Evaluation of
Potential Best Management Practices
-
Pools, Spas, and Fountains

Prepared for

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September 2010

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NOTE: For a full introduction to the
Council's Potential Best Management Practice (PBMP) process,
refer to the earlier reports that detail the purpose and
status of that process since its inception in 2004:
http://www.cuwcc.org/products/pbmp-reports.aspx

I. Introduction

Background

Pools, spas, and ornamental fountains with recirculating filtration and disinfection equipment can be found at homes, schools, hotels, apartments, public parks, and businesses. These features provide recreational opportunities and aesthetic and artful attractions that can benefit the community.

According to one recent study, over 90 percent of all in-ground pools and almost all above-ground pools and most hot tubs are in residential settings and thus represent the most significant portion of water use in this sector. According to a 2009 Kenilworth Media, Inc. study[1], there are 5.1 million in-ground pools, 3.7 above-ground pools, and 6.6 million hot tubs in the United States. In 2007, approximately 131,000 new in-ground pools were sold with the Southwest (California, Nevada, Arizona, and Utah) accounting for 23 percent of sales nationally. The number of commercial (apartments, hotels, and motels) and public pools account for only three (3) percent of existing pools, but these commercial and institutional pools are the largest in size and water capacity. The number of ornamental fountains is much smaller, but they use essentially the same type of filtration and disinfection technology as pools.

Purpose

The purpose of this document is to describe water use by pools, spas and fountains and focus on ways to achieve a higher degree of water use efficiency including information on: (1) evaporation, (2) filtration, (3) leaks, people use and maintenance, and (4) total dissolved solids control.

II. Overview

Water use is the common denominator for swimming pools, hot tubs, splash pools, ornamental fountains and similar water features. Although some "fill and dump" type systems (i.e., dumped and refilled ever day or two) are still unfortunately found, the use of recirculating filtration and disinfection equipment has been the industry standard for years. The few existing fill and dump facilities are being eliminated. This report concentrates on pools, fountains, and other facilities equipped with recirculation systems.

Evaporation, backwash, control of total dissolved solids - TDS, and cleaning and vacuuming of pools all are common, necessary elements associated with pools and fountains. Leaks, poor chemical and equipment maintenance, drag and splash-out, and other wasteful practices all result in preventable water loss.

The first step in understanding how to reduce water use for pools, hot tubs, fountains or water features is to examine how modern systems work. Components of a modern recirculating system will always contain a strainer, filter, pump, dump valve and intake (drain and skimmer) and return flow connections, and piping. Figure 1 illustrates these features for a typical

1 Pool & Spa Marketing, March 2009 www.poolspamarketing.com

swimming pool. This represents perhaps the most complicated type of system since a heater is involved.

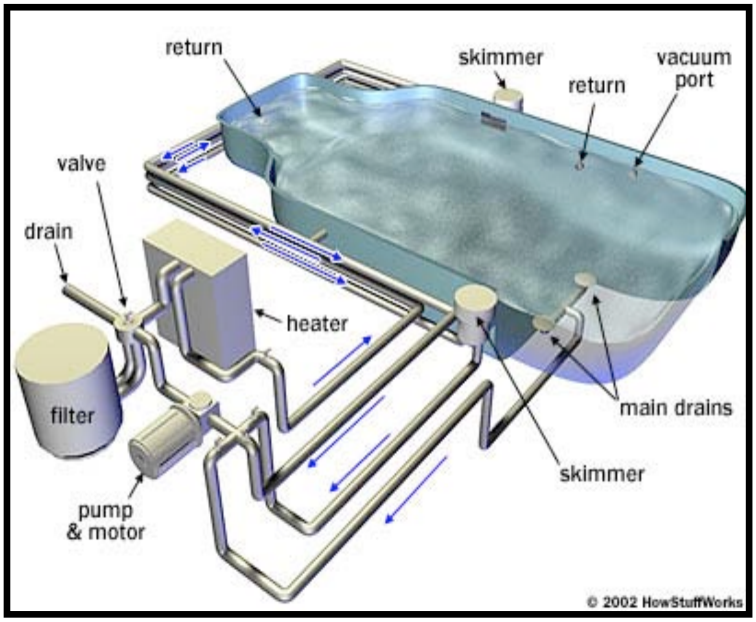


Figure 1. Diagram of a Swimming Pool Mechanical System

The overflow and fill system of a pool can include perimeter-type overflow gutters, surface skimmers, other surface water collective system components, and their interconnecting piping. Pools will also be equipped with an equalization tank that operates at the same level as the water in the pool. It provides a place that is not turbulent separate from active pool use. The equalization tank prevents the fill or float valve from bouncing around when the pool is in use, which would otherwise result in wasting water. Figure 2 illustrates such an equalization tank and float valve.

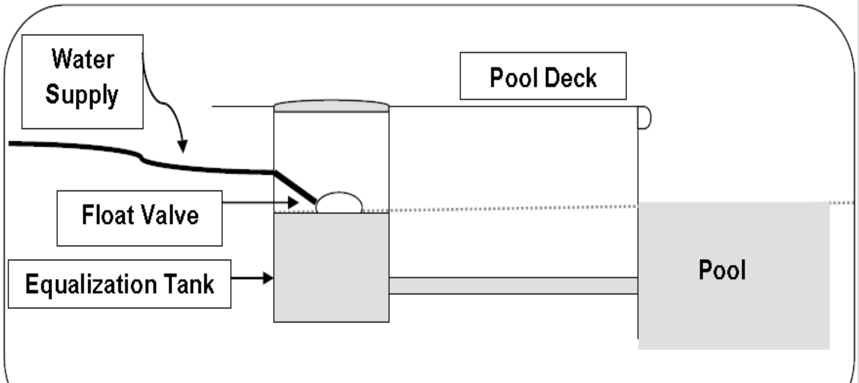


Figure 2. Refill assembly showing fill valve and equalization tank

The fill valve is most often a simple float assembly, but other water level devices ranging from sonic sensors to elevation pressure sensors are available. Pool overflows are usually simple stand pipes or overflow thresholds that allow water to flow freely into the sanitary sewer or drain when the prescribed water level is exceeded.

The type and size of pools and spas varies depending upon intended use and location. With the exception of official Olympic pool dimensions, there is no "standard size." However, Table 1 summarizes a "typical size" for pools and spas for various intended uses ranging from above-ground residential pools to public pools to hot tubs.

Table 1. Typical Pool Sizes*

Type of Facility	Area Sq. Ft.	Depth Feet	Volume Gallons
Hot tub	40	3	1,122
Above-ground	252	4	7,540
In-ground residential	450	4.5	15,147
In-ground apartment	800	4.5	26,928
In-ground hotel	1,000	4.5	33,660
In-ground public	4,000	5	149,600
Olympic	14,432	8	863,611

* Based upon examination of multiple pool installer web sites and conversation with officials from the Association of Pool and Spa Professionals - Southern California Chapter.

III. Market Dynamics

The sales, construction, operation, and maintenance of pools, spas and ornamental fountains are multimillion dollar businesses in the United States. It provides many valuable jobs to the communities where the businesses and pools are located. Companies that practice proper design and provide competent services are at the vanguard of ensuring that pools are operated efficiently to minimize both water and energy use.

National Statistics

The pool, hot tub and water feature market is a dynamic one. It has its dips during downturns in the economy, but even then the pool maintenance market remains active. According to the Pool & Spa Magazine[2], there were 6.6 million hot tubs, 5.1 million in-ground pools, 3.7 million above-ground pools and 277,000 commercial pools in the Unites States in 2007. Figure 3 shows the distribution of existing pools in the United States and Figure 4 shows the 2007 sales data by type of pool for in-ground pools. Table 2 summarizes inventory and sales information for 2007 and estimates the national 2009 inventory of pools.

Figure 3. Distribution of Existing Pools in U.S.

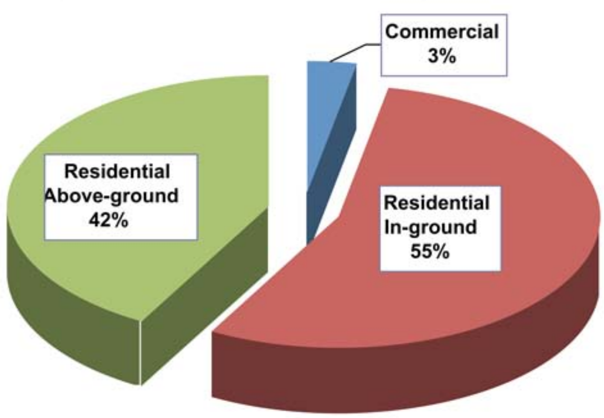
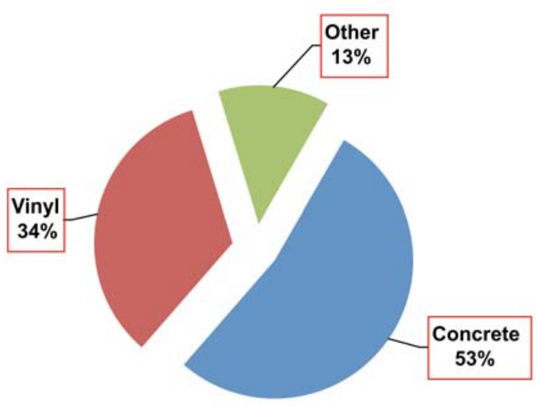


Figure 4. 2007 National In-Ground Pool Sales



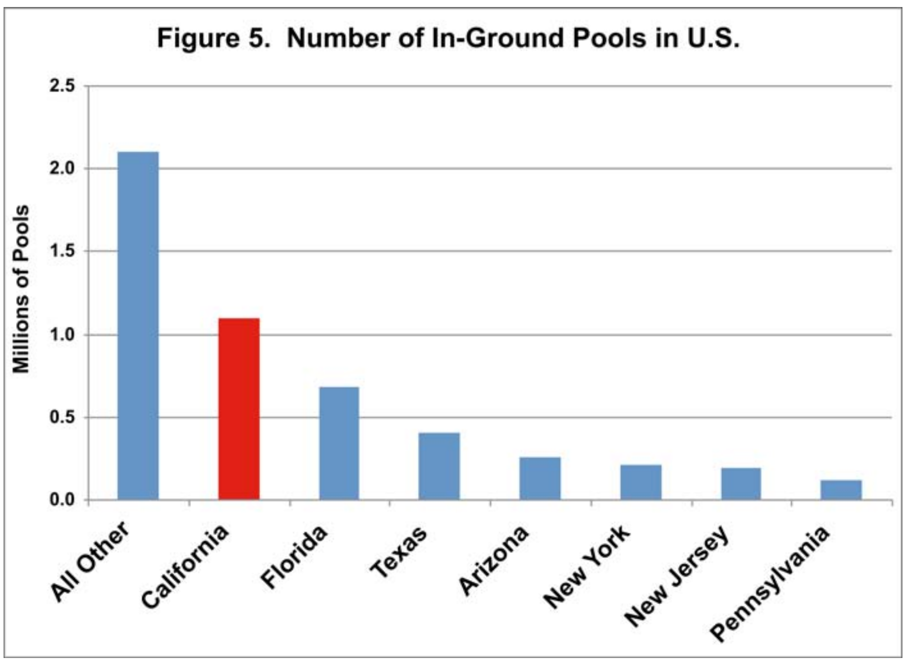
[2] Pool & Spa Magazine, March 2009

Table 2. U.S. National Pool and Hot Tub Market Data					
	Hot Tubs	In-ground Pools	Above-ground Pools	Commercial Pools	Totals
2007 Inventory	6.6 million	5.1 million	3.7 million	277,000	15.7 million
2007 Sales	305,000	131,200	222,000	Information not available	658,200
High Year Sales	295,000 in 2004	191,200 in 2005	325,000 in 2000		911,200
Estimated 2009 Inventory**	6.7 million	5.1 million	3.8 million	277,000	15.9 million

* 2007 data from the March 2009 issue of Pool & Spa Magazine (1)
** Based on 2007 data and sales extrapolated to 2009

California Statistics

According to a 2008 study for the California Energy Commission entitled *Residential Pool Pump Measure Revisions*[3], there were 1.1 million in-ground and 1.0 above-ground residential pools in California in 2007, for a total of 2.1 million residential pools in the state. This means that about one-fourth of all pools in the United States are in California. If the proportion of commercial pools in California equals that of residential pools, one would conclude that there are about 65,000 commercial pools in California[4].



[3]www.energy.ca.gov/.../PGE_Updated_Proposal_Information_Template_for_Residential_Pool_Pump_Measure_Revisions.pdf

[4] Commercial pools include recreational water features such as water parks, public pools and pools at hotels, schools, institutions, water parks, camps, etc. However, the authors believe that it is doubtful that one-fourth of all commercial pools in the U.S. are also located in California.

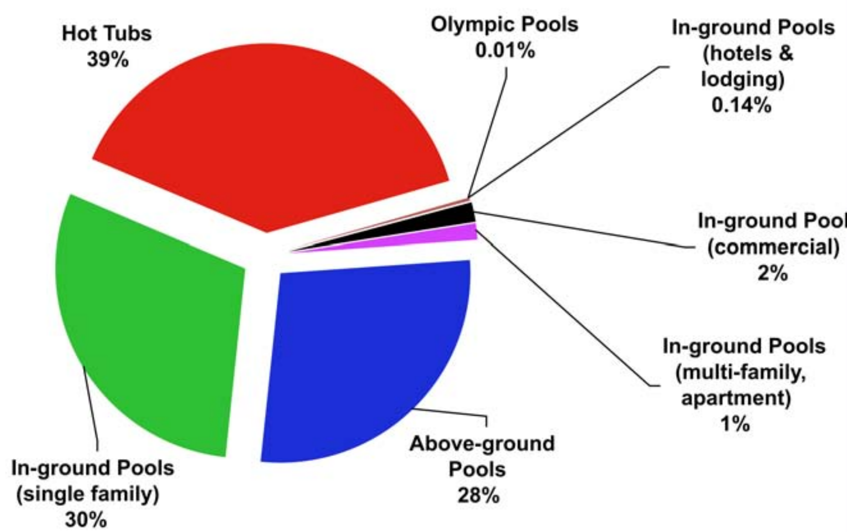
According to the 2000 U.S. Census, 31.4 percent of Californians live in housing units within multi-unit structures, equating to about 4.2 million multi-unit housing units. If the average size per complex is assumed to be 50 units, it can be concluded that there are about 84,000 apartment, condominium and similar living complexes in the state. The number of in-ground pools at these multi-unit complexes is, therefore, estimated to be about 50,000 of the 1.1 million installations, assuming that the majority of the multi-family complexes have a single in-ground pool.

Table 3 summarizes the population of pools and spas in California and Figure 6 illustrates this distribution. As the table shows, residential facilities dominate the market. Almost 100 percent of above-ground pools and hot tubs are found in residential settings and 97 percent of in-ground pools are residential pools. This includes pools at apartment complexes.

Table 3. Estimated Number of Pool and Spa Facilities in California

Type	Number
Hot Tubs	1,400,000
In-ground Pools (residential)	1,062,000
In-ground Pools (multi-family, apartment)	50,000
In-ground Pools (commercial, public)	55,000
In-ground Pools (hotels & lodging)	10,000
Above-ground Pools (residential)	1,000,000
Olympic Pools	100
TOTAL (estimated)	3,577,100

Figure 6. Types of Pools and Spas in California
(total of 3.54 million)



In 2008, there were 5,501 lodging properties in California that were members of the American Hotel and Lodging Association[5]. This association is assumed to represent about one-third of all lodging properties in the state. If it is also assumed that about 90 percent of transient lodging properties have pools, this means that of the total of 65,000 commercial pools in California, about 15,000 are at lodging facilities and about 50,000 are at other commercial, institutional, or common area facilities (e.g., schools, medical care facilities, parks, gymnasiums, and neighborhood common areas).

The smallest category of pools by type is Olympic pools. To qualify for this category, an Olympic pool must be 50 meters long and 25 meters wide. Few pools fit this exacting description. In a 1981 Sports Illustrated issue[6], it was estimated that the total of legitimate Olympic pools in the United States was only about 250. More recent figures are not available, but the number of pools in the United States has grown at a rate of about 1.7 to 1.8 percent per year. Currently about 25% of all pools of all types are found in California. Based on these assumptions and approach, it is estimated there are approximately 100 Olympic pools in the State today.

The exact number of ornamental, outdoor fountains in California is not available, but it is assumed to be several orders of magnitude less than that for pools. A number of 10,000 fountains was used for this study and it was assumed that they have the same surface area as the typical residential in-ground pools.

[5] www.ahla.com/content.aspx?id=27642. These properties, however, are members of the association. The number of other non-member properties is assumed to equal that of members. As such, the assumed total is for both categories is 11,000. Ninety per of the total amounts to about 10,000 recreational pools at California lodging facilities.

[6] Jerry Kirshenbaum, Sports Illustrated, 1981. "When is an Olympic Size Pool Not Olympic Size? Most All The Time", November 23.

IV. Equipment and Design Options

Pools, spas and fountains with recirculation equipment have many ways in which water is consumed, including:

1. Evaporation
2. Leaks
3. Splash out
4. Disinfection, cleaning and maintenance and water quality control
5. Filter operations

Controlling these losses is critical to reducing water use, and especially reducing waste. Likewise, good pool maintenance is essential. The trilogy for maintaining water quality is filtration, sanitation (disinfection and pool cleaning), and circulation (keeping the water circulating through the filter and disinfectant feed system).

Evaporation

Evaporation occurs naturally from all water surfaces. This includes:

Natural evaporation: In California, annual evaporation ranges from 40 inches in the northwest to 140 inches a year in the area in the southeast along the Arizona border. In the populated areas where most of the pools and fountains are located, the rates are in the range of 50 inches to 75 inches per year, equal to 0.085 and 0.128 gallons per square foot per day. Figure 9 shows the National Weather Service's annual average pan evaporation across the United States[7].

The size of the pool surface area and its location will determine how much evaporation occurs naturally. Pool and hot tub sizes range from 40 square feet for hot tubs to over 14,000 square feet for Olympic pools. The size of swimming pools varies considerably depending on use and design. Based on information from the Southern California Chapter of the Association of Pool and Spa Professionals[8] and information from various pool builder web sites, typical sizes can range from about 250 square feet for above-ground pools to 14,432 square feet for the official size of an Olympic regulation pool, which is 88 feet long and 164 feet wide.

Using the annual evaporation data from Figure 7 and the surface area of the water in pools and hot tubs, the average annual amount of water evaporated from each type of pool can be approximated. According to Grow Arizona, University of Arizona[6], pan evaporation can be used directly for swimming pools, especially above-ground pools and smaller residential pools. This assumes that the pools are not heated.

[7] http://www.grow.arizona.edu/Grow--GrowResources.php?ResourceId=208

[8] Personal communication, Mr. Mike Lasher, Southern California Association of Pool and Spa Professionals, February, 2009

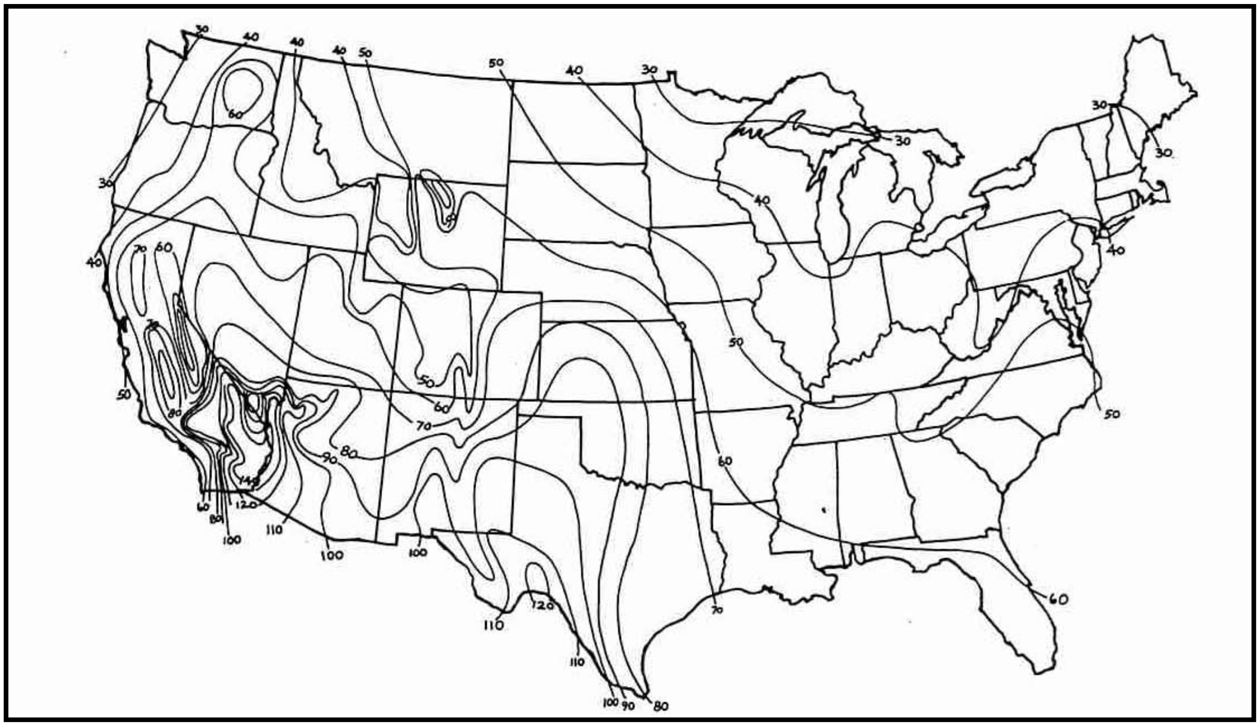


Figure 7. Average Annual Pan Evaporation
Source: National Weather Service

A 2008 NRDC report[9] states that only about 10 percent of pools nationally are heated. By contrast, hot tubs are nearly always heated. Table 4 provides estimates of water loss from heated indoor pools. As the data shows, most heated swimming pool evaporation rates are similar to pan evaporation rates of 0.085 and 0.128 gallons per square foot per day. The exception is the hot tub, which has a significantly higher evaporation rate of 0.41 to 0.45 gallons per square foot a day. Therefore, for this analysis, the average pan evaporation rate of 63.1 inches or 0.109 gallons per square foot a day is used for all pools and 0.43 gallons per square foot per day is used for hot tubs.

Table 4. Evaporation from Heated Indoor Pools

Type of indoor heated pool	Water temp °F	Air temp °F	Evaporation Factor (gal/hr/sqft) 60% humidity	Evaporation Factor (gal/hr/sqft) 50% humidity	Activity Factor	Gal/day/ sqft at 60% humidity	Gal/day/ sqft at 50% humidity
Residential	85	87	0.02	0.028	1	0.06	0.08
Hotel	82	84	0.019	0.026	1.3	0.07	0.10
Hot Tubs	104	88	0.071	0.079	2	0.41	0.45
Health/Competition	79	81	0.018	0.023	1.6	0.08	0.11
Heated Public	85	87	0.02	0.028	2	0.12	0.16

Source: Derived from Dehumidifier Corporation of America, Cedarburg WI[10]

[9] www.scribd.com/doc/17720453/NRDC-Report-Synergies-in-Swimming-Pool-Efficiency
[10] www.dehumidifiercorp.com

One factor that results in evaporation from fountains and water features in pools is the spraying of water. Spraying creates additional water surface, which, in turn, causes additional evaporation. The same effect is true for other water features of all types. Although the wetted surface and the sprays create surfaces of water from which evaporation occurs, fountains and pools typically store the majority of the water in pool sumps that are covered. This significantly reduces evaporation when these features are not in use. Table 5 summarizes evaporation estimates for different sizes of pools taken from Table 1.

Table 5. Approximate Average Annual Evaporation from Pools and Hot Tubs (gallons/year)

Typical Pool Area Square Feet		Pool Size (surface area in square feet)						
		40	252	450	800	1,000	4,000	14,432
City	Natural Evapo-ration (inches per year)	Hot tub	Above-ground pool	In-ground residen-tial	In-ground apart-ment	In-ground hotel	In-ground public	Regulation Olympic
Sacramento	65	6,278	10,210	18,233	32,413	40,517	162,067	584,737
San Francisco	50	6,278	7,854	14,025	24,933	31,167	124,667	449,797
Berkeley	60	6,278	9,425	16,830	29,920	37,400	149,600	539,757
Fresno	75	6,278	11,781	21,038	37,400	46,750	187,000	674,696
Los Angeles	60	6,278	9,425	16,830	29,920	37,400	149,600	539,757
San Diego	60	6,278	9,425	16,830	29,920	37,400	149,600	539,757
Bakersfield	75	6,278	11,781	21,038	37,400	46,750	187,000	674,696
California Average	63.6	6,278	9,986	17,832	31,701	39,626	158,505	571,885

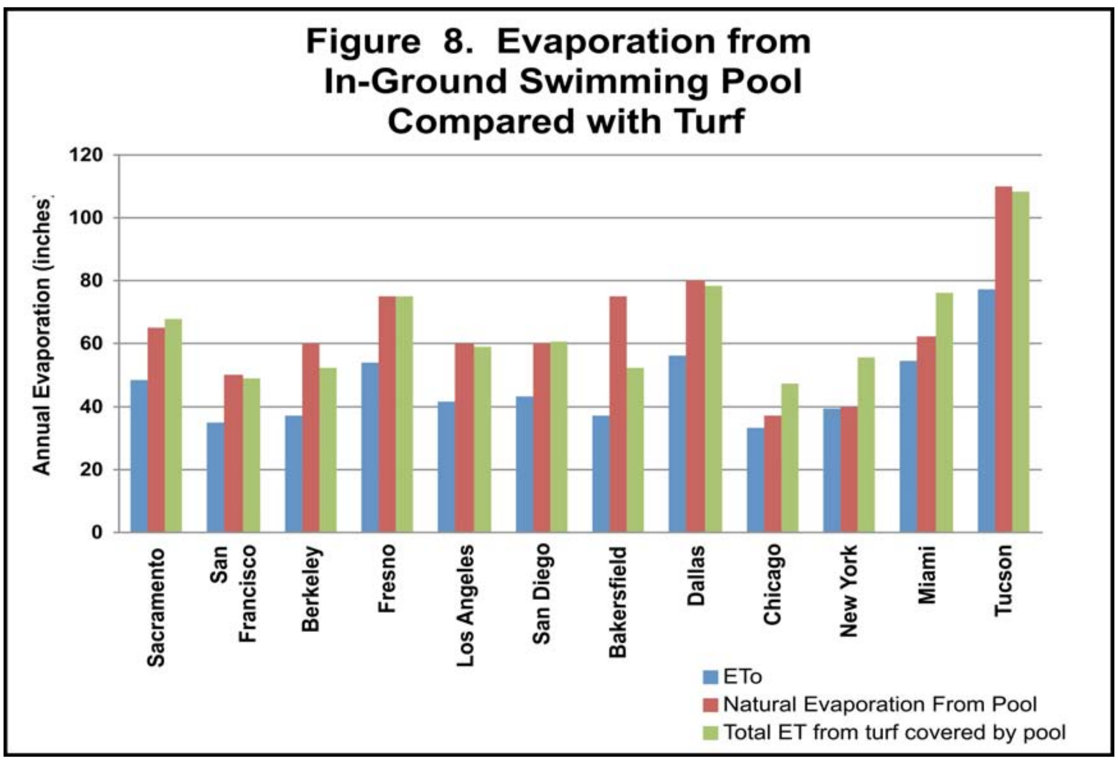
Comparing pool evaporation to evaporation from turf: In recent years, there has been controversy regarding natural evaporation from pool surfaces compared to that of the turf it may have replaced. The amount of water evaporated by turf grass is called evapotranspiration. When a typical in-ground pool is installed, it usually results in the removal of grass in both the area covered by the pool and surrounding pool decking. The evapotranspiration from the total area of turf removed must be compared to the evaporation from surface area of the pool and decking. A rule of thumb is that the impervious cover (concrete, tile, stonework, etc.) area around a typical residential pool is equal to 40 percent to 75 percent of the pool surface area. In order to compare evapotranspiration from turf areas to the evaporation from in-ground swimming pools, it was assumed for this analysis that the impervious cover area was equal to half of the pool surface area.

The base evapotranspiration rate defined for a standardized reference landscape is called ETo. The determination of ETo uses a Modified Penman-Monteith method to calculate monthly evapotranspiration. This is the method employed by the University of California Davis and by Rainbird[11], a major manufacturer of irrigation control equipment. The Rainbird site provides monthly and annual ETo values for many cities in the United States. This data was used to obtain annual ETo for seven California cities that represent the more populated areas of the state and is expressed in inches of evapotranspiration per year.

To estimate the water use associated with turf grass, the ETo value must be adjusted to the plant material being irrigated. Based upon the 2009 Model Water Efficient Landscape Ordinance proposal by the California Department of Water Resources[12], an adjustment factor of 0.8 for cold season grasses and 0.6 for warm season grasses was used. Irrigation system efficiency is a second factor that must be considered. For most systems, an efficiency factor of 0.75 represents a fairly efficient irrigation system. Therefore, assuming an in-between grass coefficient of 0.70 and an irrigation efficiency of 0.75, the estimate of actual evaporation (adjusted for crop and irrigation efficiency) that would be associated with the area to be removed for pool construction was calculated as follows.

Water required = {area (sq ft) X [ETo X (0.70/0.75)]/12}

Figure 8 shows this calculated for seven California cities as well as five cities across the United States.



[11] www.rainbird.com/landscape/products/controllers/etmanager.htm

Figure 8 compares the evaporation from the pool surface (and associated decking) with the amount of irrigation water that would otherwise be needed for a turf area equal to the pool area[13]. Many irrigation systems are less efficient than that assumed in this example. Therefore, except in arid Eastern California, the annual evaporation from the pool water surface will be equal to or less than the water that would need to be applied to a turf lawn with an automatic irrigation system. The same analysis was also performed for Dallas, Miami, Chicago, New York and Tucson so that other major cities could be compared to the California findings. For above-ground pools, where no walkway or decking around the pool is provided, or for new pools that do not replace existing turf, the analysis will show the pool as evaporating more water than that needed by the turf area it replaces.

Rainfall in most of the cities evaluated in the analyses is less than 25 inches a year. Rainfall will have similar impacts on pools or the turf they replace. Some water will soak in and become available for plant material and run off. Likewise, some rainfall will help fill the pool to the overflow and be discharged. The amount of water thus captured is dependent upon many variables such as soil condition, pool design, etc. and, therefore, was not considered in this analysis.

Leaks

All pools, hot tubs, fountains and water features are subject to leaks. The most common locations for leaks are where the pool and pipes are joined, at separations along the pool top and the bond beam, in the piping either on the suction or return lines to the filtration system, and in the liner of the pool itself. Another area where leaks are found is around the pump seals such as "O" rings.

Installing a meter on the pool makeup line is the most effective way of monitoring both pool or fountain water use as well as for checking for leaks[14]. The cost of adding a meter on the make-up line of a typical residential pool is under $150 at the time of construction, but can ultimately result in saving thousands of gallons of otherwise wasted water. For commercial and public pools and for larger water fountains containing 10,000 gallons of more, a makeup meter is essential to its efficient operation and is strongly recommended for in-ground residential pools[15].

Some pool websites and pool “experts” suggest that if a pool is losing more than two inches of water per week, it may have a leak. For high evaporation areas, this threshold may be increased to three inches per week. Also, if air bubbles are noticed in either the pump strainer basket or if bubbles appear in the water in the return line where the water enters the pool (even

[12] www.water.ca.gov/wateruseefficiency/landscapeordinance

[13] Including the area of walkways and decking surrounding the pool.

[14] This is not necessary on very small fountains pools, above-ground pools or hot tubs, but if the pool or fountain holds over 10,000 gallons, it should be considered.

[15] Owners and operators may also check for a leak in a pool by placing a five gallon bucket on a step in the pool where the bucket will be at least seventy percent submerged. The water supply to the pool should be turned off and the bucket filled to the exact same level as the water in the pool. After 12 to 24 hours, the bucket and pool water levels should be checked again. If there is no leak, the water levels should still be the same, but if the pool level is lower than the bucket level, it indicates that there is a leak below the water line of the pool. However, this method will not disclose leaks in plumbing above the water line.

after three or four minutes of the pump running), it may indicate that a leak exists in the suction side of the piping, resulting in sucking in air. The most obvious indicator of a pool leak is when wet spots appear around the pool, filter or piping.

Splash-Out Reduction

"Splash-out" is the water lost as people in the pool cause water to move and splash against and over the sides. Similar to this is what is known as "drag-out" which occurs as swimmers exit the pool. The design of the edge of the pool and the "freeboard" or level of the pool water below both the edge and the top of the pool overflow will all help reduce water loss. One of the simplest ways to reduce splash-out is to set the pool water level several inches lower than the edge of the pool and the overflow. This allows for the retention of rainfall when it occurs and reduces the amount of water splashed out. Several pool officials recommend maintaining at least four inches of freeboard.

The other directly helpful design feature is to bevel the edge of the pool so that it slightly overhangs the edge. This will help redirect splashes into the pool. It is important to remember that the area slightly back from the pool edge must be raised in order to prevent dirty rainwater from flowing across the lawn and deck into the pool.

Most commercial pools and many residential pools have gutter and grate systems around the edge of the pool to catch splashes. These are troughs that are built into the wall of the pool and drain back into the pool or can be used as a skimmer-type device. Figure 9 illustrates such a device. The system shown here is a DuraTech system[16].

Figure 9. Pool Gutter and Grate System

[16] www.renosys.com/duratech.html

Disinfection and Water Quality Control

The proper maintenance of pool water quality saves in three ways.

1. It reduces the number of times the pool must be drained to maintain total dissolved solids levels;
2. It reduces the number of backwashes needed; and
3. It reduces the potential for corrosion or other factors that can cause leaks.

Disinfection: Disinfection is an absolute necessity for all pools, hot tubs and ornamental recirculating fountains. Without it, the water would harbor harmful bacteria, grow algae, and require frequent dumping and refilling. The most common chemical used for disinfection is chlorine in its several forms. Larger pools sometimes use chlorine gas, while many use chlorine-containing chemicals such as sodium and calcium hypochlorite or chloramines. These chemicals can come in powder, tablet, gas, or liquid form. Other chemical disinfections include iodine and bromine. Chlorine stabilizers such as cyanuric acid are frequently added to help retard the loss of chlorine.

A new type of chlorine disinfection system uses salt dissolved in the pool water and an electrolysis-type device to generate chlorine from that salt. These are called "salt pools" and require the addition of salt to keep total dissolved levels between 2,000 and 3,500 ppm for proper operation of the equipment. Exact numbers are not available, but the percent of all pools currently using this method is assumed to be very small.

Ozone and ultraviolet light (UV) have also found application. With recent concern for cryptosporidium in some commercial pools, pre-coat filters such as perlite or diatomaceous earth (DE) followed by UV has been have been installed in addition to chlorine disinfection.

Algaecides are sometimes used to control both green and mustard-type algae problems. Some of the first used were cooper compounds. While these work, they are toxic to plants and can cause stains to pool surfaces. The quaternary ammonia compounds have been used successfully for a long time and do not have the plant toxicity of cooper if the pool water is ever to be used for irrigation.

Water Quality: Table 6 summarizes recommended minimum and maximum levels for constituents for conventional swimming pools.

Table 6. Recommended Ranges for Selected Parameters for Conventional Swimming Pools[17]

Constituent	Minimum*	Maximum*
Total Dissolved Solids (TDS) - Regular Pools	300 ppm	2,000 ppm
Total Dissolved Solids (TDS) - Salt Pools	2,000 ppm	3,500 ppm
Cyanuric Acid	10 ppm	100 ppm
Free Chlorine	3 ppm	10 ppm
Hardness	150 ppm @$CaCO_3$	500ppm @$CaCO_3$
Total Alkalinity	60 ppm @$CaCO_3$	180 @$CaCO_3$
pH	7.2	7.6

*-ppm: parts per million and is equal to milligrams per liter (mg/L)

Source: Center for Disease Control (CDC), Healthy Housing Reference Manual

[17] www.cdc.gov/nceh/publications/books/housing/cha14.htm

Maintaining proper pH, alkalinity, and hardness control to reduce corrosion and prevent damage to pool surfaces both extends equipment and pool life and reduces the number of times pools must be dumped and refilled. Total dissolved solids control is another major factor in how much water is used in pool operations. All pools will eventually require their water to be either exchanged or treated to remove dissolved contaminants in the pool. These include body salts, sun tan lotions or other substances that may have been applied to the body, the salts in the chemicals added to the pool to control biological growth, windblown dust and salts, and the salt concentrations in the water in the pool resulting from evaporates.

The importance of these ranges is twofold. First, the comfort and health of the swimmer depends on the water quality. Secondly, the buildup of total dissolved solids determines when it is time to exchange the water in the pool (dump and fill the pool). Cleaning the pool, and maintaining proper chemical balance and disinfection levels, all play a major role in delaying the time that the water in the pool must be exchanged.

In northern climates where freezing water is a problem, pools are often drained in the winter or drawn down to below the skimmer and return port pipe level so pipes can drain[18]. The pools are then covered with insulated blankets to minimize freezing. In warmer climates, such as much of California, the Southwest and the Gulf Coast, pools are typically kept full with circulation systems working year-round.

Some larger pools are equipped with conductivity controllers that act to dump water as a predetermined total dissolved solids level is reached. This has the advantage of not having to dump the entire pool and produces a frequent source of water that could be used for irrigation or other purposes. In all of these cases, water with high dissolved solids is simply dumped to drain and replaced with fresh water. The volume of water depends on four factors:

- The volume of the pool;
- The dissolved solids in the makeup water;
- The type and amount of treatment chemicals added; and
- The local evaporation rate.

Figure 10. Pool Reverse Osmosis System

Treatment chemicals, such as cyanuric acid, which is used to retard chlorine loss, can also build up to unacceptable levels since it does not evaporate like chlorine. The use of calcium hypochlorite tablets can add calcium hardness.

In recent years, the use of Reverse Osmosis and Nanofiltration (RO and NF) have shown significant promise for reducing water lost through the necessary dumping of pool water to reduce dissolved minerals buildup. These products have become more sophisticated. For

[18] Caution: Draining a pool can be dangerous if the underlying water table is high. Pools can act as a "boat" and literally float out of the ground when all of the water is removed, thus destroying the pool. Before completely draining a pool, experts should be consulted.

example, Clean Water Products[19] of Tucson, Arizona was one of the first to develop and market this product. As the Figure 10 shows, the system is portable. The company founder, Dr. Carwin Cluff[20] reports that they can recover up to 78% of the water that was previously wasted. Other companies throughout the Southwest are beginning to offer similar services.

The same considerations hold for fountains. They often reach high TDS levels faster than pools, because water is often sprayed in the air, thus increasing evaporation rates. Finally, the Association of Pool and Spa Professionals (APSA) also recommends that hot tubs be drained several times a year.

Filtration Equipment

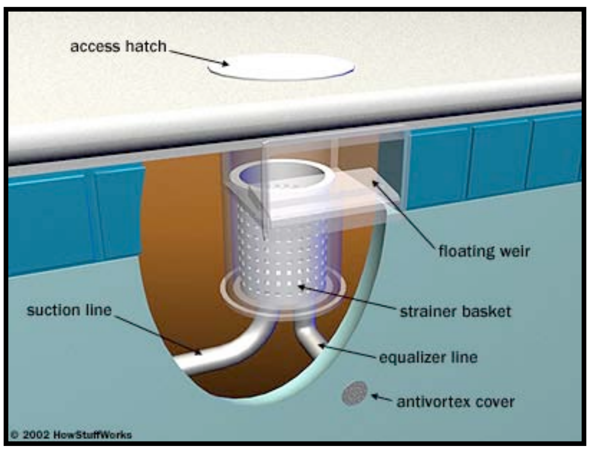


Figure 11. Skimmer and Filter Strainer Baskets

At the heart of all pool water treatment systems are filters to remove particulate matter from the water and keep the water clear. The filter systems consist of the pump to circulate water, and the actual filter. All of these systems are normally preceded by strainer baskets to catch larger debris both in the pool skimmers and just before the pump. This significantly extends the time when filters must be backwashed or cleaned, saving both water and labor. Figure 11 illustrates strainer baskets.

There are three basic filter configurations available. The most common filter in use for both residential and commercial pools is the sand filter. Pre-coat filters (diatomaceous earth - DE, perlite, and cellulose) and cartridge filters all have gained ground in recent years. The pre-coat filters include industrial systems that can significantly reduce water use in larger facilities. Each is described below.

[19] www.cleanwaterproducts.net/Swimming_Pools.html
[20] Personal conversation, March 15, 2010

Sand and zeolite filters: Sand filters such as the two shown in Figures 12 and 13 are found in both residential and commercial settings. As the name implies, they use sand as the filter media or a zeolite. The water is pumped under pressure into the top of the filter. It passes through the sand, which filters out particulates. As it operates, a layer of material filtered out of the water builds up on the top of the sand bed. When the pressure difference from the top of the bed to the bottom of the bed exceeds 8-10 pounds per square inch, the filter is backwashed.

Figure 12. Sand Filters for Hotel Pool

Figure 13. Large Public Pool - Sand Filter

Special valves allow this to happen. The water moves from the bottom of the filter up through the filter material to the top and accumulated dirt on top of the filter is discharged. A sight glass is used to determine when the dirt has been removed, which is revealed when the water in the glass appears clear. Sand filters are used on all sizes of pools. Larger pools can use horizontal filters, which are simple tanks on their sides.

Cartridge filters: Cartridge filters use pleated filters made from paper-type material. The surface area of the filter can exceed 400 square feet in modern filters. The filter elements only need cleaning a few times per year. Old, wasteful disposable filter cartridges should not be re-used. However, modern re-usable cartridges need only to be washed off with a hose and returned to the filter housing. Since these filters do not need to be backwashed, they are the most water-efficient type available for all but the largest pools and are finding wide acceptance in the residential and smaller apartment pool market. Because they are water-efficient, some local governments are encouraging their use. According to a 2008 National Resource Defense Council report to the California Energy Commission[21], properly sized cartridge filter systems use less energy than comparable sand and DE filters in home use.

Figure 14. Cartridge Filter

[21] www.scribd.com/doc/17720453/NRDC-Report-Synergies-in-Swimming-Pool-Efficiency

Pre-coat filters: Pre-coat filters include conventional diatomaceous earth[22] (DE), cellulose[23], or perlite[24] filters and regenerative filters that reuse the filter media. These filters remove particles down to 5 microns in size, while sand and cartridge filters work in the 10- to 40-micron removal range[25]. Pre-coat filters have hundreds to sometimes over 1,000 fabric-coated tubes inside a pressure container. The filter media (DE, cellulose or perlite) is made into a slurry and mixed with the water in the filter. The media is then deposited on the tubes by the water being pumped through the filter. Conventional pre-coat filters must have the DE or perlite replaced after each backwash.

With regenerative pre-coat filters, the media is periodically “bumped” off of the filter tubes by backflow, air agitation, mechanical shaking, or a combination of the three. It is then recoated onto the filter cloth. Regenerative filters save significant volumes of water and filter media since the media can be recycled up to 30 times before it is ultimately discharged to waste.

For large commercial pools, automated pre-coat, regenerative filter systems are available. These systems are also sometimes called industrial filters since their use originated in food process and water treatment operations. A significant water saving factor with these filters is that the internal filter media recycling occurs about thirty times before the media is dumped and replaced. No water is lost in the recoating process. When the media is flushed, the only water dumped is the water in the filter plus one additional filter volume to make sure the vessel is completely rinsed. This means that the backwash water needed is equal to about twice the volume of the filters themselves. This is different from home DE filters that use the pool pump to force water through the filter.

Figure 15. Defender Pre-coat Filter by Neptune Benson

In addition, these large industrial units use air to "bump" the filter media off of the filter elements. This eliminates another water use for this purpose[26]. This makes regenerative pre-coat (industrial) filters very water-efficient. Since the perlite media can be bumped and

[22] Diatomaceous earth is a white powder made from the "skeletons" of small aquatic plants in the algae family called diatoms. It is inert, but breathing the powder can be harmful since the skeletons are made up of silica materials. Residential and commercial filters typically use either DE or perlite media. In recent years, many wastewater utilities have placed bans on the discharge of diatomaceous earth to sanitary sewers since it tends to settle out and clog sewer lines. Settling tanks and bag filters are often required to remove the DE before the water can be discharged. The DE can either be disposed of in the trash or used as a soil amendment. DE has a bulk density of 19 pounds to 22 pounds per cubic foot.

[23] Cellulose is made from plant fibers. It is not widely used for pools, but is used in some food and beverage operations.

[24] Perlite is made from a silicon-based material found in volcanic deposits. When heated, it expands to form a very light weight, chemically inert material that is used for filtration, as a soil conditioner, and insulation. Because it is so light weight, it tends to float on water when dry. It does not have the strong tendency to settle out in sewer lines that DE does. For this reason, many wastewater utilities have allowed filter backwash water from perlite coated filters to be discharged to sewers. Many utilities collect the backwash water and use the perlite as a soil amendment. Perlite has a bulk density of two to eight pounds per cubic foot.

[25] www.poolplaza.com

[26] www.defenderfilter.com/

redistributed about thirty times before needing to backwash, backwashing is stretched to months rather than weeks or even days for large commercial pool sand filter systems. Table 7 summarizes selection factors for filtration systems for residential swimming pools.

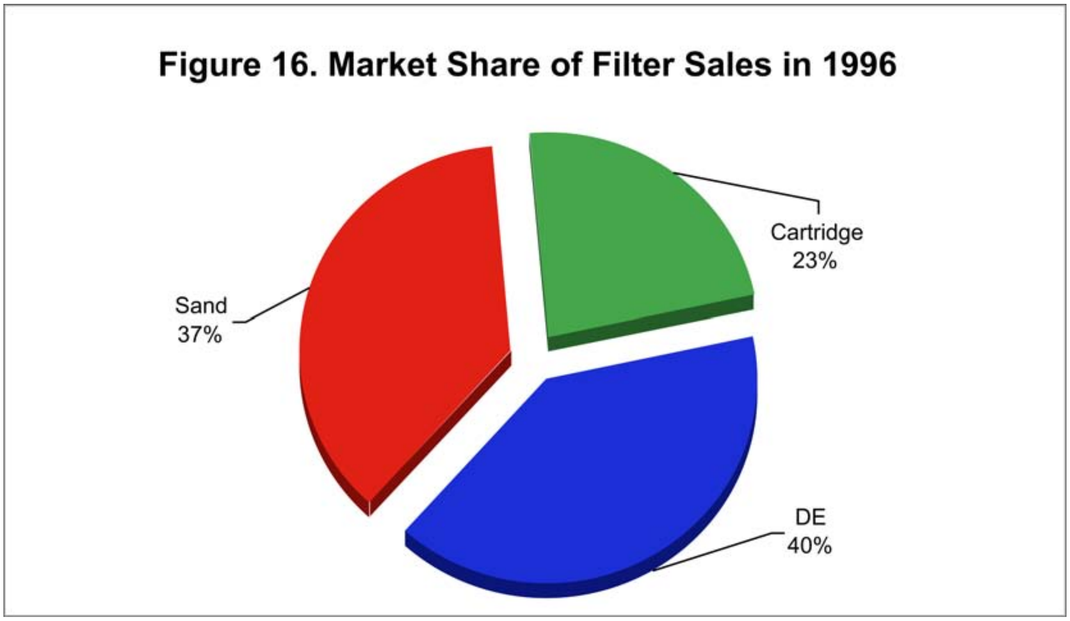
Table 7. Filter Selection Factors for Residential Pools[27]

	Sand	Coated Media	Cartridge
Frequency of Cleaning	Every week	4-8 weeks	Depends on unit
When to clean *(Difference in pressure across filter)*	5-10 psi	8-10 psi	8-10 psi
How cleaned	Backwash	Backwash[(a)]	Take apart & wash with hose
Filtration *(microns)*	20-40	5	10 (can vary on cartridge)
Time between media replacement	3-6 years	Every backwash	2-4 years depending on filter
Cost of media	$0.50 to $1.00/lb	$0.15 -$0.50/lb	$15-$100 each
Residential use	Yes	Yes	Yes
Commercial use	Yes	Yes[(b)]	Not Recommended
Backwash flow time	2-5 minutes[(c)]	1-5 minutes[(c)]	Remove & wash

(a) DE and Perlite filters should be "bumped and swirled" whenever pressure drop across filter reaches 8-10 psi.
(b) DE not recommended for apartments, condominiums or hotels since the filters quickly become clogged with the high rate of use. Specially designed DE and Perlite filters are made for high volume use though.
(c) Typical times. Filter must be backwashed until sight glass is running clear.

The types of filters sold for residential pool use are changing. Figure 16 shows sales by filter type in 1996. However, one report[28] states that cartridge filter sales are increasing by 15 percent to 25 percent a year. Telephone conversations with several Association of Pool and Spa Professional members confirms that there is a trend towards cartridge filters for residential pools. As of 2009, cartridge filters may equal sand filters in numbers. Others report a decrease in the use of DE filters in favor of cartridge filters.

[27] Personal communications, 2010. Robert Hawkin and Scott Hyland, Neptune Benson, Coventry, RI
[28] www.businessplans.org/Clear.Clearo2.html



Pool cleaners: Pool vacuum cleaning equipment is used to remove debris from the bottom and sides of pools. These include hand-operated vacuum hoses that an operator draws along the bottom of the pool as well as automatic systems that move around the pool on their own. There are four system types. The suction type is attached to the suction port on the pool and uses the pool filter to capture debris. This system is effective, but because the debris and dirt are captured on the filter, the filter will require more frequent backwashing, thus using more water.

Figure 17. Stand-alone System with Separate Filter

Three others do not use the filter to catch the removed dirt. One works off of the pressure side. The water flowing through a small turbine operates the vacuum system that discharges into a strainer bag attached to the discharge from the system. Another type is powered by electricity and uses a similar bag-type system. Stand-alone systems can also be used. These are powered by a separate pump and have filter bags to catch the debris for disposal. The filtered water is returned to the pool.

Equipment Operations

Commercially operated pools, ranging from apartment pools to public community pools, must comply with the operational requirements of the health codes. In California, pools used by the public must have turnover rates as shown in Table 8.

Table 8. Required Public Pool Turnover Rates*

Type of Pool	Turnover Rate
Swimming Pool	Every 6 hours
Wading Pool	Every hour
Spa	Every 30 minutes

**California Health and Safety Code, Sections 116025-116068*

For residential pools, the situation is very different. The Centers for Disease Control recommends that residential pools follow the same requirements as public pools, but in recent years, the emphasis on both energy and water conservation has resulted in other recommendations. For example, the following recommendation, from the Los Angeles Department of Water and Power, states the following[29]:

> "Rather than computing the turnover time, you may prefer to follow the pool filter operating recommendations established by the California Swimming Pool Industry Energy Conservation Task Force - which are as follows:
>
> 'Reduce filter operating times to no less than 4 to 5 hours per day during the summer and 2 to 3 hours per day during the winter period. *This will reduce annual electrical consumption by 40 to 50 percent. Normal and heavier swimming use may require as much as eight or more hours filtration per day. Should water* clarity or chemical imbalance indicate inadequate filtration, immediately operate the filter until acceptable water clarity has again been established. If additional filtration is still indicated, increase filter operating time in one-half hour increments until the water remains clear and properly balanced chemically. When the pool is being heavily used, it is recommended that the pool be operated manually and that the filtration system be run under such conditions. Under no circumstances should the water quality of any swimming pool be so poor that the main drain cover is not clearly visible from the deck.' "

In fact, some sources state that the turnover rate for a private residential pool can be as low as once per day.

Draining pools, spas, and fountains must be performed in accordance with local ordinances. Most require that water from swimming pools, spas, or decorative fountains be de-chlorinated or de-brominated prior to discharge to the street, storm drain, or sanitary sewer. Chlorine or bromine should dissipate within 48 hours for most pools. Draining is the easiest way to de-chlorinate or de-brominate residential pools. Some commercial pools operators may prefer to use de-chlorination chemicals, but instructions must be carefully followed. Ordinances frequently require that the drain water not be discharged to the sanitary sewer. Many residential pool owners can use this water for irrigation if the salinity is not too high. Owners of "salt pools" should consult their local wastewater and storm water officials before draining pools.

Regular inspection of equipment, checking for leaks, and keeping debris out of the pool are important components of proper pool operation. For pools with meters, readings of water use should be made at least every other week and records kept. All of these help to ensure that both water and energy are used most efficiently.

[29] www.naturalhandyman.com/iip/infpool/infpoolconservation.html

V. Analysis of Pool and Fountain Water Use in California

The estimation of water use is, by necessity, based upon several general assumptions regarding pool operations. Every pool owner will operate their pool differently. The assumptions used in this section reflect "typical" practices reported in the literature and are documented for each use. It is also assumed that fountain water use is included within the estimated 2.1 million residential pool population, since fountain numbers are less than one percent of this total.

Estimating the amount of water used annually to operate pools, hot tubs, and outdoor ornamental fountains in California must include the three main uses and losses:

1. Evaporation
2. Filter Backwash
3. Fill and Draw

In addition, there are losses through drag-out, splash-out, and leaks. These are not possible to quantify but are assumed to be smaller than the main uses. Splash-out and drag-out are dependent on both physical pool design and the number of swimmers. Some of these losses are unavoidable. Leaks on an individual pool or fountain can be significant. The author has experience with pools that lose over 200,000 gallons a month through leaks, as well as large ornamental fountains that lose even more. Metering and good pool, spa, and fountain maintenance are keys to identifying and preventing losses.

Evaporation

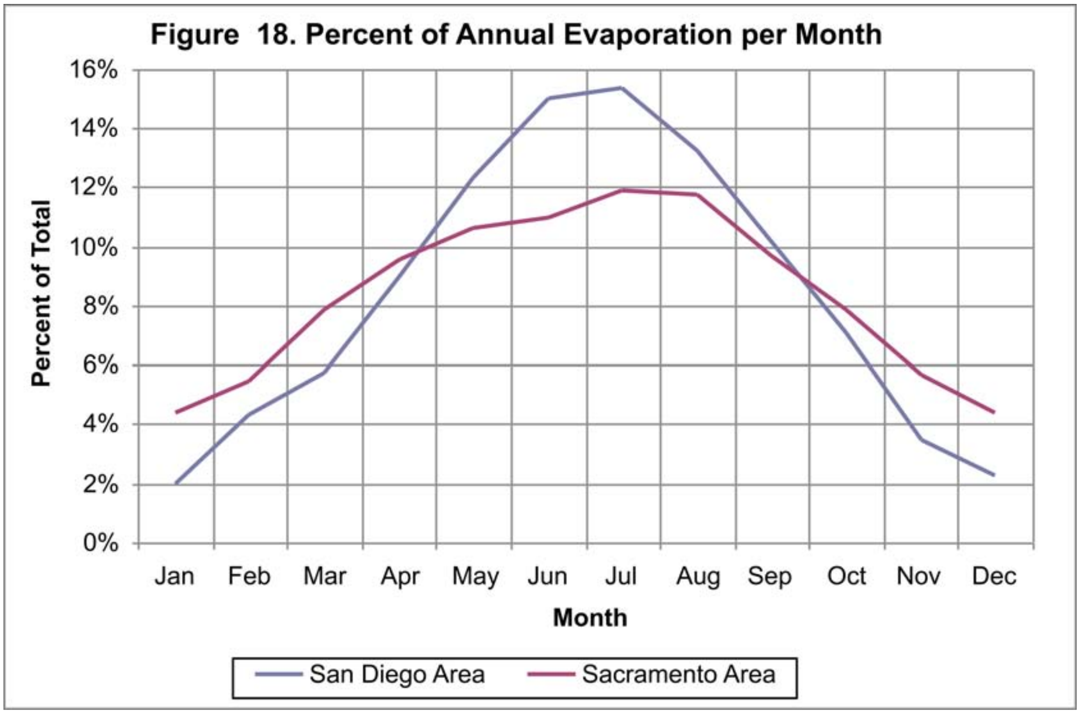
Based in Tables 3 and 4, the amount of evaporation per pool and number of each type of pool can be used to estimate total annual evaporation.

Table 9. Estimate of Total Annual Evaporation from Pools in California

Type of Pool	Average Evaporation per Pool *Gallons/Year*	Number of Pools	Millions of Gallons per Year	Acre Feet per Year
Hot Tub	1,973	1,400,000	2,762	8,477
Above-Ground*	9,946	1,000,000	9,946	30,523
In-Ground *	17,760	1,062,000	18,861	57,883
Apartment	31,574	50,000	1,579	4,845
Hotel/Motel	39,467	5,000	195	600
Public	157,869	60,000	9,538	29,272
Olympic	569,592	100	57	175
	TOTAL	**3,577,100**	**42,939**	**131,774**

*residential

Evaporation is higher in the summer as expected. Figure 18 shows the typical annual distribution of evaporation by month[30]. An important observation is that monthly evaporation rates are the highest when most pools are left uncovered, since this also corresponds to the period of maximum pool use.



Filter Backwash

Filter backwash can be one of the largest single uses of water by pools and fountains. Table 10 summarizes the assumed typical operating characteristic of each type of pool, spa and fountain. The turnover rates in hours are based on health code requirements for pools serving the public, including hotels and apartments. The number of backwashes per year shown in Table 10 is based upon Table 7 and conversations with a number of pool owners and operators.

[30] www.wrcc.dri.edu/htmlfiles/westevap.final.html

Table 10. Typical Pool Operating Characteristics								
Type of Pool	Pool Area	Pool Volume	Turnover Rate *Hours*	Run Hrs./Day	Backwashes per Year**			
					Sand	DE	Industrial **	Cartridge ***
Hot Tub	50	1,122	2	4	25	25		6
Above-ground*	252	7,540	6	6	50	30		8
In-ground *	450	15,147	6	6	50	35		8
Apartment	800	26,928	6	12	75	50		10
Hotel/Motel	1,000	33,660	6	12	80	50	10	12
Public	4,000	149,600	6	24	100	50	10	
Olympic	14,432	863,611	6	24	100	50	10	

* Residential
** System not cost effective for small pools
*** Number of times cartridge filters are removed and cleaned instead of backwashing. Cartridge filters are normally not used on large pools

Table 11 provides the assumptions for the operation of a typical pool to backwash or clean filters.

Table 11. Typical Backwash Methods	
Type of Filter	Backwash Methods
Sand	Backwash for 4 minutes at rate equal to pump circulation rate
Conventional Diatomaceous Earth	Backwash for 2 minutes at rate equal to pump circulation rate and then recoat
Industrial DE or Perlite Type System	Fill and drain vessel twice before recoating
Cartridge	Remove and wash with a hose and nozzle

For sand and conventional Diatomaceous Earth (DE) filters, the backwash rate is equal to the circulation rate of the pump. The turnover rate and volume are key to calculating the pump circulation rate. That rate in gallons per minute (gpm) is equal to the volume of the pool divided by the time to turnover in minutes. The turnover time in minutes is simply the turnover time in hours times 60 minutes per hour. For example, a pool with 25,000 gallons of water and a turnover rate of 8 hours would calculate the circulation rate as follows:

$$25{,}000/(8 \times 60) = 52.1 \text{ gpm}$$

In this example, the next largest pump will normally be chosen, but for these calculations, the circulation rate will be assumed to be equal to the actual gpm as calculated above. If this pool used a sand filter with a backwash time of 4 minutes, the volume of water need to backwash the pool would equal the circulation rate times four minutes or:

$$52.1 \times 4 = 208.3 \text{ gallons}$$

If the pool had a DE filter, the backwash time would only be 2 minutes, so the backwash volume would only be 104 gallons. For sand and DE filters, the amount of water used per backwash is summarized in Table 12.

Table 12. Volume of Water Required Per Backwash for Sand and DE Filters				
			Gallons per Backwash	
Type of Pool	Pool Volume	Turnover Rate *Hours*	Sand @ 4 Minutes/ Backwash	Conven-tional DE @ 2 Minutes/ Back-wash
Hot Tub	1,122	2	37	19
Above-ground*	7,540	6	63	31
In-ground *	15,147	6	126	63
Apartment	26,928	6	299	150
Hotel/Motel	33,660	6	374	187
Public	149,600	6	1,662	831
Olympic	863,611	6	9,596	4,798

* Residential

For large industrial-type perlite and DE filters, the filters are air-bumped to remove the coating material from the filter, while the filter tanks are drained to remove the coating material. Tanks are usually drained twice according to the manufacturers of the Defender System[31]. The filter tank volume was taken from the Defender System literature and rounded off to the nearest 10 gallons. Since these types of filters only apply to very large pools, such as hotel, public and Olympic pools, only those pool types were considered. Filter tank volumes are assumed to be 250 gallons for a hotel pool, 450 gallons for a public pool, and 850 gallons for an Olympic pool. Therefore, the volume of water required to backwash two filter tank volumes would be as follows:

- 500 gallons for a hotel pool,
- 900 gallons for a public pool, and
- 1,700 gallons for an Olympic pool.

Cartridge filters are removed and washed with a hose. The size of the filter elements and the number of elements in each filter will determine how long it takes to wash them. For estimation purposes, the assumptions shown in Table 13 were used after communicating with several pool operators.

[31] www.defenderfilter.com

Table 13. Water Used to Wash Cartridges form Cartridge Filters	
Type of Pool	Gallons per Wash
Hot tub	50
Above-ground	100
In-ground residential	150
In-ground apartment	250
In-ground hotel	300

To determine water use, the number of pools using each type of filtration equipment must be estimated. For smaller pools, Figure 16 was used to estimate the percent of pools using each type of filter. For larger pools, the author used experience of years of auditing such facilities to develop an estimate.

Table 14. Number of Pools in California by Type of Filter									
Type of Pool	Number of Pools	Percent by Type of Filter				Number of Pools and Fountains With Type of Filtration System			
		Sand	DE	Cartridge	Industrial	Sand	DE	Cartridge	Industrial
Hot Tub	1,400,000	37%	40%	23%	0%	518,000	560,000	322,000	0
Above Ground*	1,000,000	37%	40%	23%	0%	370,000	400,000	230,000	0
In Ground *	1,062,000	37%	40%	23%	0%	392,940	424,800	244,260	0
Apartment	50,000	37%	40%	23%	0%	18,500	20,000	11,500	0
Hotel/Motel	5,000	50%	40%	10%	0%	2,500	2,000	500	0
Public	60,000	80%	19%	0%	<1%	48,000	11,400	0	3
Olympic	100	94%	5%	0%	1%	94	5	0	1
TOTAL	**3,577,100**					**1,350,034**	**1,418,205**	**808,260**	**4**

* Residential

The next step was to estimate the amount of backwash water needed annually for all pools using the same type of filtration. That amount is equal to the number of pools, multiplied by the gallons per backwash or cleaning, multiplied by the estimated number of times backwashing or cleaning is performed. Total annual volumes are expressed both in millions of gallons and acre feet per year. This information is summarized in Table 15 through Table 18.

Table 15. Estimated Water Use For Backwashing Sand Filters in California						
Type of Pool	Number of Pools in California	Gallons per Backwash	Backwashes per Year	Backwash *Gallons per Year Per Pool*	Millions of Gallons per Year	Acre Feet per Year
Hot Tub	518,000	37	25	935	484	1,486
Above Ground	370,000	84	50	4,189	1,550	4,756
In Ground	392,940	168	50	8,415	3,307	10,148
Apartment	18,500	299	75	22,440	415	1,274
Hotel/Motel	2500	374	80	29,920	74	227
Public	48,000	1,662	100	166,222	8,035	24,657
Olympic	94	9,596	100	959,568	90	277
TOTAL					**13,955**	**42,825**

Table 16. Estimated Water Use For Backwashing Conventional Diatomaceous (DE) Filters in California						
Type of Pool	Number of Pools in California	Gallons per Backwash	Backwashes per Year	Backwash Gallons per Year Per Pool	Millions of Gallons per Year	Acre Feet per Year
Hot Tub	560,000	19	25	468	262	803
Above Ground	400,000	42	35	1,466	586	1,800
In Ground	424,800	84	35	2,945	1,251	3,840
Apartment	20,000	150	50	7,480	150	459
Hotel/Motel	2,000	187	50	9,350	19	57
Public	11,400	831	50	41,556	502	1,541
Olympic	5	4,798	50	239,892	1	4
TOTAL					**2,771**	**8,503**

Table 17. Estimated Water Use For Cleaning Cartridge Filter Elements in California*						
Type of Pool	Number of Pools in California	Gallons per Backwash	Backwashes per Year	Backwash Gallons per Year Per Pool	Millions of Gallons per Year	Acre Feet per Year
Hot Tub	322,000	50	6	300	97	296
Above Ground	230,000	100	8	800	184	565
In Ground	244,260	150	8	1,200	293	900
Apartment	11,500	250	10	2,500	29	88
Hotel/Motel	500	300	12	3,600	2	5
TOTAL					**604**	**1,854**

* Cartridge systems are typically not used on larger systems.

Table 18. Estimated Water Use For Backwashing Industrial Perlite and DE Filters in California*						
Type of Pool	Number of Pools in California	Gallons per Backwash	Backwashes per Year	Backwash Gallons per Year Per Pool	Millions of Gallons per Year	Acre Feet per Year
Hotel/Motel	0	500	10	5,000	0.000	0.00
Public	10	900	10	9,000	0.01	0.03
Olympic	4	1,700	10	17,000	0.05	0.2
TOTAL					**0.06**	**0.23**

* These systems are used only on very large pools because of initial capital cost.

Residential, apartment, and hotel/motel pools typically use sand, DE and cartridge filters while larger public pools and Olympic pools use sand, DE or industrial perlite or DE type filtration equipment. Since the number of residential pools far exceeds commercial pool numbers, Figure 19 summarizes backwash and cartridge cleaning water use for residential systems, while Figure 20 summarizes water use for apartment and other commercial pools.

Figure 19. Estimated Annual Backwash Water Use Per Residential Pool

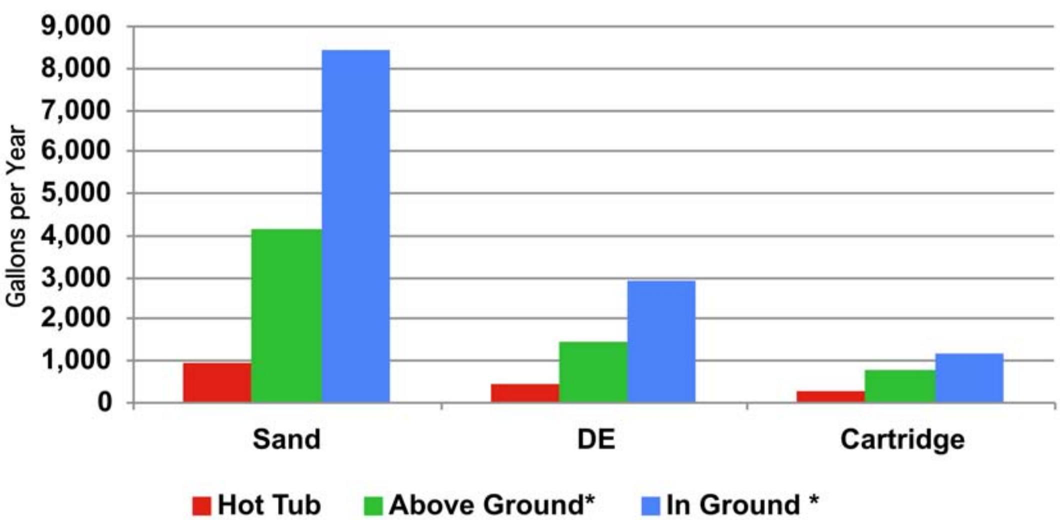
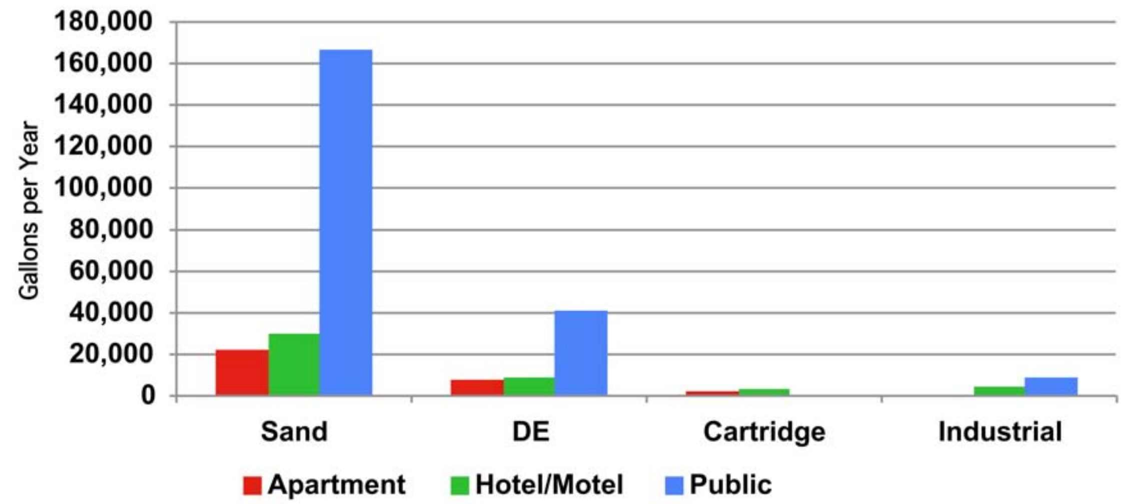


Figure 20. Estimated Annual Backwash Water Use
Per Commercial Pool



As Tables 15 through 18 show, the amount of water used by all pools in California to backwash filters and clean cartridge filters is estimated to be about 53,000 acre feet per year. Table 19 summarizes the filter backwash and cleaning use estimates.

Table 19. Summary of Annual Water Use for Backwash and Cartridge Cleaning in California

Type of Pool	Annual Water Use *Acre Feet Per Year*				
	Sand	DE	Cartridge	Industrial	Total by Type of Pool
Hot Tub	1,486	803	296		2,586
Above Ground Residential	4,756	1,800	565		7,121
In Ground Residential	10,148	3,840	900		14,887
Apartment	1,274	459	88		1,821
Hotel/Motel	227	57	5		290
Public	24,657	1,541		0.03	26,198
Olympic	277	4		0.05	281
Total by Type of Filter	42,825	8,503	1,854	0.1	
Total for All Backwash					***53,183***

Water Use to Control Total Dissolved Solids (TDS)

As water evaporates from pool surfaces, the minerals and salts in the water remain behind. The typical range of total dissolved solids at which pools are either drained and refilled or where automatic partial fill and dump occurs is between 1,500 ppm and 2,000 ppm. Based on average California evaporation rates of 5.3 feet per year (from pools that average 4.5 feet in depth) and an assumed municipal water quality of 250 to 300 ppm of TDS, pool water would normally be drained and refilled every 24 to 30 months. This can be accomplished either by draining the entire pool at once or by draining smaller volumes and refilling on a regular basis. Table 20 summarizes the amount of water that would be needed to dump and refill pools in California on an average of every 27 months.

Table 20. Water Typically Used to Control Total Dissolved Solids by Dumping Pool

Type of Pool	Pool Volume	Gallons per year *(Dump every 27 months on average)*	Number of Pools by Type	Millions of Gallons per Year	Acre Feet per Year
Hot Tub	1,122	499	1,400,000	698	2,142
Above Ground*	7,540	3,351	1,000,000	3,351	10,284
In Ground *	15,147	6,732	1,062,000	7,149	21,941
Apartment	26,928	11,968	50,000	598	1,836
Hotel/Motel	33,660	14,960	5,000	74	227
Public	149,600	66,489	60,000	4,017	12,329
Olympic	863,611	383,827	100	38	118
Total				**15,927**	**48,877**

* Residential

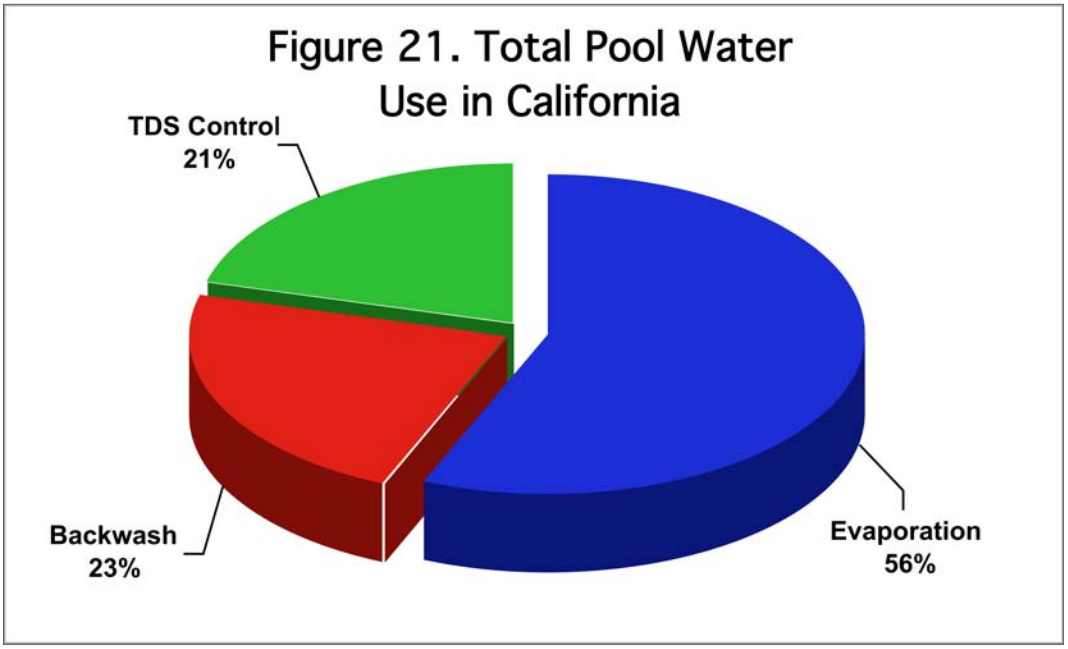
Summary of Water Use by Top Three Uses

The three largest water uses are evaporation, backwash and TDS control for all pools and spas. The total use in California is estimated to be 234,000 acre feet per year (640 acre-feet per day) or an average of about 208 million gallons of water per day. Table 21 summarizes these uses by type of pool and Figure 21 displays the totals graphically.

Table 21. Summary of Estimated Annual Water Use for California

Type of Pool	Estimated Water Use *acre feet per year*			
	Evaporation	Backwash	TDS Control	Total
Hot Tub	8,477	2,586	2,142	13,206
Above Ground *	30,523	7,121	10,284	47,928
In Ground*	57,883	14,887	21,941	94,710
Apartment	4,845	1,821	1,836	8,503
Hotel/Motel	600	290	227	1,117
Public	29,272	26,198	12,329	67,799
Olympic	175	281	118	573
Total	**131,774**	**53,183**	**48,877**	**233,835**

* Residential



Other Losses - Leaks

The amount of water lost through pool and fountain leaks is nearly impossible to quantify. The Alliance for Water Efficiency offers the following information[32]:

> "Even minor swimming pool leaks can cause substantial damage and result in huge water bills and it is estimated that one pool in every 20 has a leak. Just how serious can a leak become? A pinhole-sized leak in a pool plumbing system with 40-pound pressure (psi) will lose approximately 970 gallons (3.67 m^3) of water in a 24-hour period. This comes to about 30,000 gallons (113.5 m^3) a month or 360,000 gallons per year (1,361 m^3). That's enough to drain and refill the average residential swimming pool more than a dozen times."

A leak of the magnitude described above should be observed by the person paying the water bill and corrective action taken soon thereafter. However, smaller leaks can go unnoticed for months. If one in 20 pools (as noted above), or 5 percent, are leaking, the water lost can be equal to tens of thousands of acre feet per year. A meter on the fill line to the pool would be able to disclose most of these leaks; the pool owner or operator, however, must *read* the meter in order for the meter to be useful.

Other Losses – Splash-Out and Drag-Out

Splash-out and drag-out are related directly to pool usage and water waste associated with these activities is also impossible to quantify. For example, if it is assumed that the result of splash-out is to keep a two to three foot wide strip of the deck around the pool wet, then that could increase evaporation by as much as 50 percent, simply because a larger surface area is wet and exposed to evaporation. Drag-out is a little different since it is the water that wets the swimmers' skin and clothing. Water that drips onto the area around the pool or evaporates while the person is out of the pool is considered lost, but if the person re-enters the pool while

[32] www.allianceforwaterefficiency.org/Swimming_Pool_and_Spa_Introduction.aspx

wet, losses are reduced. Both of these water losses depend on the number of people using a pool each day. Since there are long periods of inactivity in winter months as well as times during the summer day when the pool is not being used, this loss is somewhat limited. While no attempt was made to quantify these losses, they do have the potential to increase evaporative losses beyond those already predicted.

The use of pool vacuum and cleaning devices that do not suck dirt into the filters will also save water by extending the time between backwashes. Quantifying this potential savings was not possible.

VI. Potential for Reducing Water Use Associated with Pools, Spas and Fountains in California

Reducing water use by pools, hot tubs and ornamental recirculating fountains depends on four factors:

1. Reducing evaporation loss,
2. Choosing the most efficient filtration equipment,
3. Providing proper maintenance, and
4. Changing human behavior.

The areas where possible savings can be found parallel these factors. Evaporation is the most significant component of water use and also drives the use of water for TDS control. The choice of the type of filtration equipment is the second most significant way to reduce water use, but the most readily achievable. Providing proper operation of the equipment, maintenance of the pool and equipment, and timely repair of leaks all require more human intervention on a regular basis. The following section will examine the water saving potential for the following five potential measures:

1. Evaporation Reduction
2. Filter Selection
3. Control of TDS
4. Leak Detection and Control
5. Changing Human Behavior

Evaporation Reduction

There are three basic ways to reduce pool water evaporation. The first is to simply shade the pool and using fences and walls, non-shedding hedges or other barriers to reduce wind movement across the pool. The second is to limit sprays, waterfalls, and other features that increase contact area to atmosphere to just those needed for aesthetic value or for aeration of the pool water. The third is to use chemicals or pool covers to retard evaporation.

Pool covers have been used for years to reduce heat loss from heated pools, to protect pools in the winter from debris, and to reduce evaporation. Covers can be made from several plastics such as UV-stabilized polyethylene or polypropylene, or vinyl. They can be clear or opaque. The designs range from single sheet plastic membranes to bubble wrap type material, to specially designed multi-layer insulated covers. In California, Title 24 now requires that heated pools be covered when not in use.

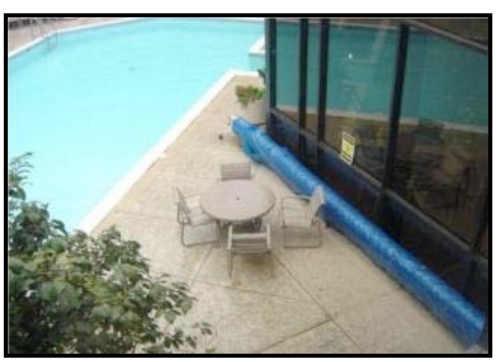


Figure 22. Pool Cover Rolled Up

<u>Traditional pool covers</u> reduce evaporation by simply covering the water surface. Covers also reduce the amount of debris falling into the pool, thus reducing backwash frequency. They also save water by extending the time between pool drain-and-fill events by reducing evaporation. This also reduces chemical use. Literature varies on how much evaporation pool covers can eliminate, but a range of 30 to 60 percent reduction is reported. The US Department of Energy estimates

the percent of energy lost by evaporation to be 70 percent[33]. They also report that energy savings of 50 to 70 percent and water savings of 30 to 50 percent are possible if pool covers are used properly.

However, covers are only effective if they are used. A 2004 study[34] of pool cover usage in an inland area of Southern California revealed that the vast majority of consumers that purchase a pool cover will not use it regularly.

For this report, an average potential reduction in evaporation of 40 percent is assumed for pools with plastic covers.

Liquid evaporation barriers are water-safe chemicals that form a thin layer at the water surface. Some of the more commonly used pool covers use long chain alcohols and an alumina salt. They are non-toxic and do not interfere with pool operations. The liquid must be replenished on a regular basis since it eventually evaporates.

Liquid barriers have been used for years and offer both heat and evaporation loss. However, they work best where there is little movement of the water surface. Although some claims are much higher, studies have shown that they reduce heat loss by 15 to 55 percent[35]. Much depends on how the pool is used; the higher energy savings are for pools used the least. Liquid barriers can be assumed to reduce evaporation in the range of 10 to 30 percent. For this report, an average reduction of 20 percent is assumed as a result of their use.

The overall evaporation reduction from the use of covers of all types is assumed to be 30 percent. This means that evaporation reduction could be somewhere in the neighborhood 40,000 acre feet per year.

The most important thing to consider with liquid barriers is that they are in place and minimizing evaporation as long as the liquid feed equipment is operating, even when the pool is being used. By contrast, pool covers must be removed and replaced by the pool owner and operator, something that many owners are not inclined to do on a regular basis, especially during heavy usage periods in the Summer months.

Backwash and Cartridge Cleaning Water Savings

The water used for backwash and filter cartridge cleaning varies significantly based upon the type of filter system used. For smaller pools, cartridge filters use significantly less water than sand and DE filters; for larger pools, industrial type filters use the least. Table 22 shows that the most efficient filters use between 68 and 98 percent less water than conventional sand filters.

[33] www.energysavers.gov/your_home/water_heating/index.cfm/mytopic=13140
[34] Koeller & Company for Inland Empire Utilities Agency, 2004. Swimming Pool Cover Rebate Program, Follow-up Customer Survey, April 26.
[35] www.liquidpoolcovers.com/effectiveness.html

Table 22. Comparison of Backwash and Cartridge Water Use per Pool Per Year for Different Types of Filters					
	Use in Gallons Per Pool Per Year				Maximum Possible Reduction
	Sand	DE	Cartridge	Industrial	
Hot Tub	935	468	300		68%
Above-ground	4,189	1,466	800		81%
In-ground	8,415	2,945	1,200		86%
Apartment	22,440	7,480	2,500		89%
Hotel/Motel	29,920	9,350	3,600	5,000	88%
Public	166,222	41,556		9,000	95%
Olympic	959,568	239,892		17,000	98%

However, many pools already use DE and cartridge filters and a few industrial filters are also being used. Based upon the information in Tables 15 through 19, there are 1.35 million sand filters, 1.42 million DE filters and 808,000 cartridge filters that already use the most efficient filtration systems. If the sand and DE filters were <u>all</u> converted to the most efficient types, filter backwash use would decrease from 53,000 acre feet a year to an estimated 10,000 acre feet a year, a 81% reduction in water use.

TDS Control

Based on Table 20, almost 49,000 acre feet of water are dumped each year to control TDS in California pools, spas, and fountains. If reverse osmosis systems similar to those used by Dr. Cluff (report Section IV) were employed, water use for this operation could potentially be reduced to only 10,700 acre feet a year, a 78 percent reduction.

Reductions in evaporation also reduce the number of times a pool must be dumped and refilled. Overall, this may amount to a 10% to 30% reduction in this use also.

If pool covers were used to reduce evaporation and the RO systems were used, water use could be reduced by another 1,000 to 3,000 acre feet a year. For this report, a maximum possible savings of 35,000 acre feet a year is assumed, making TDS control water use only 8,990 acre feet a year if all measures were taken.

Other Savings

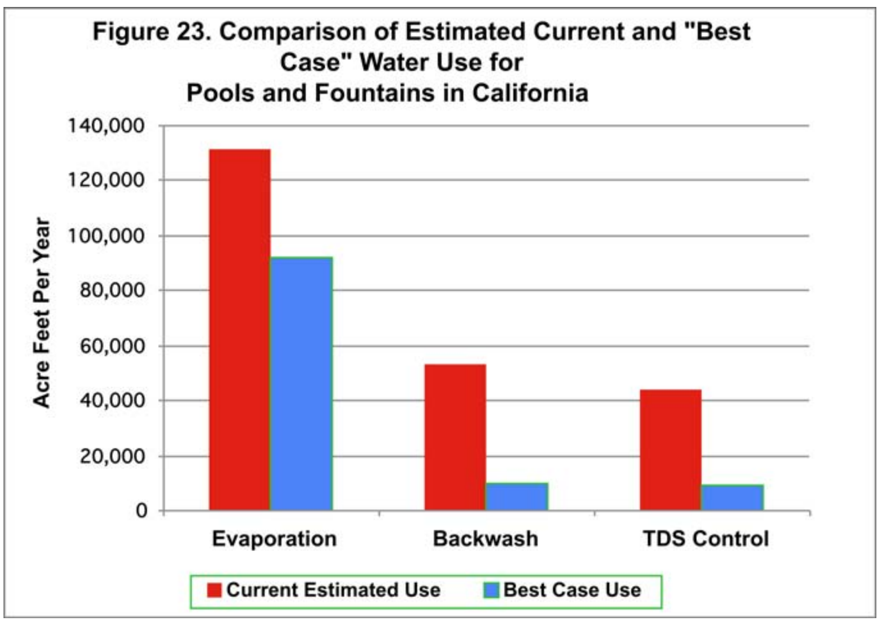
Finding and fixing leaks, controlling splash-out and drag-out, providing shade and wind breaks, and similar measures are difficult to quantify. The same is true with leaks. Even though it is estimated that five percent of pools have leaks, the volume cannot be quantified. If modifying human behavior, using properly installed gutters and grates, installing and reading water supply meters to detect leaks, ensuring proper operation of equipment, and similar factors were combined, water use reductions could be in the range of tens of thousands of acre feet per year.

Summary of Maximum Possible Savings Potential

The following summary shows what total savings would be possible if all potential measures were implemented successfully. Water use would be reduced from a current estimate of about 229,000 acre feet per year to somewhere near 113,000 acre feet per year, a 51% savings. This is summarized by measure in Table 23 and Figure 23. In addition, leak detection and human behavior measures, including reducing splash-out and drag-out, could potentially reduce this loss by another 10,000 to 20,000 acre feet per year if implemented successfully.

Table 23. Comparison of Maximum "Best Case" Water Savings Estimates

Use	Estimated Use	Best Case *Use*	Best Case *Savings*
Evaporation	131,774	92,242	39,532
Backwash	53,183	9,573	43,610
TDS Control	43,990	8,990	35,000
Total	**228,947**	**112,568**	**116,379**



This water use reduction scenario assumes a 100 percent successful implementation of all measures. The *true* potential savings will be less than these estimates, since full implementation requires substantial behavioral changes by users and maintenance personnel *and* additional capital investments for meters, filtration systems, and other equipment. Nonetheless, significant savings in the operation of pools, spas, and ornamental fountains in California is definitely possible.

Further investigation is required to establish the investments (by owners, water providers, and/or others) needed to implement these measures on a statewide basis. As such, no judgment can be made at this time as to the viability of these measures as water provider Best Management Practices.