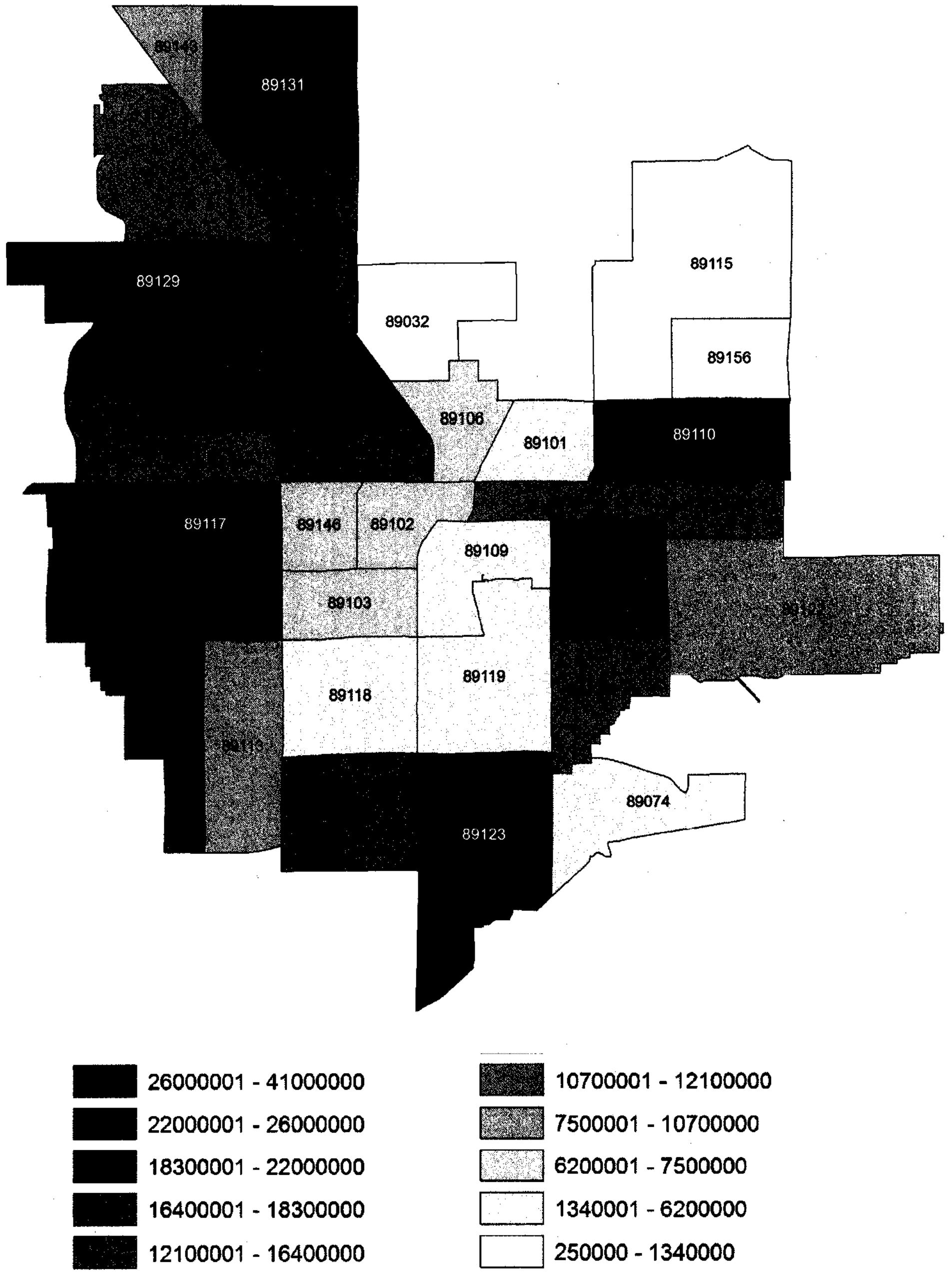
Zip codes 89146, 89117, 89120, 89144, 89102 and 89109 are the highest consumers of average annual water in the LVVWD. Whereas, the zip codes 89032, 89134 and 89139 consumes less than 50% of the total water consumed by the highest consumers.

Fig. 4.2.30: 2005- Total Number of Single Family Residence: Las Vegas Valley Water District.



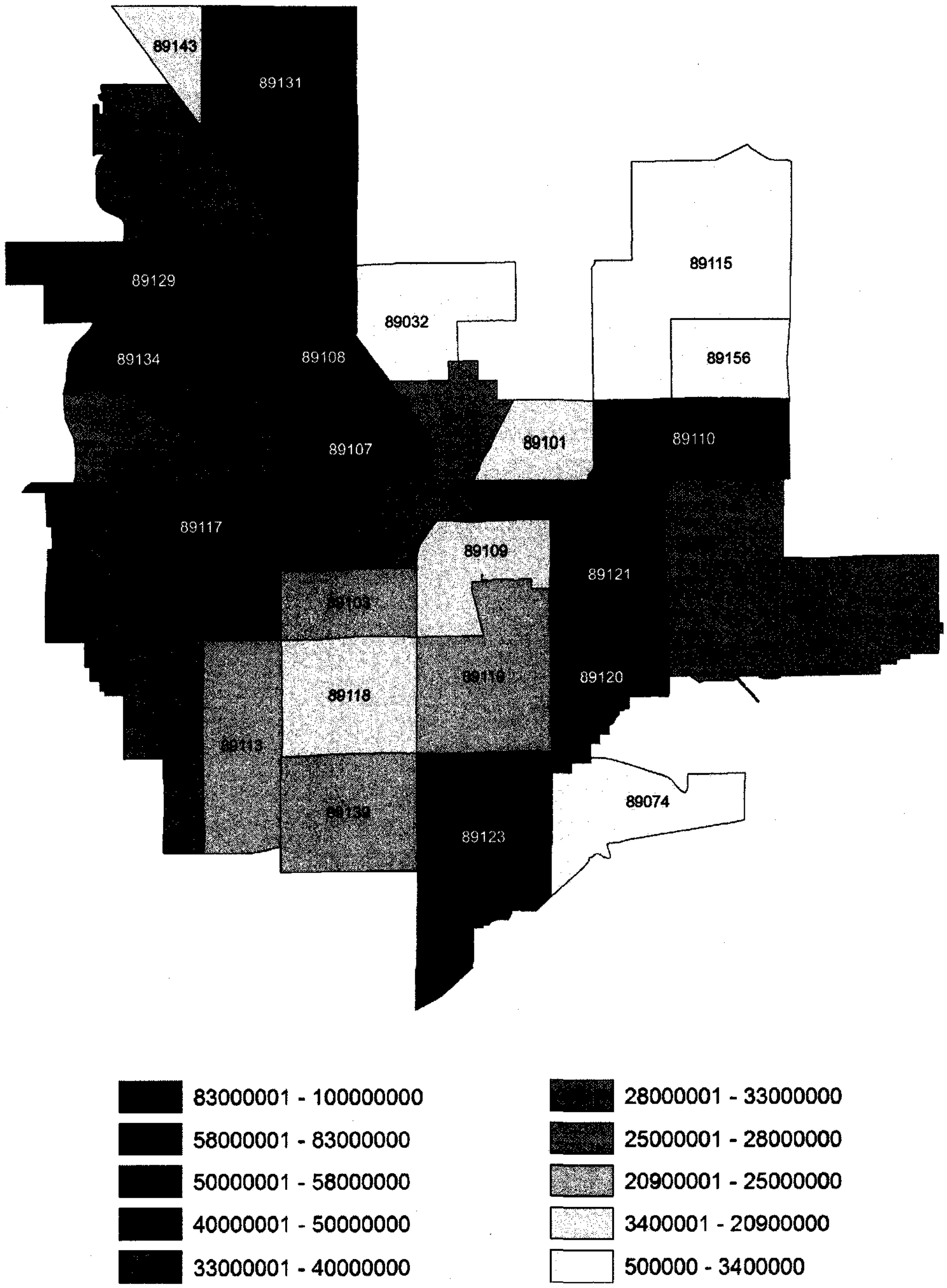
When the fig. 4.2.28 is overlapped with the above figure, it is obvious that the zip codes where the total number of single family residence is high are the highest consumers of total annual water. Also, the zip codes with less number of SFR are the lowest consumers. In other words, the denser the SFR in a zip code, the higher the total water use.

Fig. 4.2.31: 2005- Total Built-up Area: Las Vegas Valley Water District.



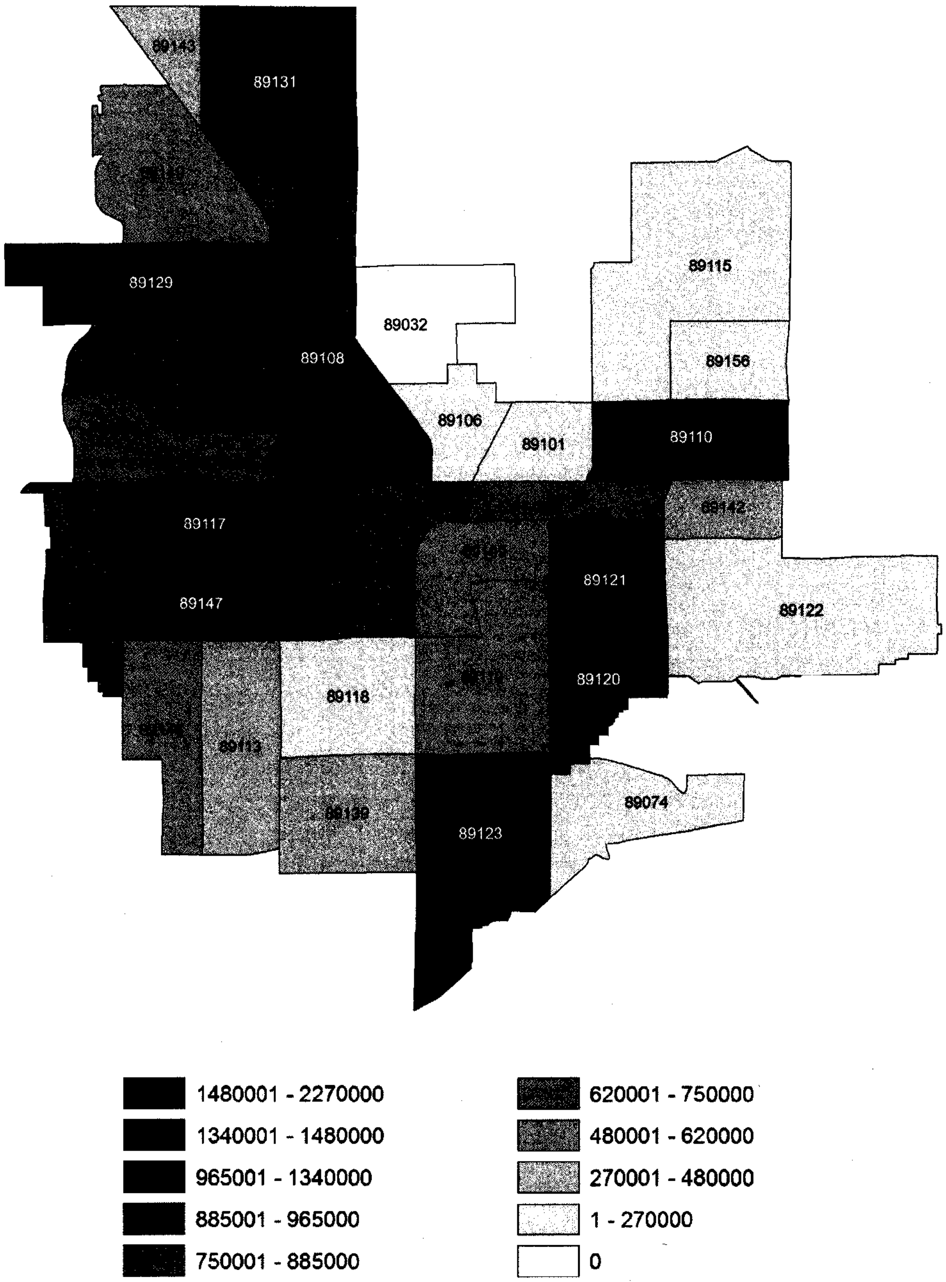
When the fig. 4.2.28 is overlapped with the above figure, it is evident that the zip codes where the total built-up area is high are the highest consumers of total annual water. Also, the zip codes with less total built-up area are the lowest consumers. In other words, the higher the built-up area, the higher the total water use and vice versa. This proves that the size of the built-up area has strong correlation to the total quantity of water used in that region.

Fig. 4.2.32: 2005- Total Un-built Area in Square Feet: Las Vegas Valley Water District.



When the fig. 4.2.28 is overlapped with the above figure, it is evident that the zip codes where the total un-built area is high are the highest consumers of total annual water. Also, the zip codes with less total built-up area are the lowest consumers. In other words, the higher the un-built area, the higher the total water use and vice versa. This proves that the size of the un-built area has strong correlation to the total quantity of water used in that region.

Fig. 4.2.33: 2005- Total Pool Area: Las Vegas Valley Water District.



When the fig. 4.2.28 is overlapped with the above figure, it is evident that the zip codes where the total pool area is high are the highest consumers of total annual water. Also, the zip codes with less total pool area are the lowest consumers. In other words, the higher the pool area, the higher the total water use and vice versa. This proves that the total area of the pool has strong correlation to the total quantity of water used in that region.

Table 4.2.10: Rankings: 2005 Zip-wise Totals of, Water Use, Built-up Area, Un-built Area and Pool Area of the LVVWD.

Zip	Water Use in Kilo Gals	Rank (WC)	Built Area in Sq. Ft	Rank (B)	Un-built Area in Sq. Ft	Rank (UB)	Pool Area in Sq. Ft	Rank (P)
89117	3232731	1	31901902	2	82891195	3	2260788	1
89123	3215785	2	40111210	1	99351312	1	1936044	2
89108	2289237	3	21394740	8	82833322	4	1107260	8
89110	2219970	4	22746073	5	88327627	2	1076956	9
89129	2182682	5	28444699	3	61478332	6	1476542	4
89134	1966130	6	21618327	7	58021618	8	858240	14
89147	1944142	7	22018315	6	47903107	11	1138268	7
89121	1711732	8	16677555	12	58041690	7	1913428	3
89131	1581552	9	25949420	4	63746322	5	1281652	5
89128	1522573	10	16746095	11	33395810	16	890350	11
89107	1488832	11	14231411	14	51467764	9	964844	10
89135	1473828	12	18307876	10	38446961	15	791070	16
89130	1395879	13	16370107	13	45514444	12	750520	17
89120	1261057	14	10701388	21	49934115	10	1141122	6
89144	1232982	15	13533060	16	26774339	22	746250	18
89145	1200186	16	12098362	17	32230225	17	742556	19
89148	1185349	17	20695171	9	31148722	18	517488	23
89104	1093436	18	11084194	20	39898289	13	634908	20
89146	992981.4	19	7286386	26	39502150	14	888188	12
89142	917113.7	20	11136123	19	27999532	21	364896	27
89102	851231.2	21	7270131	27	29252635	20	799268	15
89103	841748.2	22	7464054	25	23592566	26	884552	13
89149	827643.2	23	11950843	18	29553789	19	616292	21
89113	822295.7	24	10643183	22	21581641	27	472410	25
89139	669652.6	25	13689322	15	24923703	25	376352	26
89122	654342.6	26	9655654	23	26435099	23	268180	29
89119	645351.7	27	6165309	29	20976415	28	555390	22
89106	590901.7	28	6410465	28	25407578	24	171466	32
89101	560408.6	29	5199580	30	20881128	29	181010	31
89143	550866.4	30	8419489	24	15615275	31	346436	28
89109	434025.9	31	4222898	32	14051222	32	496702	24
89118	399861.1	32	4450812	31	16363663	30	245940	30
89074	124592.6	33	1344870	33	3365603	33	92210	33
89156	51579.74	34	565193	34	2628976	34	28408	34
89032	23209.13	35	258410	36	951494	35	0	36
89115	23030.59	36	269778	35	515456.6	36	1050	35

Table 4.2.11: Rankings: 2005 Zip-wise Averages of, Water Use, Built-up Area, Un-built Area and Pool Area of the LVVWD.

Zip	Water Use in Kilo Gals	Rank (WC)	Built Area in Sq. Ft	Rank (B)	Un-built Area in Sq. Ft	Rank (UB)	Pool Area in Sq. Ft	Rank (P)
89146	305.815	1	2244.036	7	12165.74	1	273.5411	1
89117	248.1372	2	2448.718	1	6362.542	8	173.533	7
89120	246.7822	3	2094.205	12	9771.843	2	223.3115	3
89144	215.2552	4	2362.615	4	4674.291	27	130.2811	10
89102	214.254	5	1829.884	22	7362.858	3	201.1749	6
89109	201.4977	6	1960.491	18	6523.316	7	230.5952	2
89103	193.4164	7	1715.086	25	5421.086	18	203.2518	5
89135	192.9094	8	2396.319	2	5032.325	23	103.5432	19
89145	192.3066	9	1938.529	19	5164.273	20	118.9803	11
89134	192.0611	10	2111.783	11	5667.834	13	83.83706	25
89074	188.7766	11	2037.682	14	5099.398	22	139.7121	9
89121	186.4429	12	1816.529	23	6321.936	9	208.4117	4
89113	181.3221	13	2346.898	5	4758.906	25	104.1698	18
89128	180.9141	14	1989.793	15	3968.133	33	105.7925	17
89118	176.7732	15	1967.645	17	7234.157	5	108.7268	16
89119	171.8189	16	1641.456	26	5584.775	17	147.8674	8
89110	169.5669	17	1737.402	24	6746.687	6	82.26062	26
89147	169.3061	18	1917.471	21	4171.654	30	99.12636	20
89107	168.3818	19	1609.524	27	5820.828	11	109.1206	15
89129	165.6182	20	2158.335	9	4664.871	28	112.0375	14
89108	164.2915	21	1535.434	32	5944.691	10	79.46462	27
89130	163.9318	22	1922.502	20	5345.208	19	88.14093	24
89123	159.3314	23	1987.376	16	4922.524	24	95.92449	21
89149	157.1077	24	2268.573	6	5610.059	16	116.9879	12
89104	153.94	25	1560.495	31	5617.104	15	89.38589	23
89131	144.21	26	2366.137	3	5812.558	12	116.8644	13
89143	143.7918	27	2197.726	8	4076.031	31	90.42965	22
89156	142.8802	28	1565.632	30	7282.483	4	78.69252	28
89101	137.1533	29	1272.535	36	5110.408	21	44.30005	33
89106	131.0785	30	1422.02	33	5636.109	14	38.03594	34
89142	130.6616	31	1586.568	29	3989.106	32	51.98689	31
89148	123.3326	32	2153.28	10	3240.945	35	53.8433	30
89032	116.0457	33	1292.05	35	4757.47	26	0	36
89115	115.7316	34	1355.668	34	2590.234	36	5.276382	35
89122	108.7309	35	1604.462	28	4392.672	29	44.56298	32
89139	100.1275	36	2046.848	13	3726.63	34	56.27273	29

Table 4.2.10 and 4.2.11 lists the total and average water use rankings of all the 36 zip codes of the year 2005 in the LVVWD. This ranking is compared with the individual rank of every zip code for the built-up area, un-built area and pool area of SFR. It is obvious from the table 4.2.10 and the table 4.2.11 that the total annual water use and the average annual water use rankings of the zip codes correlates very closely with the total square feet values of built-up area, un-built area and pool area of SFR. In other words the zip codes that rank high, medium and low in the total water use are the same zip codes that rank high, medium and low in the total square feet of built-up area, un-built area and pool area of SFR. For instance, the zip codes 89108, 89123, 89117, 89110 and 89121 rank high in terms of total water use, total built-up area, total un-built area and total pool area of SFR. Whereas the zip codes 89142, 89131, 89132 rank low both in water use and built-up, un-built & pool areas.

The next step is the street wise analysis. In this stage, 13,220 streets from the LVVWD are considered and their total annual water uses are plotted against the total built-up area. This is shown in the figure 4.2.34. Similarly, for the same number of streets, the total annual water uses are plotted against the total un-built area, as shown in the figure 4.2.35. In both the cases the correlation between water use and the built-up area is as high as the correlation between water use and the un-built area. It is also evident through the charts that due to high correlation, the plots could easily fit in a linear equation.

In the year 2005, only 10,396 streets out of 13,220 streets have swimming pools. Hence, the total annual water uses of the streets with swimming pools are plotted against the total square feet area of the pools. Figure 4.2.36 shows that though swimming pool is one of the contributing factors of high water use, SFR with similar size swimming pools varies greatly in their water uses due to the influence of other factors.

In table 4.2.12, through regression analysis, the equations with water use and each one of the factor that affects the water use are derived. At the same time, a combined equation is derived through regression analysis with water use and all the factors that affects the water use. Thus for a given year, the total annual water used in kilo gallons can be determined by plugging in the square feet values of built-up area, un-built area and swimming pool area of SFR.

Fig. 4.2.34: 2005- Street-wise Total Built-up Area of SFR: Las Vegas Valley Water District.

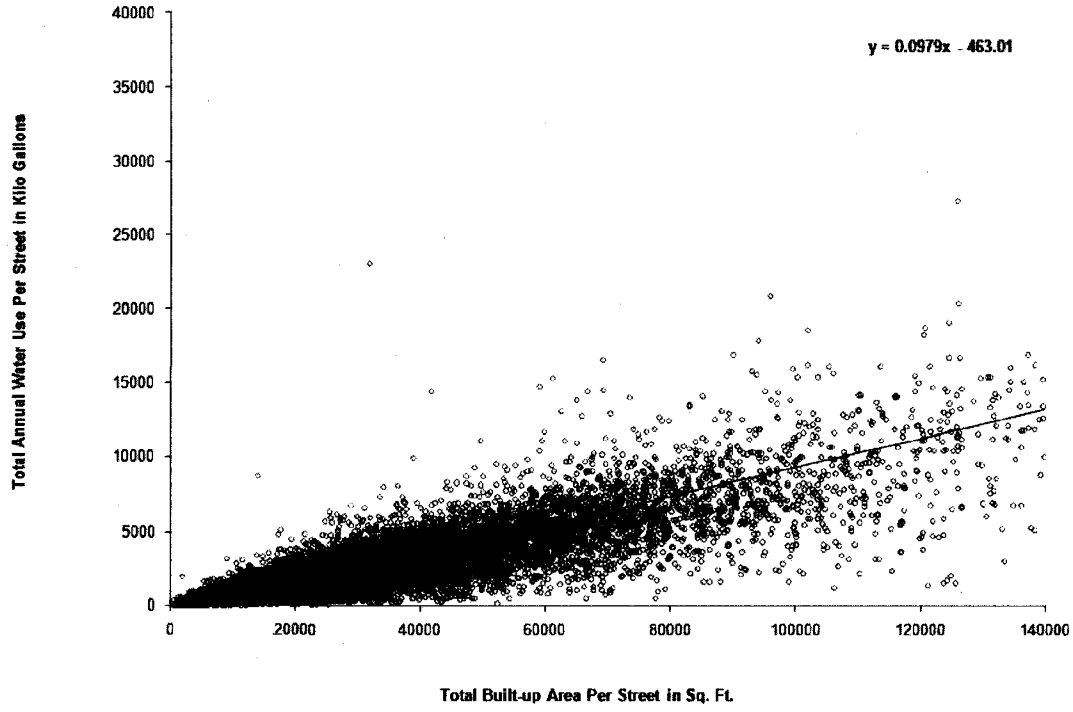


Fig. 4.2.35: 2005- Street-wise Total Un-built Area of SFR: Las Vegas Valley Water District.

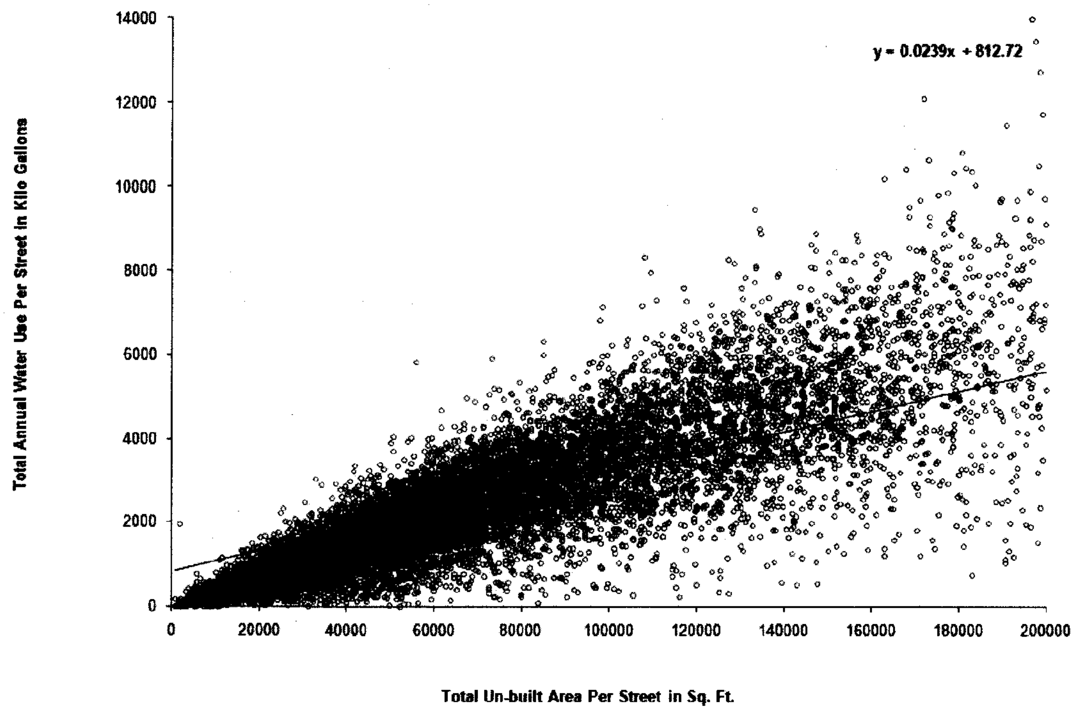


Fig. 4.2.36: 2005- Street-wise Total Pool Area of SFR: Las Vegas Valley Water District.

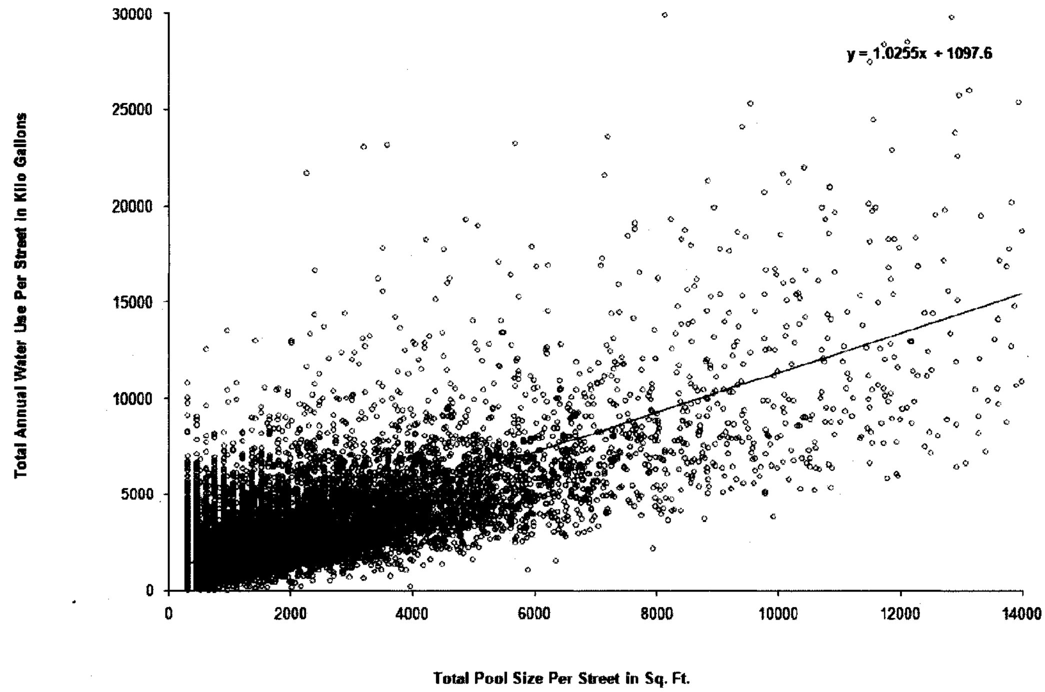


Table 4.2.12: Regression Statistics - With Water Use and Built-up/Un-built/Pool Areas: LVVWD

Year - 2005	Correlation	Linear Equation
B	0.912727	Y = 0.097914B-463.063
UB	0.916228	Y = 0.023877UB+812.8435
P	0.862651	Y = 1.019017P+1148.828
B, UB	0.956356	Y = 0.052545B+0.013298UB-106.011
B, P	0.943434	Y = 0.065762B+0.452622P-184.571
UB, P	0.938717	Y = 0.016494UB+0.412511P+709.6155
B, UB, P	0.963741	Y=0.044406B+0.010366UB+0.255379P-27.5938

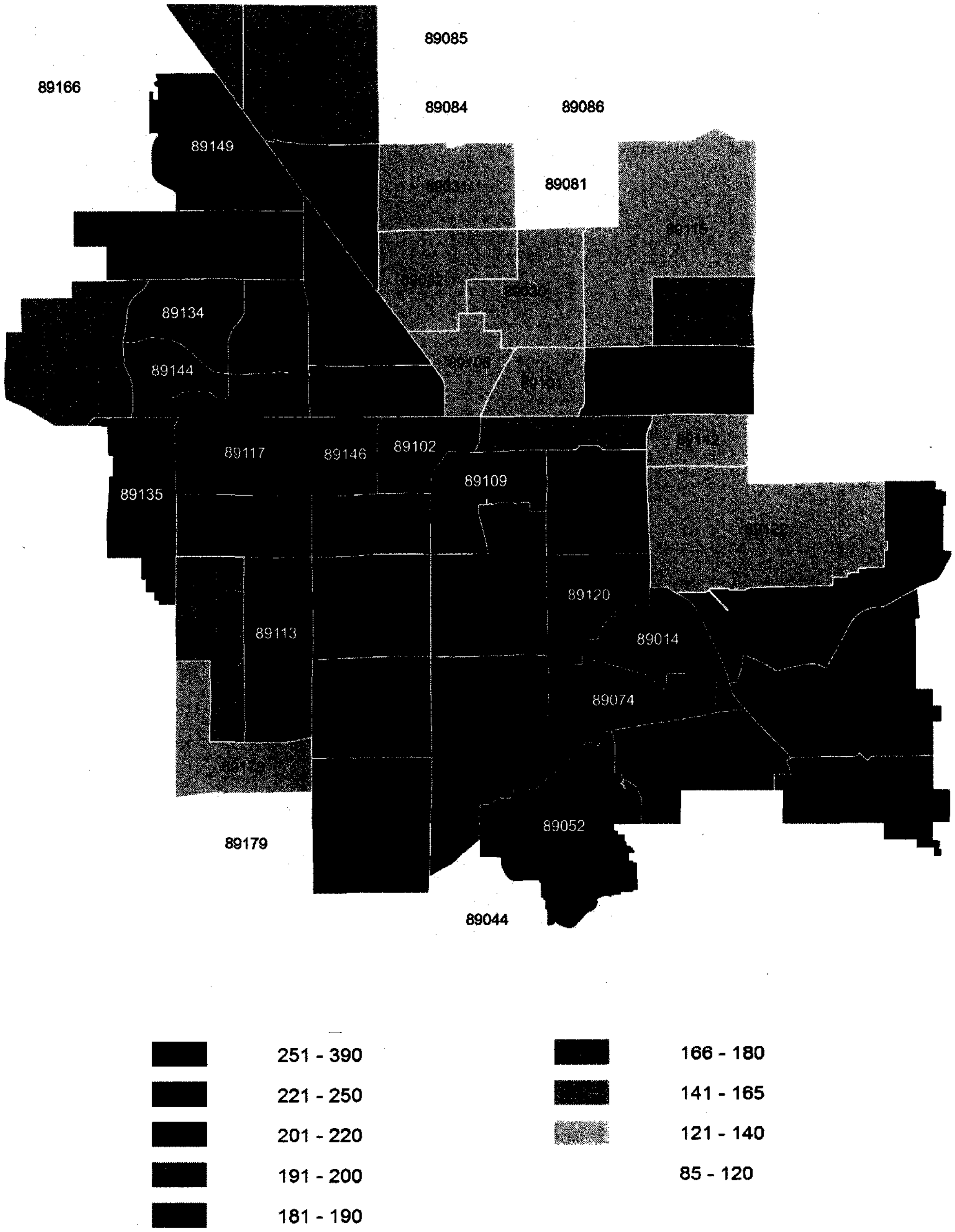
Where, Y = Total water consumption of SFR in a street (Kilo Gals), B = Total built-up area of SFR in a street (Square Feet), UB = Total Un-built Area of SFR in a street (Square Feet) and P = Total pool area of SFR in a street (Square Feet).

Part 3: Water Use Analysis in LVMA- 2006

As explained in the summary of this chapter, the recent data year analysis is done for the year 2006. Similar to the historic analysis, the total and average water uses are analyzed in both the zip code level and the street level. The zip level analysis includes mapping the total & average water use, the total built-up area, turf area, tree-shrub area & swimming pool area and listing their rankings with respect to the total and average water use of the SFR. Whereas the street level analysis includes plotting the street level water use with the total built-up area, turf area, tree-shrub area and pool area separately. The last part of the street level analysis includes the statistical analysis that involves finding the correlation coefficients and regression equations for each one of the factor that affects the water use such as the built-up area, turf area, tree-shrub area and pool area of the single family residences.

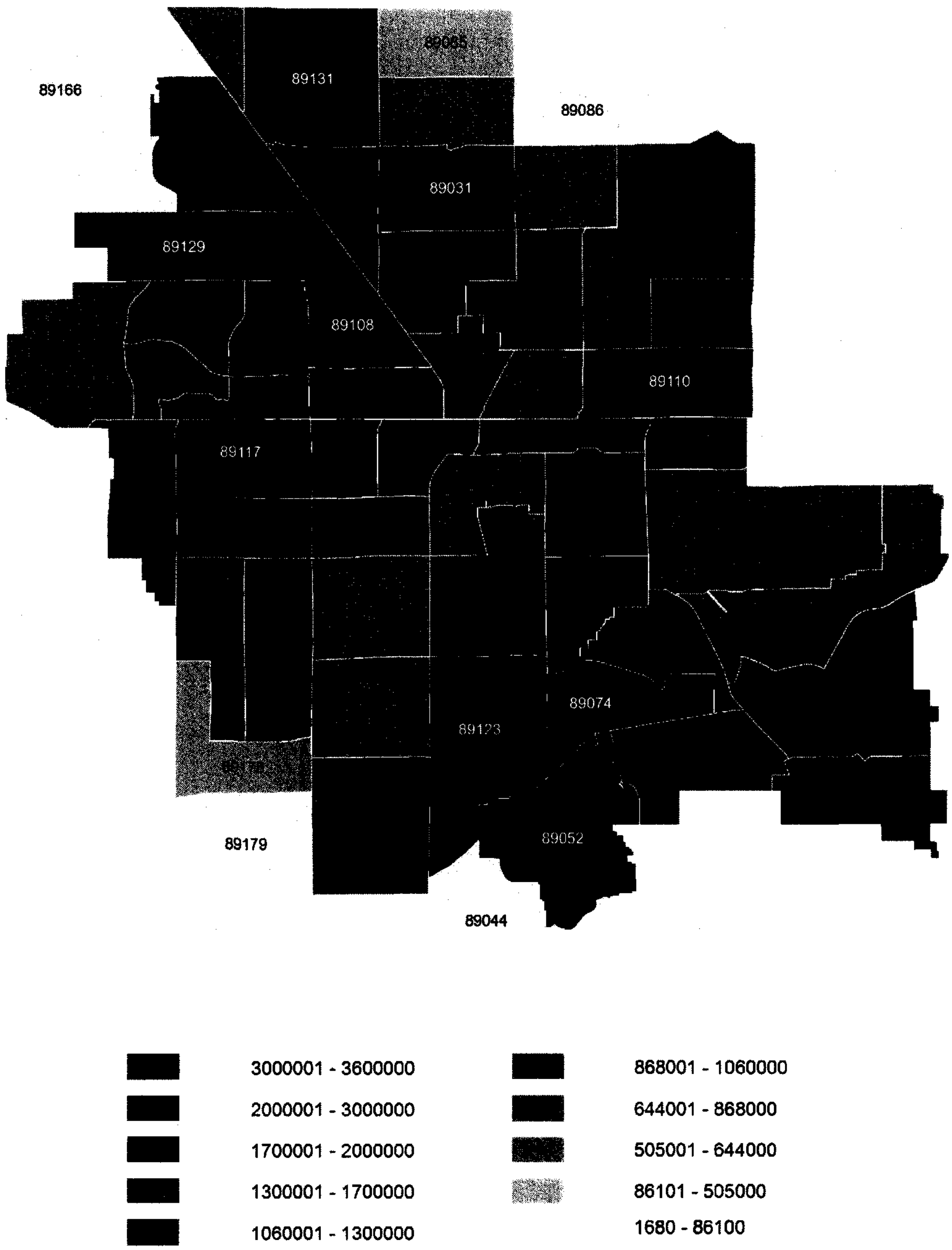
For the year 2006, the zip level analysis includes all the 54 zip codes of the LVMA for which the water use data and the built-up, turf, tree-shrub and pool data are obtained from the SNWA and the Clark County Assessor office respectively. The zip level mappings and ranking tables are intended to be studied side by side to understand the real cause of high and low water use in each one of the zip code. When the maps below shows the range within which each zip code lies, the rankings table shows the respective cause and position of each zip code with respect to the other zips. For the uniformity and simplicity of the zip code maps and the street level charts, the water use is colored blue-green-yellow, the density is colored brown, the built-up area is colored maroon, the turf area and tree-shrub area are colored green and the swimming pool area is colored blue throughout this section.

Fig. 4.3.1: 2006- Average Water Consumption per SFR in Kilo Gallons: Las Vegas Metro Area.



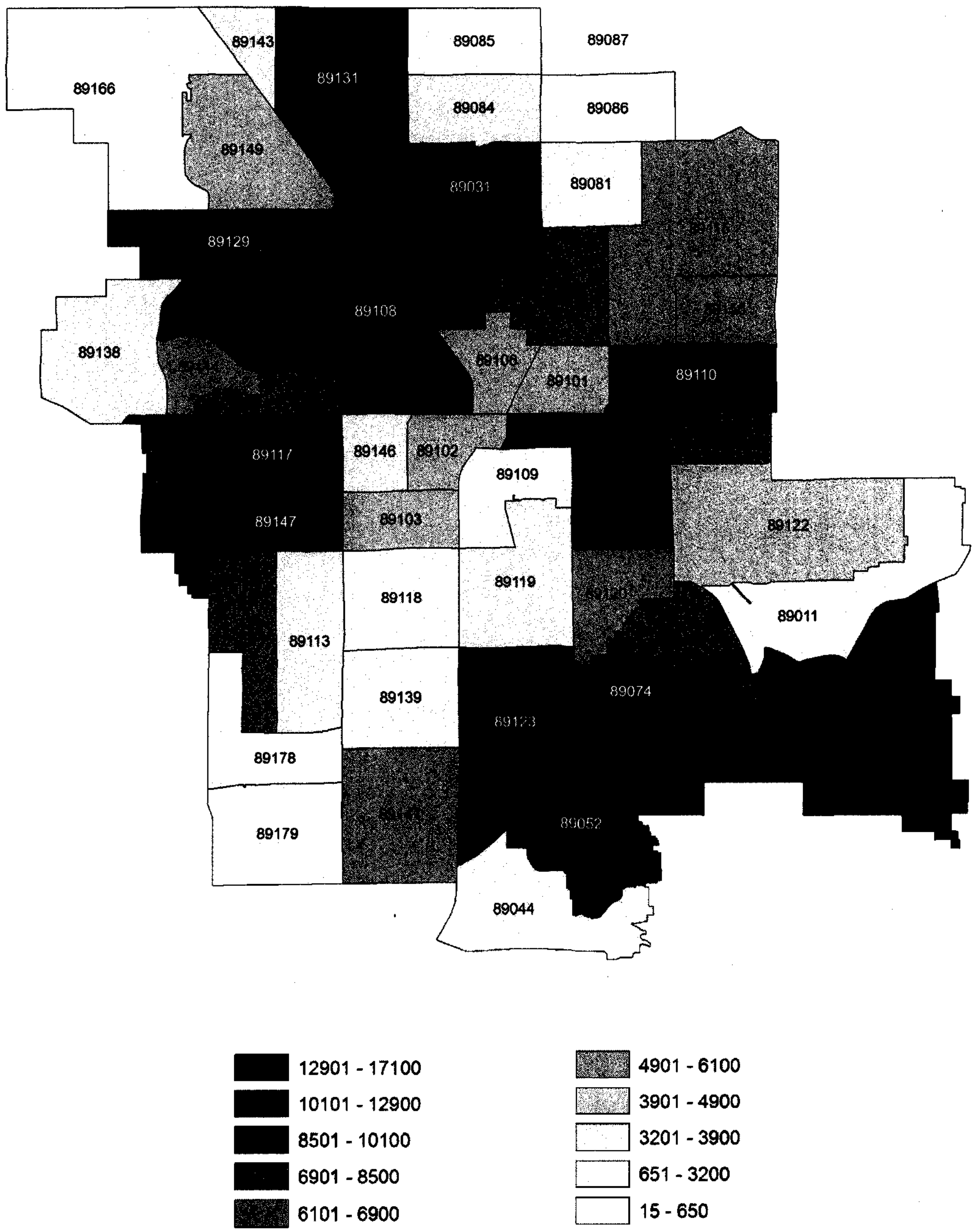
Zip codes 89117, 89146, 89120, 89144, 89102, 89014, 89074, 89052 and 89113 are the highest consumers of average annual water in the LVMA. Whereas, the zip codes 89166, 89084, 89085, 89081, 89086, 89179 and 89044 consumes less than 50% of the average water consumed by the highest consumers.

Fig. 4.3.2: 2006- Total Water Consumption in Kilo gallons: Las Vegas Metro Area.



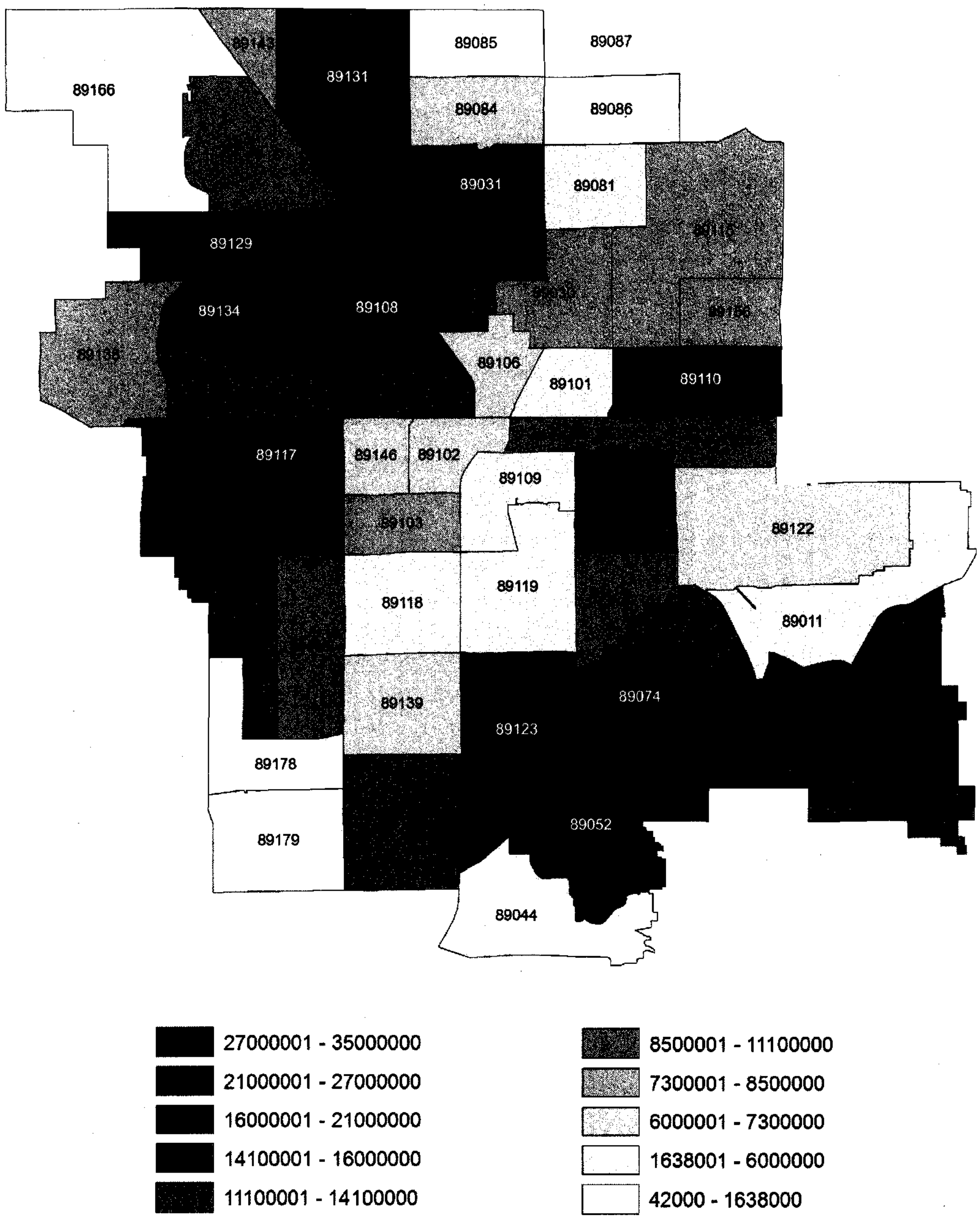
Zip codes 89117, 89108, 89110, 89129, 89134, 89031, 89123, 89052 and 89074 are the highest consumers of total annual water in the LVMA. Whereas, the zip codes 89166, 89086, 89085, 89179 and 89044 consumes less than 2.86% of the total water consumed by the highest consumers.

Fig. 4.3.3: 2006- Total Number of Single Family Residence: Las Vegas Metropolitan Area.



When the fig. 4.3.2 is overlapped with the above figure, it is obvious that the zip codes where the total number of single family residence is high are the highest consumers of total annual water. Also, the zip codes with less number of SFR are the lowest consumers. In other words, the denser the SFR in a zip code, the higher the total water use.

Fig. 4.3.4: 2006- Total Built-up Area in Square Feet: Las Vegas Metropolitan Area.



When the fig. 4.3.2 is overlapped with the above figure, it is evident that the zip codes where the total built-up area is high are the highest consumers of total annual water. Also, the zip codes with less total built-up area are the lowest consumers. In other words, the higher the built-up area, the higher the total water use and vice versa. This proves that the size of the built-up area has strong correlation to the total quantity of water used in that region.

Table 4.3.1: Rankings: 2006 Zip-wise Averages of, Water Use and Built-up Area: LVMA

Zip	Water Use in Kilo Gals	Rank (WC)	Built Area in Sq. Ft	Rank (B)	Zip	Water Use in Kilo Gals	Rank (WC)	Built Area in Sq. Ft	Rank (B)
89146	316	1	2251	16	**89147**	177	28	1934	33
89120	260	2	2103	23	**89107**	176	29	1620	45
89117	258	3	2453	7	**89139**	173	30	2389	9
89144	230	4	2370	10	**89015**	171	31	1659	42
89113	228	5	2488	6	**89108**	170	32	1538	50
89074	228	6	2240	17	**89138**	165	33	2356	13
89014	225	7	2054	24	**89148**	164	34	2330	15
89052	225	8	2507	5	**89131**	161	35	2363	11
89102	225	9	1841	35	**89104**	161	36	1562	48
89135	211	10	2430	8	**89156**	160	37	1576	47
89109	207	11	1960	30	**89143**	154	38	2216	18
89145	203	12	1946	32	**89031**	146	39	1744	39
89134	202	13	2121	22	**89122**	142	40	1561	49
89149	201	14	2353	14	**89142**	140	41	1594	46
89103	199	15	1718	41	**89106**	140	42	1423	51
89118	195	16	1984	29	**89101**	139	43	1274	53
89121	194	17	1823	36	**89115**	136	44	1385	52
89002	192	18	1954	31	**89032**	134	45	1633	44
89128	187	19	1994	28	**89178**	133	46	2530	2
89011	185	20	2010	26	**89030**	122	47	1260	54
89123	184	21	2038	25	**89179**	112	48	2838	1
89012	183	22	2185	20	**89081**	105	49	1996	27
89141	182	23	2521	4	**89044**	103	50	1810	37
89129	182	24	2194	19	**89084**	99	51	2136	21
89130	181	25	1915	34	**89085**	94	52	2522	3
89119	179	26	1645	43	**89086**	91	53	2359	12
89110	179	27	1730	40	**89166**	87	54	1777	38

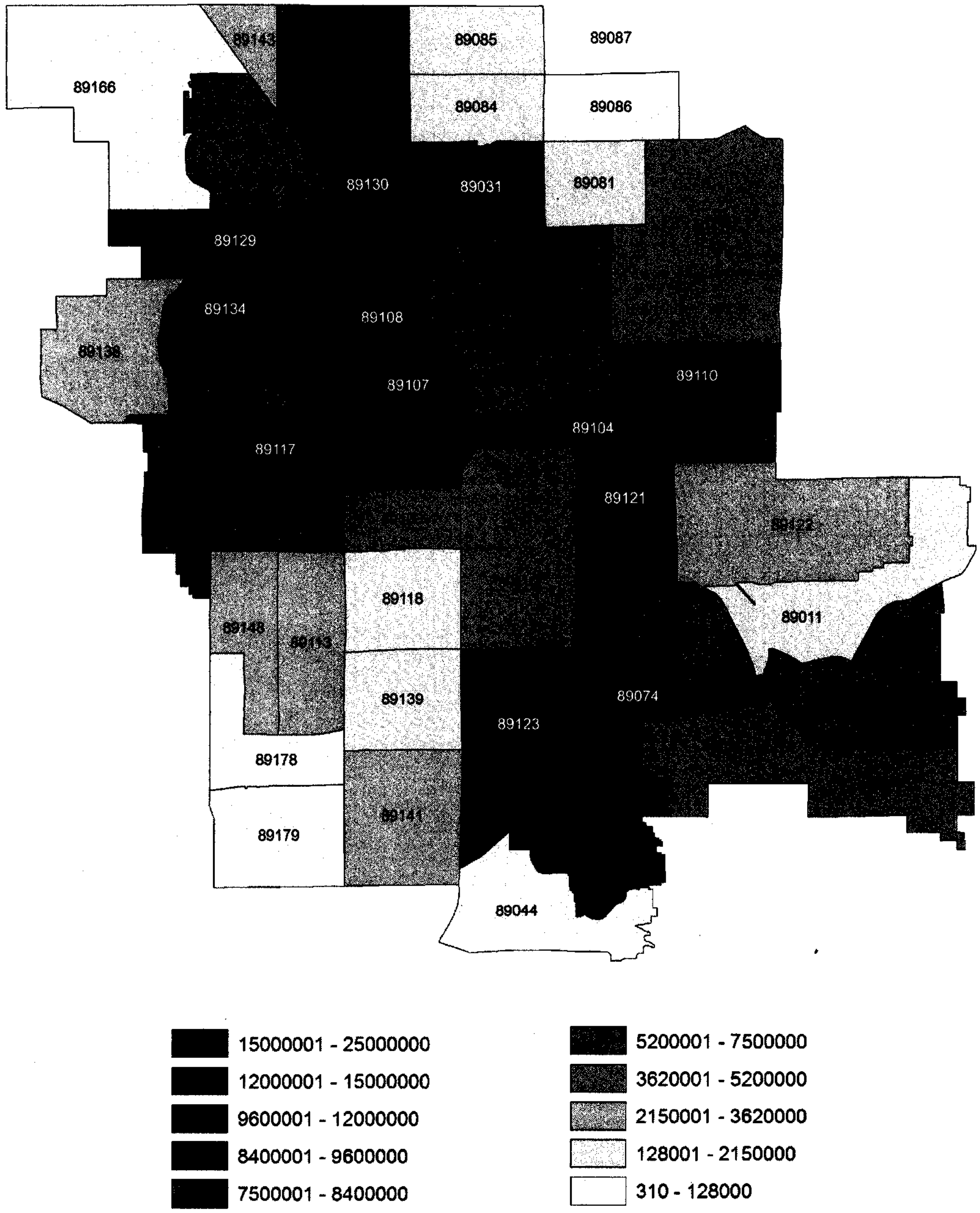
Table 4.3.2: Rankings: 2006 Zip-wise Totals of, Water Use and Built-up Area: LVMA

Zip	Water Use in M Gals	Rank (WC)	Built Area in Sq. Ft	Rank (B)	Zip	Water Use in M Gals	Rank (WC)	Built Area in Sq. Ft	Rank (B)
89146	3358	1	31917372	3	**89141**	1012	28	14044416	21
89120	3128	2	34717525	1	**89142**	943	29	10705778	27
89117	3023	3	33677254	2	**89102**	884	30	7236001	38
89144	2834	4	27883619	4	**89149**	868	31	10172339	29
89113	2351	5	21269198	10	**89103**	852	32	7369658	36
89074	2304	6	22281209	8	**89030**	819	33	8485004	31
89014	2259	7	27285388	5	**89156**	816	34	8060615	33
89052	2256	8	26884087	6	**89113**	798	35	8702439	30
89102	2036	9	21389725	9	**89115**	742	36	7539931	35
89135	1922	10	20983167	11	**89119**	644	37	5915580	43
89109	1751	11	16448496	15	**89106**	607	38	6171881	42
89145	1740	12	25466002	7	**89122**	573	39	6312508	41
89134	1612	13	18577327	12	**89101**	569	40	5193025	46
89149	1612	14	17066242	13	**89143**	565	41	8111031	32
89103	1563	15	16635623	14	**89138**	530	42	7575442	34
89118	1545	16	14180520	19	**89011**	505	43	5482114	45
89121	1515	17	13820561	22	**89139**	502	44	6910831	40
89002	1457	18	14160673	20	**89109**	448	45	4233864	47
89128	1329	19	15851175	16	**89118**	402	46	4096384	48
89011	1324	20	13495206	23	**89084**	319	47	6921777	39
89123	1309	21	13463108	24	**89081**	299	48	5670239	44
89012	1282	22	10358056	28	**89178**	86	49	1637011	49
89141	1254	23	15236317	17	**89085**	36	50	960849	50
89129	1246	24	11925775	25	**89086**	32	51	842088	51
89130	1139	25	11083632	26	**89044**	30	52	524914	52
89119	1062	26	15110563	18	**89166**	26	53	524246	53
89110	1019	27	7266078	37	**89179**	2	54	42567	54

Table 4.3.1 and 4.3.2 lists the average and total water use rankings of all the 54 zip codes of the year 2006 in the LVMA. This ranking is compared with the built-up area ranking of the SFR. It is obvious from the table 4.3.2 that the total annual water use rankings of the zip codes correlates very closely with the total square feet values of built-up area of SFR. In other words the zip codes that ranks high, medium and low in the total water use are the same zip codes that ranks high, medium and low in the total square feet of built-up area. For instance, the zip codes 89146, 89120 and 89117 ranks high in terms of total water use and total built-up area. Whereas the zip codes 89179, 89166 and 89044 ranks low in water use and built-up area. But this may not be true in table 4.3.1. This is because of the difference in the density of SFR in each of the zip codes.

Similarly, the table 4.3.3 and 4.3.4 lists the average and total water use rankings of all the 54 zip codes of the year 2006 along with the tree area ranking of the SFR. It is obvious from the table 4.3.3 and 4.3.4 that the total annual water use and the average annual water use rankings of the zip codes correlates very closely with the total square feet values of tree area of SFR. In other words the zip codes that ranks high, medium and low in the total water use are the same zip codes that ranks high, medium and low in the total square feet of tree area. For instance, the zip codes 89117, 89123 and 89052 ranks high in terms of total water use and total built-up area. Whereas the zip codes 89086, 89179 and 89044 ranks low in water use and built-up area.

Fig. 4.3.5: 2006- Total Tree Area in Square Feet: Las Vegas Metropolitan Area.



When the fig. 4.3.2 is overlapped with the above figure, it is evident that the zip codes where the total un-built area is high are the highest consumers of total annual water. Also, the zip codes with less total built-up area are the lowest consumers. In other words, the higher the un-built area, the higher the total water use and vice versa. This proves that the size of the un-built area has strong correlation to the total quantity of water used in that region.

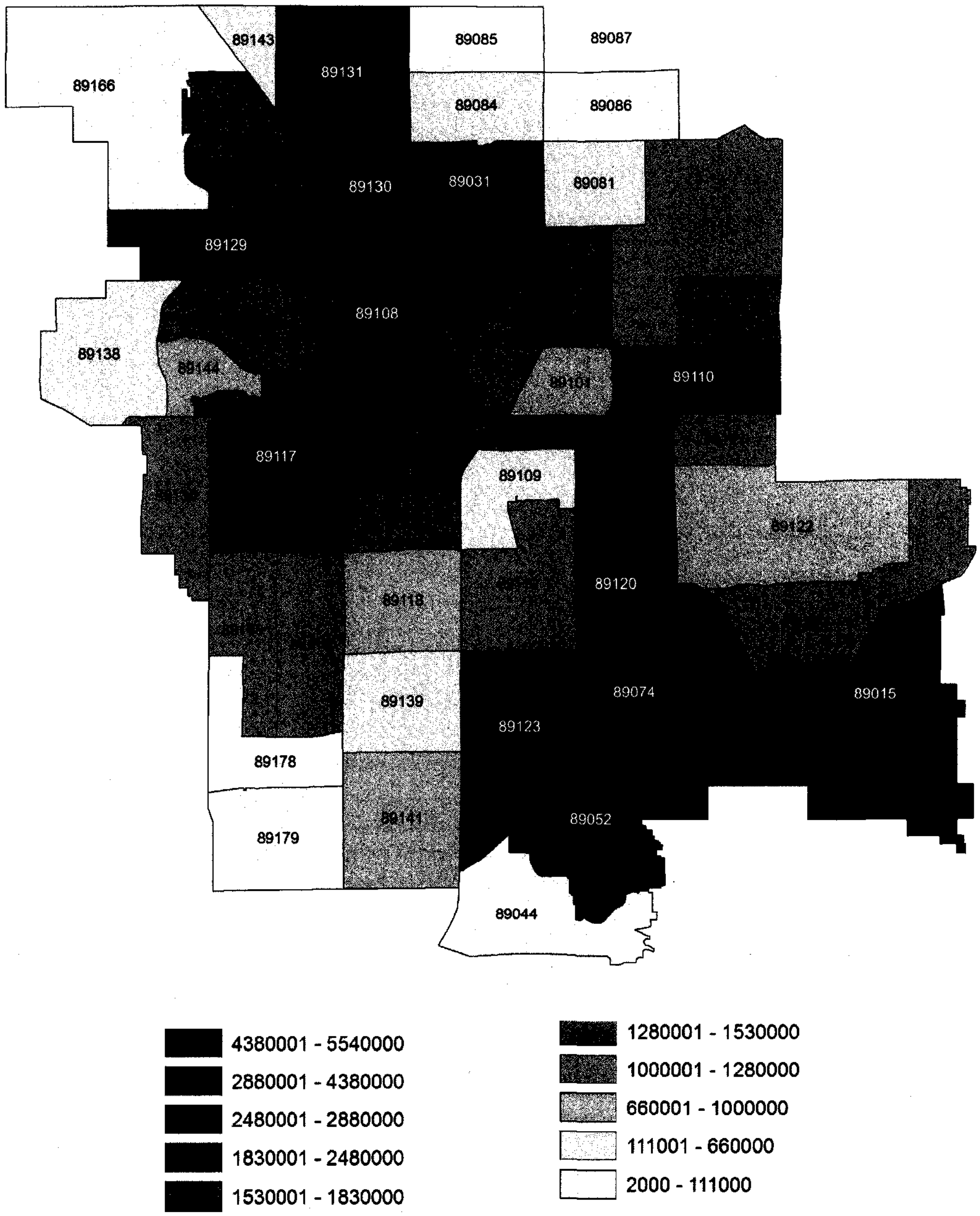
Table 4.3.3: Rankings: 2006 Zip-wise Averages of, Water Use and Tree Area: LVMA

Zip	Water Use in Kilo Gals	Rank (WC)	Tree Area in Sq. Ft	Rank (TR)	Zip	Water Use in Kilo Gals	Rank (WC)	Tree Area in Sq. Ft	Rank (TR)
89146	316	1	2990	1	**89143**	154	38	914	28
89102	225	9	2728	2	**89131**	161	35	885	29
89109	207	11	2223	3	**89115**	136	44	876	30
89107	176	29	1979	4	**89156**	160	37	860	31
89120	260	2	1945	5	**89032**	134	45	808	32
89117	258	3	1909	6	**89113**	228	5	803	33
89104	161	36	1845	7	**89002**	192	18	744	34
89134	202	13	1786	8	**89031**	146	39	727	35
89108	170	32	1743	9	**89123**	184	21	726	36
89101	139	43	1645	10	**89147**	177	28	710	37
89144	230	4	1624	11	**89015**	171	31	686	38
89121	194	17	1586	12	**89138**	165	33	673	39
89110	179	27	1529	13	**89012**	183	22	633	40
89145	203	12	1370	14	**89052**	225	8	626	41
89130	181	25	1351	15	**89011**	185	20	542	42
89128	187	19	1316	16	**89122**	142	40	540	43
89106	140	42	1273	17	**89139**	173	30	498	44
89149	201	14	1209	18	**89141**	182	23	490	45
89135	211	10	1206	19	**89148**	164	34	404	46
89129	182	24	1198	20	**89166**	87	54	401	47
89103	199	15	1176	21	**89085**	94	52	337	48
89030	122	47	1151	22	**89084**	99	51	315	49
89142	140	41	1118	23	**89081**	105	49	269	50
89014	225	7	1111	24	**89178**	133	46	154	51
89074	228	6	1037	25	**89086**	91	53	120	52
89119	179	26	1007	26	**89044**	103	50	34	53
89118	195	16	921	27	**89179**	112	48	21	54

Table 4.3.4: Rankings: 2006 Zip-wise Totals of, Water Use and Tree Area: LVMA

Zip	Water Use in Kilo Gals	Rank (WC)	Tree Area in Sq. Ft	Rank (TR)	Zip	Water Use in Kilo Gals	Rank (WC)	Tree Area in Sq. Ft	Rank (TR)
89117	3358	1	24836626	1	**89141**	1012	28	2727422	40
89123	3128	2	12371458	10	**89142**	943	29	7510001	25
89052	3023	3	8406575	20	**89102**	884	30	10724844	14
89074	2834	4	12909442	9	**89149**	868	31	5225810	30
89108	2351	5	24096905	2	**89103**	852	32	5042237	32
89110	2304	6	19695943	3	**89030**	819	33	7753554	22
89129	2259	7	14903722	6	**89156**	816	34	4398807	36
89031	2256	8	11208951	12	**89113**	798	35	2808716	39
89134	2036	9	18009412	4	**89115**	742	36	4770741	34
89147	1922	10	7697339	23	**89119**	644	37	3621821	37
89121	1751	11	14306881	7	**89106**	607	38	5522688	29
89131	1740	12	9533609	17	**89122**	573	39	2182348	42
89135	1612	13	9222988	19	**89101**	569	40	6706256	27
89130	1612	14	12037246	11	**89143**	565	41	3346717	38
89128	1563	15	10980045	13	**89138**	530	42	2163795	43
89107	1545	16	17316652	5	**89011**	505	43	1479234	45
89014	1515	17	7473404	26	**89139**	502	44	1440921	46
89015	1457	18	5851268	28	**89109**	448	45	4800933	33
89012	1329	19	4594884	35	**89118**	402	46	1902439	44
89002	1324	20	5141310	31	**89084**	319	47	1019229	47
89144	1309	21	9226252	18	**89081**	299	48	763393	48
89120	1282	22	9578423	16	**89178**	86	49	99406	51
89032	1254	23	7538039	24	**89085**	36	50	128346	49
89145	1246	24	8394180	21	**89086**	32	51	42710	52
89104	1139	25	13088124	8	**89044**	30	52	9824	53
89148	1062	26	2622261	41	**89166**	26	53	118429	50
89146	1019	27	9652081	15	**89179**	2	54	314	54

Fig. 4.3.6: 2006- Total Turf Area in Square Feet: Las Vegas Metropolitan Area.



When the fig. 4.3.2 is overlapped with the above figure, it is evident that the zip codes where the total un-built area is high are the highest consumers of total annual water. Also, the zip codes with less total built-up area are the lowest consumers. In other words, the higher the un-built area, the higher the total water use and vice versa. This proves that the size of the un-built area has strong correlation to the total quantity of water used in that region.

Table 4.3.5: Rankings: 2006 Zip-wise Averages of, Water Use and Turf Area: LVMA

Zip	Water Use in Kilo Gals	Rank (WC)	Turf Area in Sq. Ft	Rank (TU)	Zip	Water Use in Kilo Gals	Rank (WC)	Turf Area in Sq. Ft	Rank (TU)
89146	316	1	756	2	**89147**	177	28	194	38
89120	260	2	763	1	**89107**	176	29	321	17
89117	258	3	337	12	**89139**	173	30	228	32
89144	230	4	139	48	**89015**	171	31	291	23
89113	228	5	334	14	**89108**	170	32	329	15
89074	228	6	336	13	**89138**	165	33	74	52
89014	225	7	367	7	**89148**	164	34	197	37
89052	225	8	412	4	**89131**	161	35	238	29
89102	225	9	418	3	**89104**	161	36	263	27
89135	211	10	151	46	**89156**	160	37	280	24
89109	207	11	223	34	**89143**	154	38	127	51
89145	203	12	265	25	**89031**	146	39	340	11
89134	202	13	139	49	**89122**	142	40	222	35
89149	201	14	365	9	**89142**	140	41	188	39
89103	199	15	308	20	**89106**	140	42	301	22
89118	195	16	367	8	**89101**	139	43	171	42
89121	194	17	319	18	**89115**	136	44	224	33
89002	192	18	326	16	**89032**	134	45	265	26
89128	187	19	182	40	**89178**	133	46	171	43
89011	185	20	368	6	**89030**	122	47	231	31
89123	184	21	310	19	**89179**	112	48	152	45
89012	183	22	251	28	**89081**	105	49	217	36
89141	182	23	172	41	**89044**	103	50	143	47
89129	182	24	236	30	**89084**	99	51	168	44
89130	181	25	398	5	**89085**	94	52	31	54
89119	179	26	302	21	**89086**	91	53	131	50
89110	179	27	343	10	**89166**	87	54	37	53

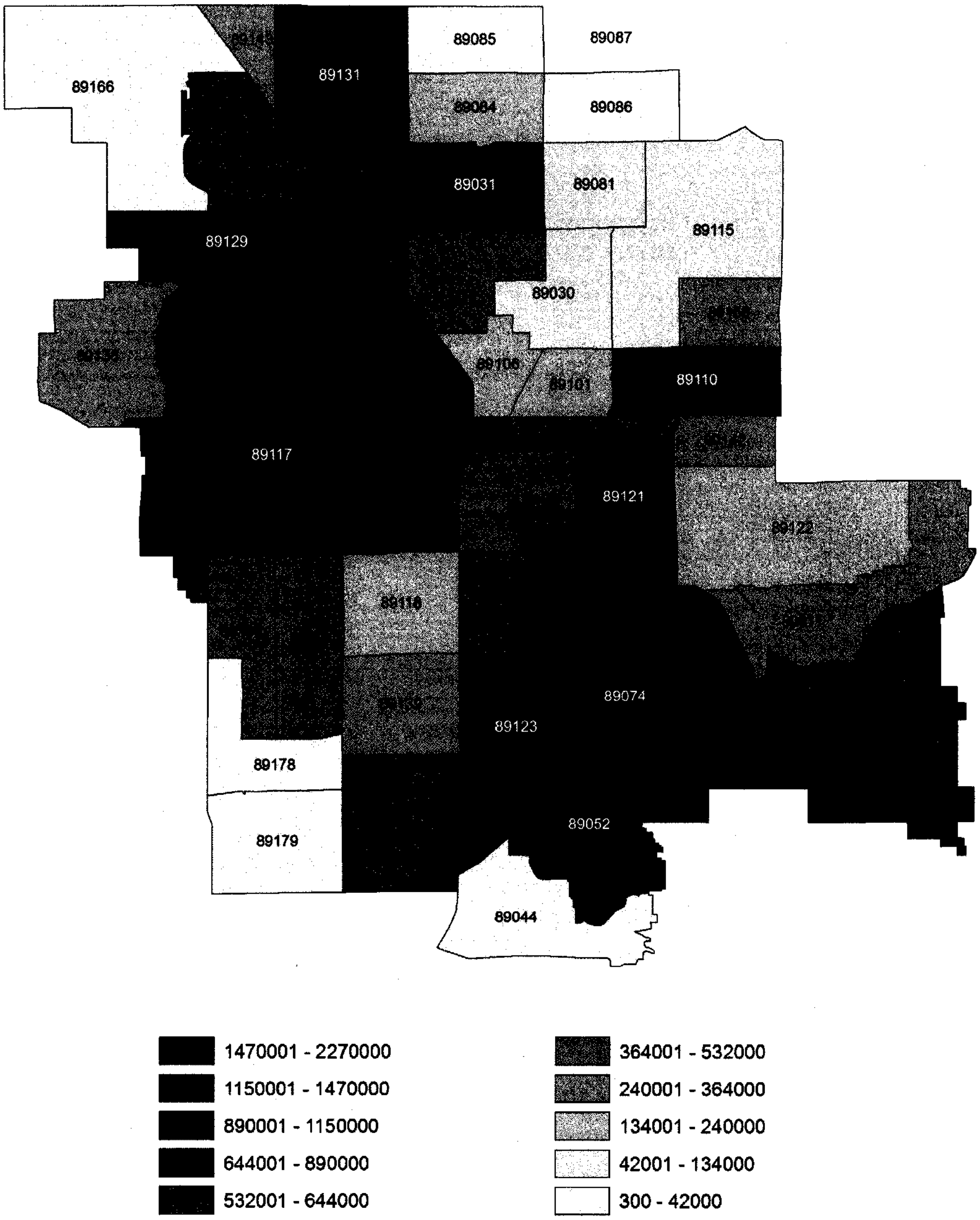
Table 4.3.6: Rankings: 2006 Zip-wise Totals of, Water Use and Turf Area: LVMA

Zip	Water Use in Kilo Gals	Rank (WC)	Turf Area in Sq. Ft	Rank (TU)	Zip	Water Use in Kilo Gals	Rank (WC)	Turf Area in Sq. Ft	Rank (TU)
89117	3358	1	4380583	6	**89141**	1012	28	956520	38
89123	3128	2	5285138	2	**89142**	943	29	1260326	32
89052	3023	3	5530287	1	**89102**	884	30	1641909	22
89074	2834	4	4185862	7	**89149**	868	31	1579705	24
89108	2351	5	4549314	4	**89103**	852	32	1321426	29
89110	2304	6	4418133	5	**89030**	819	33	1557201	25
89129	2259	7	2939396	10	**89156**	816	34	1430202	27
89031	2256	8	5245824	3	**89113**	798	35	1167461	34
89134	2036	9	1400485	28	**89115**	742	36	1218733	33
89147	1922	10	2102775	19	**89119**	644	37	1085938	36
89121	1751	11	2875484	11	**89106**	607	38	1307419	30
89131	1740	12	2561884	13	**89122**	573	39	896019	39
89135	1612	13	1151972	35	**89101**	569	40	697491	42
89130	1612	14	3545678	9	**89143**	565	41	464154	47
89128	1563	15	1522072	26	**89138**	530	42	238660	48
89107	1545	16	2812697	12	**89011**	505	43	1003859	37
89014	1515	17	2470779	16	**89139**	502	44	658697	43
89015	1457	18	2482338	14	**89109**	448	45	482142	46
89012	1329	19	1822469	21	**89118**	402	46	757606	41
89002	1324	20	2251083	18	**89084**	319	47	545487	45
89144	1309	21	790820	40	**89081**	299	48	615097	44
89120	1282	22	3758478	8	**89178**	86	49	110589	49
89032	1254	23	2472011	15	**89085**	36	50	11893	52
89145	1246	24	1625656	23	**89086**	32	51	46930	50
89104	1139	25	1865184	20	**89044**	30	52	41556	51
89148	1062	26	1276210	31	**89166**	26	53	10833	53
89146	1019	27	2441315	17	**89179**	2	54	2275	54

Table 4.3.5 and 4.3.6 lists the average and total water use rankings of all the 54 zip codes of the year 2006 in the LVMA. This ranking is compared with the turf area ranking of the SFR. It is obvious from the tables 4.3.5 and 4.3.6 that the total annual water use and the average annual water use rankings of the zip codes correlates very closely with the total square feet values of the turf area of SFR. In other words the zip codes that ranks high, medium and low in the total water use are mostly the same zip codes that ranks high, medium and low in the total square feet of turf area. For instance, the zip codes 89117, 89123 and 89052 ranks high in terms of total water use and total turf area. Whereas the zip codes 89179, 89166 and 89044 ranks low in water use and turf area.

Similarly, the table 4.3.7 and 4.3.8 lists the average and total water use rankings of all the 54 zip codes of the year 2006 along with the pool area ranking of the SFR. It is obvious from the table 4.3.7 and 4.3.8 that the total annual water use and the average annual water use rankings of the zip codes correlates very closely with the total square feet values of the pool area of SFR. In other words the zip codes that ranks high, medium and low in the total water use are mostly the same zip codes that ranks high, medium and low in the total square feet of pool area. For instance, the zip codes 89117, 89123 and 89052 ranks high in terms of total water use and total pool area. Whereas the zip codes 89086, 89179 and 89044 ranks low in water use and pool area.

Fig. 4.3.7: 2006- Total Pool Area in Square Feet: Las Vegas Metropolitan Area.



When the fig. 4.3.2 is overlapped with the above figure, it is evident that the zip codes where the total pool area is high are the highest consumers of total annual water. Also, the zip codes with less total pool area are the lowest consumers. In other words, the higher the pool area, the higher the total water use and vice versa. This proves that the total area of the pool has strong correlation to the total quantity of water used in that region.

Table 4.3.7: Rankings: 2006 Zip-wise Averages of, Water Use and Pool Area: LVMA

Zip	Water Use in Kilo Gals	Rank (WC)	Pool Area in Sq. Ft	Rank (P)	Zip	Water Use in Kilo Gals	Rank (WC)	Pool Area in Sq. Ft	Rank (P)
89146	316	1	275	1	**89147**	177	28	102	27
89120	260	2	228	3	**89107**	176	29	111	20
89117	258	3	174	7	**89139**	173	30	106	24
89144	230	4	131	13	**89015**	171	31	71	37
89113	228	5	129	14	**89108**	170	32	80	35
89074	228	6	164	9	**89138**	165	33	102	29
89014	225	7	170	8	**89148**	164	34	75	36
89052	225	8	132	12	**89131**	161	35	118	17
89102	225	9	202	6	**89104**	161	36	89	32
89135	211	10	106	26	**89156**	160	37	60	40
89109	207	11	231	2	**89143**	154	38	93	31
89145	203	12	120	15	**89031**	146	39	64	39
89134	202	13	85	33	**89122**	142	40	58	42
89149	201	14	139	11	**89142**	140	41	54	43
89103	199	15	204	5	**89106**	140	42	40	48
89118	195	16	116	18	**89101**	139	43	44	45
89121	194	17	210	4	**89115**	136	44	25	50
89002	192	18	109	22	**89032**	134	45	49	44
89128	187	19	106	25	**89178**	133	46	64	38
89011	185	20	102	28	**89030**	122	47	18	52
89123	184	21	108	23	**89179**	112	48	20	51
89012	183	22	110	21	**89081**	105	49	40	47
89141	182	23	116	19	**89044**	103	50	10	54
89129	182	24	118	16	**89084**	99	51	59	41
89130	181	25	94	30	**89085**	94	52	31	49
89119	179	26	148	10	**89086**	91	53	41	46
89110	179	27	83	34	**89166**	87	54	11	53

Table 4.3.8: Rankings: 2006 Zip-wise Totals of, Water Use and Pool Area: LVMA

Zip	Water Use in Kilo Gals	Rank (WC)	Pool Area in Sq. Ft	Rank (P)	Zip	Water Use in Kilo Gals	Rank (WC)	Pool Area in Sq. Ft	Rank (P)
89117	3358	1	2267782	1	**89141**	1012	28	643612	26
89123	3128	2	1841060	4	**89142**	943	29	363846	35
89052	3023	3	1777754	5	**89102**	884	30	794480	22
89074	2834	4	2043678	2	**89149**	868	31	599638	29
89108	2351	5	1105048	11	**89103**	852	32	874548	17
89110	2304	6	1065004	12	**89030**	819	33	124398	47
89129	2259	7	1467936	6	**89156**	816	34	304702	39
89031	2256	8	985158	13	**89113**	798	35	450770	34
89134	2036	9	858602	18	**89115**	742	36	133502	46
89147	1922	10	1108858	10	**89119**	644	37	532312	30
89121	1751	11	1891324	3	**89106**	607	38	172076	45
89131	1740	12	1270084	7	**89122**	573	39	234820	42
89135	1612	13	809256	20	**89101**	569	40	180362	44
89130	1612	14	840704	19	**89143**	565	41	340810	36
89128	1563	15	887712	15	**89138**	530	42	327108	37
89107	1545	16	969676	14	**89011**	505	43	277978	40
89014	1515	17	1142932	8	**89139**	502	44	307898	38
89015	1457	18	608182	28	**89109**	448	45	499588	31
89012	1329	19	798550	21	**89118**	402	46	239784	41
89002	1324	20	754086	23	**89084**	319	47	192394	43
89144	1309	21	745902	24	**89081**	299	48	113486	48
89120	1282	22	1124132	9	**89178**	86	49	41706	49
89032	1254	23	456534	33	**89085**	36	50	11762	51
89145	1246	24	734114	25	**89086**	32	51	14504	50
89104	1139	25	634808	27	**89044**	30	52	3000	53
89148	1062	26	484218	32	**89166**	26	53	3124	52
89146	1019	27	887588	16	**89179**	2	54	300	54

Fig. 4.3.8: 2006- Total Built Area of SFR in a Street: Las Vegas Metropolitan Area

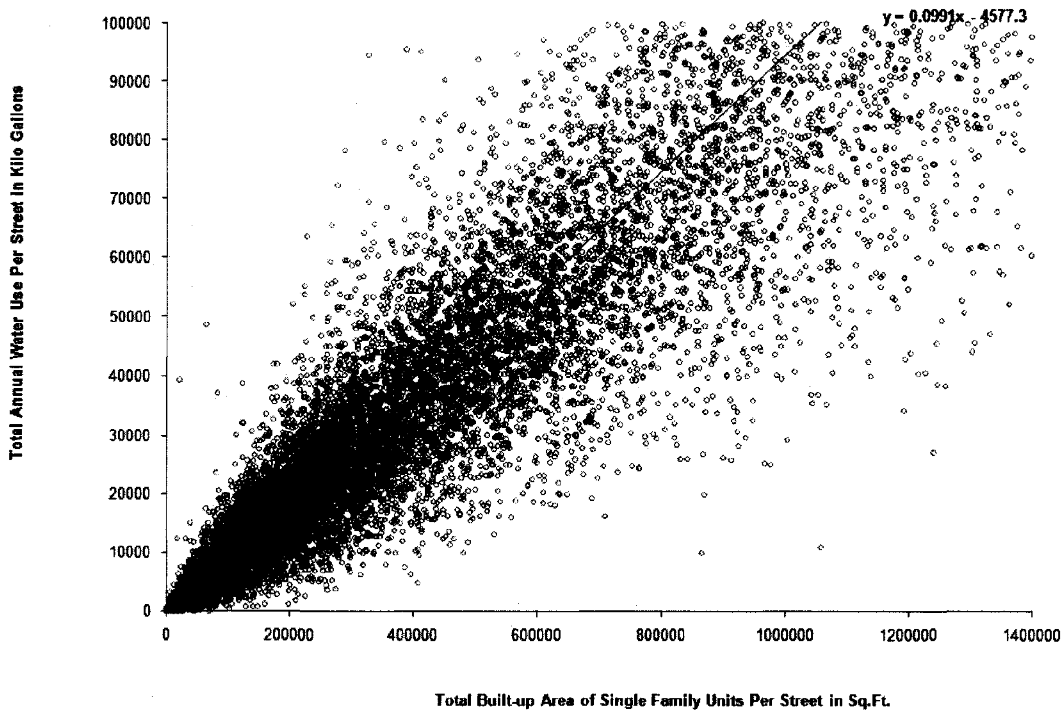


Fig. 4.3.9: 2006- Total Area of Trees & Shrubs in a Street: Las Vegas Metropolitan Area

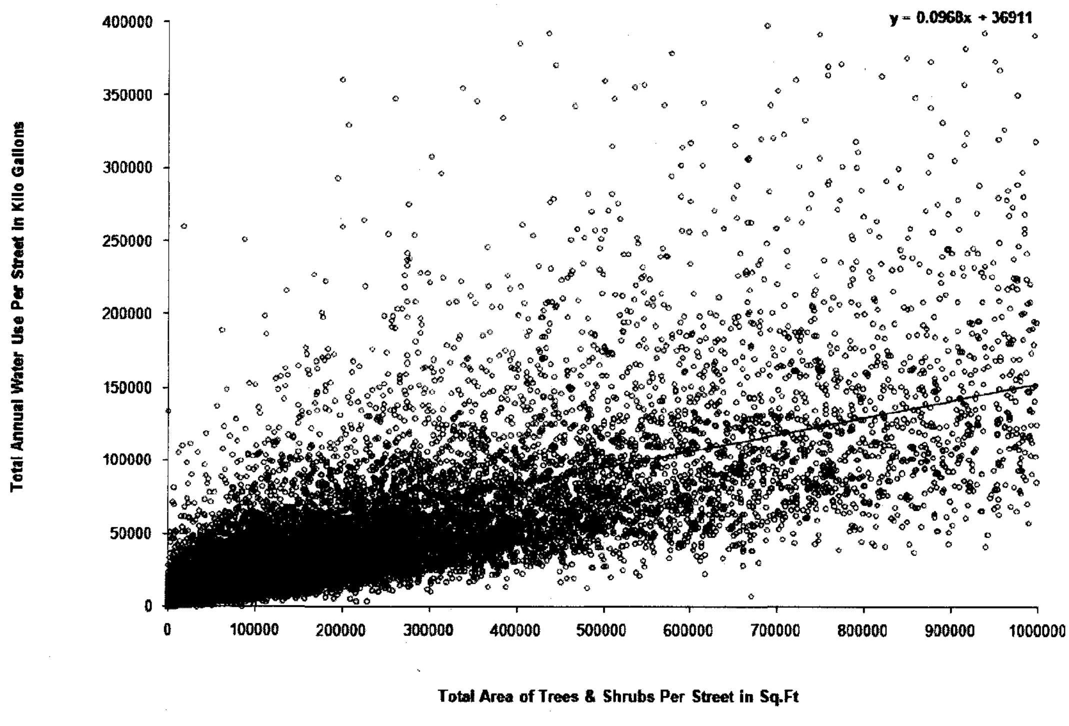
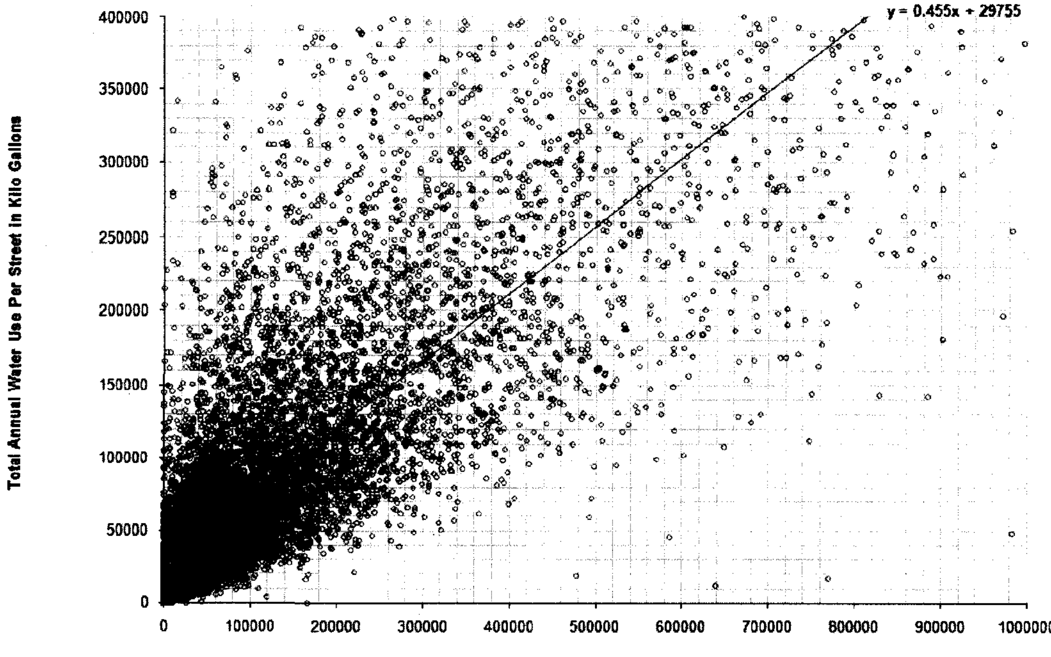
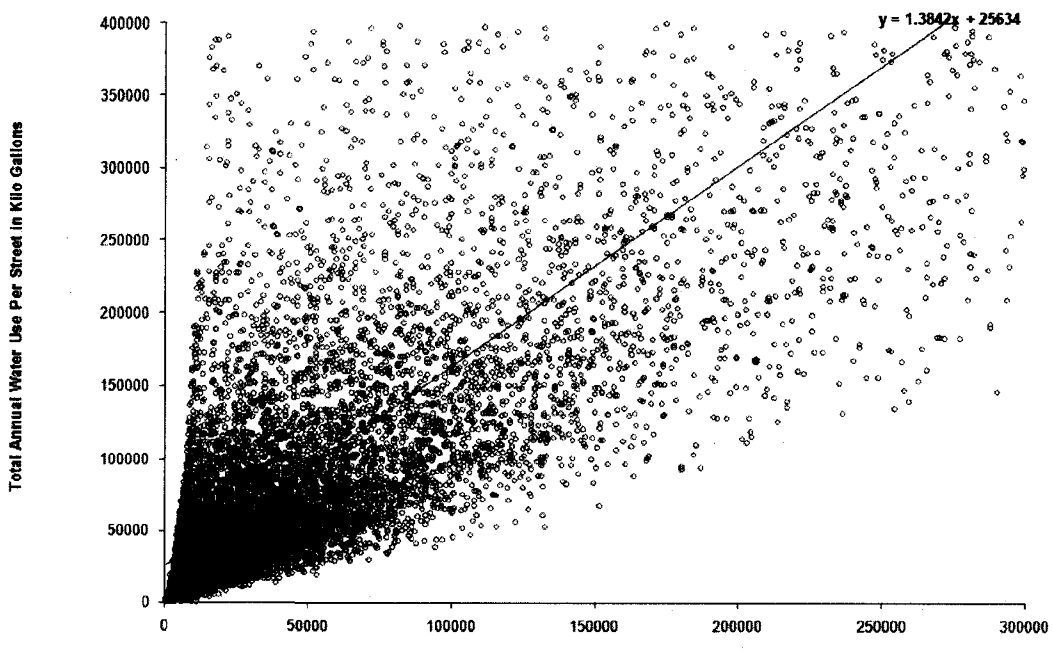


Fig. 4.3.10: 2006- Total Area of Turf in a Street: Las Vegas Metropolitan Area



Total Area of Turf Per Street in Sq.Ft.

Fig. 4.3.11: 2006- Total Pool Area of SFR in a Street: Las Vegas Metropolitan Area



Total Pool Size Per Street in Sq. Ft.

Table 4.3.9: Regression Statistics - With Water Use and Built-up/Tree/Turf/Pool Areas: LVMA

Year - 2006	Correlation	Linear Equation
B	0.970036913	Y = 0.099077B-4577.55
TR	0.937268694	Y = 0.096815TR+36913.06
TU	0.914544655	Y = 0.454969TU+29756.93
P	0.889637397	Y = 1.384278P+25574.94
TRTU	0.952051029	Y = 0.061804TR+0.188001TU+30183.36
TRTUP	0.963879031	Y = 0.044935TR+0.144558TU+0.447032P+23313.66
BTRTUP	0.992362699	Y = 0.05623B+0.017556TR+0.10707TU+0.165483P+2737

Where, Y = Total water consumption of SFR in a street (Kilo Gals), B = Total built-up area of SFR in a street (Square Feet), TR = Total Tree area of SFR in a street (Square Feet), TU = Total turf area of SFR in a street and P = Total pool area of SFR in a street (Square Feet).

The next step is the street wise analysis. In this stage, 18,858 streets from the LVMA are considered and their total annual water uses are plotted against the total built-up area. This is shown in the figure 4.3.8. Similarly, for the same number of streets, the total annual water uses are plotted against the total turf area, tree area and pool area separately, as shown in the fig. 4.3.9, fig. 4.3.10 and fig. 4.3.11 respectively. Here, the correlation between water use and the built-up area is as high as the correlation between water use and the tree area, turf area and pool area. It is also evident through the charts that, due to high correlation, the plots could easily fit in a linear equation.

In table 4.3.9, through regression analysis, the equations with water use and each one of the factor that affects the water use are derived. At the same time, a combined equation is derived through regression analysis with water use and all the factors that affects the water use. Thus for a given year, the total annual water used in kilo gallons can be determined by plugging in the square feet values of built-up area, un-built area and swimming pool area of the SFR of LVMA.

Part 4: Historic Monthly Water Use Analysis in LVVWD- Dec and Jul from 1990 to 2005

Monthly Historic Analysis – Dec 1990

It is evident through the climatic analysis that the monthly water uses of the extreme summer and winter months such as Jul and Dec respectively have close correlations with the built-up area, un-built area and pool area of the single family residences of LVVWD. Based on this finding, the street wise water use for the months Jul and Dec are analyzed below individually for each one of the factors of study for the year 1990. Fig. 4.4.1 shows the relationship between the street-wise water use and the total built-up area of SFR for the month of Dec. In other words, each one of the dots in the fig. 4.4.1 shows December's water use for a street in LVVWD in Y axis and their corresponding total built-up area in X axis for the year 1990. It is obvious from this chart that the plots can easily fit in a linear equation; thereby, by plugging in the total built-up area for a street, their respective water use for the month of Dec could be devised.

In the same way the relationship between Dec's water use and the total un-built area of SFR in a street is shown in the fig. 4.4.2. It is evident that the clustering of the streets with respect to Dec's water use and both the total built-up area and the total un-built area of the streets are quite similar, though their ranges vary due to the values of the total un-built area being higher that the values of the total built-up area of an average street in LVVWD.

Whereas, the relationship between the total areas of swimming pools in a street doesn't strictly follow the same linear pattern that the built-up areas and the un-built areas followed. This is because of the fact that though the size of the swimming pools in a street is one of the factors that determine the quantity of water consumed in a street, they are not the prime factor that influences the amount of water used in a street. In other words, the built-up area and the un-built area determine the amount of water consumed in a street more that the swimming pools of the SFR.

Fig. 4.4.1: Dec 1990- Street-wise Water Use vs. Total Built-up Area of SFR: LVVWD.

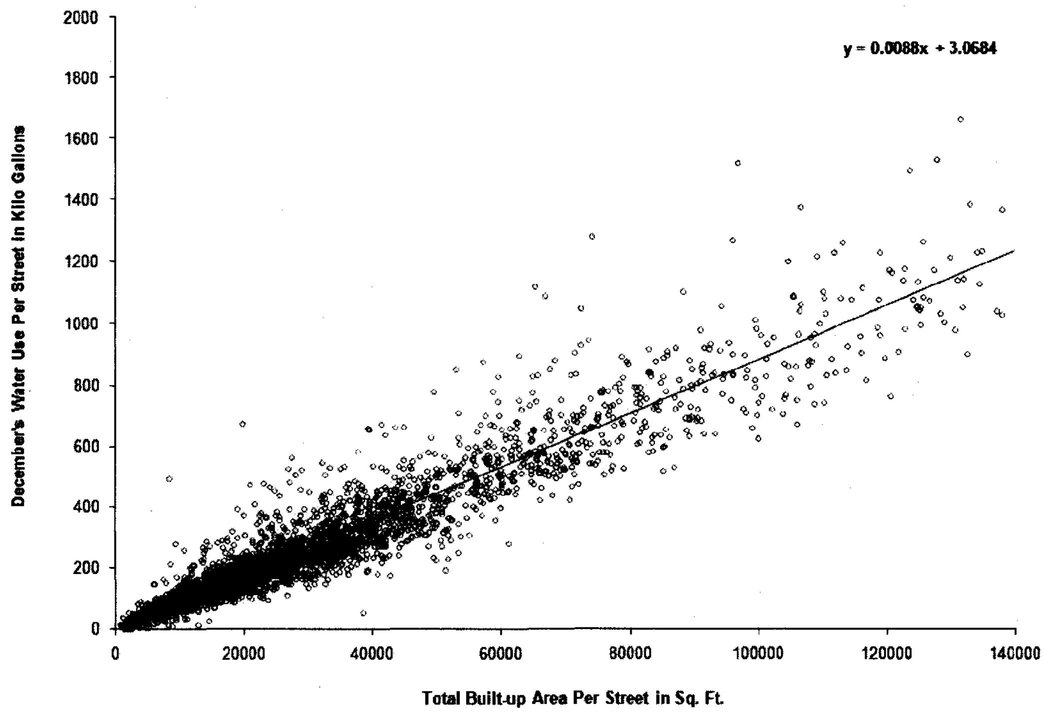


Fig. 4.4.2: Dec 1990- Street-wise Water Use vs. Total Un-built Area of SFR: LVVWD.

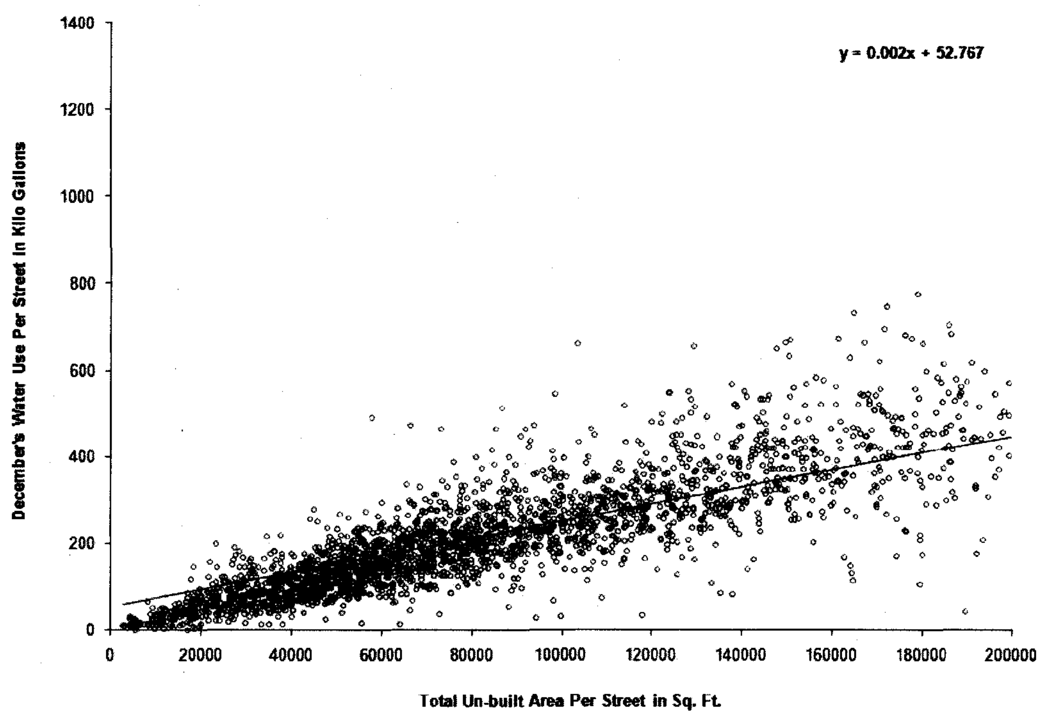


Fig. 4.4.3: Dec 1990- Street-wise Water Use vs. Total Pool Area of SFR: LVVWD.

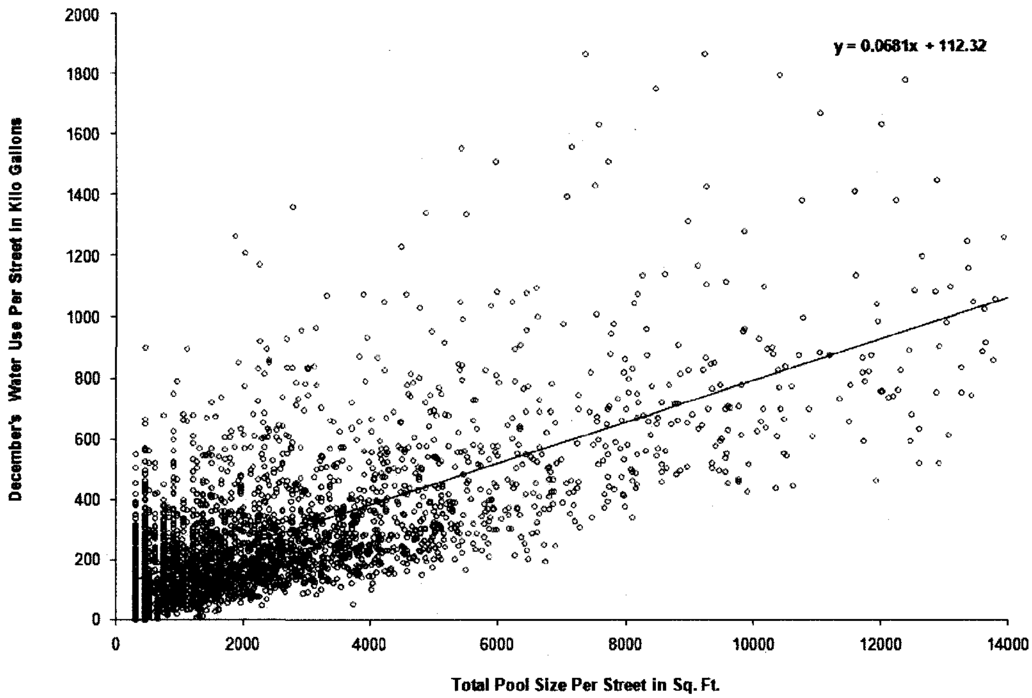


Table 4.4.1: Dec 1990 Regression Statistics - With Water Use and Built-up/Un-built/Pool Areas: LVVWD

Dec - 1990	Correlation	Linear Equation
B	0.964054766	Y = 0.008787326B+3.035125498
UB	0.931309066	Y = 0.001979UB+52.78254
P	0.780996415	Y = 0.068122P+112.2835
B, UB	0.9769795	Y = 0.005944177B+0.000743269UB+5.104845419
B, P	0.9672069	Y = 0.007963B+0.010413P+881104
UB, P	0.9417965	Y = 0.001654UB+0.018084P+41.25669
B, UB, P	0.9780609	Y = 0.005623B+0.000697UB+0.006279P+3.677975

Where, Y = Total Water Consumption of SFR in a street (Kilo Gals), B = Total Built-up Area of SFR in a street (Square Feet), UB = Total Un-built Area of SFR in a street (Square Feet), P = Total Pool Area of SFR in a street (Square Feet).

The table 4.4.1 lists the correlation coefficients and the linear equations derived from the regression analysis of each one of the factors of study for the year 1990. Along with the separate regression equation of each of the factor, the regression equations are also derived for all the four different combinations of the presence of the factors of study in a typical street of the LVVWD.

Monthly Historic Analysis – Jul 1990

Finding the correlation between the monthly water use of Jul 1990 and the factors of study such as the built-up area, un-built area and the pool area of SFR by means of 'X-Y Scatter' chart are done in the same way as mentioned in the beginning of this section. Similarly the regression analyses for the month of Jul are done in the same manner as explained above for the month of Dec for the same year.

It is within the scope of this thesis to run similar statistic analysis for the years 1995, 2000, 2005 and 2006.

Fig. 4.4.4: Jul 1990- Street-wise Water Use vs. Total Built-up Area of SFR: LVVWD.

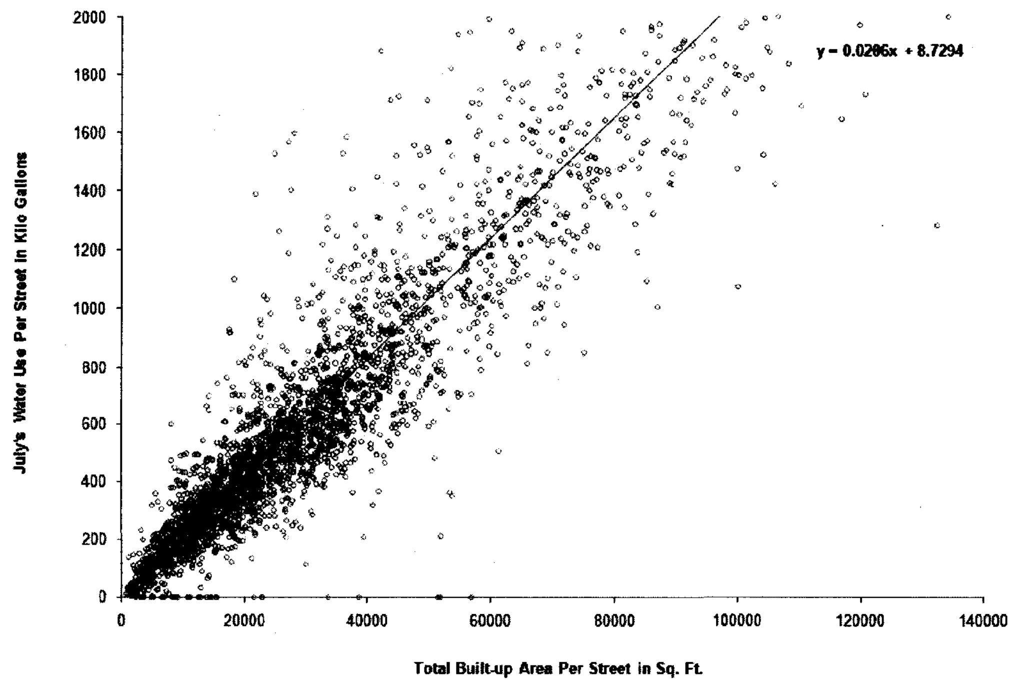


Fig. 4.4.5: Jul 1990- Street-wise Water Use vs. Total Un-built Area of SFR: LVVWD.

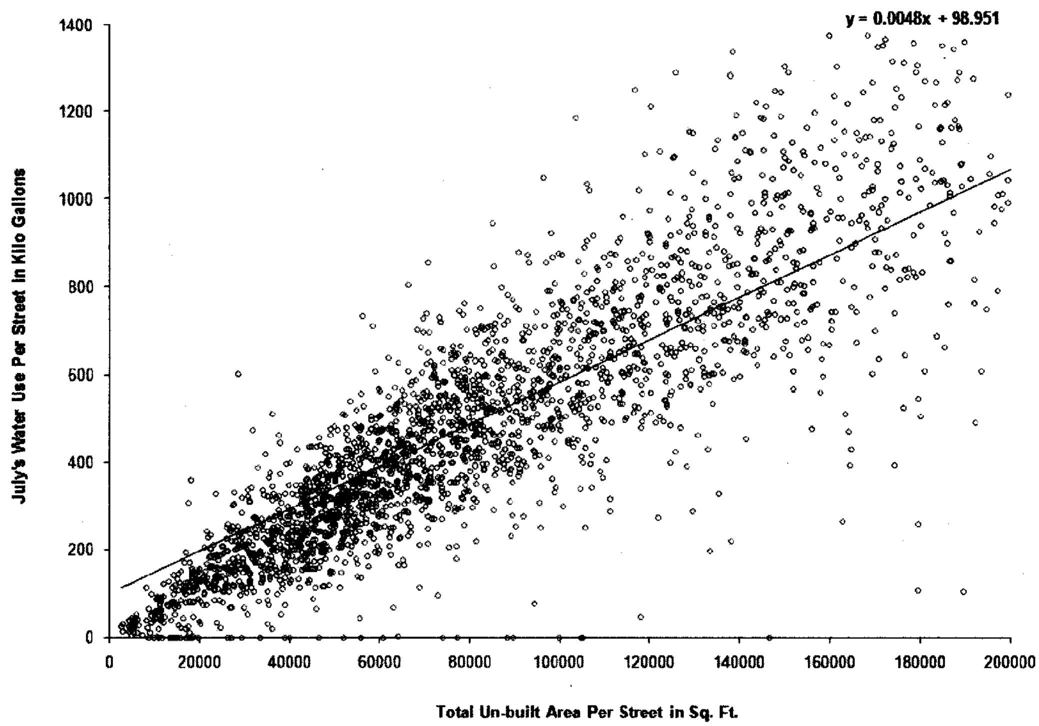


Fig. 4.4.6: Jul 1990- Street-wise Water Use vs. Total Pool Area of SFR: LVVWD.

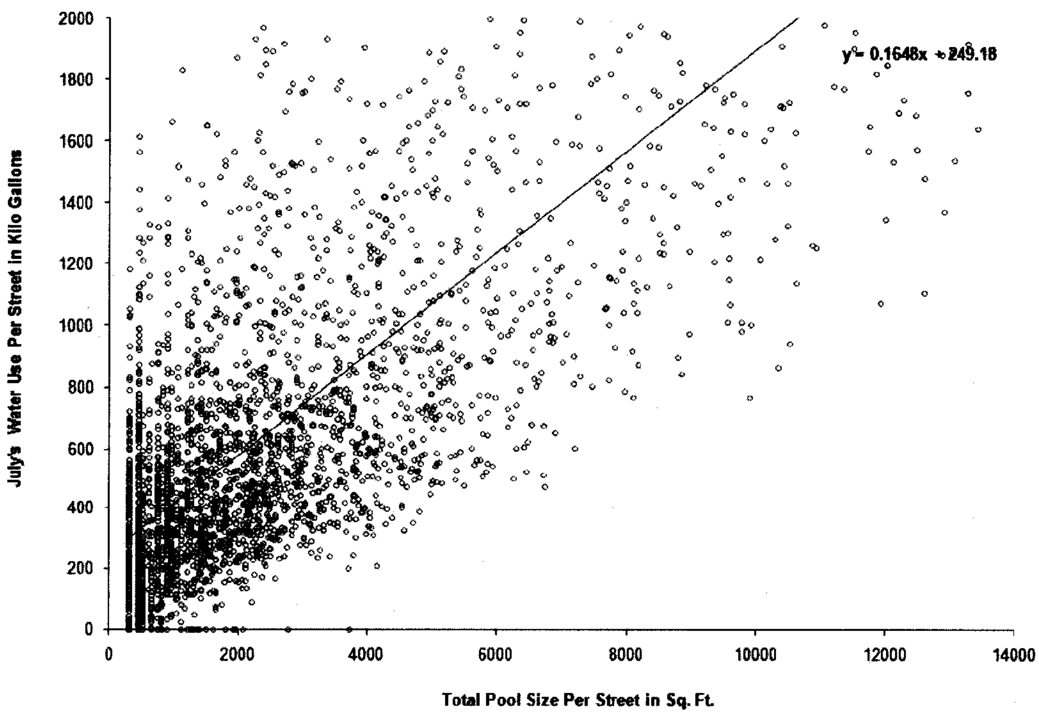


Table 4.4.2: Jul 1990 Regression Statistics - With Water Use and Built-up/Un-built/Pool Areas.

Jul - 1990	Correlation	Linear Equation
B	0.944765	Y = 0.020601266B+8.686552293
UB	0.950682	Y = 0.004832UB+99.01053
P	0.789784	Y = 0.164801P+249.1198
B, UB	0.97457	Y = 0.010328747B+0.002685491UB+16.16461357
B, P	0.95159	Y = 0.017724B+0.036356P+1.166247
UB, P	0.95981	Y = 0.004101UB+0.040752P+73.03737
B, UB, P	0.97676	Y = 0.009237B+0.002529UB+0.021361P+11.3105

Where, Y = Total Water Consumption of SFR in a street (Kilo Gals), B = Total Built-up Area of SFR in a street (Square Feet), UB = Total Un-built Area of SFR in a street (Square Feet), P = Total Pool Area of SFR in a street (Square Feet).

Monthly Historic Analysis – Dec 1995

Fig. 4.4.7: Dec 1995- Street-wise Water Use vs. Total Built-up Area of SFR: LVVWD.

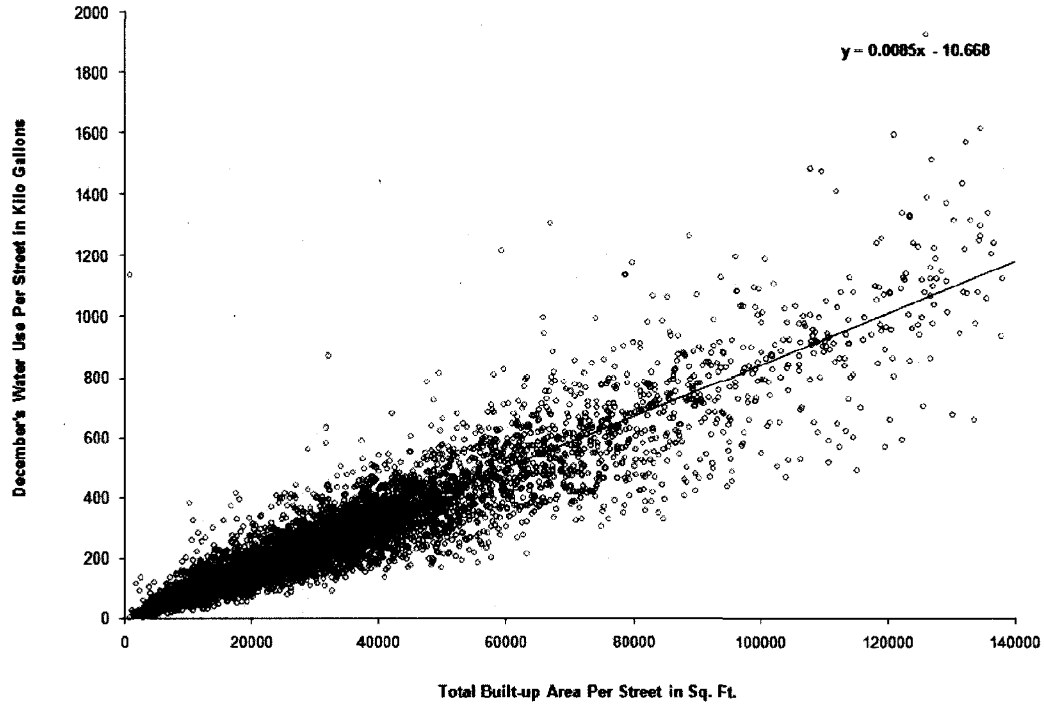


Fig. 4.4.8: Dec 1995- Street-wise Water Use vs. Total Un-built Area of SFR: LVVWD.

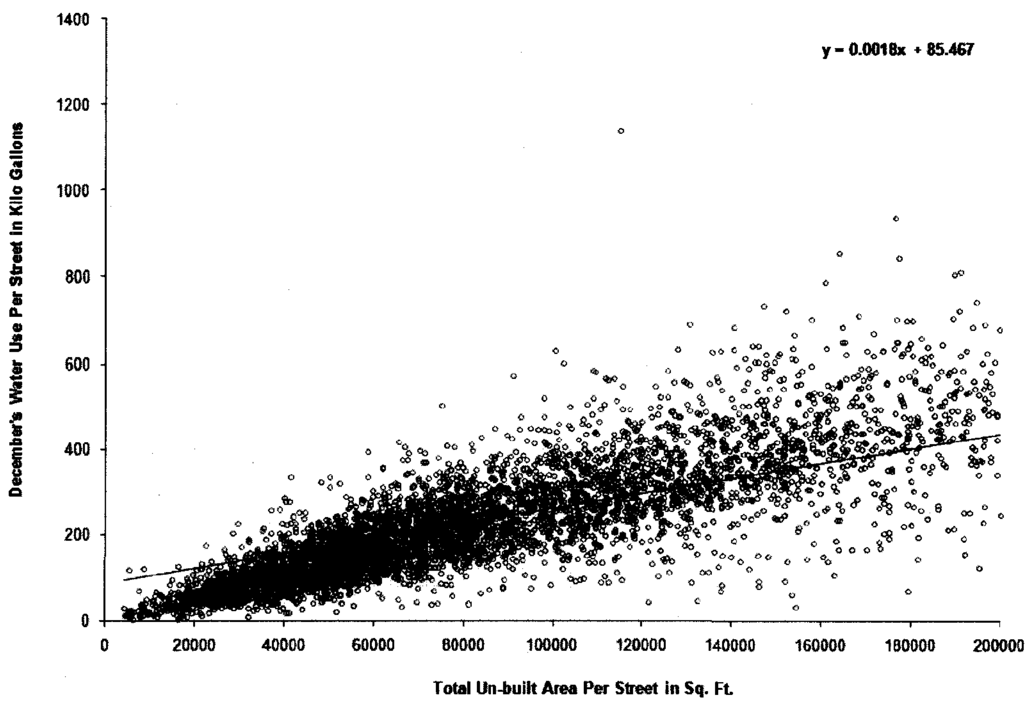


Fig. 4.4.9: Dec 1995- Street-wise Water Use vs. Total Pool Area of SFR: LVVWD.

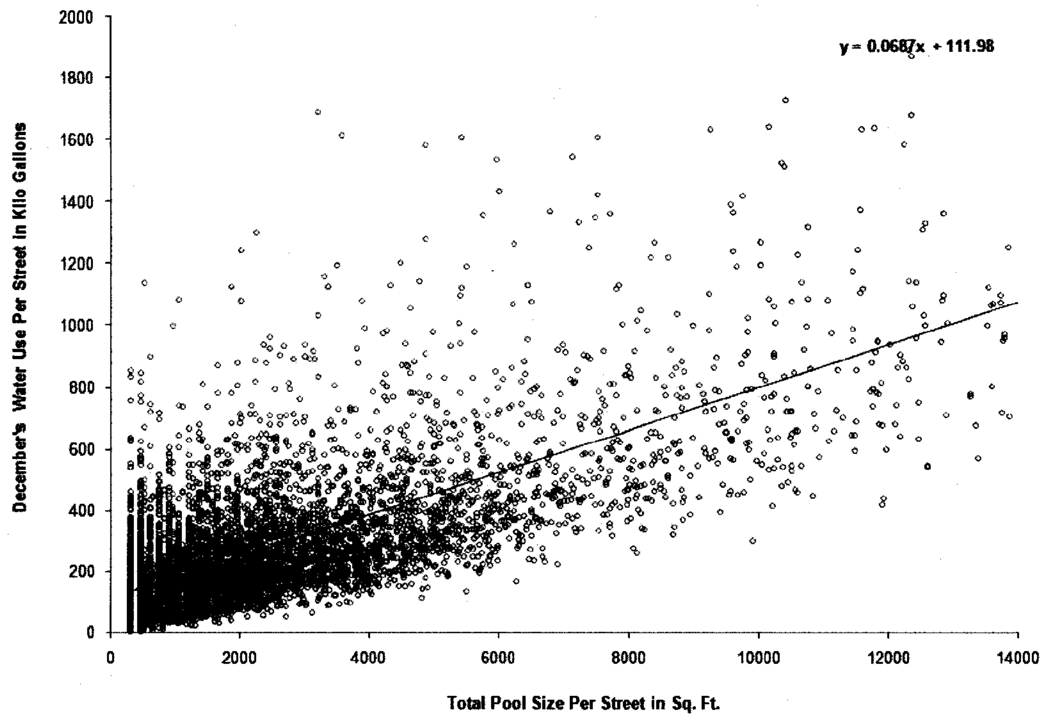


Table 4.4.3: Dec 1995 Regression Statistics - With Water Use and Built-up/Un-built/Pooi Areas.

Dec - 1995	Correlation	Linear Equation
B	0.948984	Y = 0.008526B-10.741
UB	0.897445	Y = 0.001756UB+85.44386
P	0.79138	Y = .068726P+111.9148
B, UB	0.968572	Y = 0.005911B+0.000684UB-0.47941
B, P	0.956026	Y = 0.007336B+0.015253P-10.5861
UB, P	0.914745	Y = 0.001361UB+0.023311P+67.85535
B, UB, P	0.969998	Y = 0.005591B+0.000616UB+0.007395P-1.4145

Where, Y = Total Water Consumption of SFR in a street (Kilo Gals), B = Total Built-up Area of SFR in a street (Square Feet), UB = Total Un-built Area of SFR in a street (Square Feet), P = Total Pool Area of SFR in a street (Square Feet).

Fig. 4.4.10: Jul 1995- Street-wise Water Use vs. Total Built-up Area of SFR: LVVWD.

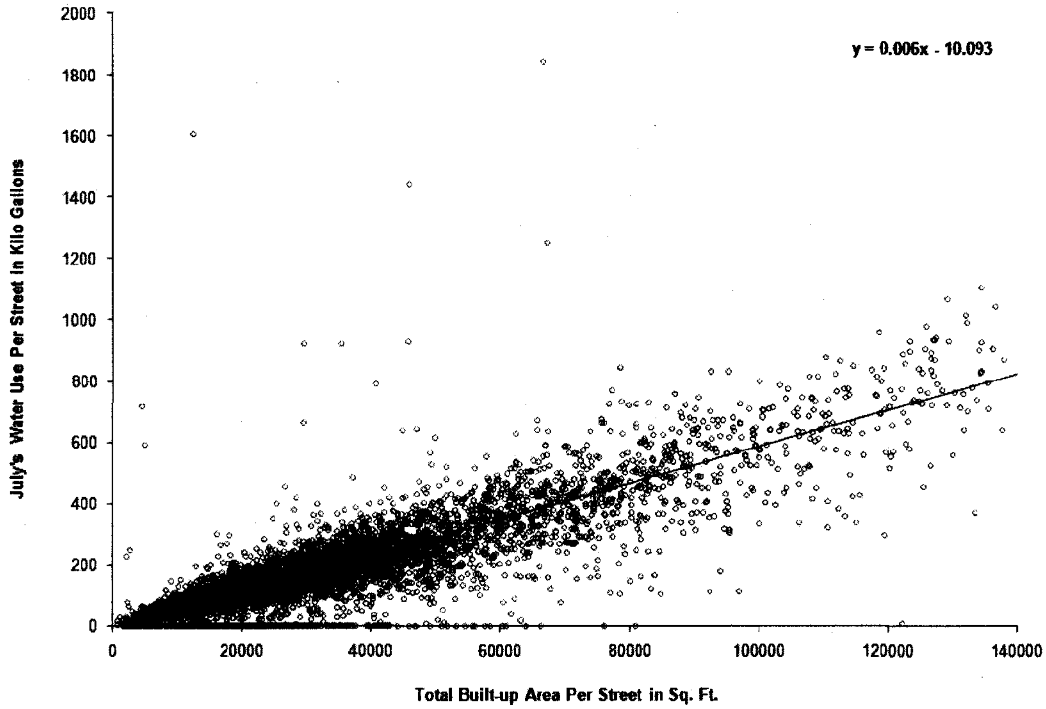


Fig. 4.4.11: Jul 1995- Street-wise Water Use vs. Total Un-built Area of SFR: LVVWD.

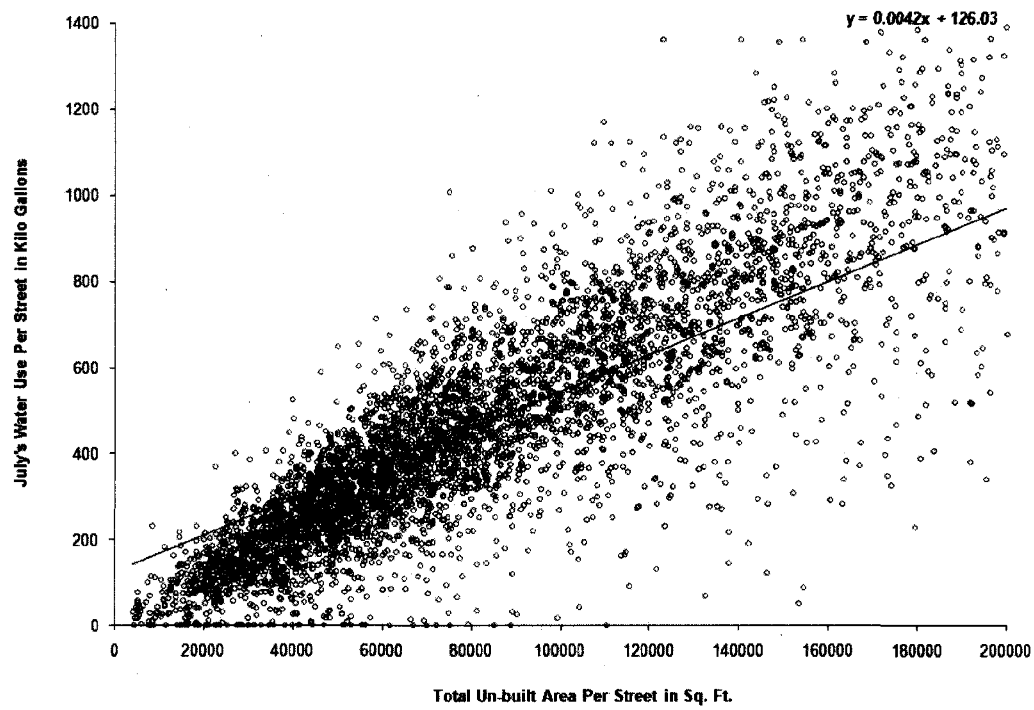


Fig. 4.4.12: Jul 1995- Street-wise Water Use vs. Total Pool Area of SFR: LVVWD.

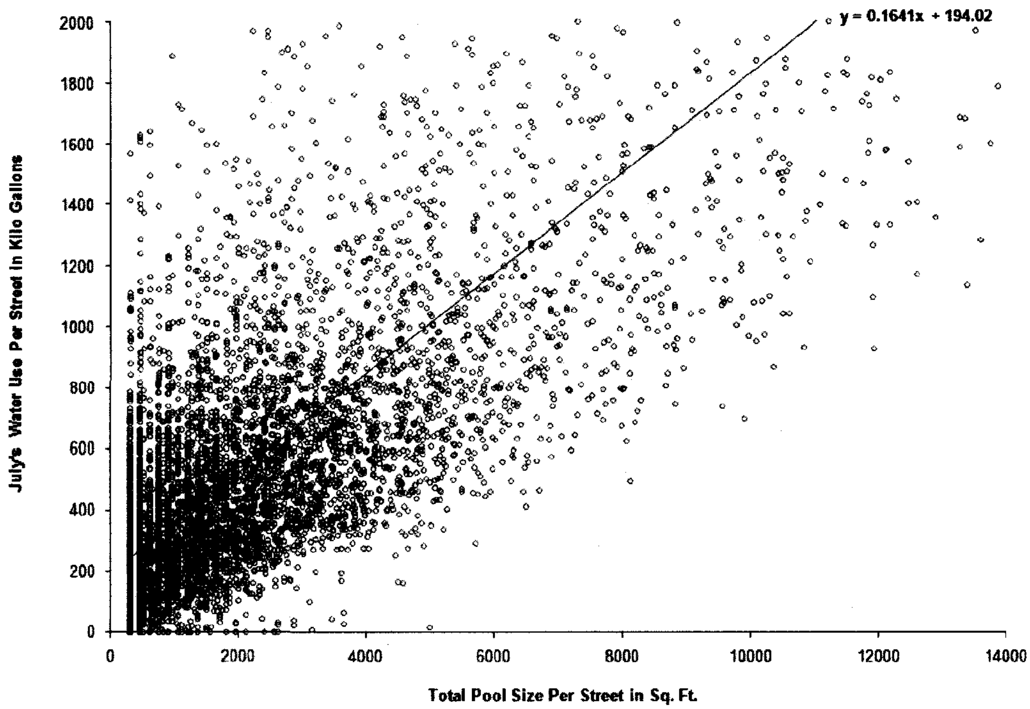


Table 4.4.4: Jul 1995 Regression Statistics - With Water Use and Built-up/Un-built/Pool Areas.

Jul - 1995	Correlation	Linear Equation
B	0.909008	Y = 0.018967B-45.2678
UB	0.930669	Y = 0.004228UB+125.9841
P	0.813846	Y = .164149P+193.8729
B, UB	0.96165	Y = 0.009123B+0.002574UB-6.63897
B, P	0.929833	Y = 0.014284B+0.060028P-44.6582
UB, P	0.946653	Y = 0.003331UB+0.052972P+86.01544
B, UB, P	0.966259	Y = 0.007793B+0.002294UB+0.03079P-10.5321

Where, Y = Total Water Consumption of SFR in a street (Kilo Gals), B = Total Built-up Area of SFR in a street (Square Feet), UB = Total Un-built Area of SFR in a street (Square Feet), P = Total Pool Area of SFR in a street (Square Feet).

Fig. 4.4.13: Dec 2000- Street-wise Water Use vs. Total Built-up Area of SFR: LVVWD.

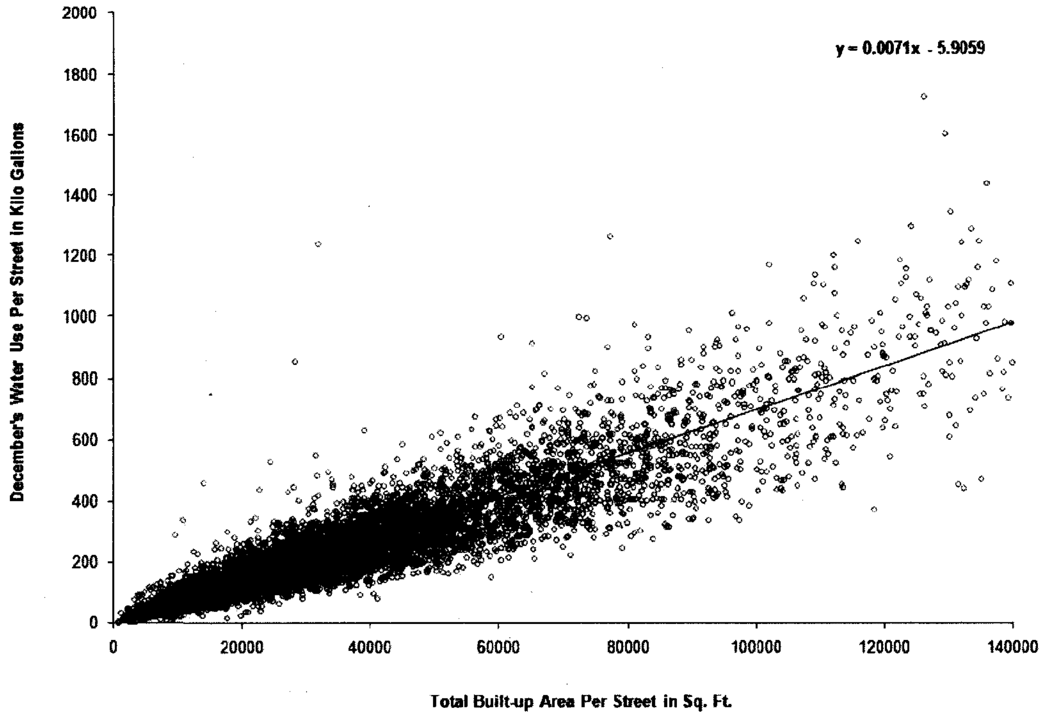


Fig. 4.4.14: Dec 2000- Street-wise Water Use vs. Total Un-built Area of SFR: LVVWD

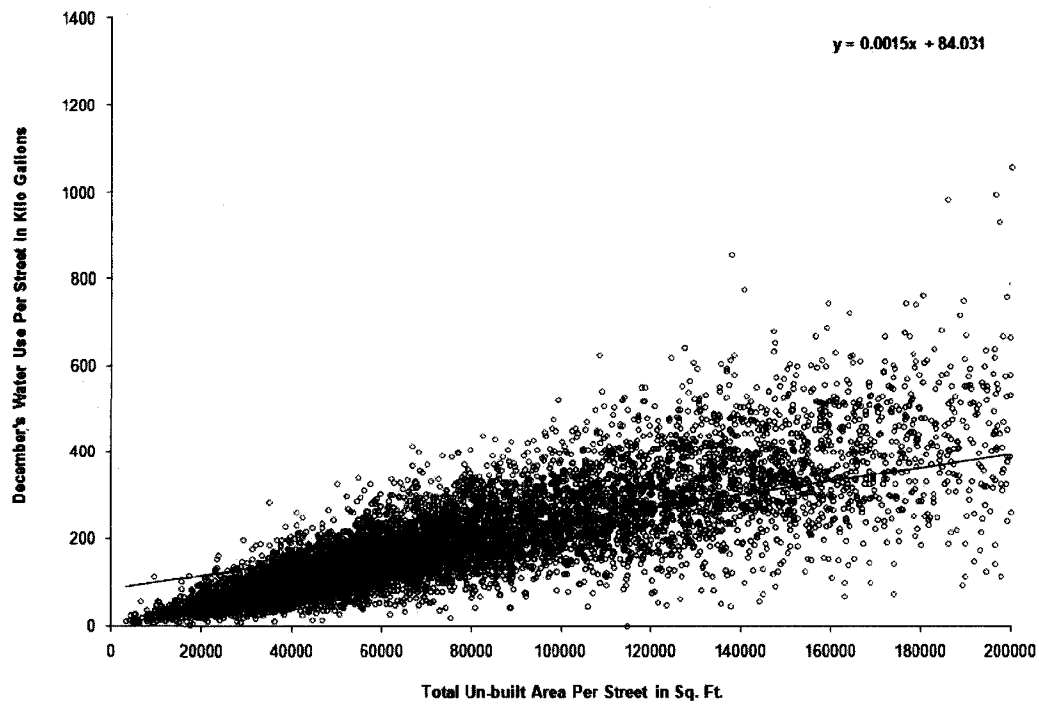


Fig. 4.4.15: Dec 2000- Street-wise Water Use vs. Total Pool Area of SFR: LVVWD.

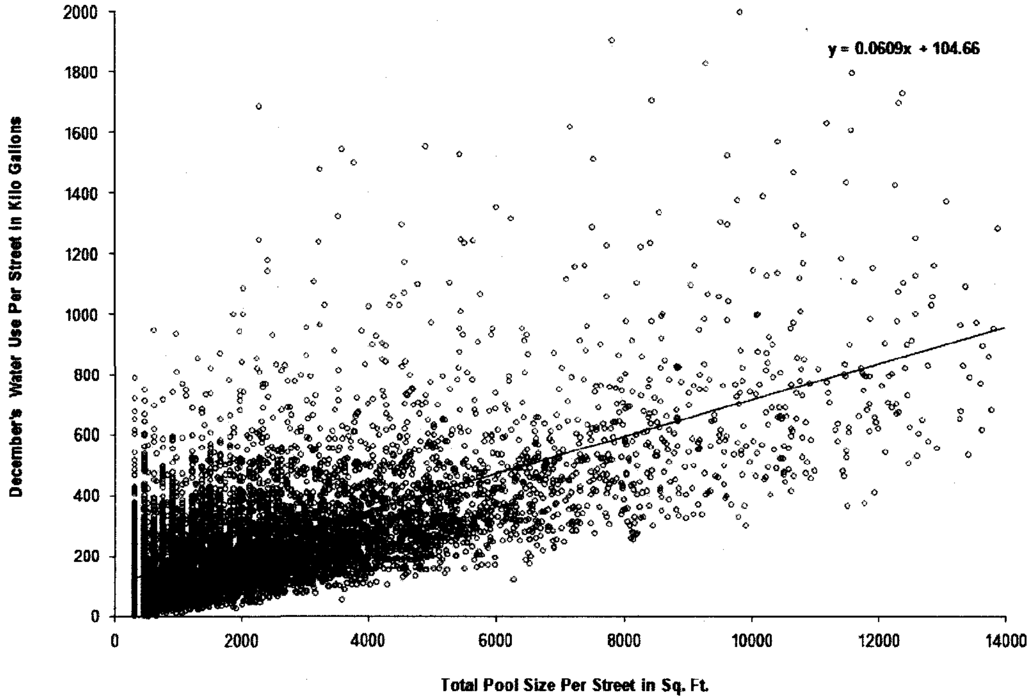


Table 4.4.5: Dec 2000 Regression Statistics - With Water Use and Built-up/Un-built/Pool Areas.

Dec - 2000	Correlation	Linear Equation
B	0.938515	Y = 0.007055B-5.89927
UB	0.873187	Y = 0.00154UB+84.04734
P	0.772518	Y = 0.060862P+104.6715
B, UB	0.961778	Y = 0.004989B+0.00061UB+0.9618
B, P	0.946922	Y = 0.006039B+0.014555P-5.92848
UB, P	0.892007	Y = 0.00118UB+0.02155P+68.65106
B, UB, P	0.962889	Y = 0.004779B+0.000552UB+0.005823P+0.297291

Where, Y = Total Water Consumption of SFR in a street (Kilo Gals), B = Total Built-up Area of SFR in a street (Square Feet), UB = Total Un-built Area of SFR in a street (Square Feet), P = Total Pool Area of SFR in a street (Square Feet).

Fig. 4.4.16: Jul 2000- Street-wise Water Use vs. Total Built-up Area of SFR: LVVWD.

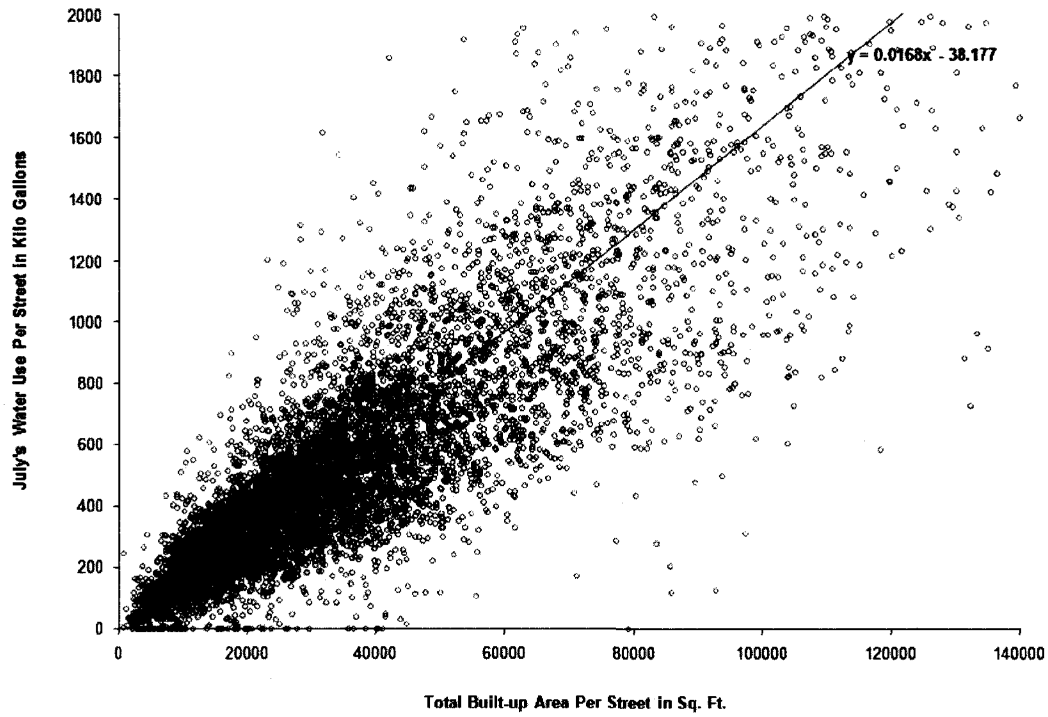


Fig. 4.4.17: Jul 2000- Street-wise Water Use vs. Total Un-built Area of SFR: LVVWD

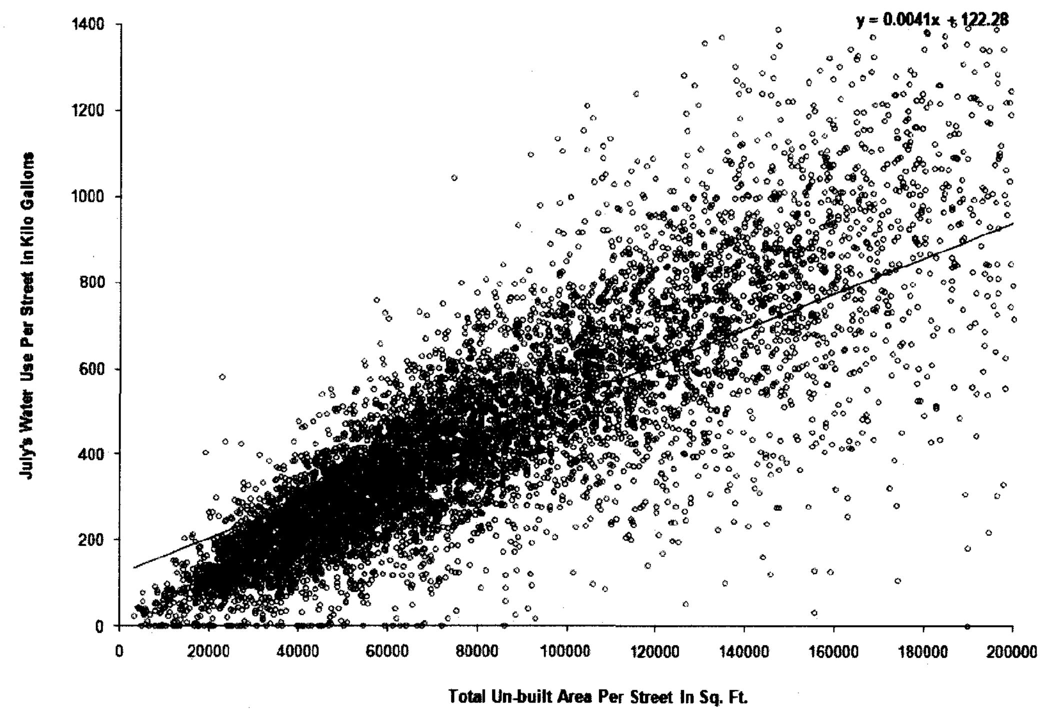


Fig. 4.4.18: Jul 2000- Street-wise Water Use vs. Total Pool Area of SFR: LVVWD.

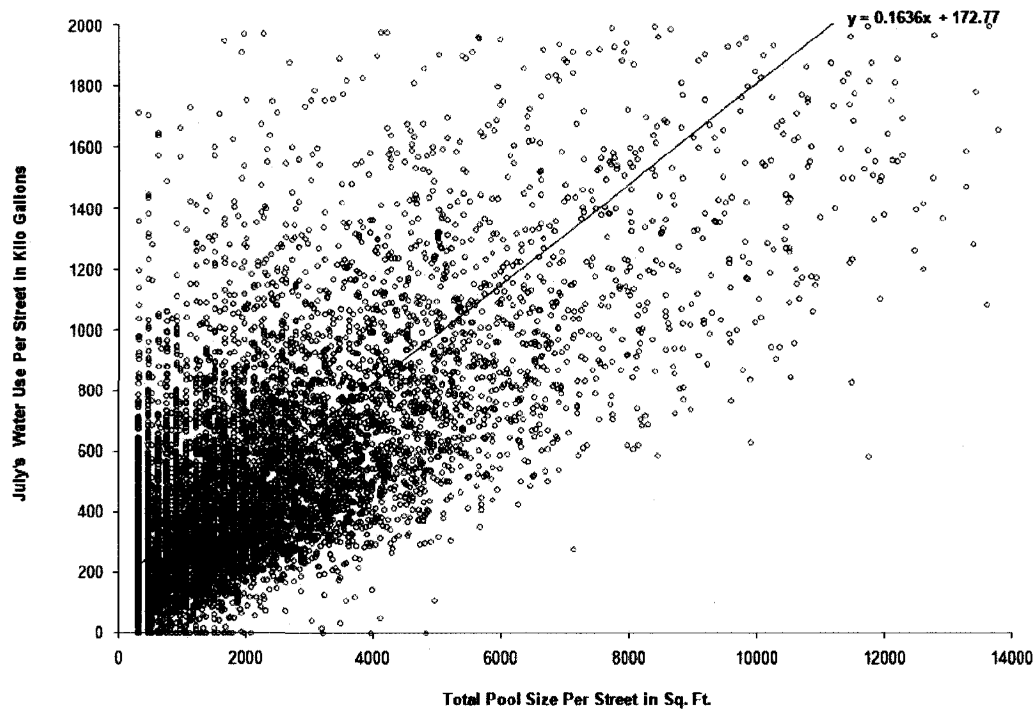


Table 4.4.6: Jul 2000 Regression Statistics - with Water Use and Built-up/Un-built/Pool Areas.

Jul - 2000	Correlation	Linear Equation
B	0.878714	Y = 0.016778B-38.1573
UB	0.915071	Y = 0.004099UB+122.3177
P	0.817587	Y = 0.163607P+172.7956
B, UB	0.948607	Y = 0.007857B+0.002635UB-8.53713
B, P	0.915305	Y = 0.011527B+0.075221P-38.3082
UB, P	0.937328	Y = 0.003082UB+0.060973P+78.75505
B, UB, P	0.956752	Y = 0.006421B+0.002238UB+0.039844P-13.0837

Where, Y = Total Water Consumption of SFR in a street (Kilo Gals), B = Total Built-up Area of SFR in a street (Square Feet), UB = Total Un-built Area of SFR in a street (Square Feet), P = Total Pool Area of SFR in a street (Square Feet).

Monthly Historic Analysis – Dec 2005

Fig. 4.4.19: Dec 2005- Street-wise Water Use vs. Total Built-up Area of SFR: LVVWD.

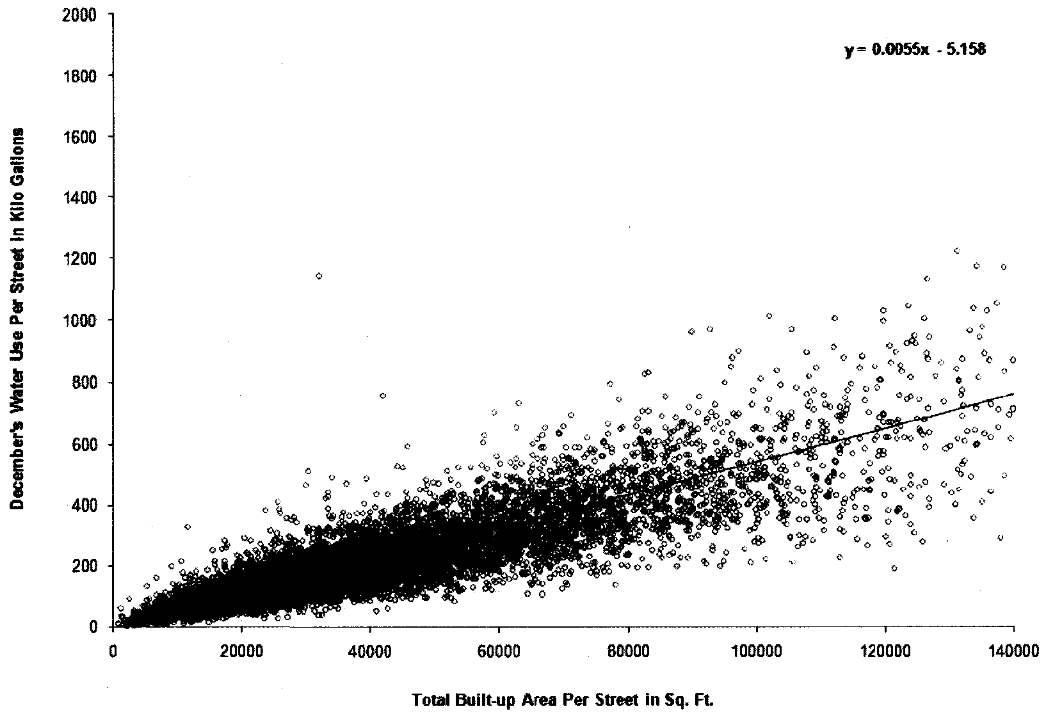


Fig. 4.4.20: Dec 2005- Street-wise Water Use vs. Total Un-built Area of SFR: LVVWD.

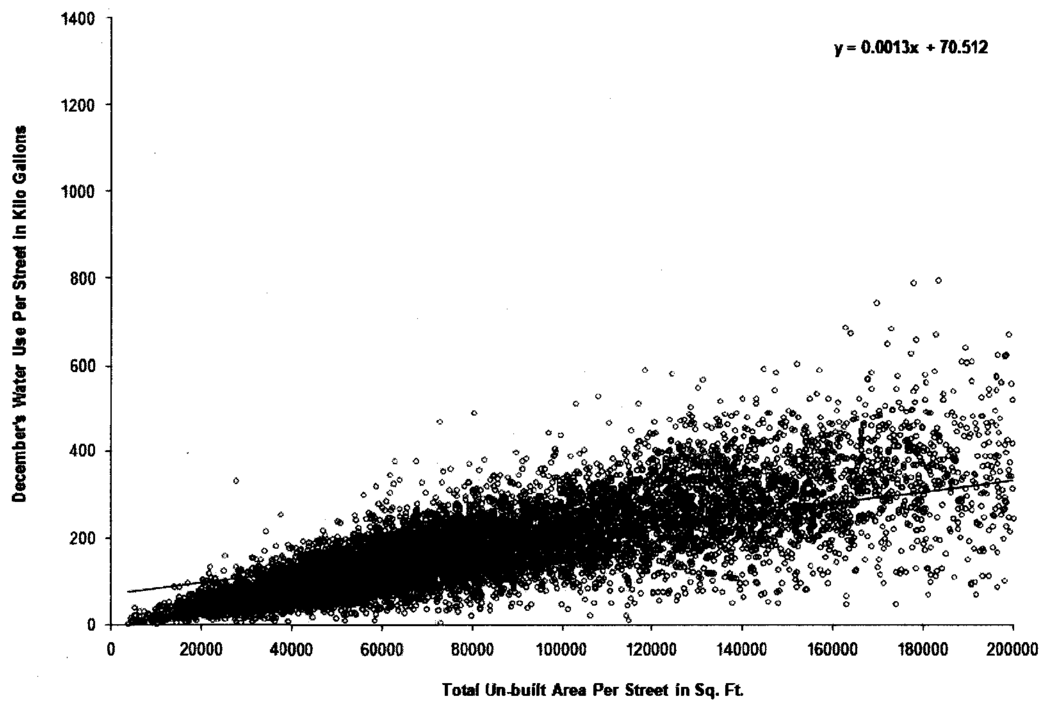


Fig. 4.4.21: Dec 2005- Street-wise Water Use vs. Total Pool Area of SFR: LVVWD.

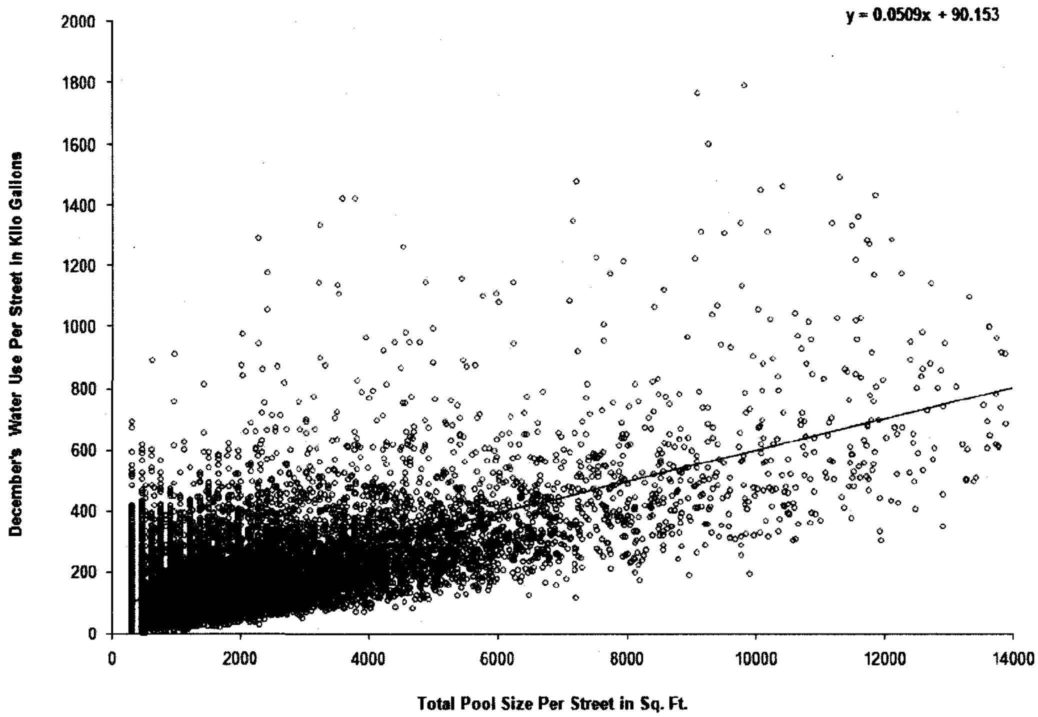


Table 4.4.7: Dec 2005 Regression Statistics - with Water Use and Built-up/Un-built/Pool Areas.

Dec - 2005	Correlation	Linear Equation
B	0.916042	Y = 0.005484B-5.16745
UB	0.858288	Y = 0.001302UB+70.50555
P	0.762312	Y = 0.050942P+90.10701
B, UB	0.948955	Y = 0.00374B+0.00058UB-0.5517
B, P	0.929733	Y = 0.004525B+0.015082P-4.58177
UB, P	0.878231	Y = 0.000988UB+0.018584P+58.75886
B, UB, P	0.950531	Y = 0.003562B+0.000517UB+0.005794P-0.83125

Where, Y = Total Water Consumption of SFR in a street (Kilo Gals), B = Total Built-up Area of SFR in a street (Square Feet), UB = Total Un-built Area of SFR in a street (Square Feet), P = Total Pool Area of SFR in a street (Square Feet).

Jul 2005

Fig. 4.4.22: Jul 2005- Street-wise Water Use vs. Total Built-up Area of SFR: LVVWD.

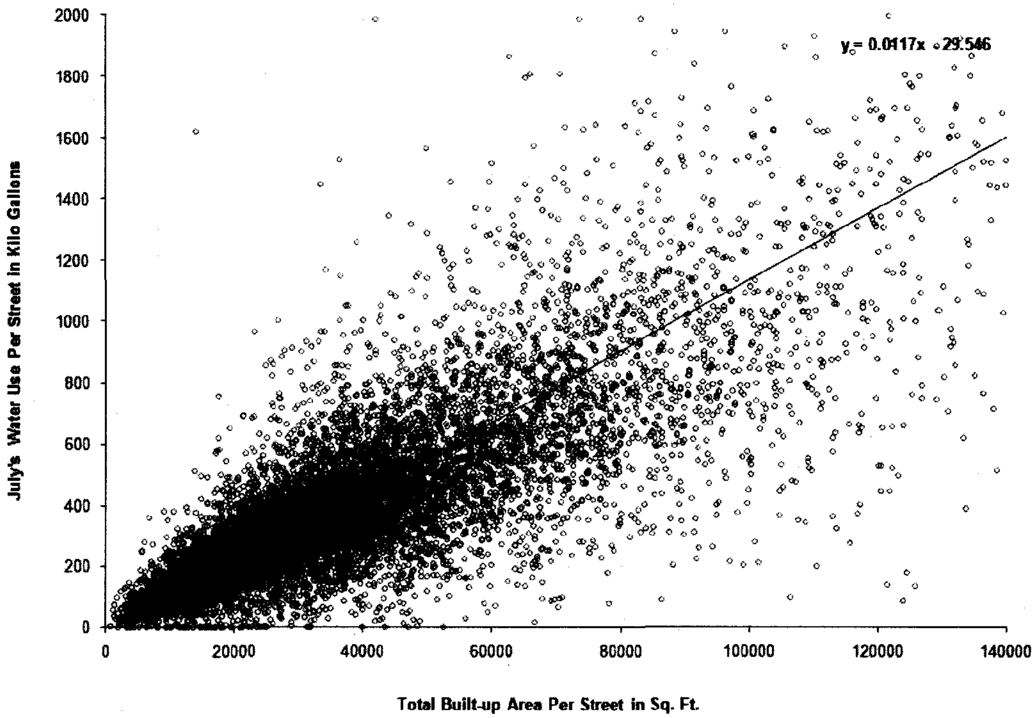


Fig. 4.4.23: Jul 2005- Street-wise Water Use vs. Total Un-built Area of SFR: LVVWD.

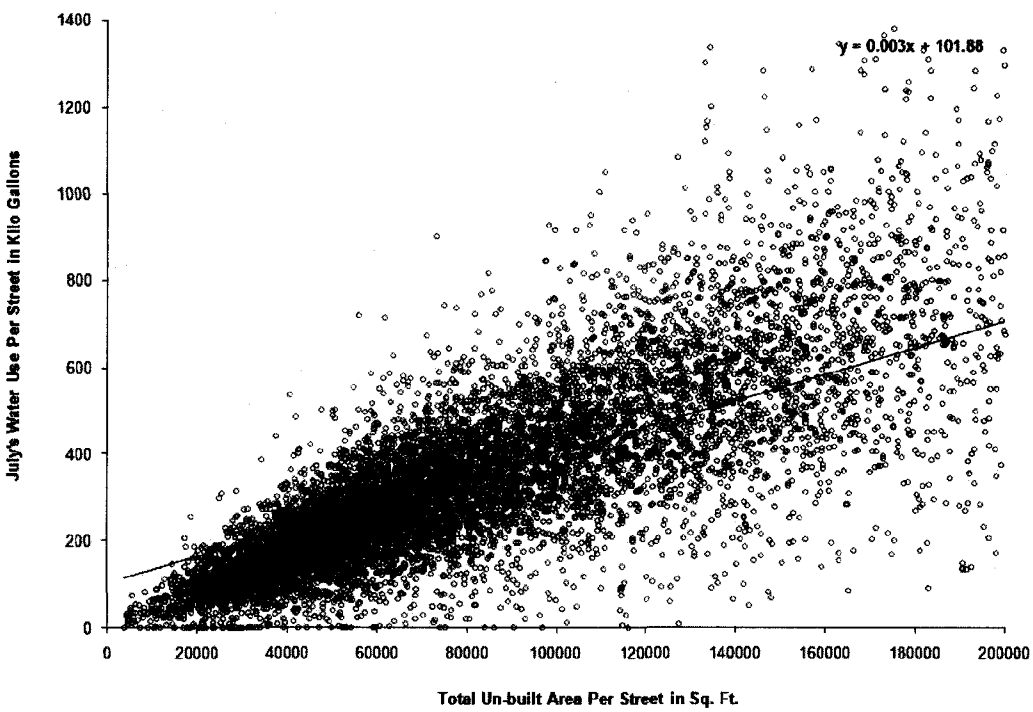


Fig. 4.4.24: Jul 2005- Street-wise Water Use vs. Total Pool Area of SFR: LVVWD.

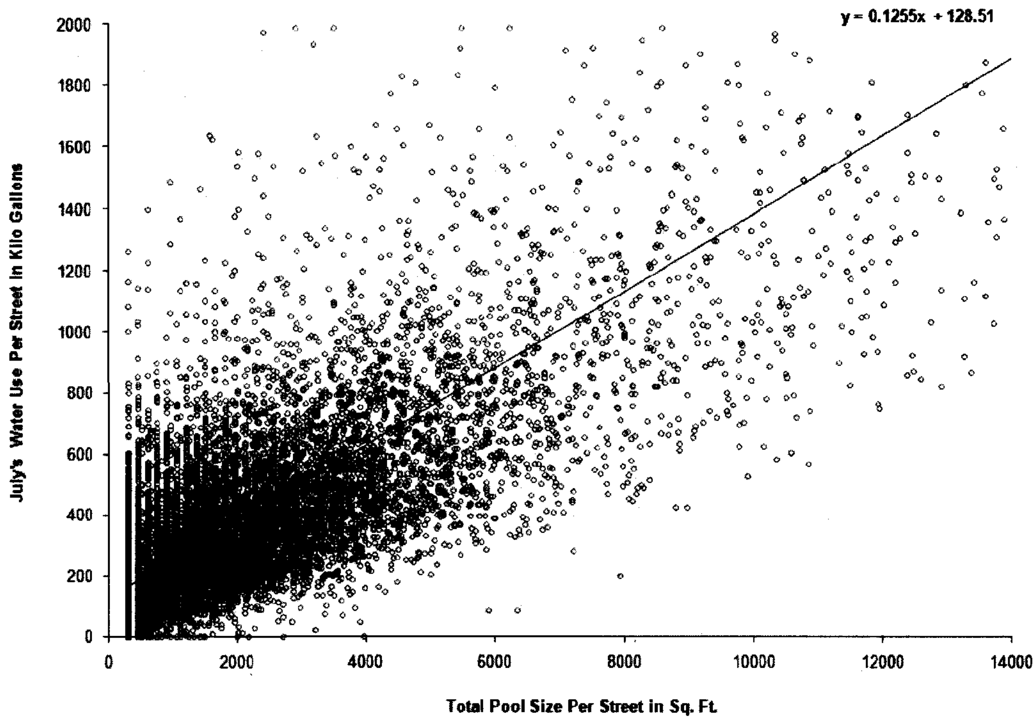


Table 4.4.8: Jul 2005 Regression Statistics - with Water Use and Built-up/Un-built/Pool Areas.

Jul - 2005	Correlation	Linear Equation
B	0.849989	Y = 0.011668B-29.5971
UB	0.86893	Y = 0.003022UB+101.8879
P	0.81922	Y = 0.125493P+128.4576
B, UB	0.916189	Y = 0.006153B+0.001835UB-14.9999
B, P	0.903533	Y = 0.007429B+0.066615P-27.0102
UB, P	0.906766	Y = 0.002021UB+0.059347P+64.3755
B, UB, P	0.932287	Y = 0.004866B+0.001376UB+0.041877P-17.0203

Where, Y = Total Water Consumption of SFR in a street (Kilo Gals), B = Total Built-up Area of SFR in a street (Square Feet), UB = Total Un-built Area of SFR in a street (Square Feet), P = Total Pool Area of SFR in a street (Square Feet).

Part 5: Monthly Water Use Analysis in LVMA- Dec and Jul 2006

Dec 2006

Fig. 4.5.1: Dec 2006- Street-wise Water Use vs. Total Built-up Area of SFR: LVVWD.

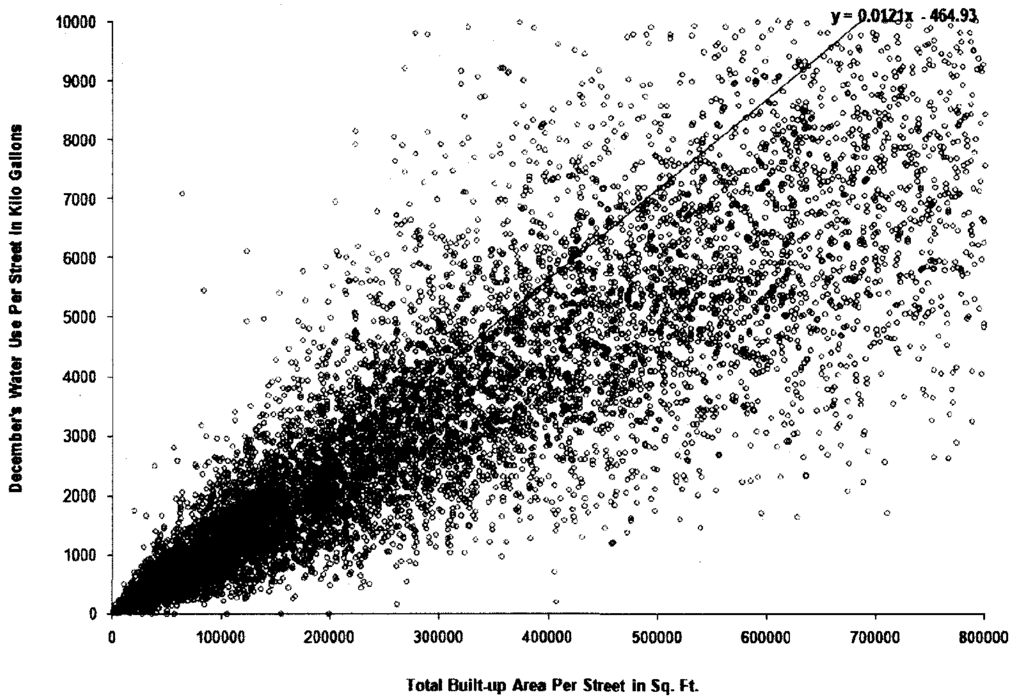


Fig. 4.5.2: Dec 2006- Street-wise Water Use vs. Total Trees & Shrubs Area of SFR: LVVWD.

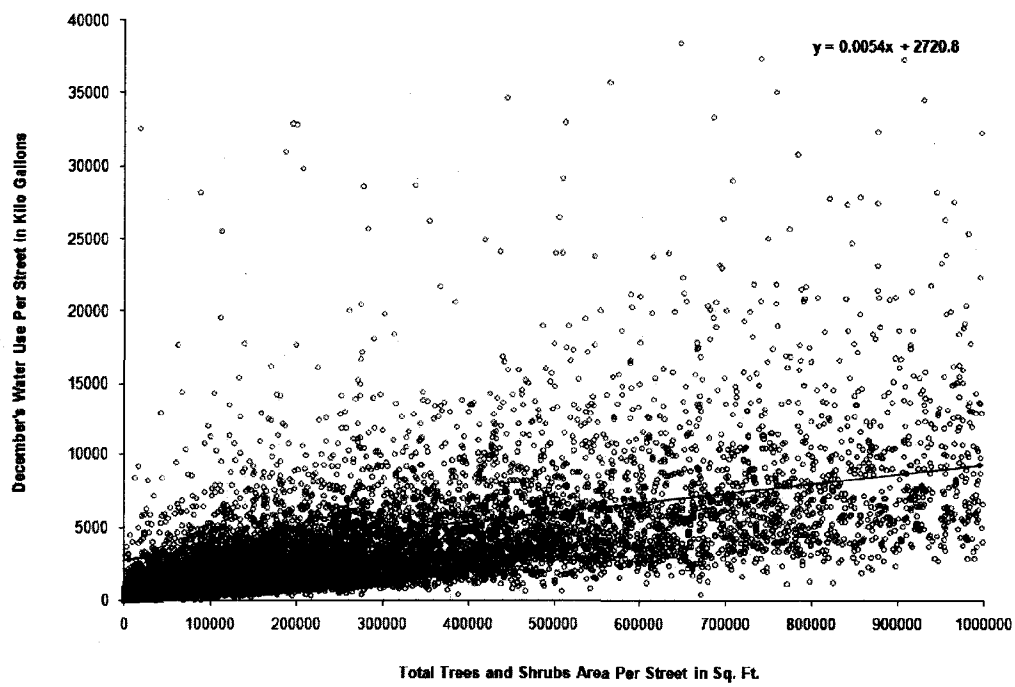
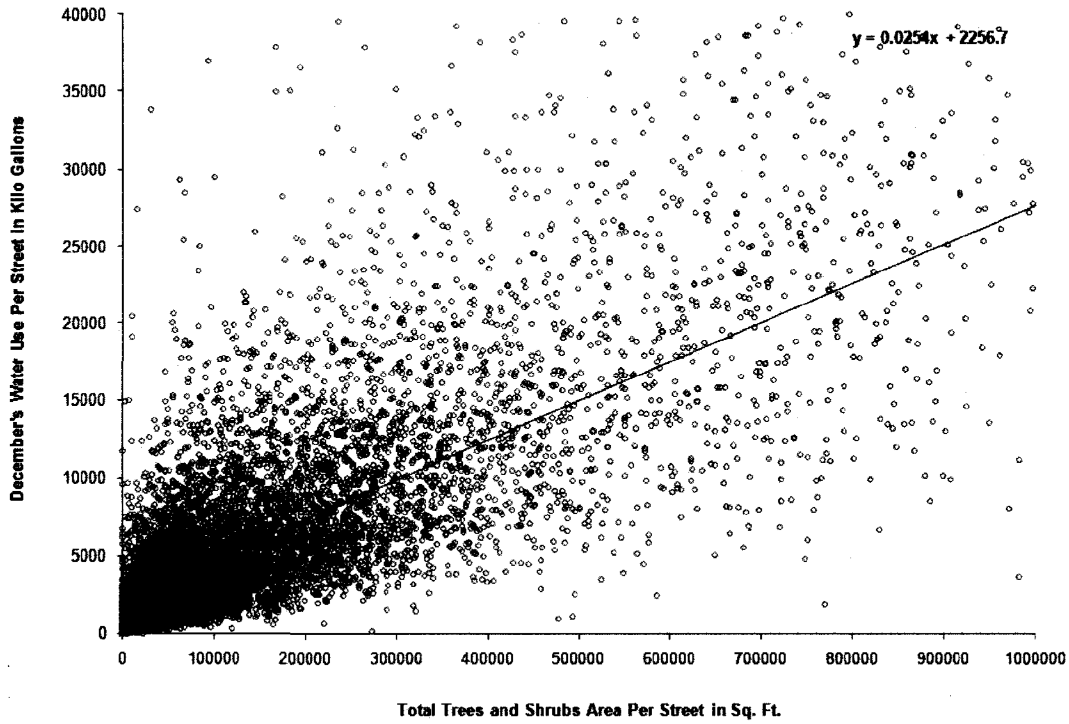


Fig. 4.5.3: Dec 2006- Street-wise Water Use vs. Total Turf Area of SFR: LVVWD.



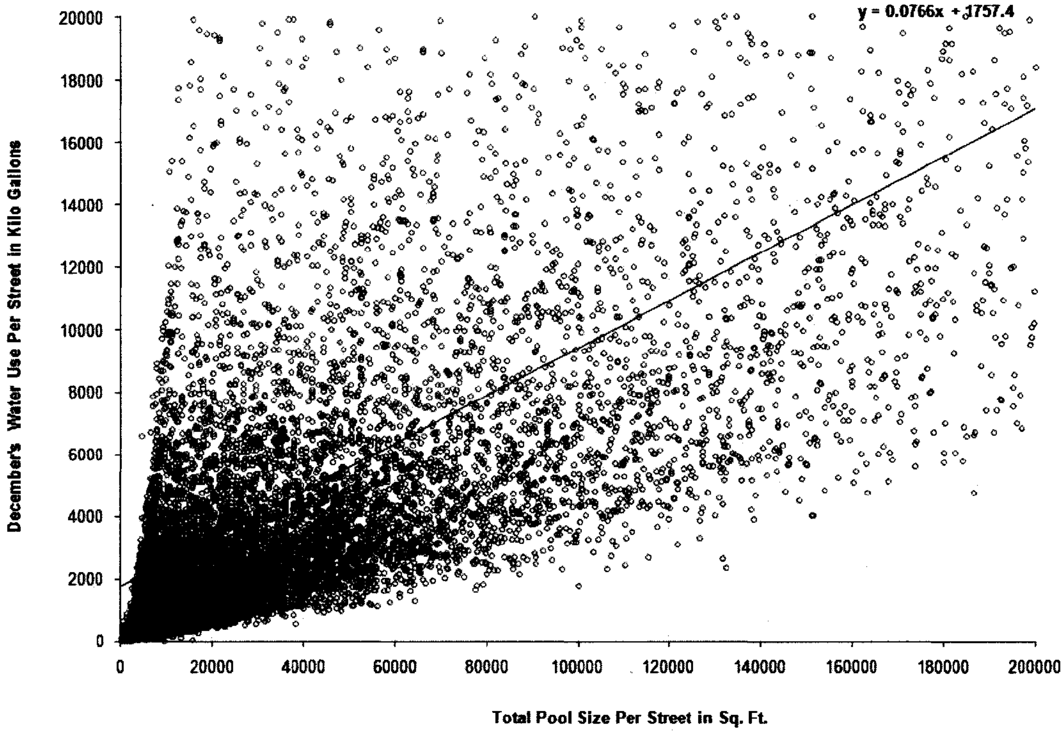


Fig. 4.5.4: Dec 2006- Street-wise Water Use vs. Total Pool Area of SFR: LVVWD.

Table 4.5.1: Dec 2006 Regression Statistics - with Water Use and Built-up/Un-built/Pool Areas.

Dec - 2006	Correlation	Linear Equation
B	0.972653	Y = 0.005727B-212.205
TR	0.919725	Y = 0.005475TR+2278.022
TU	0.889778	Y = 0.025523TU+1909.501
P	0.85484	Y = 0.076649P+1736.264
TRTU	0.931349	Y = 0.00369TR+0.009584TU+1934.95
TRTUP	0.938691	Y = 0.002933TR+0.007635TU+0.020055P+1626.752
BTRTUP	0.984593	Y = 0.004079B+0.000947TR+0.004916TU-0.00037P+134.0174

Where, Y = Total Water Consumption of SFR in a street (Kilo Gals), B = Total Built-up Area of SFR in a street (Square Feet), TR = Total Tree area of SFR in a street (Square Feet), TU =

Total turf area of SFR in a street (Square Feet) and P = Total Pool Area of SFR in a street (Square Feet).

Jul 2006

Fig. 4.5.5: Jul 2006- Street-wise Water Use vs. Total Built-up Area of SFR: LVVWD.

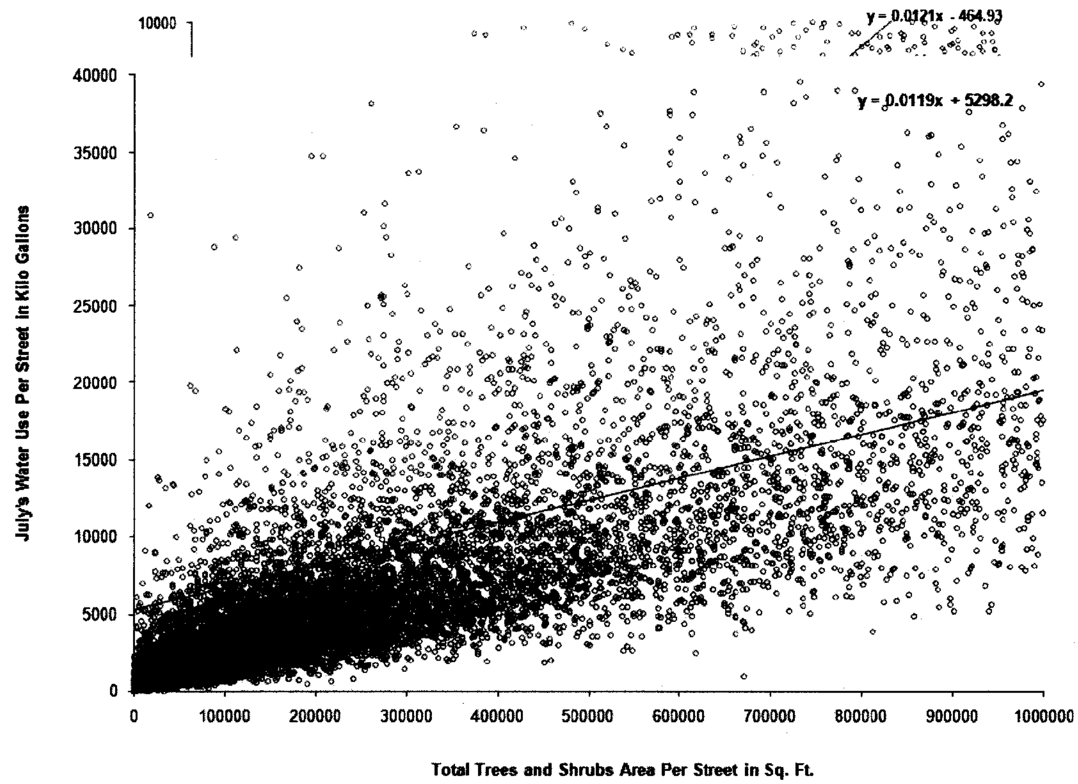


Fig. 4.5.6: Jul 2006- Street-wise Water Use vs. Total Trees and Shrubs Area of SFR: LVVWD.

Fig. 4.5.7: Jul 2006- Street-wise Water Use vs. Total Turf Area of SFR: LVVWD.

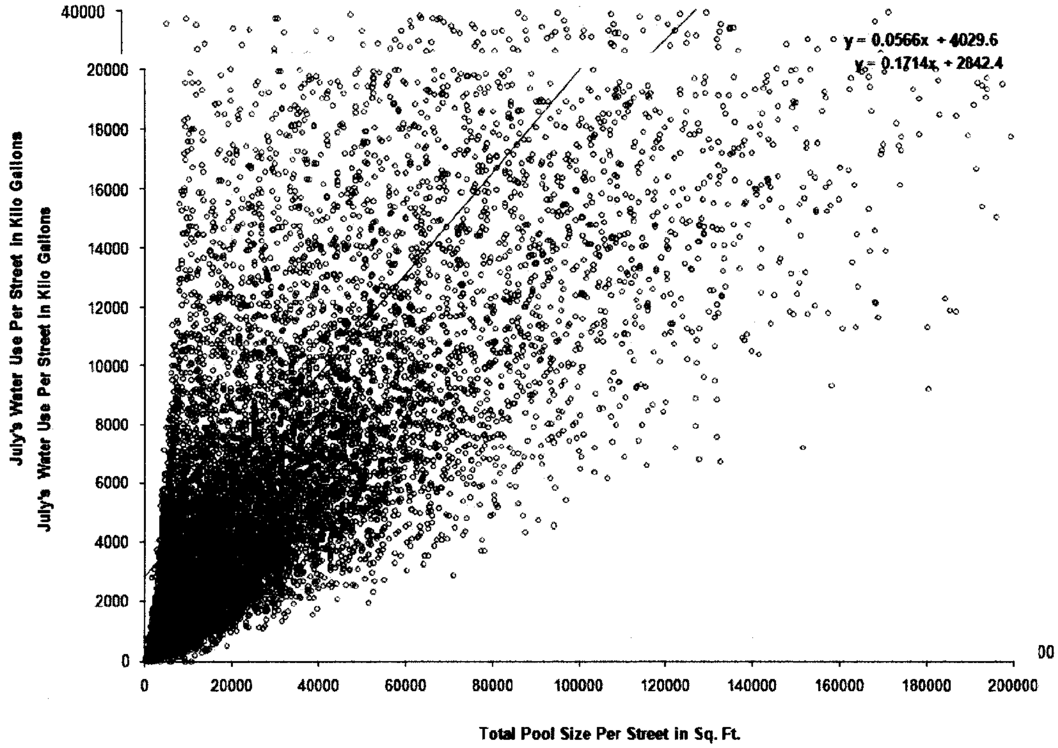


Fig. 4.5.8: Jul 2006- Street-wise Water Use vs. Total Pool Area of SFR: LVVWD.

Table 4.5.2: Jul 2006 Regression Statistics - with Water Use and Built-up/Un-built/Pool Areas.

Jul - 2006	Correlation	Linear Equation
B	0.957458	Y = 0.012044B-625.37
TR	0.937701	Y = 0.011928TR+4298.384
TU	0.92623	Y = 0.056755TU+3293.2
P	0.89484	Y = 0.171437P+2847.518
TRTU	0.957403	Y = 0.006948TR+0.026743TU+3341.12
TRTUP	0.969517	Y = 0.00484TR+0.021313TU+0.055872P+2482.51
BTRTUP	0.989697	Y = 0.005833B+0.002TR+0.017424TU+0.026667P+348.2174

Where, Y = Total Water Consumption of SFR in a street (Kilo Gals), B = Total Built-up Area of SFR in a street (Square Feet), TR = Total Tree area of SFR in a street (Square Feet), TU =

Total turf area of SFR in a street (Square Feet) and P = Total Pool Area of SFR in a street (Square Feet).

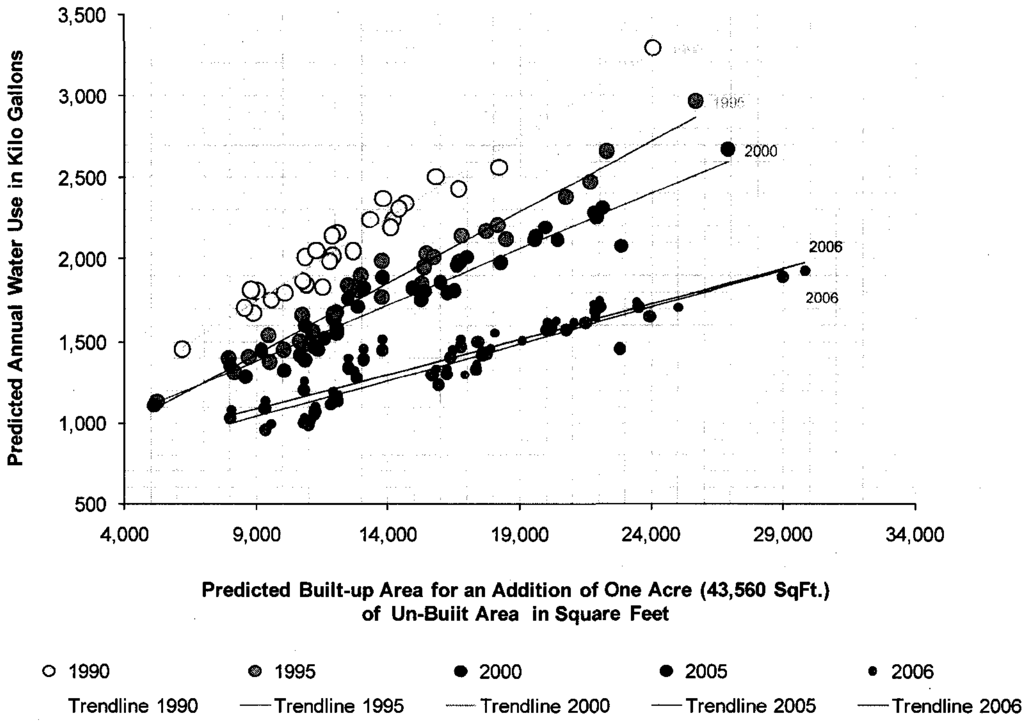
Part 6: Projection of Water Use Limits

The previous sections of this chapter deals with analyzing and understanding the historic trends of water use in the SFR of LVVWD for the years 1990, 1995, 2000, 2005 and 2006. It has been found that water use has strong relationship with the size of built-up area, un-built area and swimming pool area of SFR. In the 2nd, 3rd, 4th and 5th part of this chapter the correlation coefficients are derived for each one of the three factors of study with water use and their regression equations are established both on annual and monthly basis. This chapter is an extension of the statistical analysis, as it is based on the correlation coefficients and regression equations. It is the aim of this section to calculate the total water used for an addition of one acre increase in built-up and un-built area of SFR in LVVWD.

The first part of the calculations deals with finding the ratio of built area vs. un-built area and un-built area vs. pool area. By using these ratios the new built-up area for an addition of one acre increase in un-built area and the new un-built area for an addition of one acre increase in built-up area are found. Similarly the new pool area is found using the un-built area vs. pool area ratio and the new pool area. Finally, using the appropriate regression equations for each one of the study year and the new built area, new un-built area and new pool area, the water used for an addition of one acre of built and un-built area are derived.

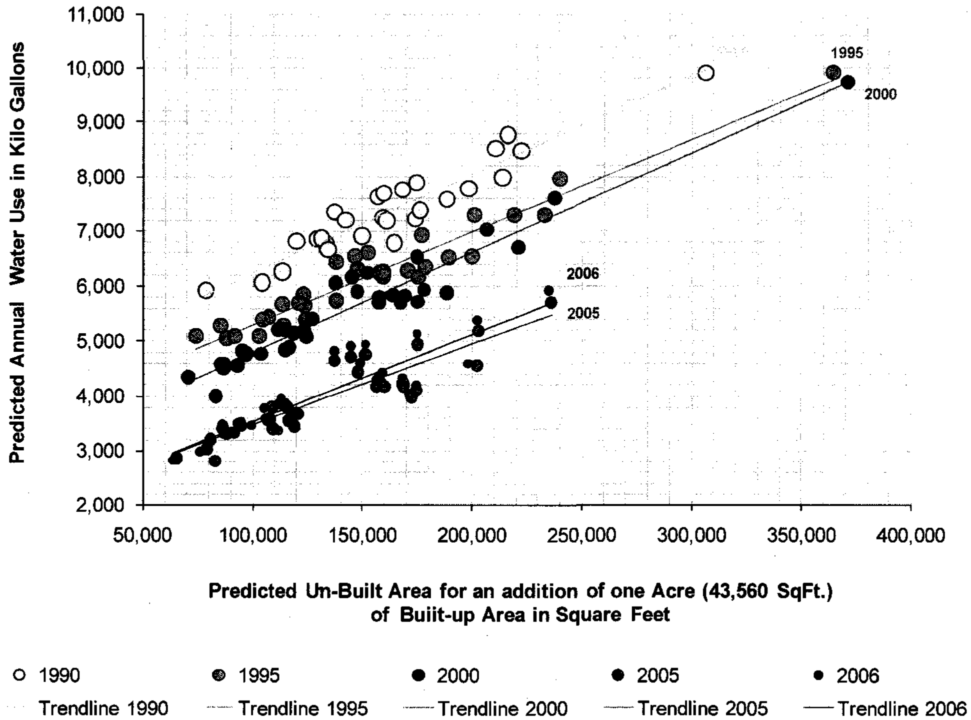
The fig. 4.6.1 shows the annual water use range for an addition of one acre (43, 560 Sq. Ft.) of un-built area. During the year 1990, for one acre increase in un-built area, the built area ranges from 6,200 sq. ft to 24,000 sq. ft. and the annual water use ranges from 1,450 kilo gallons to 3,300 kilo gallons. During the year 1995, for one acre increase in un-built area, the built area ranges from 5,200 sq. ft to 25,700 sq. ft. and the annual water use ranges from 1,150 kilo gallons to 2,950 kilo gallons. During the year 2000, for one acre increase in un-built area, the built area ranges from 5,100 sq. ft to 26,900 sq. ft. and the annual water use ranges from 1,100 kilo gallons to 2,650 kilo gallons. During the year 2005, for one acre increase in un-built area, the built area ranges from 8,030 sq. ft to 34,800 sq. ft. and the annual water use ranges from 1,050 kilo gallons to 1,900 kilo gallons. The values are almost the same for the year 2006. It is obvious from fig. 4.6.1 that there is gradual decline in the annual water use range from the year 1990 to 2005.

Fig. 4.6.1: Annual Water Use Range for an Addition of One Acre Un-built Area: LVVWD



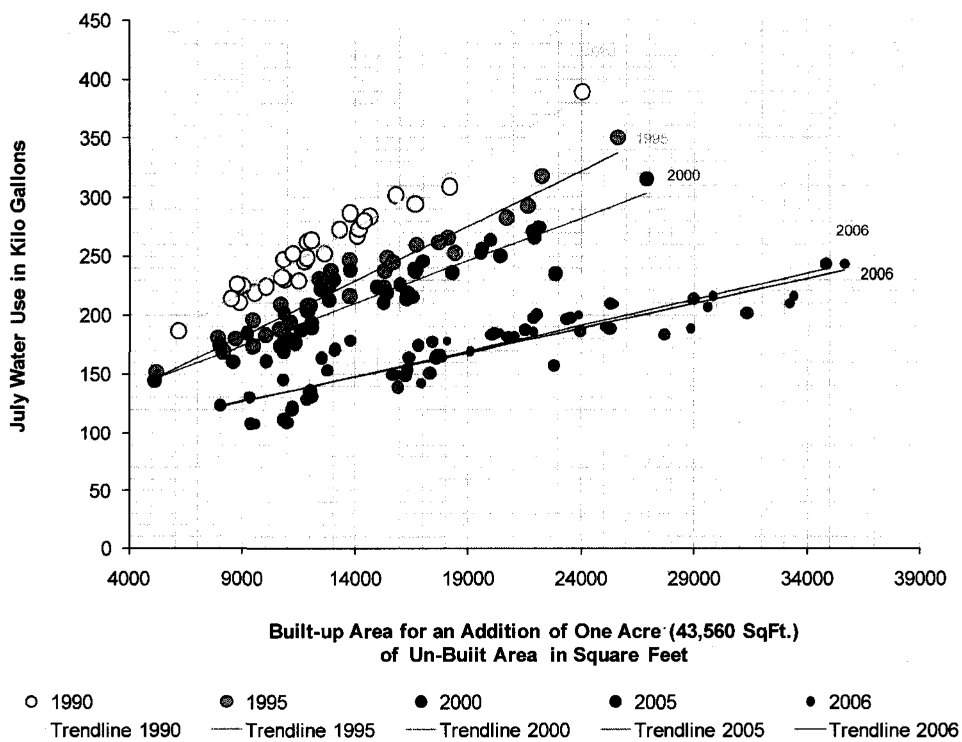
The fig. 4.6.2 shows the annual water use range for an addition of one acre (43, 560 Sq. Ft.) of built area. During the year 1990, for one acre increase in built area, the un-built area ranges from 79,000 sq. ft to 306,200 sq. ft. and the annual water use ranges from 5,850 kilo gallons to 9,850 kilo gallons. During the year 1995, for one acre increase in built area, the un-built area ranges from 74,000 sq. ft to 364,000 sq. ft. and the annual water use ranges from 5,100 kilo gallons to 9,850 kilo gallons. During the year 2000, for one acre increase in built area, the un-built area ranges from 70,550 sq. ft to 370,900 sq. ft. and the annual water use ranges from 4,300 kilo gallons to 9,750 kilo gallons. During the year 2005, for one acre increase in built area, the un-built area ranges from 54,500 sq. ft to 235,200 sq. ft. and the annual water use ranges from 2,900 kilo gallons to 5,800 kilo gallons. The values are almost the same for the year 2006. It is obvious from fig. 4.6.2 that there is gradual decline in the size of un-built area and annual water use range from the year 1990 to 2005.

Fig. 4.6.2: Annual Water Use Range for an Addition of One Acre Built-up Area: LVVWD



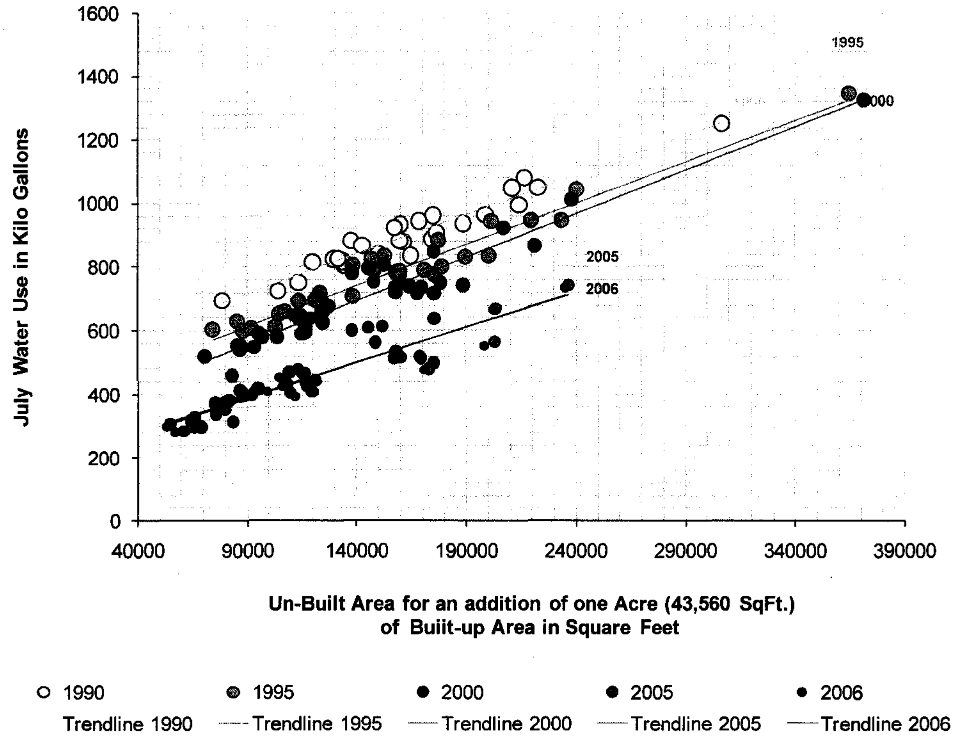
The fig. 4.6.3 shows the water use range for the month of July for an addition of one acre (43, 560 Sq. Ft.) of un-built area. During the year 1990, for one acre increase in un-built area, the built area ranges from 6,200 sq. ft to 24,000 sq. ft. and the water use ranges from 190 kilo gallons to 390 kilo gallons. During the year 1995, for one acre increase in un-built area, the built area ranges from 5,200 sq. ft to 25,700 sq. ft. and the water use ranges from 150 kilo gallons to 350 kilo gallons. During the year 2000, for one acre increase in un-built area, the built area ranges from 5,100 sq. ft to 26,900 sq. ft. and the water use ranges from 140 kilo gallons to 315 kilo gallons. During the year 2005, for one acre increase in un-built area, the built area ranges from 8,030 sq. ft to 34,800 sq. ft. and the water use ranges from 120 kilo gallons to 240 kilo gallons. The values are almost the same for the year 2006. It is obvious from fig. 4.6.3 that there is gradual decline in the water use range from the year 1990 to 2005.

Fig. 4.6.3: Water Use Range for July for an Addition of One Acre Un-built Area: LVVWD.



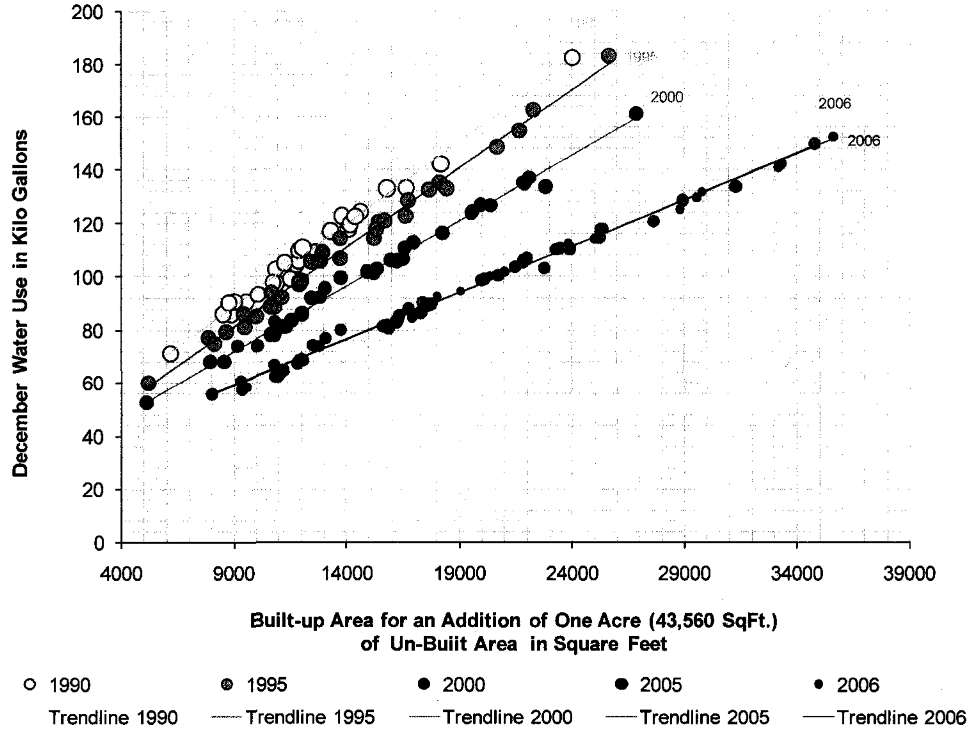
The fig. 4.6.4 shows the water use range for July for an addition of one acre (43, 560 Sq. Ft.) of built area. During the year 1990, for one acre increase in built area, the un-built area ranges from 79,000 sq. ft to 306,200 sq. ft. and the annual water use ranges from 697 kilo gallons to 1,248 kilo gallons. During the year 1995, for one acre increase in built area, the un-built area ranges from 74,000 sq. ft to 364,000 sq. ft. and the annual water use ranges from 602 kilo gallons to 1,347 kilo gallons. During the year 2000, for one acre increase in built area, the un-built area ranges from 70,550 sq. ft to 370,900 sq. ft. and the annual water use ranges from 519 kilo gallons to 1,327 kilo gallons. During the year 2005, for one acre increase in built area, the un-built area ranges from 54,500 sq. ft to 235,200 sq. ft. and the annual water use ranges from 308 kilo gallons to 740 kilo gallons. The values are almost the same for the year 2006. It is obvious from fig. 4.6.2 that there is gradual decline in the annual water use range from the year 1990 to 2005.

Fig. 4.6.4: Water Use Range for July for an Addition of One Acre Built-up Area: LVVWD



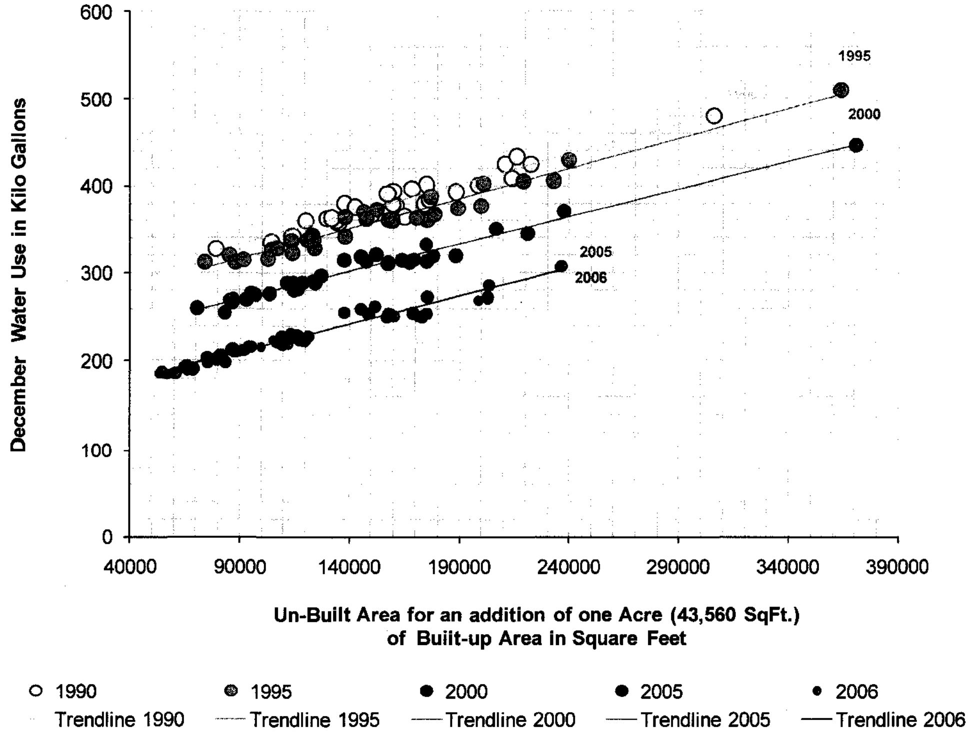
The fig. 4.6.5 shows the water use range for the month of December for an addition of one acre (43, 560 Sq. Ft.) of un-built area. During the year 1990, for one acre increase in un-built area, the built area ranges from 6,200 sq. ft to 24,000 sq. ft. and the water use ranges from 72 kilo gallons to 182 kilo gallons. During the year 1995, for one acre increase in un-built area, the built area ranges from 5,200 sq. ft to 25,700 sq. ft. and the water use ranges from 60 kilo gallons to 184 kilo gallons. During the year 2000, for one acre increase in un-built area, the built area ranges from 5,100 sq. ft to 26,900 sq. ft. and the water use ranges from 53 kilo gallons to 162 kilo gallons. During the year 2005, for one acre increase in un-built area, the built area ranges from 8,030 sq. ft to 34,800 sq. ft. and the water use ranges from 56 kilo gallons to 152 kilo gallons. The values are almost the same for the year 2006. It is obvious from fig. 4.6.5 that there is gradual decline in the water use range from the year 1990 to 2005.

Fig. 4.6.5: Water Use Range for December for an Addition of One acre Un-built Area: LVVWD.



The fig. 4.6.6 shows the water use range for December for an addition of one acre (43, 560 Sq. Ft.) of built area. During the year 1990, for one acre increase in built area, the un-built area ranges from 79,000 sq. ft to 306,200 sq. ft. and the annual water use ranges from 328 kilo gallons to 480 kilo gallons. During the year 1995, for one acre increase in built area, the un-built area ranges from 74,000 sq. ft to 364,000 sq. ft. and the annual water use ranges from 313 kilo gallons to 510 kilo gallons. During the year 2000, for one acre increase in built area, the un-built area ranges from 70,550 sq. ft to 370,900 sq. ft. and the annual water use ranges from 260 kilo gallons to 447 kilo gallons. During the year 2005, for one acre increase in built area, the un-built area ranges from 54,500 sq. ft to 235,200 sq. ft. and the annual water use ranges from 188 kilo gallons to 306 kilo gallons. The values are almost the same for the year 2006. It is obvious from fig. 4.6.6 that there is gradual decline in the annual water use range from the year 1990 to 2005.

Fig. 4.6.6: Water Use Range for December for an Addition of One Acre Built-up Area: LVVWD.



Conclusion

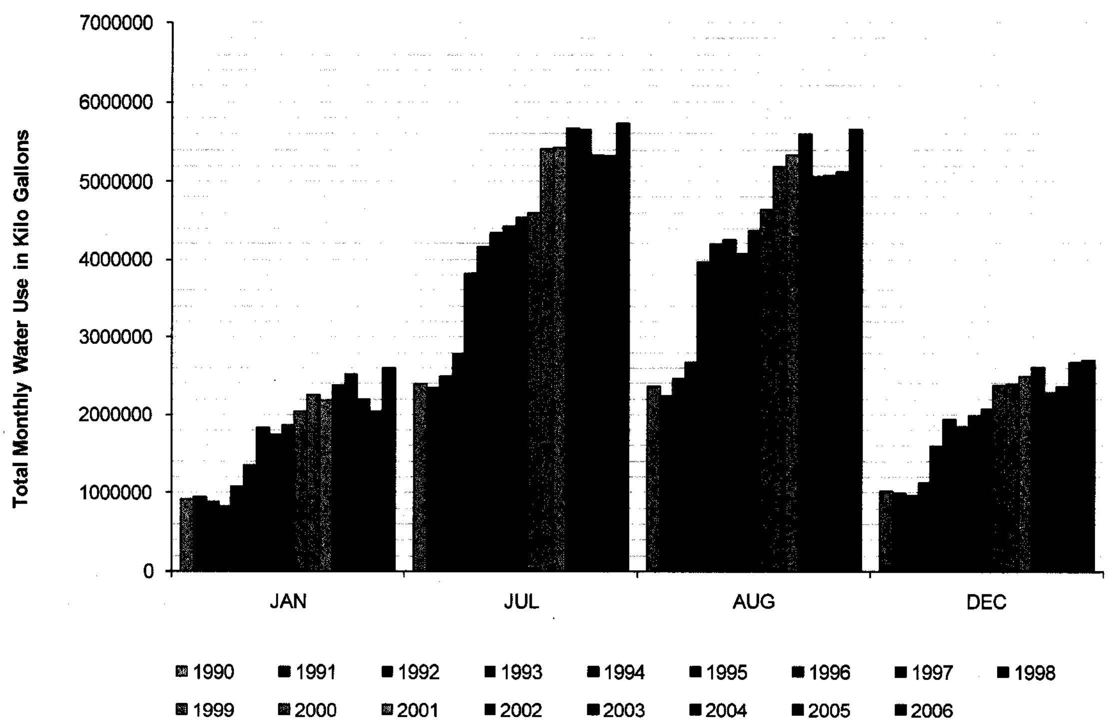
It is clear from the above analysis that both the monthly and annual water use of SFR has declined gradually from the year 1990 to 2005 along with the size of the un-built area in LVVWD. But during the year 2006 there is a slight increase in the water use, when compared with the previous year. While water is a precious resource of the desert and it is intrinsic for the long-term survival of the valley, there should be stipulated limits to the consumption of water. The above charts open the opportunities for holistic planning and sustainable growth of LVVWD for every acre increase in built-up area and un-built area of the SFR of LVVWD. As every study year follows a slightly different slope for their trend lines, it is significant that the trend line followed during the year 2005 is the most conservative of all. 2005 is the most recent year for which the water use is the lowest among the other years. Keeping the 2005's projection values as the benchmark, developers and planners could predict the amount of water required for one acre increase in built-up area and un-bullt area of SFR in the LVVWD.

Part 7: Climatic Analysis of LVVWD

As water consumption is tied to outdoor environmental changes, outdoor ambient temperature plays a major role in overall water demand. It is a widely known fact that high temperature increases water use. This part of the chapter studies the impact of monthly water use due to the variation in mean, mean maximum and mean minimum monthly outdoor ambient temperature. The first part of this section studies the relationship of monthly water use and the variation in temperature from the year 1990 to 2006, whereas the second part of this section compares the monthly water use with the monthly electricity use and studies their relationship with outdoor ambient temperature from the year 2002 to 2006.

Climatic Analysis of LVVWD – 1990 to 2006

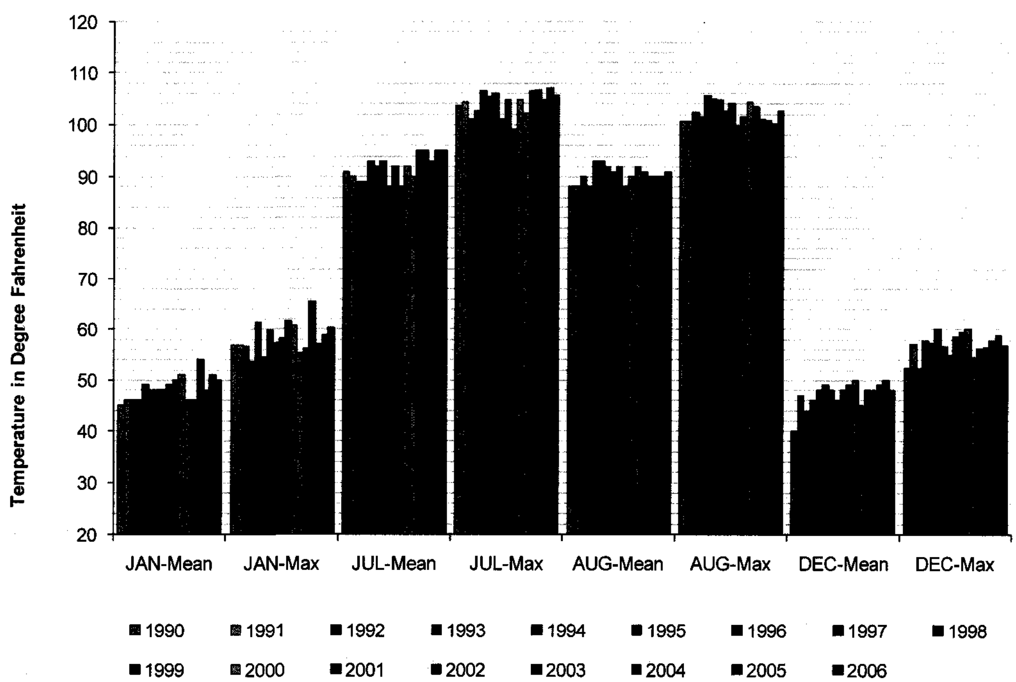
Fig. 4.7.1 Total Monthly Water Use in Peak Summer & Winter Months



The correlation coefficient between water consumption and outdoor ambient temperature from January to December is above 0.95 for all the seventeen years. But the correlation coefficient for individual months for all the seventeen years between water use and temperature varies considerably. It is noticed in LVVWD that during the peak summer months, July and August and during the peak winter months, January and December the correlation coefficient remains high, whereas during the remaining months, the correlation between water use and outdoor ambient temperature is very low.

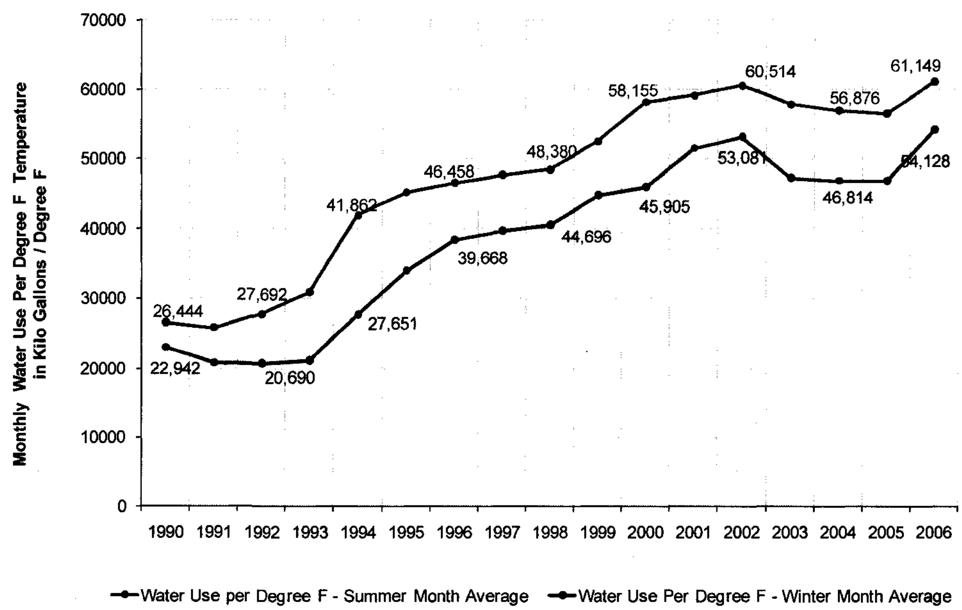
During the month of January, the total water use was as low as 820,176 kilo gallons in 1993 and as high as 2,592,158 kilo gallons in 2006. During the month of December, the total water use was as low as 967,539 kilo gallons in 1992 and 2,707,836 kilo gallons in 2006. Whereas during the month of July and Aug the total monthly water uses were as low as 2,490,736 kilo gallons and 2,238,426 kilo gallons respectively in 1992 and as high as 5,718,249 kilo gallons and 5,651,720 kilo gallons respectively in 2006. It is obvious from fig. 4.7.1 that it is during the year 2006, the peak summer and peak winter water uses were overall the highest from the year 1990.

Fig. 4.7.2 Outdoor Ambient Temperature in Peak Summer & Winter Months



When the months from May to June are considered as summer months and when the months from November to January are considered as winter months, the average summer month temperature was as low as 69.18 degree F in the year 1992 and as high as 76.08 degree F in the year 2006. Whereas, the average winter month temperature was as low as 34.76 degree F in the year 1990 and as high as 44.56 degree F in the year 2005. When the above figure is overlapped with the fig. 4.7.1, it is seen that though temperature has strong influence on the amount of water consumed in a month, it also relies on the density and growth of the region. Hence it is not possible to find the amount of water consumed for every degree raise or drop in temperature. Though there is more than one factor that affects the water use, the following graph considers only the temperature, to find the kilo gallons usage of water per degree Fahrenheit of outdoor ambient temperature.

Fig. 4.7.3 Total Monthly Water Use per Degree F. of Outdoor Ambient Temperature



It is shown in the above graph that there is gradual increase in the amount of water used for one degree Fahrenheit of temperature from the year 1990 to 2006. It is seen from this graph that for every degree raise in temperature, water use has increased almost threefold. As the total number of SFR considered in the year 1990 is not the same as the total number of SFR considered in the year 2006, it is not appropriate to state that the water use has increased almost threefold for every degree Fahrenheit. This study includes a total of 70,223 SFR of LVVWD in the year 1990 and 272,043 SFR of LVVWD in the year 2006. The increase in the total number of SFR in the year 2006 is 3.8 times the number of SFR in the year 1990. As the water conservation programs go hand in hand with the growth of the region, for one degree raise in outdoor ambient temperature, the water use has raised threefold, whereas the population has grown fourfold.

Correlation between Water Use and Outdoor Ambient Temperature – 1990 to 2006

The correlations between monthly water use and outdoor ambient temperature are studied separately for the years 1990, 1995, 2000 and 2006. It is seen from this analysis that water use has strong correlations with the mean, mean maximum and mean minimum monthly temperatures of LVVWD. The correlation coefficient is well above 0.95, which proves a substantively high correlation.

Fig. 4.7.4(a) 1990 Correlation between Water Use and Outdoor Ambient Temperature

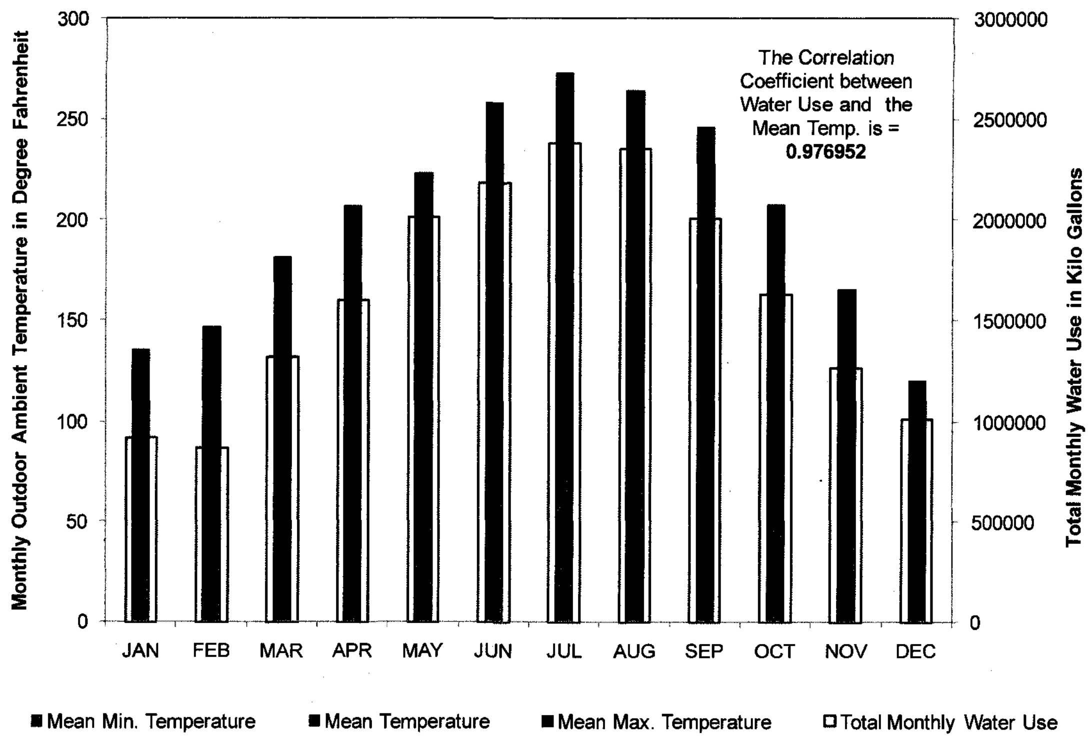


Fig. 4.7.4(b) 1995 Correlation between Water Use and Outdoor Ambient Temperature

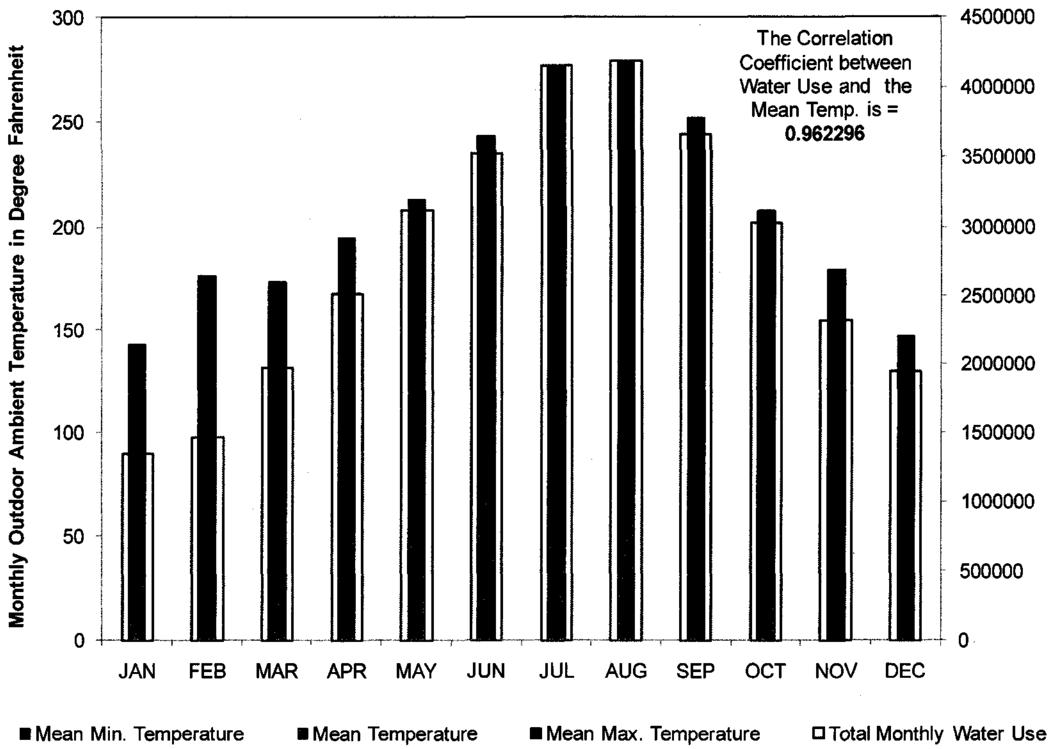


Fig. 4.7.4(c) 2000 Correlation between Water Use and Outdoor Ambient Temperature

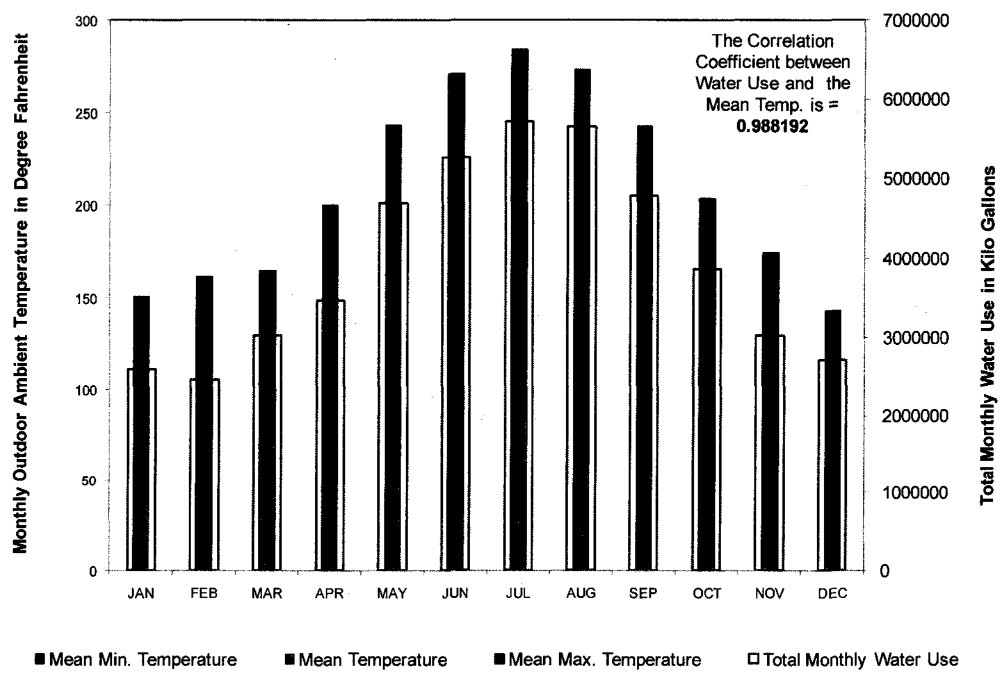
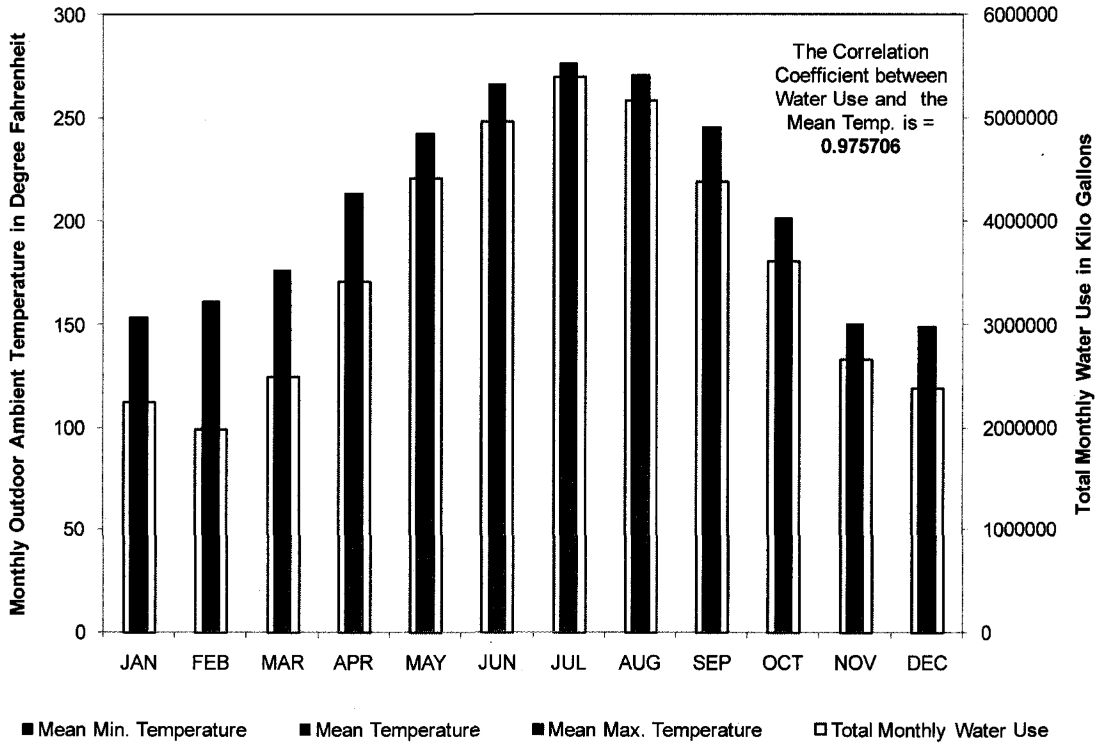


Fig. 4.7.4(d) 2006 Correlation between Water Use and Outdoor Ambient Temperature



<u>Monthly Water Use and the Cooling and Heating Degree Days</u>

As cooling and heating degree days are the quantitative indices that reflect the total degrees above and below the base temperature – 65 degree Fahrenheit in a day, comparison of water consumption trends with the cooling and heating degree day trends would give an understanding of how well the LVVWD has been performing with respect to water use from the year 1990 to 2006 due to temperature fluctuation.

The recorded data of cooling and heating degree days is monitored at the McCarran International airport of Las Vegas and downloaded online from the National Climatic Data Center for the years 1990 to 2006.

Fig. 4.7.5 Total Annual Water Use vs. Cooling and Heating Degree Days

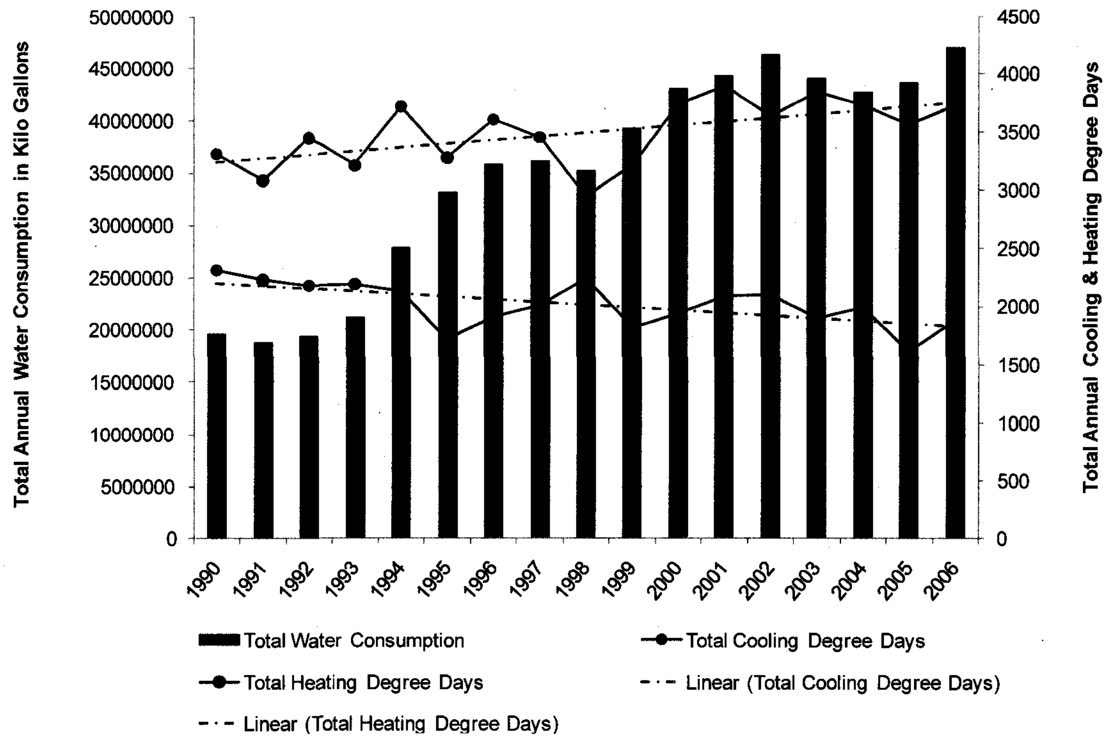
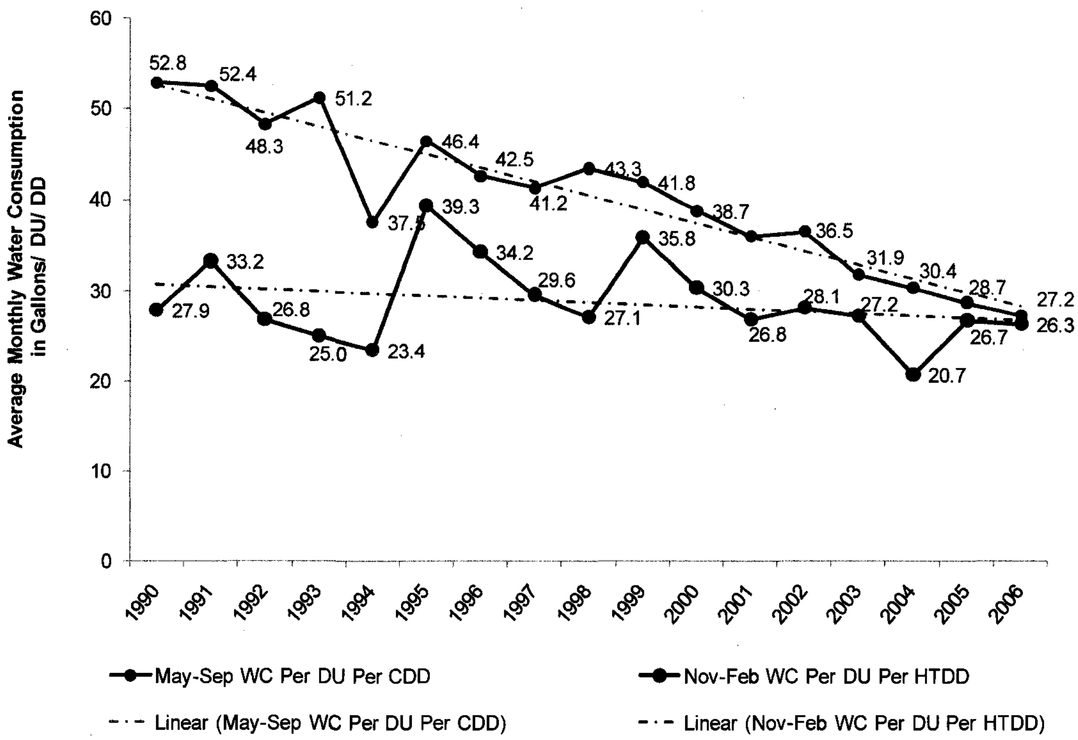


Fig. 4.7.5 summarizes the total annual water consumption and the annual cooling – heating degree days of the LVVWD from the year 1990 to 2006. The trend lines of cooling and heating degree days shown as dotted lines in the above chart indicate the overall inclination and declination of cooling and heating degree days respectively. Between the years 1990 and 2006, when the difference in cooling degree days was 12.6 percent, the difference in heating degree days was 18.9 percent. This signifies that over a period of seventeen years, there is gradual increase in the ambient temperature. Thereby, on an average, the cooling degree days have increased 26.1 points and the heating degree days have decreased 27.3 points every year from 1990 to 2006.

Fig. 4.7.6(a) summarizes the average monthly water consumption of a single family residence per cooling and heating degree day, during summer and winter months. As a first step the average monthly water consumption per dwelling of the five peak summer months of the Valley such as May, June, July, August and September are computed against the average monthly water consumption of the four peak winter months - January, February, November and December. Similarly the summer and winter monthly averages of cooling and heating degree days are computed. The ratios of these values are plotted as the two major lines in the fig. 4.7.5.

Fig. 4.7.6(a): Water Use per Single Family Residence in Summer and Winter Months.



It is obvious from fig.4.7.6 (a) that these lines almost converge during the year 2006. When the difference between summer and winter months was 24.9 Gallons/ SFR/ Degree day in 1990, it was only 0.9 Gallons/ SFR/ Degree day in 2006. This implies that though there is gradual increase in ambient temperature, water consumption per SFR has declined in the Valley. In summer months, the decline was 48.5 percent, whereas in winter months, the decline was only 5.7 percent. This should be because of the fact that it is comparatively easier to snip the excessive use of water during summer months, when the overall consumption is high, so is the percentage of water wasted.

Fig. 4.7.6(b): Water Use per Sq. Ft. of Lot Area of Single Family Residence in Summer and Winter Months.

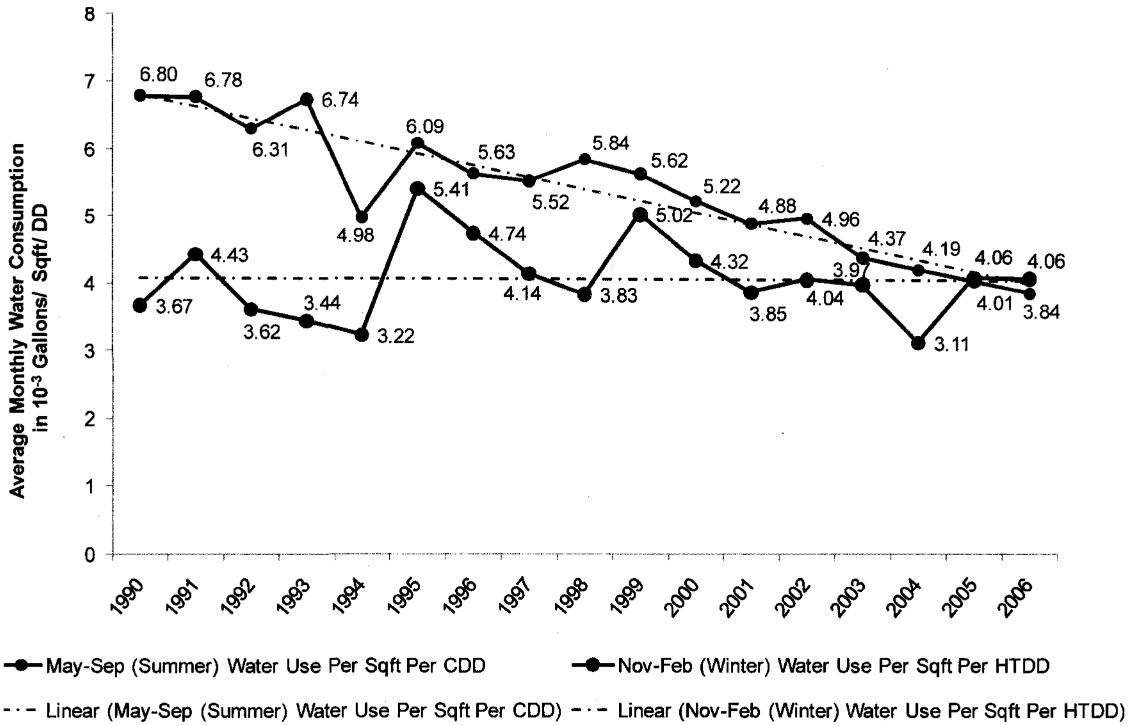


Fig. 4.7.6(b) is same as the previous figure except that the average monthly water consumptions for summer and winter months are normalized per square footage lot area of single family residences. This figure shows that it was the first time in LVVWD's history that during the year 2005, the average water consumed in winter months by one square feet of a single family residence for one heating degree day has marginally superseded, the average water consumed in summer months by one square feet of a single family residence for one cooling degree day. In 2006, water use per sq. ft of SFR during an average winter month is well above the summer month average. Same as the average monthly water use per SFR, per degree days, the average monthly water use per square feet, per degree day has declined gradually irrespective of the increase in the number of SFR. The decline during the summer months was 57.5 percent and decline during the winter months was 19.9 percent from the year 1990 to 2006.

CHAPTER 5

CONCLUSIONS

Las Vegas Metro Area is the fastest growing large metropolitan area in the nation. The incorporated Clark County and the City of Las Vegas have experienced rapid growth in the total number of single family residences. Together with the population increase, the steep increase in the total number of SFR from 73,000 to 265,000 units from the year 1990 to 2006 challenges the water use. But the average water used by a SFR has declined from 290 gallons to 175 gallons per day. Meanwhile the average lot area of SFR has decreased gradually from 8100 sq. ft. to 7000 sq. ft and the average un-built area of SFR has decreased from 6300 sq. ft to 5200 sq. ft. By contrast there is noticeable increase in the average built-up area of SFR from 1600 sq. ft to 1850 sq. ft. Though the average lot area, built-up area, and un-built area of the single family residences has changed from the year 1990 to 2006, their correlation with the water use remains high for all the seventeen years.

The total and average water use of each zip code from the year 1990 to 2006 is charted along with the zip wise water use rankings. Thereby it is found that zip codes such as 89117 and 89146 have been consuming more water compared to other zip codes constantly from the year 1990 to 2006. Meanwhile the physical aspects such as built-up area, un-built area and pool areas of such zip codes continue to be high. It is evident from this analysis that more than behavioral and microclimatic factors, it is the size of the physical aspects that contributes to the high and low consumption of water.

Through regression analysis, the correlation coefficient of each one of the physical aspect with total water use is found. It is evident that built-up area, un-built area and pool area has constantly high correlations with the total water use from 1990 to 2006. The annual and monthly regression equations are derived from the correlation statistics and they are summed up in the 2nd, 3rd, 4th

and 5th sections of the fourth chapter. For the years 1990, 1995, 2000 and 2005, the regression equations are derived for the Las Vegas Valley, whereas for the recent data year 2006, the regression equations are derived for the Las Vegas Metropolitan Area. Using these equations, the water used for an addition of one acre (43,560 sq. ft.) of built-up area and un-built area are found. As 2005 is the most recent year for which the water use is the lowest, by using the calculations for the year 2005 as the benchmark, the water use limits for one acre increase in built-up area and un-built area are found. During the year 2005, for one acre increase in un-built area, the built area ranges from 8,030 sq. ft to 34,800 sq. ft. and the annual water use ranges from 1,050 kilo gallons to 1,900 kilo gallons. Whereas, for one acre increase in built area, the un-built area ranges from 54,500 sq. ft to 235,200 sq. ft. and the annual water use ranges from 2,900 kilo gallons to 5,800 kilo gallons.

Thus this thesis becomes a useful tool for the planners of single family residences to predict the quantity of water used, both annually and monthly, for an addition of one acre of built-up or un-built area in the Las Vegas Valley Water District.

Future Research

This research compares the water use trend with the trends of the physical factors such as the built-up area, un-built area and pool area. The following are some of the venues that still remain untouched,

- While this research concentrates only on the size of the built-up, un-built, and pool areas, the nature of the other physical aspects such as the type of the building, age of construction, nature of roofing, type of landscape, landscape with and without water smart vegetation, type and age of trees, pools with and without pool cover, dwelling with and without water efficient appliances, etc. remains unexplored.
- This research explores the overall water use of the LVVWD and LVMA at the macro level. A study that concentrates on a small portion of the LVMA could delve into the micro climatic aspects of that region.

- While the type of vegetation commonly considered effective to reduce residential consumption in the valley, could possibly contribute to urban heat islands, in turn increasing the cooling loads in residences and perhaps requiring more water to be used at the power plant than would have been used for selective irrigated landscaping. In a 2001 study done by the Lawrence Berkeley National Laboratory, it was found that 5–10% of the urban electricity demand was spent to cool buildings just to compensate for the increased 0.5–3°C in urban temperatures (Akbari et al 295).
- Water use patterns established in this study are highly accurate, however many unanswered questions as to the exact reason for these patterns still remain. The effects of vegetation, orientation, materials, urban densities, housing typologies, and analysis of individual attributes are some of the relations that can be explored at a micro-scale for any and all of the neighborhoods documented in this research.
- This study considers only the single family residences of the Las Vegas Metro Area. Similar studies can be carried out for other land uses to facilitate a more complete study of the residential sector of LVMA.
- Lastly, through this research and through previous research done by Wadhwa (2007) on energy consumption of LVMA, not only can one visualize the residential consumption picture, but also create a model of the complete ecological footprint of the valley.

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