City of San Antonio Public Swimming Pool Energy Efficiency Retrofit Final Report

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Photos by Steve Easley

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Introduction

The City of San Antonio (COSA), Texas owns twenty-six (26) public swimming pools that are an important part of the community fabric, providing free-admittance recreation for thousands of San Antonio's children and residents. All pools are open May through September, approximately four months, four pools operate seven months a year, and the two indoor pools operate year round. The smallest of these pools is 66,000 gallons and the largest, at 805,000 gallon, is the historic San Pedro Springs Park Pool located in the center of a 46 acre reserve officially established by the City of San Antonio in 1852. San Pedro is unique in that it began as a spring fed, flow-through pool that was later converted to a conventional recirculating pool. San Pedro Springs Park is a true national treasure and there is only one public park in America that is older — Boston Common, which dates to 1630.

In addition to providing vital community services, COSA pools also offered a unique opportunity to tie into existing energy efficiency and sustainability efforts being spearheaded by the City of San Antonio. As a large and rapidly growing municipality, there is a need to manage the use of electricity wisely. This is especially true in light of increasing energy costs and concerns over air quality at the local, state, and federal levels. Additionally, by reducing operating costs at public recreation facilities, the City is better able to ensure their long-term viability as resources for public well-being and enjoyment.

Project Background

The City of San Antonio's Office of Sustainability (OS) established an Energy Management Division in 2011 to make San Antonio a national leader in energy efficiency. The Office of Sustainability is responsible for reducing the City $33 million annual utility expenditures and associated environmental impact. This is achieved through energy efficiency improvements to City-owned properties, which have consisted primarily of interior & exterior lighting retrofits, HVAC system replacements and controls improvements, installation of solar window film, and retro-commissioning and optimization of key facilities. This began with seed funding through the American Recovery and Reinvestment Act in the amount of over $6 million and laid the foundation for ongoing projects that have made significant progress across almost every major energy consuming facility under City ownership.

The centerpiece of the City of San Antonio's energy management strategy is a revolving Energy Efficiency Fund. This is a financial mechanism that is designed to capture the energy savings from completed projects into a revolving account so that funds accumulate over time, ensuring that dollars are available for projects in perpetuity. The Energy Efficiency Fund also pays for associated personnel costs and training, ensuring that the City has in-house technical expertise at no cost to its General Fund. OS staff benchmarks the energy consumption at all significant City properties using the EPA's Portfolio Manager as a way to quantify energy savings and identify properties in need of energy efficiency upgrades.

Tracking municipal facilities' energy performance enabled the Office of Sustainability to identify municipal swimming pools as a source of potential energy efficiency improvements. By isolating the energy meters at each of the City's 26 municipal pools, it was possible to quantify the annual energy consumption and costs associated with each location over several years. During 2013 total annual energy consumption across all locations amounted to 3,693,217 kWh at a cost of $320,133. While several of these locations experienced additional loads by sharing meters with adjacent buildings, exterior lighting, or other sources it became clear that significant opportunities existed to reduce energy consumption related to pool circulation equipment.

Staff members Philip Eash-Gates (Energy Manager) and Aaron Stein (Senior Energy Analyst) began to research energy conservation options through more efficient operation of pool circulation equipment. Upon discovering a Department of Energy paper authored by Steve Easley as part of the Building America Retrofit Alliance[1], Office of Sustainability staff contacted Steve to learn more about variable speed pumping technology for commercial and public pool applications. Easley reached out to colleagues at Pentair Aquatics to bring in additional expertise in the field of commercial swimming facilities. It was determined that an economically viable project could be developed specifically for San Antonio pool facilities based on energy consumption, annual hours of operation, and circulation rates across locations.

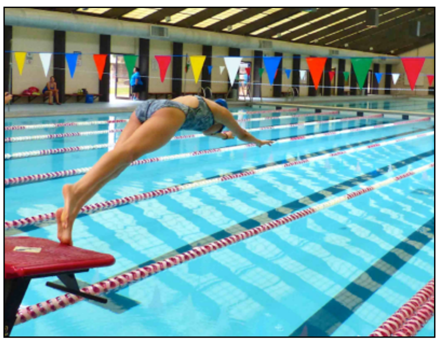
Once the project viability was determined there was still the need to achieve the support and approval of the stakeholders that would be impacted by this initiative. These included the Parks & Recreation Department that owns and manages all pool locations, the San Antonio Metro Health Department, the Texas Department of State Health Services (TDSHS), and the City's Executive Leadership Team. Parks and Rec staff was supportive from the start, with the understanding that all retrofits would be compliant with Texas health codes. Approval was mainly predicated on collaborating with the TDSHS to ensure that the new technology and control methods would meet the health requirements for equipment certification, turnover rate, and water clarity.

The project team was unable to find a precedent for an initiative of this type in Texas, so a thorough review was needed to ensure that the design of the retrofit work was compliant with the Texas Administrative Code. Regulations for pool health and safety are covered under the Texas Administrative Code, Title 25, Part 1, Section 265, Subchapter L: Standards for Public Pools and Spas[2]. Texas requires that all public pools built before 1999 have adequate circulation to achieve an 8-hour turnover and those built after 1999 to achieve a 6-hour turnover. Since almost all of the pools under consideration exceeded code-mandated flow rates, circulation at most locations could be reduced while still meeting health and safety standards. City staff contacted TDSHS to discuss the feasibility of this project and was informed that Texas Administrative Code requires that all pool equipment be ANSI/NSF 50 certified. Because NSF 50-certified variable speed commercial pool equipment was not

1 Measure Guideline: Replacing Single-Speed Pool Pumps with Variable Speed Pumps for Energy Savings. May 2012
2 Texas Department of State Health Services Website: https://www.dshs.state.tx.us/poolspa/default.shtm

available, the alternative was to install external variable speed control drives. However, TDSHS initially determined that installing drives on existing equipment could cause NSF certification to be revoked, rendering the project incompatible with health and safety statutes.

The City of San Antonio along with the Steve Easley/Pentair Aquatics/AquaStar team conceptualized that the retrofits would consist of variable speed pump controls tied to digital flow meters to regulate circulation as necessary to meet or exceed the minimum flow requirements per location. Using variable speed pump controllers would allow the City to maintain constant flow rates to ensure adequate clarity and chemical dispersion, regardless of filter saturation or other sources of increased system Total Dynamic Head (TDH). In addition, maintenance practices by Parks and Recreation staff are such that clarity and chemical levels are properly monitored and sustained through regular site visits and maintenance. Office of Sustainability staff communicated regularly with TDSHS to outline these points and it was determined that installing variable speed pump controllers on NSF 50 equipment would not cause their certification to be revoked, provided use of the drives did not adversely affect water quality.



Photos by Steve Easley

With TDSHS and City approval across multiple departments, the Office of Sustainability was granted permission to pursue implementation of retrofits at all facilities where energy savings would exceed the project cost and result in a net-positive return on investment. This began more than a year and a half of research, field investigations, and collaboration among multiple entities that resulted in retrofits to 22 City-owned pools.

In August 2013 the City of San Antonio, through the Office of Sustainability, issued a Request for Proposals (RFP) seeking professional services from qualified Consultants with experience in swimming pool energy efficiency to provide mechanical assessments for energy conservation. The City manages 6,334,992 gallons of water across the twenty-six swimming pools and is responsible for the energy and maintenance costs at each facility. The energy required to filter, sanitize, and circulate these pools is significant, consuming nearly 1.4 million kWh per year. Through unprecedented research by the Energy Management Division within the Office of Sustainability, the installation of variable speed pump control technology was identified as a viable retrofit opportunity capable of saving over 500,000 kWh and $40,000 annually. These estimates were greatly exceeded based on post-retrofit energy measurements taken at all locations where variable speed pumps controls were installed.

Actual project metrics far exceeded initial estimates and amounted to savings of 707,517 kWh and approximately $63,000 annually[3].

Project Team Members, Outside Consultants

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How Swimming Pool Pumping Energy Savings Are Achieved

The energy saving science behind variable speed pumping is the Affinity Law, which applies to centrifugal pumps (e.g., pool pumps) and fans (e.g., HVAC). This law of physics states: pump shaft speed is proportional to the volumetric flow it produces; pressure is proportional to the square of shaft speed, and power is proportional to the cube of the shaft speed. This means reducing pump speed by half (½) reduces the flow by half (½), while pressure drops to one quarter (¼) and power consumption drops to one eighth (⅛), or about 12.5% the power consumed at full speed. Table 1 provides the formulaic representation of the Affinity Law.

[3] It is believed that additional savings may be achieved by further reducing flow at San Pedro Springs Park (Pool 15 in Appendix A charts) during the approximately 8.5 months during which the pool is not open to the public but the pumps still circulate water.

$$\frac{Q_1}{Q_2} = \frac{N_1}{N_2} \qquad \left(\frac{H_1}{H_2}\right) = \left(\frac{N_1}{N_2}\right)^2 \qquad \left(\frac{P_1}{P_2}\right) = \left(\frac{N_1}{N_2}\right)^3$$

Where:

Q = Flow
N = Shaft Speed
H = Head Pressure
P = Power

Table 1: Formulaic representations of the Affinity Law

The one-to-one relationship between pump speed (N) and flow (Q) makes identifying energy savings opportunities a straightforward process. Surplus flow (think wasted energy) is recognized by comparing full speed flow to the flow actually needed to meet health code turnover rates.

Energy Conservation and Water Quality

Historically swimming pool recirculation systems were invented in part as a means to conserve heating energy while protecting the public health by maintaining required water quality. Early in the 20th century, many public swimming pools were 'flow-through' pools where municipal water was heated before entering one end of the pool causing it to continuously overflow at the other end, or around the edge, into a 'scum gutter.' In both configurations the overflow water drained to wastewater. The loss of heat energy was significant and costly. This was a driving factor behind the move to recirculation systems using pumps, filters, and sanitizing chemicals. The San Pedro Springs Park Pool is one of these retrofitted, flow-through pools.

'Fill & drain' pools are another type found throughout the country, including the City of San Antonio. These pools used a 'main drain,' just like a bathtub, that when opened, allows water to drain to wastewater. As fill & drain pools were converted to recirculating pools, the main drain provided a convenient means to connect a recirculation pump without having to jackhammer through the existing pool structure. In technical terms, this process converted the literal 'drain' to a 'suction outlet', which is why they are referred to as main drains to this day.

Initially there was resistance to recirculating what was considered 'used' water, calling pools equipped with pumps and filters re-purified water systems. To address those legitimate concerns two separate public health groups[4] began meeting in 1920 the to address

[4] Committee on Bathing Places of the Public Health Engineering Section of the American Public Health Association and Conference of State Sanitary Engineers

public swimming pools, including recirculation system design[5]. Six years later, in 1925 the groups voted to unit as The Joint Committee on Bathing Places of the A. P. H. A. and Conference of State Sanitary Engineers, publishing reports that became the standard for design, construction, equipment, and operation of public swimming pools. Updates to the standard were published annually via the American Journal of Public Health in cooperation with the U.S. Treasury Department of Standards for Drinking Water. This science-based work is the foundation on which modern pools codes are built.

A century ago, energy conservation (heat) helped transform public swimming pool policies though the retrofitting of recirculation systems and today it is doing it again as some of those same pools are being retrofitted with variable speed technology. Digital technology provides cost effective and reliable ways to continuously monitor filtration flow rates, allowing the real-time adjustments to pump speed to maintain the code-compliant flow rates, significantly reducing wasted energy in the process. This is analogous to setting the speed control in a vehicle, which continuously adjusts the engine throttle to use only as much fuel as required to maintain the programmed speed. Similarly, this project added flow control to the retrofitted COSA swimming pool pumps, providing continuous speed adjustment to maintain the pool's turnover flow rate as required by state and local health code.

Determining COSA'S Pool Retrofit Eligibility

Surplus turnover flow rate is the primary factor used to identify pools that will benefit from variable speed pumping technology. Absent an opportunity to safely reduce the existing flow rate and pump speed, energy savings that generate cost savings are not possible. Project viability was initially determined by reviewing pool facility data including pool ages, dimensions, flow rates, pump and motor information, filter types, and energy consumption. At least four years of electric consumption and cost data was compiled for each location to allow a review of trends over multiple swim seasons. Analysis of this information was the first step in identifying the potential scope of the project and the quantifying energy savings and cost-effectiveness of retrofits.

It is important to note, the apparent lack of surplus turnover does not mean a pool cannot be retrofitted to save energy. Surplus flow is often possible by reducing resistance to flow within existing recirculation systems by improving system hydraulics. This project identified multiple hydraulic conditions that were preventing the recirculation systems from achieving optimal turnover flow rates.

When evaluating swimming pools for retrofit eligibility, two hydraulics-based variables need to be considered:

Inadequate Filter Backwashing — Minimum backward flow rates are required to effectively clean filters and there are common reasons this cannot be achieved: Pump(s) is too small to deliver the minimum backwash flow rate,

[5] Report of the Joint Committee on Bathing Places of the A. P. H. A. and the Conference of State Sanitary Engineers presented to the Public Health Engineering Section of the American Public Health Association at the Fifty-fifth Annual Meeting, at Buffalo, N. Y., October 12, 1926.

multiple filter systems where the filters cannot be isolated to achieve required backwash flow rates, inoperable or leaking backwash valves, and backwash waste lines incapable of handling the minimum backwash flow rate.

System Flow Restrictions — Undersized pipe and filters (or inadequate quantity) causing excessive pressure-side system resistance, suction-side resistance and/or air vacuum leaks causing pump cavitation, and heaters with improperly adjusted bypass valves or no bypass valve.

These are areas where a qualified pool professional with advanced hydraulic design experience is needed to evaluate existing systems to identify retrofit opportunities and their associated costs in order to calculate the pool specific ROI.

Another important consideration is existing motor compatibility with Variable Frequency Drive (VFD) technology. In the COSA project, some motors had to be replaced, while others were fitted with power conditioning filters that enabled the motors to operate reliably at lower power frequencies, thus lower pump speeds. The pump itself is not a factor, though 'wet end' efficiency does impact energy use and in some cases replacing a very inefficient pump can be a cost-effective retrofit opportunity. Older pumps with worn impellers can also represent good retrofit opportunities.

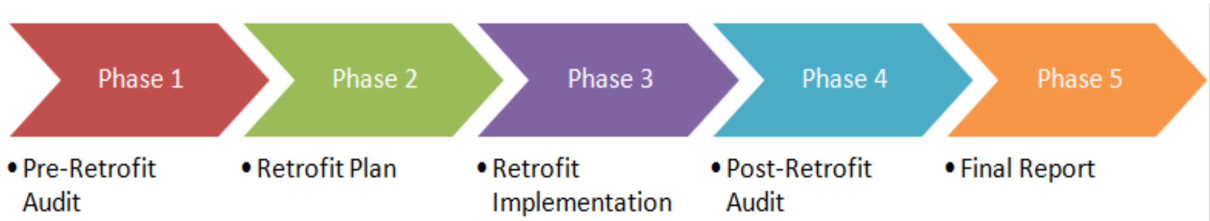
Project Purpose

The primary purpose of this project was to employ variable speed motor and drive technology to reduce excess recirculation flow to safe, code-compliant levels, effectively eliminating over pumping and wasted electricity. A secondary goal was to measure and quantify the hydraulic efficiency of each pool filtration and circulation system. A tertiary purpose was to collect copious amounts of data to facilitate water quality and energy saving research, energy and hydraulic efficiency education, and for science based updates to health and safety codes and standards.

Prior to this project, all COSA pools used single-speed motor technology that could only operate or run at full speed or at a constant rpm, regardless of the flow requirements for water quality. Variable speed motor and drive technology can reduce the frequency of the power input to the pumping motor and thus vary and regulate the pump motor speed to match the pool pumps motor speed to the individual pool water flow requirements, saving substantial amounts of energy without impacting water quality or public health. This process employs the science behind variable speed technology as it relates to the Affinity Law.

Phase one objectives — Collection of utility bill data and information on facility-specific characteristics unique to each pool based on available COSA records. This was followed by site visits to each pool to conduct a comprehensive energy and hydraulic efficiency audit, collecting recirculation system data in sufficient detail to determine whether or not the facility is suitable for the energy conservation retrofit.

Phase two objectives — Organize, analyze and use the data collected to compute estimated energy savings, cost savings, and payback time for retrofits to each pool recirculation system. Confirm existing pumps and flow meters conform to applicable State Health & Safety Code and NSF / ANSI Standard 50. Evaluate existing flow meter accuracy by crosschecking the measured Total Dynamic Head (TDH) against the published pump curve and identify existing hydraulic system improvements with energy savings potential. Use these data to prepare a retrofit plan, delivered to COSA in the form of bid specification. This was used as part of a competitive solicitation, through which a contractor was selected to perform the retrofits.



Phase three objectives – Perform retrofits at all eligible pool facilities. COSA staff issued a competitive solicitation to select a contractor to perform the retrofits as designated in the bid specification developed by the consultant team. All work had to be performed within an approximately 6-week window between when the pools were filled and the beginning of the regular swim season. City staff and the consultant team assisted the retrofit contractor in project administration and provided technical support.

Phase four objectives — Return visits to each retrofitted pool to conduct post-retrofit energy audits, quality assurance inspections, and confirm the retrofit work was completed in conformance with the bid specification. Provide training for City of San Antonio Parks & Recreation Staff in the proper use and operation of the retrofitted equipment and provide a pool and system-specific operating plan.

Phase five objectives — Analyze and report pre- and post-retrofit performance data, to compare actual energy savings to pre-project energy savings estimates produced by 1) COSA, and 2) during phase two. Quantify the differences between projected energy savings, using the Affinity Law, and what was actually measured. This document is the final report, although the City continues to track pool energy consumption on a monthly basis.

Assessment Approach and Scope of Work Performed

The City established a financial metric that the project must save enough energy to achieve a net-positive payback within the useful life of the installed equipment. The consulting team then developed the data required to determine facility-specific retrofit eligibility based on surplus pumping capacity and retrofit cost. The key factors are:

Existing surplus turnover capacity, or Potential for surplus turnover capacity through hydraulic efficiency improvements, which can be as straightforward as thorough filter media cleaning or replacement

Ancillary equipment and installation costs including:

- Retrofit equipment specification and operational plan development (Note this service is typical provided by equipment manufacturers through a trained and qualified swimming pool professional.)
- Installation Labor
- Existing pump motor(s) not with VFD
- Hydraulic efficiency upgrades, such as lower head loss; filter and/or filter media, backwash/control valves, in-line to off-line sanitizers, and heater bypass valves

Pre and Post-Retrofit Data Collection

The consulting team performed the pre-retrofit assessments and data acquisition on 26 pools August 12th through the 20th 2013. Post-retrofit data assessments were taken June 10th through the 23rd 2014 for 22 pools that were chosen by COSA for retrofits. Three pools were not retrofitted because they did not have surplus flow capacity and were meeting the required flow rates at full speed or they were identified as having significant plumbing or hydraulic deficiency issues. One was excluded because it was scheduled for demolition. These assessments were part of a comprehensive scope of work to determine the actual energy use as well observe COSA pools plumbing design and hydraulics for inefficiencies. This report includes summary data from 22 separate pool facility assessments, which include data that documents pool energy and hydraulic improvements.

Data recorded at each operating point included: Flow (GPM) as indicated by existing rotameter flowmeter. New digital equipped paddle wheel flow meters were installed as part of the 3rd party retrofit project, therefore these data are only available post-retrofit. Phases 1 and 4 data collection include: power (volts, amps, & kW), Total Dynamic Head (ft/H_2O), suction-side (psi), pressure-side (psi) and photographs of the pools, equipment rooms, pumps, gauges, flow meters, electrical control panels, and the sanitizing equipment.

Data Acquisition Theory and Quality Control Methods

Based on data collected from energy audits, twenty-six (26) pre-retrofit audits were performed, representing all City-owned swimming pools. Twenty-two (22) pools were selected as retrofit candidates and received post-retrofit audits to measure improvements. The on-site investigation included detailed measurements as the recirculation systems were operating under clean filter conditions and, where possible, simulated dirty filter conditions. Data collected under two or more operating conditions proved valuable as a tool for determining why measured TDH and Flow did not align with the published pump curve at all locations. There were a few instances where flow meter issues weren't the cause, one location where a vacuum leak caused pump cavitation, and another case the cause was a damaged pump impeller. Charts 1 through 3 illustrate the process used to identify and resolve the flow data mismatch.

All charts use the same pump curve (blue), clean filter system curve (purple), and simulated dirty filter curve (red dashes). The chart 1 plot shows as-measured TDH and Flow data points well below the pump curve. After identifying a data quality problem, the three variables were evaluated to find the source of the error.

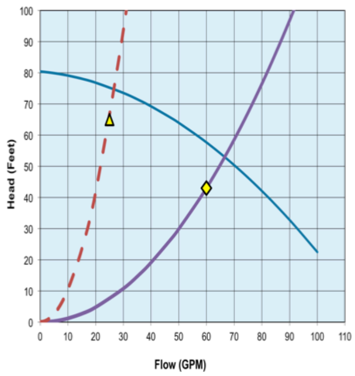


Chart 1: Flow rate error

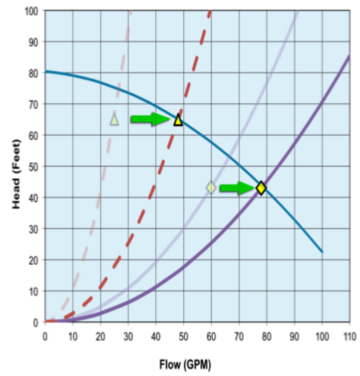


Chart 2: Error correction

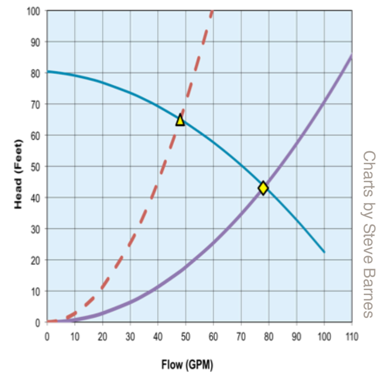


Chart 3: Flow rate corrected

1) **Pump curve** — The pump is certified in accordance with NSF/ANSI Standard 50, which requires 3rd-party pump curve accuracy, eliminating it as the likely suspect.

2) **TDH** — This data is from a lab-quality differential pressure gauge with a high degree of intrinsic accuracy, which was confirmed using a second differential gauge and by crosschecking it against vacuum and pressure readings collected contemporarily with the TDH measurement.

3) **Flow** — The flowmeter technology is known to be quite accurate, provided it is installed in accordance with the manufacturer's instructions, including only operating in a clean water environment. Proper flow meter installation location (10 pipe diameters downstream, and 5 pipe diameters upstream from the nearest pipe fitting or valve) is frequently not possible causing erroneous flow readings. This process identified the existing flow meter as the likely source of the discrepancy and the error was satisfactorily corrected by adjusting Flow data to the right in Chart 2 until the GPM, TDH, and pump curve fit together as seen in Chart 3.

Swimming Pool Retrofit Eligibility

This data was analyzed and used to calculate facility-specific payback times, with pre-retrofit information establishing retrofit eligibility policies guided and approved by COSA. A payback time under the ten-year life expectancy of the VFD equipment was used as the retrofit approval threshold. The majority had projected payback times well below this benchmark, making the retrofit candidate list without question. A few were well above the decision point, eliminating the need for further consideration, and a few more were very near the threshold.

Pools near the retrofit eligibility threshold required more detailed review and analysis to more precisely estimate retrofit costs. Some facilities with surplus turnover rates and considerable energy savings potential did not have payback times under the threshold because of much higher equipment costs. For example, some existing motors were not compatible with VFD technology, and new motor costs combined with VFD and ancillary costs would have pushed ROI outside the payback time threshold. In another example, the detailed hydraulic audit helped identify filter media and backwash system piping/valve problems that were causing extreme back-pressure (high TDH) and poor water quality. Given the preexisting water quality challenges associated with this pool, the payback time threshold was discounted and retrofit energy efficiency savings were used to offset both the energy saving and hydraulic retrofit costs.

Non-compliant filter media causing high TDH

Phase 1 — Pre-Retro Fit Pool Audits

The City of San Antonio owns medium to large public swimming pools with twenty-four (24) located outdoors and two (2) located indoors. All had single-speed pump recirculation systems and of retrofitted pools fourteen (14) are single pump systems[6], seven (7) are two-pump systems pipe in parallel, and one (1) is a three-pump system where each pump is paired with a filter. These pump/filter sets are piped in parallel through common suction and return piping to the pool. All pools utilize sand as the filter media; three of which are suction-side, gravity feed systems and all others are pressure-side filters. The majority these pressure-side systems use two (2) filters piped in parallel through a common backwash manifold. Of these, most can be backwashed one filter at a time, maximizing available pump performance to lift the sand for a more thorough cleaning. The other pools had either a single filter, or three filters; all of which can backwashed individually.

In general the recirculation systems are well designed using large pipe and filters, resulting in low TDH systems. The average pipe velocity at the code required flow rate was 3.6 feet per second (fps) for suction-side piping and 4.9 fps for return-side piping. These are well within modern design standards of 6 fps, and half historic velocity sizing standards of 8

[6] One location, Roosevelt Park, was originally a single-pump system but was retrofitted to include 2 pumps to increase the circulation rate.

fps suction and 10 fps returns. Filter capacity is about double (2x) the minimum required across all pools.

Photo 1: Single pump system

Photo 2: Dual pump system

Photos by Steve Easley

Photo 3: Gravity filter system

The City of San Antonio Parks & Recreation Department cleans and vacuums all pools before they open to the public each day. Filters and debris screens are serviced three times each week with the exception of the gravity fed, suction-side filters beds, which are cleaned on an as-needed basis. Phase 1 Pre-retrofit Site Collected Data

The consultant team performed detailed measurements of energy use and hydraulic performance on 26 pools throughout San Antonio. When all twenty-six (26) pools are operating with freshly backwashed filters the combined demand is 319 kW, using 7,665 kWh per operating day, and 1,368,144 kWh per operating year.

The below data was collected for each pool:

- Documented the number, nameplate horsepower, motor service factor, insulation class, type and manufacturer for all pumps currently in place
- Documented the KW, kWh, amperage, voltage and current pump electrical circuit capacity, associated components
- Documented pool age, location, and type to determine applicable minimum turnover flow rate, compliance measures and certification requirements
- Measured and documented all pool pump voltage, amperage and wattage draw for existing pool pumps
- Measured TDH measurements, pressure and suction side psi measurements, under clean filter conditions and at +10 psi to simulate clean versus dirty filter performance
- Documented the pool equipment environment, i.e., outdoor, indoor, indoor with chemical feeder(s)
- Documented visible pipe, filter, and valve sizes
- Documented filter(s) including make, model, size, and type
- Documented the flow meter type
- Used measured system TDH and available pump curves to estimate flow

- Documented control systems, including make, model, and type
- Took detailed photographs of pumps filters and plumbing at all site visited

(A more detailed list of specific tasks completed can be found in Appendix A)

Phase 2 — Audit Data Analysis & Recommendations

A detailed energy analysis was performed to compute savings based on measured pump energy and hydraulic data. The consultant team's initial analysis found 69.2% of the pool retrofits had an economic payback less than 6 years, 7.7% 6-10 years and 15.4% of the pools 10 years or greater. The flow rates used in the calculations were based on state required minimum flow rates. The consultant team also compared historic energy consumption provided by COSA to energy consumption data measured and collected during the pre-retrofit site visits to quantify differences between historic and collected data.

The consultant team then quantified differences between CITY estimates and collected data to further analyze the accuracy of the preliminary estimates. A detailed payback analysis was performed based on the energy saving estimates from actual measured energy use. The paybacks were based on an estimated ten (10) year product life of a VFD.

Pump nameplate data was used to confirm conformance to NSF/ANSI Standard 50 and to look up the associated pump performance curve. Measured TDH was plotted against the pump curve to; 1) identify if the existing flow meter was accurate to within 10%, 2) validate the pre-audit surplus turnover rate estimates, 4) confirm pump(s) performing nominally, and 4) to characterize the hydraulic efficiency of the recirculation system under clean filter and simulated dirty filter operating conditions. The Affinity Law was applied to calculate the estimated post-retrofit energy and cost savings potential for each pool.

Pump motor nameplate data, measured facility power, and existing power infrastructure detail were used to identify VFD equipment compatibility and the associated implementation costs. This was used to calculate the estimated payback time for each pool. Pools were separated into three categories; those with the clear potential to meet the retrofit eligibility policies, those that clearly do not meet them, and for which further analysis was needed to determine their eligibility. These findings were communicated to COSA, who made the final determination of which facilities to retrofit.

Equipment Selection

Using information provided and data collected during site visits, the consulting team developed a manufacturer-neutral proposal of recommendations to reduce energy consumption at all eligible COSA-owned pools. For the other pools, it was recommended that hydraulic upgrades to pump, filter, accessible pipe, and valves be made, where applicable, if such upgrades will result in reduced energy consumption. Recommendations for flow control improvements included:

- Equipment and minimum requirements for each filtration system, at each COSA-owned pool
- Minimum operating flow rate required to comply with State and local health code turnover rates for the type, size, and age of the pool
- Ensuring specifications for all flow meters are represented by the manufacturer to be accurate within 10% of true flow as stated in the Texas Administrative Code
- Determined if a pump performance curve is available for use in validating flow meter accuracy within +/-10%
- New properly-sized motor and pump equipment, where applicable
- Variable speed pump or external VFD with control systems, as needed to adjust flow rate to maintain the pool-specific, minimum operating flow rate
- Minimum electrical circuit requirements to operate the pump and controller in compliance with the current National Electric Code
- Lightning/surge protection equipment
- Recommended hydraulic improvements to reduce TDH to increase equipment surplus turnover capacity such that the energy savings will offset the cost of the renovations

Phase 3 — Retrofit Implementation

The installation contractor, Commercial Swim Management (CSM), was selected through a competitive bid process to perform municipal swimming pool retrofits for the City of San Antonio. Using the bid specification developed by the consultant team, CSM developed a schedule and work plan in conjunction with COSA staff. A trial installation was performed at the SA Natatorium to measure the impacts, if any, of reducing flow rates on chemical levels and water clarity. Once it was determined that no adverse effects were measured, CSM was granted approval to proceed with remaining installations. Retrofits were completed over a roughly 6 week period, in advance of the swim season opening. The consultant team was in regular communication with COSA staff and CSM and their primary roles during the installation process were:

- Logistical support to ensure that the appropriate equipment arrived on time;
- Responding to technical questions or equipment operational problems;

- Customer service support to ensure that equipment installations or operational issues did not interfere with scheduled recreational activities;
- Serving as an intermediary between COSA staff and the equipment manufacturer for technical assistance or material replacement inquiries;
- Reviewing appropriateness of ancillary improvements not included within the original scope of work (e.g. filter or piping upgrades)

Phase 4 — Post Retrofit Pool Audits

The consulting team revisited the twenty (22) retrofitted pools to verify the retrofit equipment and installation conformed to the bid specification. Full speed and program speed operating capabilities were tested and documented. Minor bid specification discrepancies were identified and communicated to COSA. After the retrofit contractor corrected the discrepancies, the consulting team returned to the affected pools to confirm completion of the corrective action and to complete the post retrofit data collection process.

The same audit procedures used during phase 1 were used throughout post retrofit data collection. In addition to those data collections, two additional sets were collected when possible, 1) flow controlled operating with clean filters and 2) with simulated dirty filters. Under both filter conditions the VFD was set to operate in program mode, where pump speed is adjusted every fifteen to thirty seconds to maintain the pool specific health code defined turnover flow rate, where possible. In some cases the dirty filter simulation could not be approximated with the drives and digital flow sensors in place. In these instances only clean filter data was captured.

Phase 5 — Final Analysis

The final step was to compare pre-retrofit energy use and water quality to post-retrofit results at the end of the 2014 summer swimming season. Actual energy savings measured during Phase were compared to pre-retrofit estimates that were based on COSA evaluations of pool electricity bills, existing surplus turnover flow rates, and the affinity law. Post-retrofit results were also compared to Phase 1 measured energy use, measured flow rates, confirmed surplus turnover rates and the Affinity Law.

No discernible differences on water quality were observed, with the notable exception of those pools identified in Phase 1 where pool Audits identified hydraulic and/or filter media issues that were subsequently corrected. In these cases, water quality improved, matching that of the other pools. All operate near the eight (8) hour, health code required turnover flow rate for pools constructed before October 1, 1999, with the exception of one remodeled pool that operates within the six (6) hour turnover rate for pools built or remodeled after October 1, 1999. These historical turnover rates are consistent with the recommendations published in NSF/ANSI Standard 50 -2013, Annex L, Sand-type filter recommendations for installation and operation.

Filter Efficacy

Variable speed technology is not new and has been used in industrial applications for decades; for swimming pools, it has nearly a ten-year performance history that has been demonstrated to be very reliable. This technology is also shown to extend motor life in addition to providing energy savings and noticeably clearer water. This benefit is observable during the day, but it is especially noticeable at night, in front of the pool light — absent are the floating particulates that were typically only removable with Diatomaceous Earth (DE) filters.

Improved filter efficacy was also observed as early adopters and utilities offering rebates for variable speed retrofits received reports of quickly clogging filters. As a result, trained industry professionals plan for a thorough, post VFD retrofit filter cleaning approximately a week to ten days after installation and start-up. This timing tracks closely with what was published in 1926 by the Joint Committee on Bathing Places of the A. P. H. A. and Conference of State Sanitary Engineers, referring to recirculation as the law of purification by consecutive dilution, applicable to both recirculation and flow through pools. The paper says "At the end of the first turnover the purification will be about 63 per cent, after two turnovers about 86 per cent, at the end of three turnovers about 95 per cent, after four turnovers about 98 per cent, after five turnovers 99.3 per cent, and after six turnovers 99.7 per cent. To accomplish a purification of 99.99 per cent 10 turnovers will be required." The paper goes on to state it takes about nine days for a pool to reach equilibrium when operating at one turnover a day following the doubling of the dirt load. One turnover a day is common for residential pools.

Filter Backwash Design & Frequency Impact on Energy Savings

ANSI swimming pool standards and building codes have long required pumps to be large enough to overcome the back pressure caused by dirty filters. This means single speed pumps will typically consume more electricity when the filter is clean compared to when it is dirty, because clean filters provide higher flow rates (chart 4). The increase energy consumption is due to the fact the pump is doing more work. For this reason, filter loading usually does not impact energy consumption associated with single speed pump systems. It would if single speed filtration were programmed for a fixed number of turnovers per day using a totalizing flow sensor and control system that turns off the pump once the program turnovers are achieved. Chart 4 is the pump and system curves as measured at Pool 1. The pump used 13.22 kW when the filter was clean and only 12.99 kW when a 10 psi filter pressure rise was simulated.

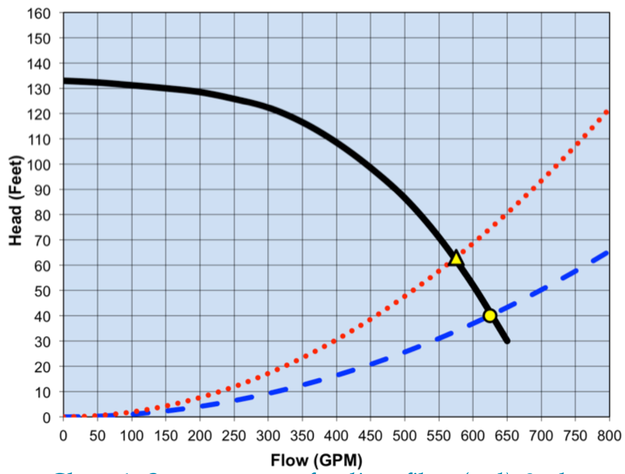


Chart 4: System curves for dirty filter (red) & clean filter (blue) with pump at full speed

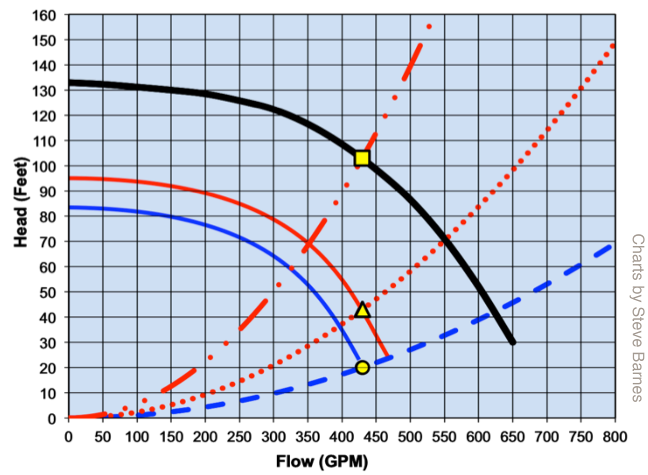


Chart 5: Code turnover pump speed curves for dirty filter (red), clean filter (blue), full speed (black)

In contrast, when a variable speed pump equipped with flow control technology is used (chart 5) filter loading negatively impacts energy use significantly. As the filter collects dirt and debris, raising system resistance, the pump must be sped up to maintain the code compliant turnover flow rate and higher speeds use more energy. Chart 5 shows post retrofit Pool 1 data with the pump operating at three speeds; the blue pump and system curves are when the filter was clean, using 3.17 kW. The red pump curve and dotted system curve are from a simulated 10 psi filter increase, using 6.05 kW. The red dashed, double dot system represents that maximum possible filter loading, which would use approximately 12.5 kW.

COSA's standard water quality operating procedure is to backwash filters three times each week, limiting the maximum recorded filter pressure increase to less than three (3) psi, well below the ten (10) to fifteen (15) psi increase limit specified by filter manufacturers. For this reason, the consulting team applied a 1.5 psi filter pressure increase presumption during post retrofit energy use, which represents an approximate 3% energy use increase. It was further presumed the filter loading will accrue uniformly over the filter operating cycle so the averaged of 1.5% was applied to more accurately reflect COSA pools' post-retrofit energy consumption. This was done in lieu of averaging clean and simulated dirty filter energy consumption pre and post-retrofit while still capturing the increased energy consumption of dirty filters with the drives in place.

While pre and post-retrofit pool maintenance practices are the same, the 1.5% increase was not applied to the pre-retrofit energy uses because energy use data shows the difference between clean and dirty filter conditions are well within the error bars of the data acquisition instrumentation, driven by the +/- 10% accuracy of the flow meters. This phenomenon reveals two important concepts that impact both energy efficiency and water quality. First is the importance of flow-based pump speed control to assure the pool specific filtration flow rate does not fall below health code standards as the filter collects dirt and debris. Second, that even for single-speed filtration systems where energy savings are not a factor, dirty filters can still cause non-compliant filtration flow rates if the filter is not backwashed frequently enough, or not thoroughly enough.

Summary of Results

The COSA retrofit project was highly successful. This project provided significant energy savings with an extremely short payback period. It should be noted that there was no apparent negative impact on water quality and in fact retrofits potentially afford better filtration in many circumstances due to reduced flow rates across sand media filters. High flow rates create more pressure, which forces water through the sand medium at a faster rate, thus trapping fewer particulates.

In addition the project resulted in a number of implemented recommendations to improve system hydraulic efficiencies.

The total saving was 707,517 kWh per year for an annual savings $62,847. This is based on current utility costs with an average blended rate of approximately $.096/kWh. With any rate increases or in regions where energy and demand costs are higher the payback will be even more favorable. The kW demand avoided was 151 kilowatts.

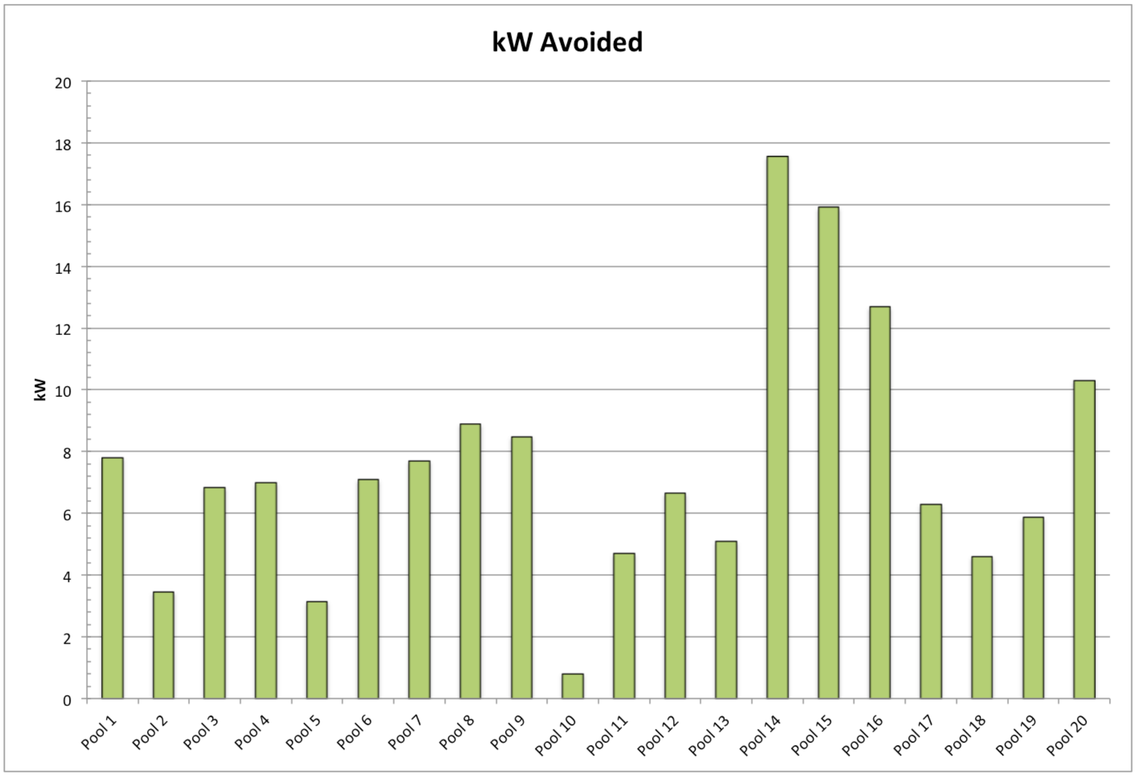
This project was extremely cost effective. The equipment retrofit cost, including labor, was $136,674.75[7]. The payback averaged just over 2.1 years with 8 pools recouping the investment costs in 6-10 months before utility rebates. The total project cost amounted to $145,747.98, which included motor and filter upgrades outside of the scope of energy retrofits. Because these additional expenses are considered deferred maintenance costs they are not calculated as part of the project payback analysis.

Utility rebates from CPS Energy for KW and kWh reductions totaled $86,801.00, resulting in a net cost for the pools retrofits of $49,873.75 and therefore reduced the payback to 0.8 years.

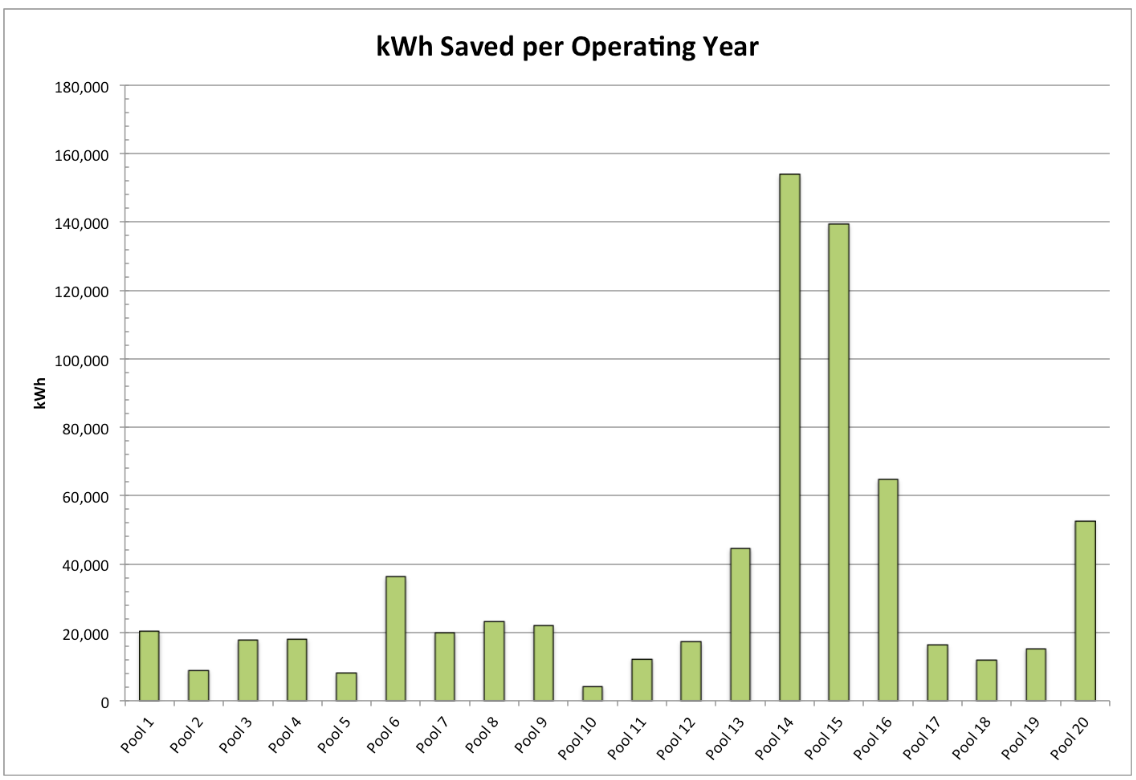
In addition to the money this project is saving the taxpayers of San Antonio, the project also has tremendous positive environmental impacts. Every kWh of electricity that is produced results in 1.5 pounds of greenhouse gas being emitted into the atmosphere[8]. This project will reduce the City San Antonio's greenhouse gas emissions by 1,075,567 pounds per year, every year going forward.

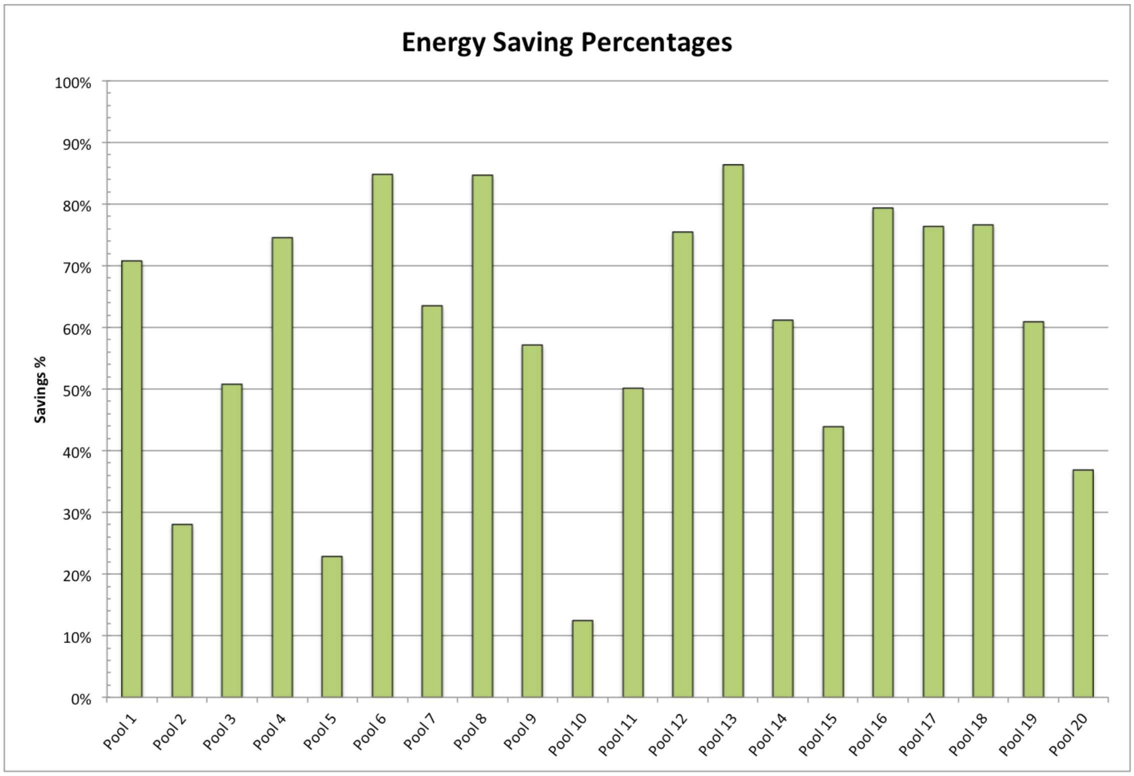
[8] http://www.epa.gov/cleanenergy/energy-resources/calculator.html#results

Appendix A

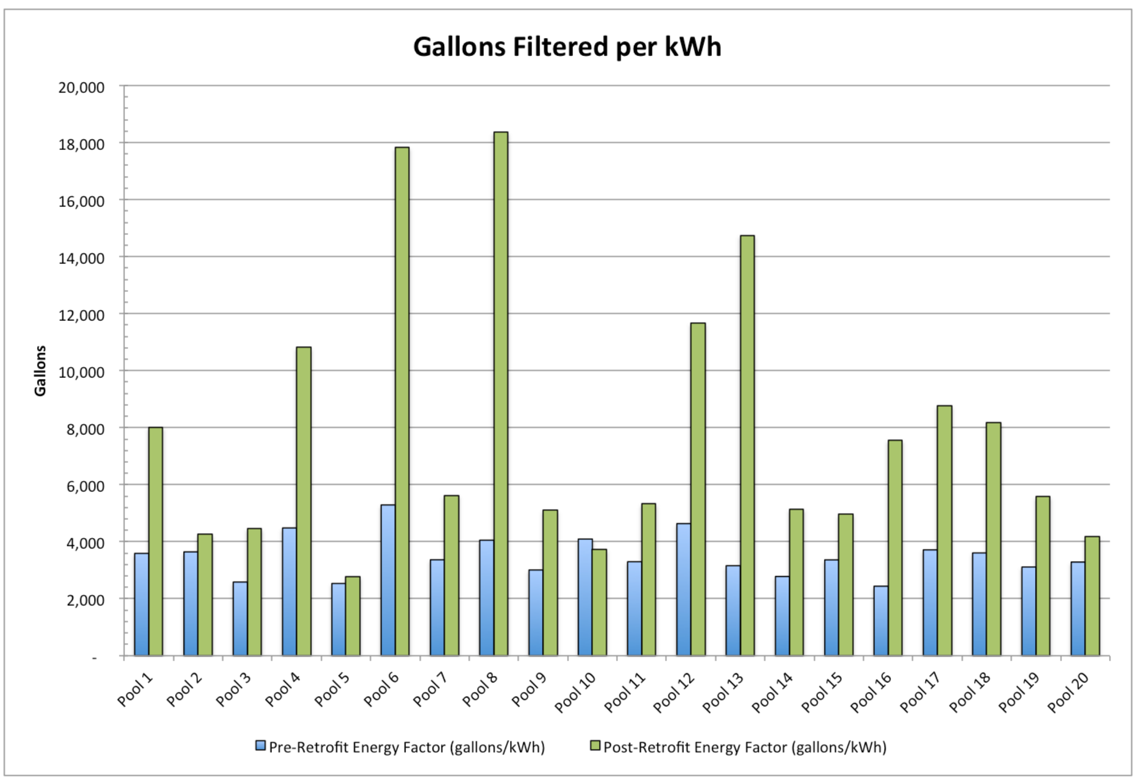


Charts by Steve Barnes

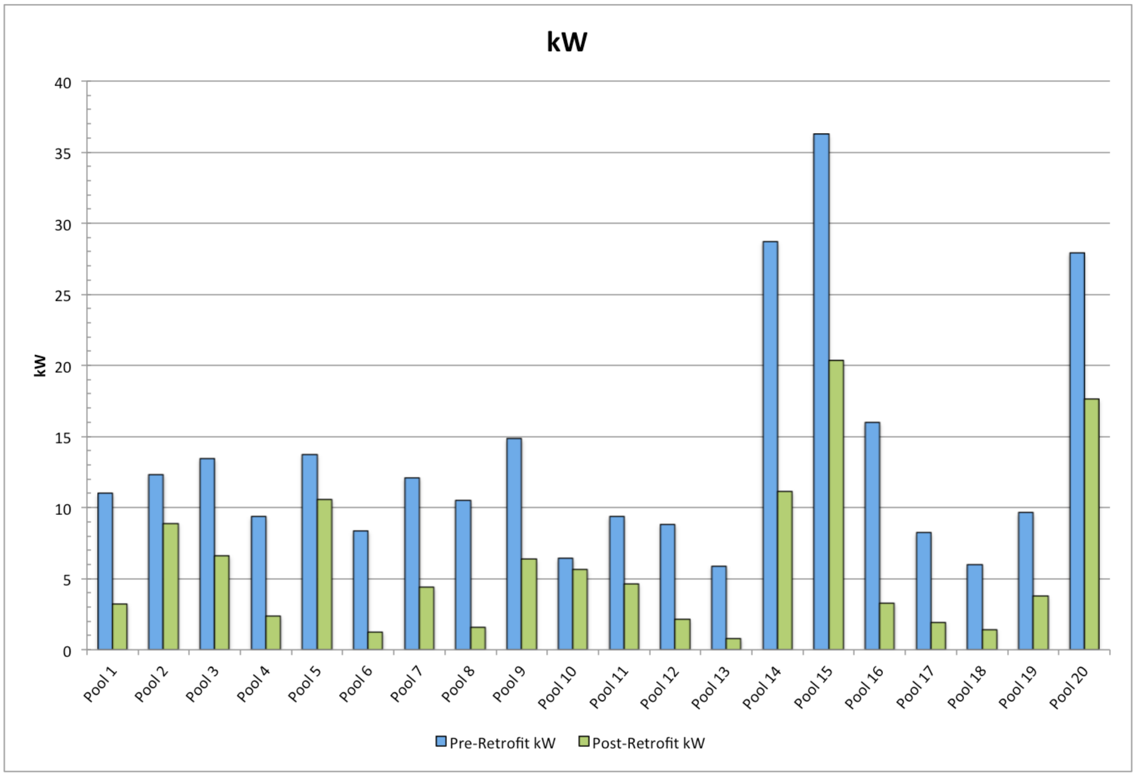


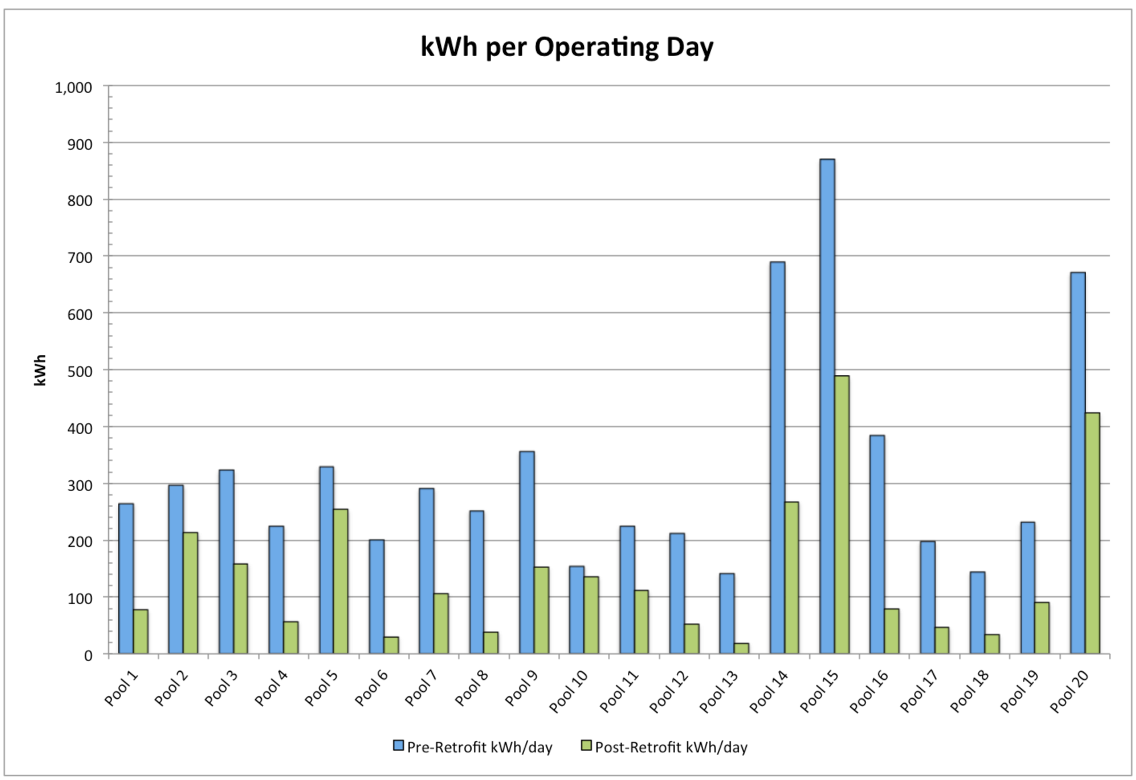


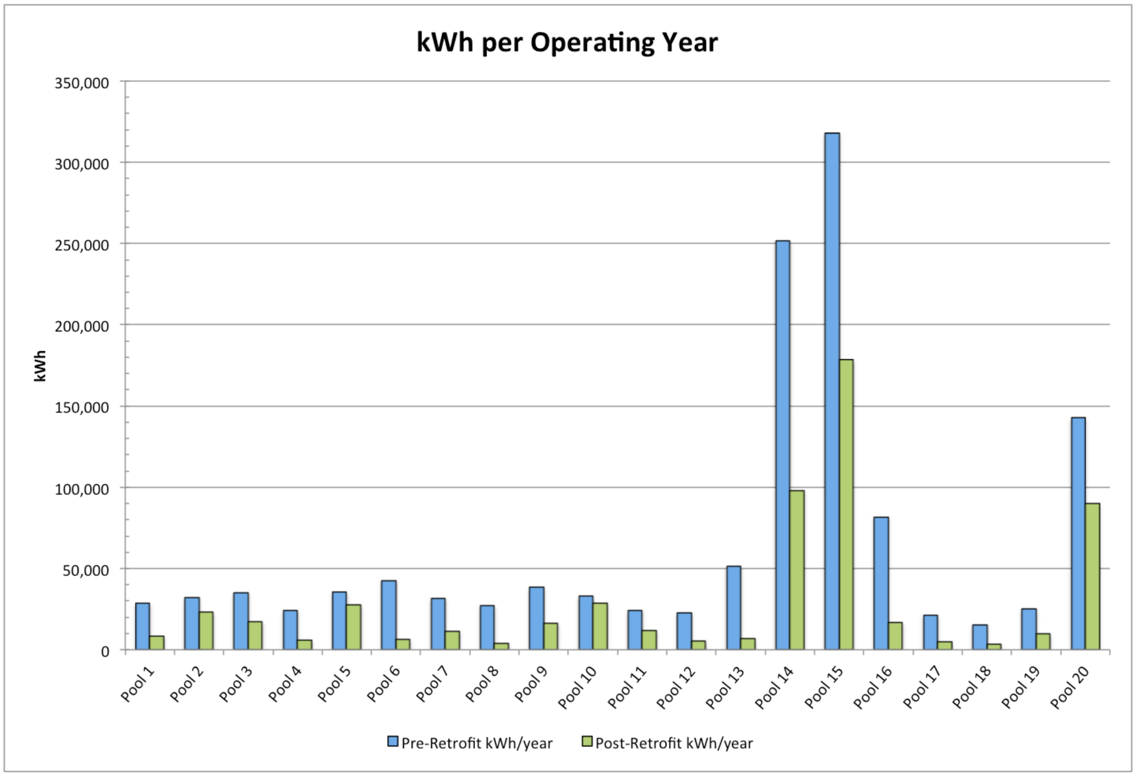
Energy Saving Percentages
Savings %
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
Pool 1
Pool 2
Pool 3
Pool 4
Pool 5
Pool 6
Pool 7
Pool 8
Pool 9
Pool 10
Pool 11
Pool 12
Pool 13
Pool 14
Pool 15
Pool 16
Pool 17
Pool 18
Pool 19
Pool 20

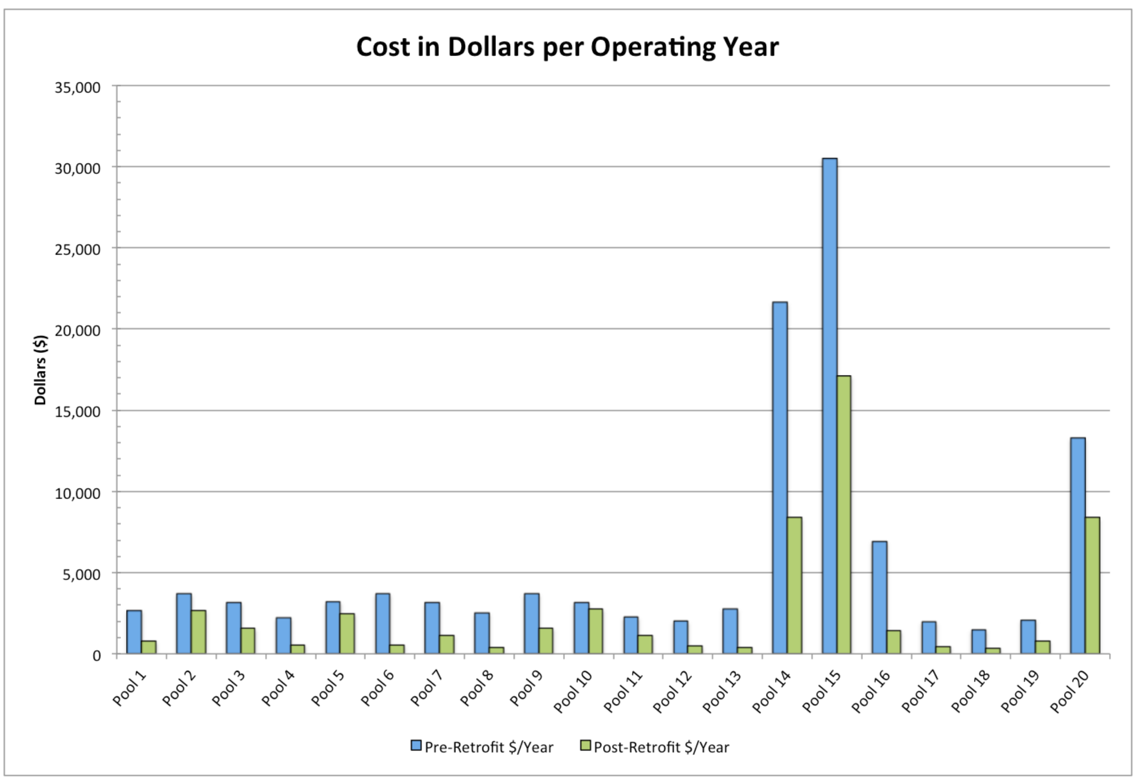


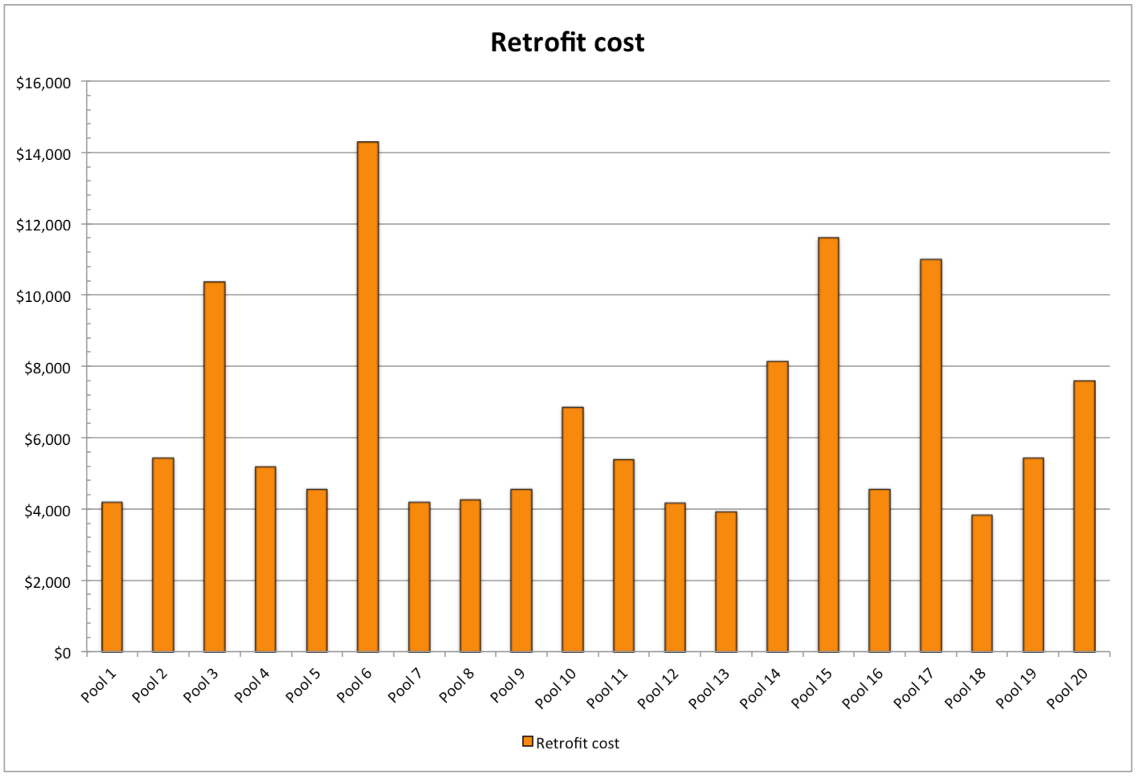
Gallons Filtered per kWh
Gallons
20,000
18,000
16,000
14,000
12,000
10,000
8,000
6,000
4,000
2,000
-
Pool 1
Pool 2
Pool 3
Pool 4
Pool 5
Pool 6
Pool 7
Pool 8
Pool 9
Pool 10
Pool 11
Pool 12
Pool 13
Pool 14
Pool 15
Pool 16
Pool 17
Pool 18
Pool 19
Pool 20
Pre-Retrofit Energy Factor (gallons/kWh)
Post-Retrofit Energy Factor (gallons/kWh)

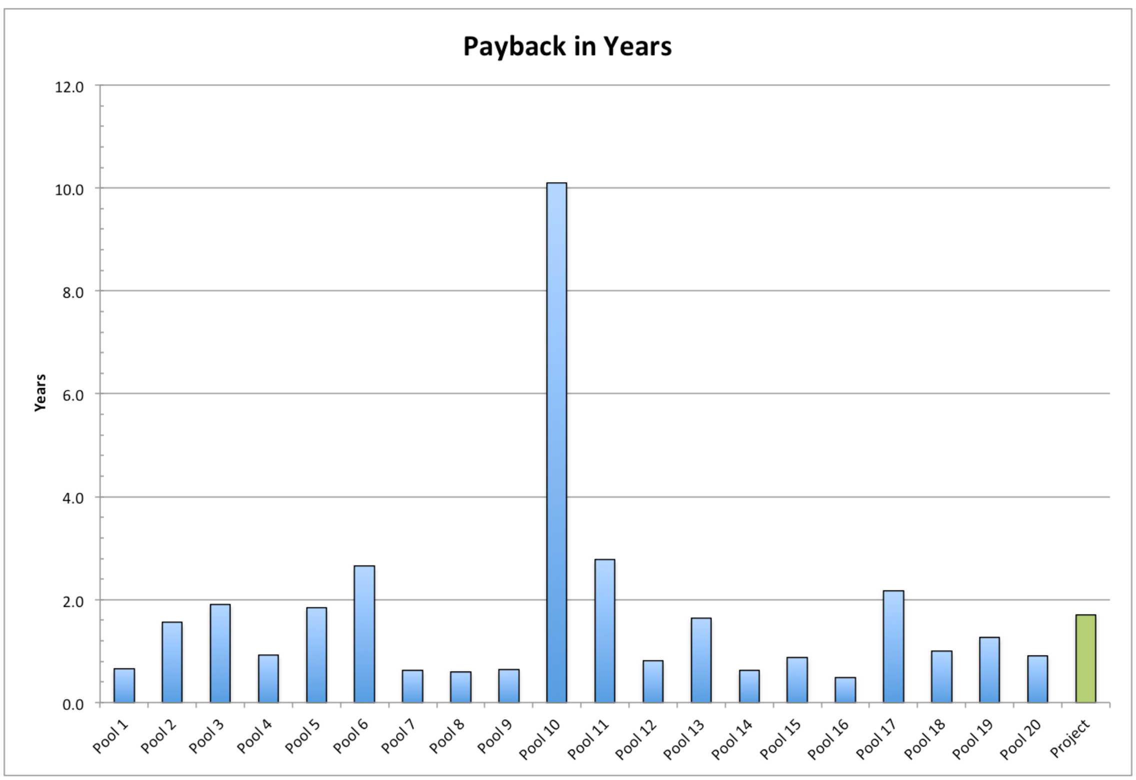

kW
kW
40
35
30
25
20
15
10
5
0
Pool 1
Pool 2
Pool 3
Pool 4
Pool 5
Pool 6
Pool 7
Pool 8
Pool 9
Pool 10
Pool 11
Pool 12
Pool 13
Pool 14
Pool 15
Pool 16
Pool 17
Pool 18
Pool 19
Pool 20
Pre-Retrofit kW
Post-Retrofit kW

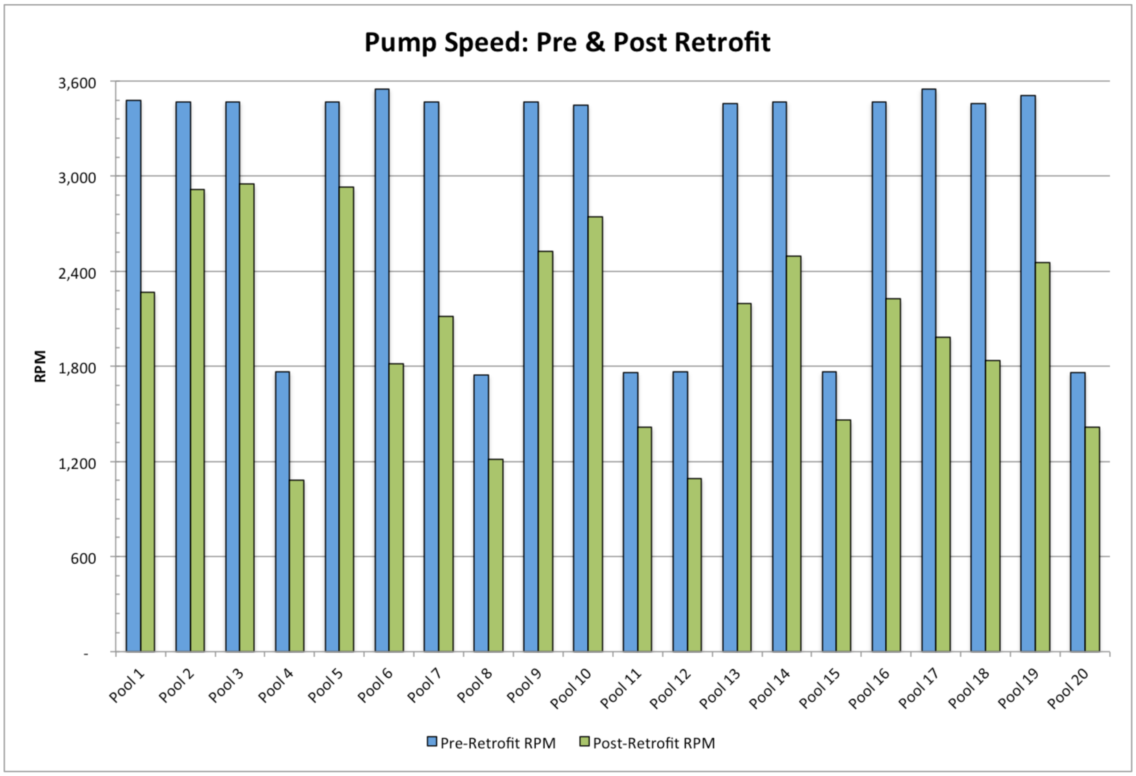

kWh per Operating Day
kWh
1,000
900
800
700
600
500
400
300
200
100
0
Pool 1
Pool 2
Pool 3
Pool 4
Pool 5
Pool 6
Pool 7
Pool 8
Pool 9
Pool 10
Pool 11
Pool 12
Pool 13
Pool 14
Pool 15
Pool 16
Pool 17
Pool 18
Pool 19
Pool 20
Pre-Retrofit kWh/day
Post-Retrofit kWh/day


kWh per Operating Year
kWh
350,000
300,000
250,000
200,000
150,000
100,000
50,000
0
Pool 1
Pool 2
Pool 3
Pool 4
Pool 5
Pool 6
Pool 7
Pool 8
Pool 9
Pool 10
Pool 11
Pool 12
Pool 13
Pool 14
Pool 15
Pool 16
Pool 17
Pool 18
Pool 19
Pool 20
Pre-Retrofit kWh/year
Post-Retrofit kWh/year

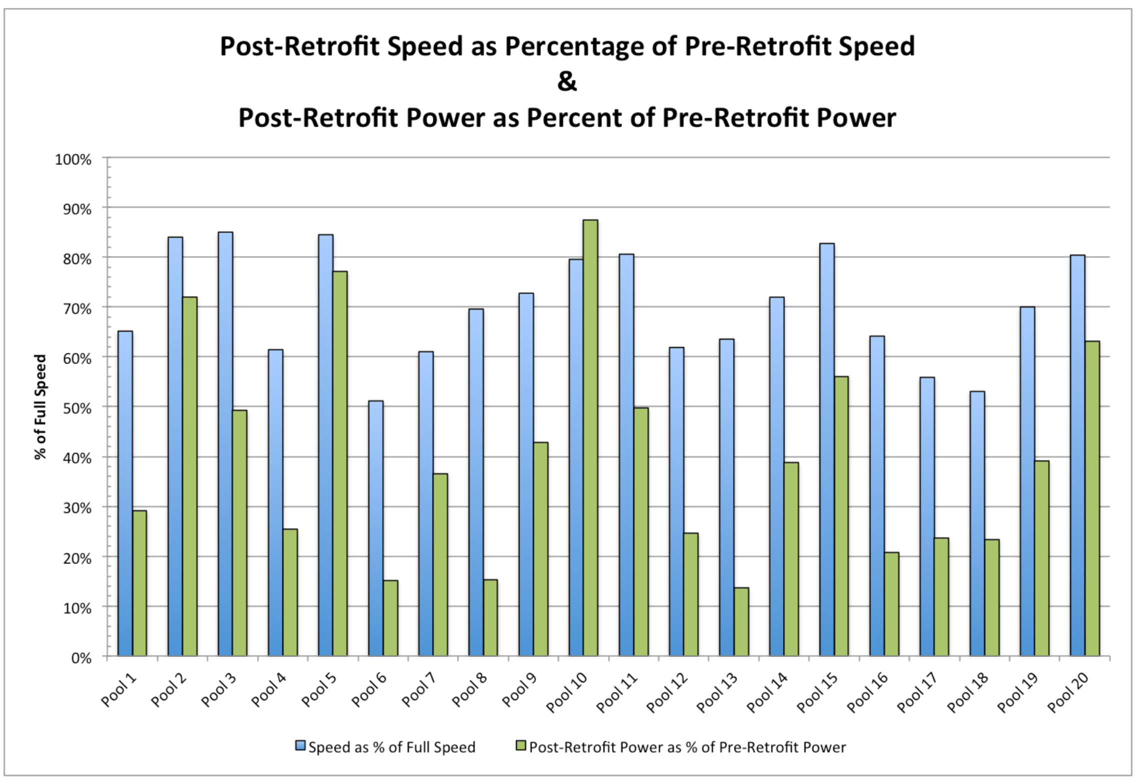

Cost in Dollars per Operating Year
Dollars ($)
35,000
30,000
25,000
20,000
15,000
10,000
5,000
0
Pool 1
Pool 2
Pool 3
Pool 4
Pool 5
Pool 6
Pool 7
Pool 8
Pool 9
Pool 10
Pool 11
Pool 12
Pool 13
Pool 14
Pool 15
Pool 16
Pool 17
Pool 18
Pool 19
Pool 20
Pre-Retrofit $/Year
Post-Retrofit $/Year


Retrofit cost
$16,000
$14,000
$12,000
$10,000
$8,000
$6,000
$4,000
$2,000
$0
Pool 1
Pool 2
Pool 3
Pool 4
Pool 5
Pool 6
Pool 7
Pool 8
Pool 9
Pool 10
Pool 11
Pool 12
Pool 13
Pool 14
Pool 15
Pool 16
Pool 17
Pool 18
Pool 19
Pool 20
Retrofit cost

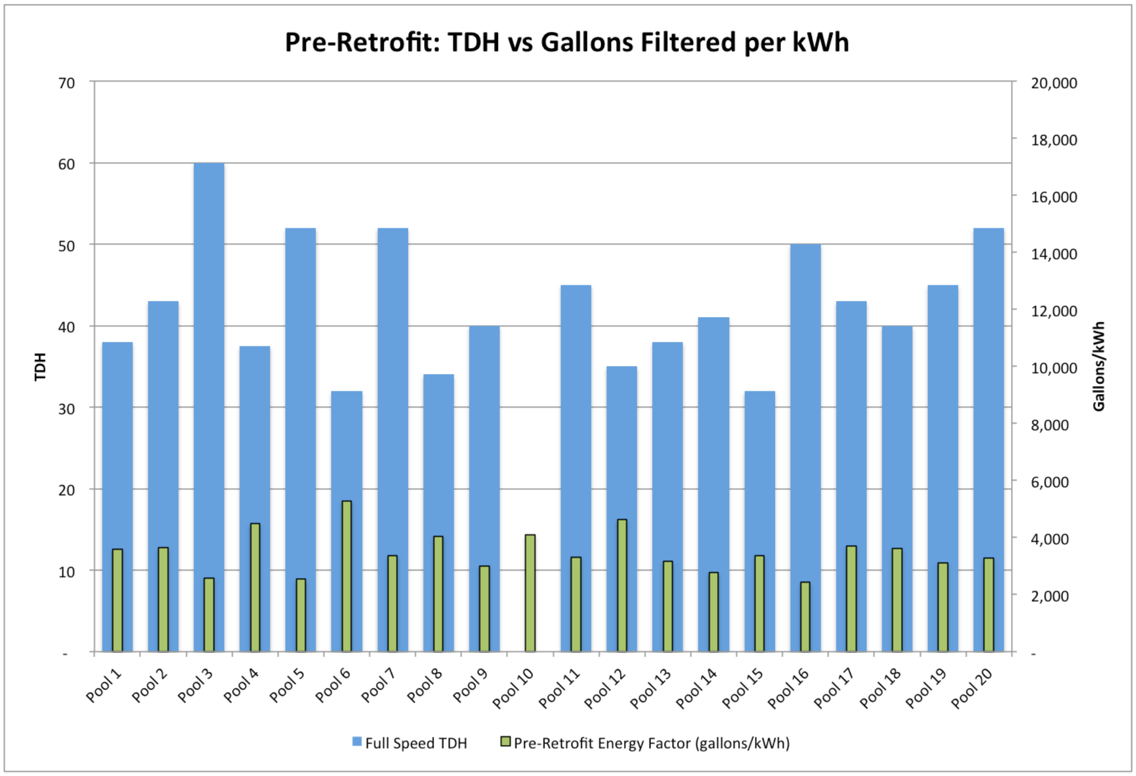

Payback in Years
12.0
10.0
8.0
6.0
4.0
2.0
0.0
Years
Pool 1
Pool 2
Pool 3
Pool 4
Pool 5
Pool 6
Pool 7
Pool 8
Pool 9
Pool 10
Pool 11
Pool 12
Pool 13
Pool 14
Pool 15
Pool 16
Pool 17
Pool 18
Pool 19
Pool 20
Project



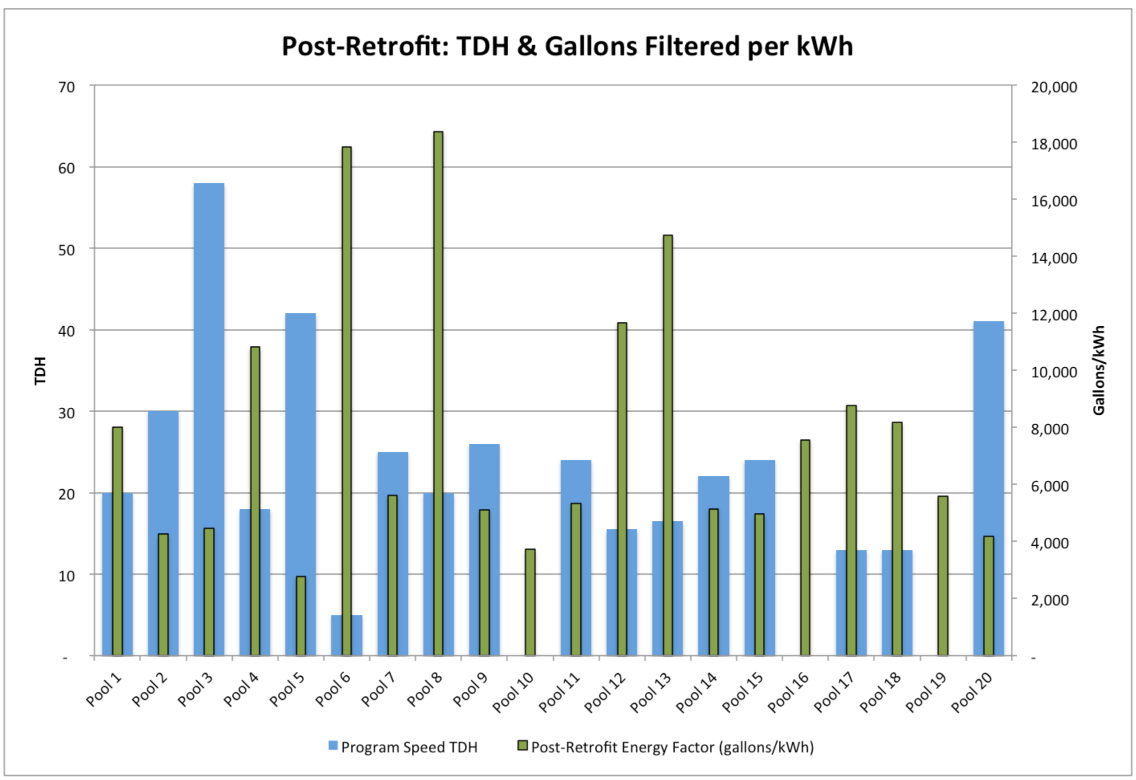
Note: Pool 3 post-retrofit speed data was collected prior to non-compliant filter media replacement.



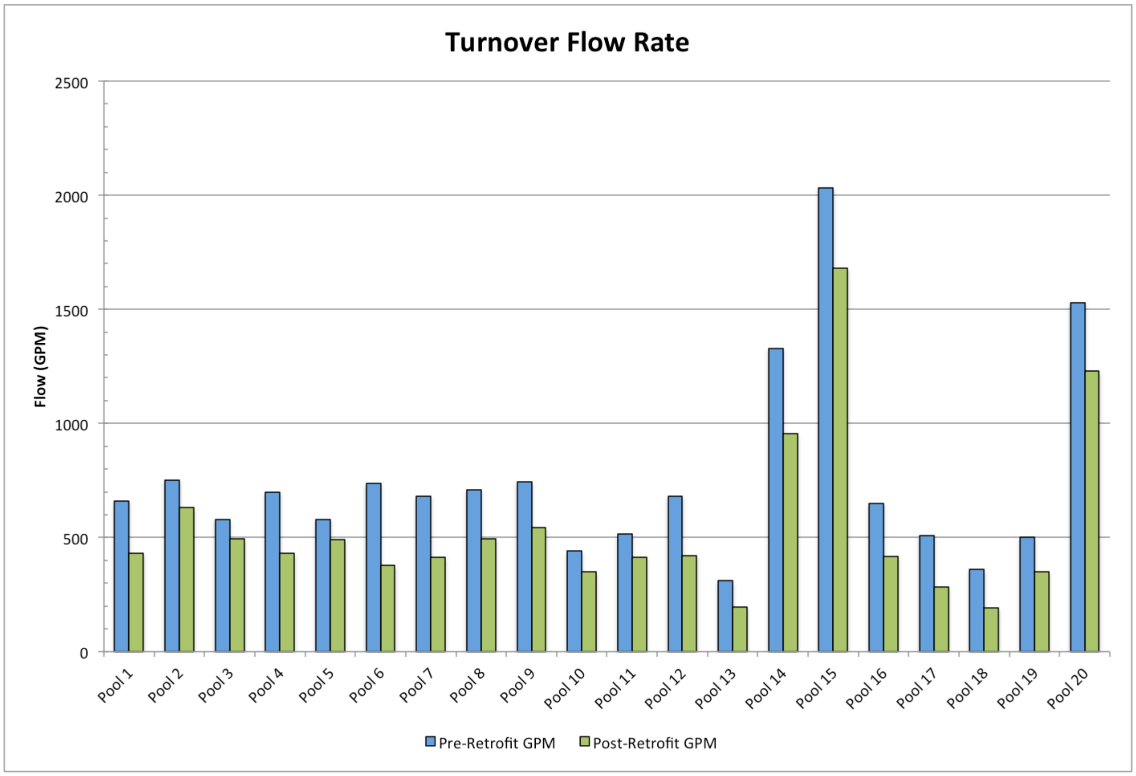
Note: Pool 3 post-retrofit speed data was collected prior to non-compliant filter media replacement.

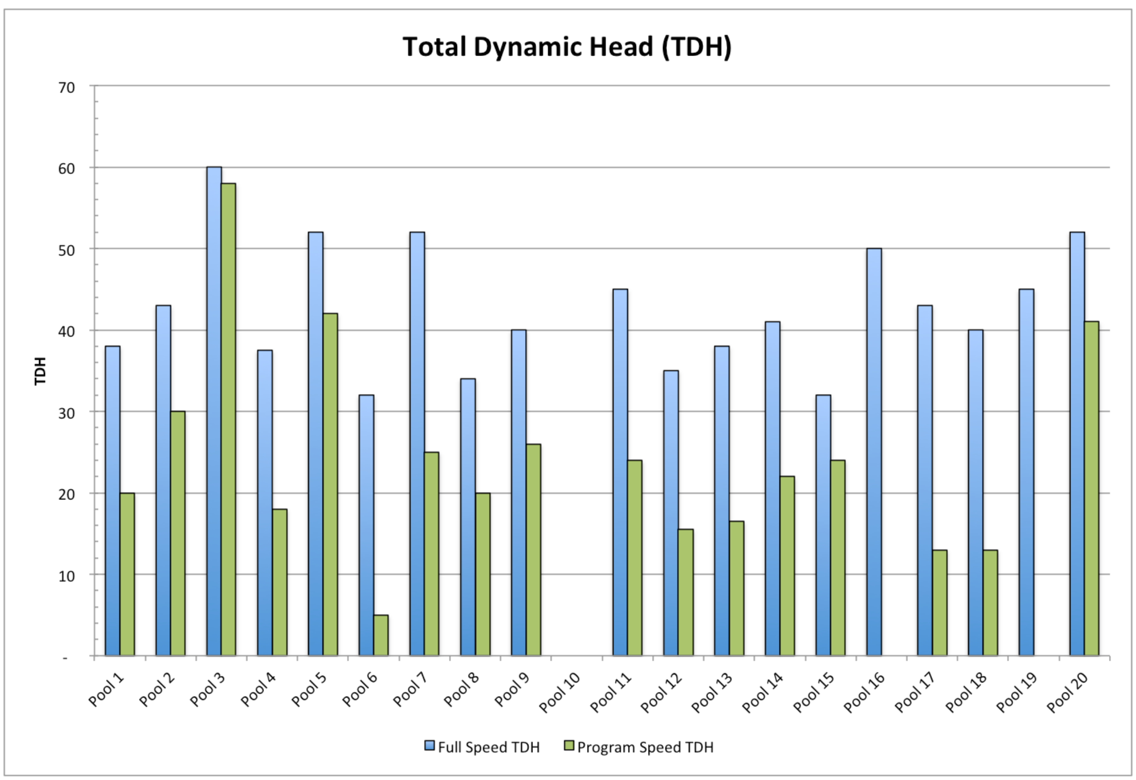


Note: Pool 3 TDH data was collected prior to non-compliant filter media replacement.

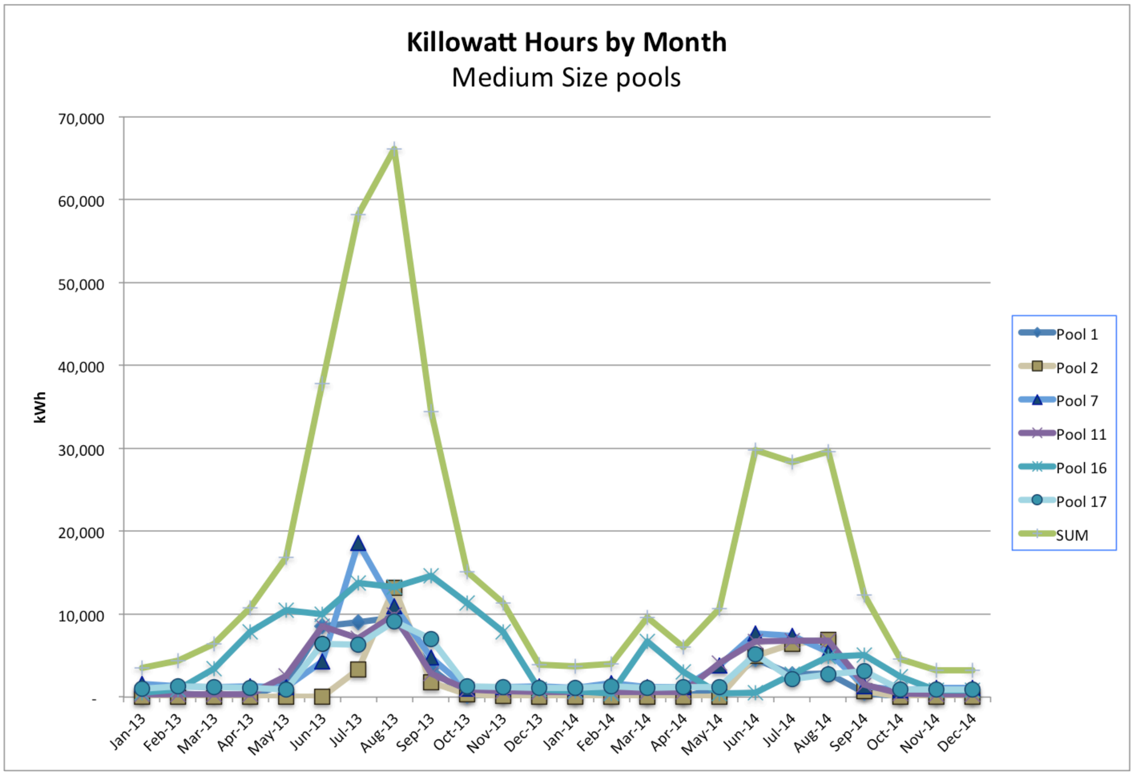


Note: Pool 3 TDH data was collected prior to non-compliant filter media replacement.

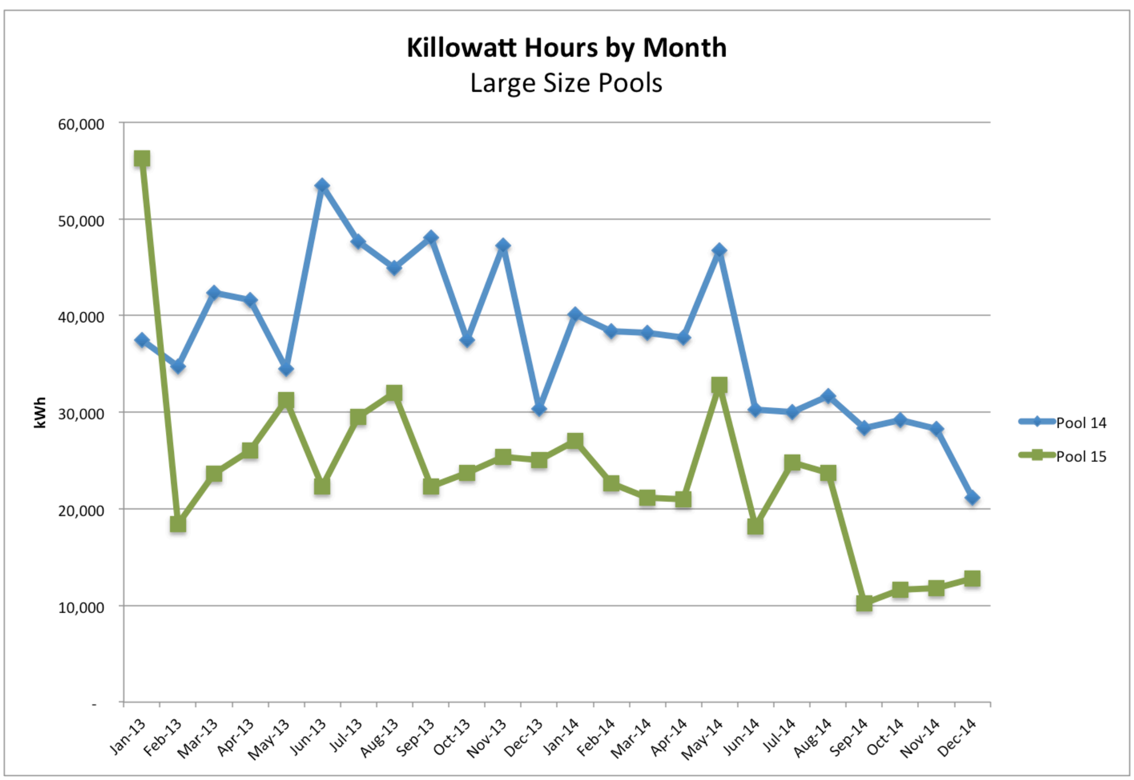




Note: Pool 3 TDH data was collected prior to non-compliant filter media replacement.



Note: Pre-retrofit and post-retrofit kWh from utility meters. Retrofit process completed May 2014



Note: Pre-retrofit and post-retrofit kWh from utility meters. Retrofit process completed May 2014

Appendix B: Summary of Tasks Completed

Phase 1 — Pool Audits: Summary of Completed Tasks	
1	Define data to be collected, specify data acquisition equipment specification, coordinate field audit scheduling and procedures with City of San Antonio, Parks & Recreation Department
2	The consulting team visit each city-own pool between August 12 — 20, 2013.
2.1	Document pool volume, age, location, type, operating hours, health code required turnover flow rate, and filtration system configurations known to impact energy savings, e.g., gravity filter vs. pressure filter.
2.2	Document equipment specifications including pump(s), pump motor(s), electrical system, filter(s), pipe, backwash system, and flow meter.
2.3	Measure motor input power, operating flow rate, pump vacuum, pump discharge pressure, and the system's Total Dynamic Head (TDH).
2.4	In-field crosscheck TDH measured with a differential pressure gauge to the calculated TDH using vacuum and pressure gauge readings.
2.5	In-field crosscheck kW data acquired by measuring the supply voltage and the in-phase component of the load current with calculated kW using volt and amp readings.
2.6	Simulate extreme dirty filter conditions (where possible) by adding 10 psi (23 ft/H2O) via control valve to collection of two sets of performance data used to identify anomalies in data, malfunctioning flow meters, worn/mismatched pump impellers and motor.
2.7	Photographically document pool, equipment area, pumps, motors, filters, piping, and the data acquisition system setup.
3	Compile Phase 1 *Energy Conservation Site Visit Report for City-Owned Pools*
4	Develop and populate project database to process and analyze data as part of Phase 2

Phase 2 — Retrofit Plan: Summary of Completed Tasks	
1	Defined and applied criteria used to evaluate potential energy savings using current equipment retrofitted with VFD pump control.
2	Evaluate data from each filtration system to identify opportunities to lower Total Dynamic Head (TDH) to maximize existing surplus turnover capacity, or to create surpluses where it did not exist previously.
3	Identify pools eligible for retrofits.
4	Identify pools ineligible for retrofit (based on hydraulics, unacceptable ROI etc).

Phase 2 — Retrofit Plan: Summary of Completed Tasks	
5	Perform flow & TDH analysis to compare the installed flow meter flow readings to the flow estimates determined using measured TDH and pump curves, flagged any deviation greater than 10%.
6	Confirm existing pump(s) is certified in conformance with NSF/ANSI Standard 50 and if a pump performance curve is available for use in validating flow meter accuracy within +/-10%.
7	Confirm existing flow meters are represented by the manufacturer to be accurate within 10% of true flow as stated in the Texas Administrative Code.
8	Prepared a detailed energy and payback analysis using the affinity law to compute savings estimates based on measured pump data. Current energy consumption was compared to estimated energy consumption that was anticipated after implementation of recommended retrofit improvements.
9	Formatted and organized pre-project data collected by COSA as needed to identify any missing data, and to compare it to that collected during site visits. This was used to crosscheck COSA estimated savings using utility meter data with measured data in the field.
10	Provided cost-effective energy conservation and hydraulic improvement recommendations.
10.1	Using information provided and data collected during site visits the consultants developed a manufacturer-neutral proposal of recommendations to reduce energy consumption at all pools WITH surplus turnover rates.
10.2	For pools WITHOUT surplus turnover rates, hydraulic upgrades to pump, filter, accessible pipe, and valves, were recommended (where applicable), if such upgrades were projected to result in reduced energy consumption sufficient to payback the total retrofit cost within the time.
10.3	Designated which pools are best suited for variable speed pumps with onboard VFD control, and those for external VFD control.
10.4	Identified minimum electrical circuit requirements to operate the VFD controlled pump in compliance with the current National Electric Code. Specified lightning protection equipment.
11	Prepared bid specifications for each retrofit candidate pool, including (where applicable) replacement pumps and/or motors, system specific VFD with digital flow meter feedback loop to maintain code compliant flow rate, new digital flow meter, electrical alterations, other mechanisms, and equipment changes to reduce TDH.

Phase 3 — Retrofit Implementation	
1	Attended pre-construction meeting to provide a summary and clarifying details related to the bid specifications and project scope of work.
2	Provided logistical support to ensure that the appropriate equipment was delivered to the contractor on time.

Phase 3 — Retrofit Implementation	
3	Provided technical assistance to CoSA and the contractor throughout the retrofit process.
4	Provided customer service support with equipment installation and startup.
5.	Served as intermediary between CoSA staff and equipment manufacturer.
6.	Reviewed specifications and proposals for the installation of circulation and filtration equipment installed outside of the original project scope.

Phase 4 — Post-Retrofit: Summary of Completed Tasks	
1	Performed quality assurance inspections at each pool where Energy Retrofit work was completed prior to August 2014. Confirmed retrofit conformance with the bid specification, providing corrective actions reports where needed.
2	Provided training on VFD operating procedures, including backwashing, and manual override functionality in conjunction with quality assurance visits when possible and separately when not pools for City of San Antonio, Parks & Recreation Staff.
3	The consulting team visited each retrofitted pool between July — August, 2014.
4	Detailed post retrofit data was collected at all 22 retrofit sites. Measurements were taken under four recirculation system operating conditions:
4.1	Full speed with CLEAN filter
4.2	Full speed with simulate DIRTY filter at +10 psi over clean filter pressure (where possible, e.g., pressure filter systems equipped with throttling valve)
4.3	New, flow controlled program speed with simulated DIRTY filter (where possible)
4.4	New, flow controlled program speed with CLEAN filter
4.5.1	Under each of the four operating condition: measured pool pump voltage, amperage, VFD operating frequency (Hz) and wattage draw. (Hz frequency at full speed is 60Hz).
4.6	Observed water clarity at all pools.
4.6.1	Measured TDH, pressure and suction side pressure (psi)
4..6.2	Documented VFD drive KW readings and compared to watt meter readings
4.6.3	Documented the pool equipment environment, i.e., outdoor, indoor, indoor with chemical feeder(s). Noted issues with pressure activated chemical feeders and pressure switch locations.
4.6.4	Documented preexisting hydraulic problems that prevented post retrofit VFD's from operating pumps at designed flow rates. Provided detailed resolution suggestion.
5	Evaluated Phase 2 recommend hydraulic system improvements.

Phase 5 — Final Report: Summary of Completed Tasks	
1	Reviewed field data with CoSA staff to develop agreed-upon methodology to quantify energy and cost savings.
2	Verified annual operating hours and utility rates per location for use in energy and cost savings calculations.
3	Adjust savings, lowering the total by 1.5% to reduce dirty filter energy penalty
3	Developed spreadsheet template with kW, kWh and cost savings data comparing pre and post-retrofit conditions at all retrofit locations.
4	Submitted final report to CoSA, which was used for internal energy and cost savings as well as support for the utility rebate application.