Nick Baniel Research Summary (2012-2013)

Project Objectives:

- Survey and evaluate existing Madison Water Utility facilities to determine characteristics of energy consumption
- Better understand the factors that produce site inefficiencies and explore ways to improve efficiency and conserve energy
- Develop a long-term method to monitor and predict preventable future energy increases at all site locations due to infrastructure or operational inefficiencies

Research was divided into three phases of work as follows:

- Phase 0: comprehensive review of daily operating records for each site for the years 2009-2012. Using these records a baseline energy efficiency was developed for each site
- Phase I: field sampling to determine efficiency of several motors in the system
- Phase II: detailed site analysis of seven sites in system with varying drawdown, age, piping configuration, and energy use; energy parameters, pressure readings, SCADA data, pump tests, operational data used to determine the accuracy of Phase 0 analysis as well as determine which operating conditions optimized energy efficiency

Results of each phase is as follows:

- Phase 0: Calculated average unit well site power use efficiency was 60% with an average deep well pump efficiency of 70% and average booster pump efficiency of 69%, all lower than expected. Average unit well pumped 1.7 Mgal at a cost of 3285 kWh daily and average pumping level of 207 feet; baseline values were developed and wells were selected for Phase II (Unit Wells 9, 14, 6, 26, 25, and Booster Station 118)
- Phase I: Efficiency for motors not previously measured was found to be between 91% and 95%. Efficiency for all motors in system found to be over 90%
- Phase II: Site efficiency, pump efficiency and energy intensity were measured for all sites except for UW 29. Well 29 was off line and unavailable at the time of sampling due to a broken pump shaft. Measured site efficiencies were on average 9.6% greater than the calculated site efficiencies in Phase 0.

Conclusions:

- Phase II sampling showed that site efficiencies were between 6% and 15% greater than those estimated during Phase 0, mainly due to friction losses and more accurate pressure readings
- Focusing efforts on sites with low specific capacities and high efficiencies simplest way to reduce energy consumption
- Phase II sampling suggested most pumps were operating slightly below the original factory pump curve due to natural wear or impeller trimming
- Over 99% of site energy used at Madison facilities is attributable to pumping operations
- Energy use rating and site efficiency rating for each well tested can be found below

- Average (within one standard deviation of average for all sites)
- Poor (greater than one standard deviation worse than average for all sites)
- Good (greater than one standard deviation better than average for all sites)

Site	Energy Use Rating	Site Efficiency Rating	Comments
Unit Well 9	Good	Poor	Low efficiencies during periods of low pumpage
Unit Well 14	Good	Good	Low drawdown
Unit Well 6	Average	Good	High pump efficiency
Unit Well 26	Average	Average	Deep well pump efficient at wide range of flows and heads
Booster Station 118	Good	Poor	Most operational points outside best efficiency range
Unit Well 25	Average	Average	Versatile deep well pump at wide range of flows

Recommendations:

- Establish an energy monitoring baseline at each site to better understand energy use for each facility
- Consider moving operational point of some pumps closer to best efficiency point using VFD or head change in pressure zone or reservoir level
- Monitor SCADA recording instruments to ensure proper readings
- Reduce number of pump starts system-wide to improve efficiency. This is especially true on high frequency startup wells (UW14)
- Investigate cause of iron and manganese buildup at inlet of deep well pump at UW29
- Replace undersized motors (UW20)
- Consider replacing pumps that are extremely underperforming (UW9)
- Pressure zones with one or two unit wells should be investigated to ensure operation of pumps is optimal
- Pressure zones with multiple unit wells should be operated based on pumping level and efficiency values to reduce energy use
- Analyze use of VFDs on booster pumps to determine their value in reducing energy use
- Overall system efficiency should be considered when using booster stations for intra-zone pumping as opposed to different unit well sites; in some cases, it may be less energy intensive to pump water across pressure zones than pump water from two different wells

Matt Hayes Research Summary (2014-2015)

Project Objectives:

- Develop variable frequency drive protocol for optimization of deep well pumps
- Using the Utility water distribution system model, evaluate and determine most energy efficient operation of Pressure Zone 4 with proposed UW31 on line
- Develop procedure of energy conserving well practices for pressure zones with few unit wells, derived from Pressure Zone 4 results, to predict most energy efficient operation

Potential energy saving opportunities were divided into three major categories:

- A VFD study was performed to characterize energy savings potential of wells with below average, average, and above average specific well capacity
- Flow bins were developed to better understand what system demand conditions account for the majority of energy use
- Hydraulic modeling software was used to:
    - Model Pressure Zone 4 to determine the optimal VFD speed of UW31 deep well, hydraulic grade line of PZ4 in winter, and flow distribution between wells, all to minimize energy use
    - Graphically show pipe headloss, hydraulic grade line variation, and average pressure of various regions of Pressure Zone 4, under varying flow distributions
    - Energy grade line shape and variation with different modeled flow distributions and tank levels

Preliminary results and conclusions of the three phases of research are as follows:

- Sites with high specific well capacities (UW9) were found to be poor candidates for VFD installation, but generally had low energy consumption already due to minimal drawdown
- Sites with low specific well capacities (UW25) were found to be good candidates for VFD installation as head reduction is significant compared to efficiency losses as a result of speed reduction
- Average water demand conditions across the system for each well (1 - 1.75 MGD) accounted for 86% of yearly flow events and 94% of yearly energy bill
- Several undersized pipe segments exist in PZ4 distribution system but account for small headloss, 1.6 feet in worst pipe segment, 11.6 feet overall between UW9 and UW31
- VFD speed at UW31 was found to be optimal at 80%, saving $15,000 per year and 24,000 kWh of energy
- Off-peak pumping was found to save an additional $6,000 per year, but sacrifices 9,000 kWh per year relative to the 80% VFD speed reduction
- Distribution of flow between wells was found to be most energy and cost efficient using only UW9 due to significantly lower specific well capacity and pumping water level
- For Pressure Zone 4, operationally this is not desired by the MWU. While a 50/50 split would be ideal, movement towards 40% of the water being pumped from UW31 deep well and 60% from UW9 is suggested due to increased operational efficiency.

- Winter tank level modification in PZ4 is not expected to be beneficial from an energy use standpoint. Only $1,000 per year and 5,000 kWh per year savings result when UW9 tank level is reduced by 10 feet

Continuing work includes:

- Sample UW19 to characterize an average specific capacity well with no factors impacting projected VFD savings (filtration, air stripping, etc.)