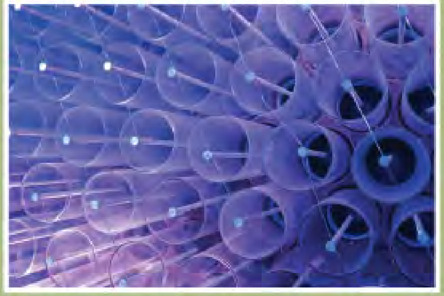
PENNSYLVANIA AMERICAN WATER

Improving Pump Efficiency to Decrease Energy Consumption



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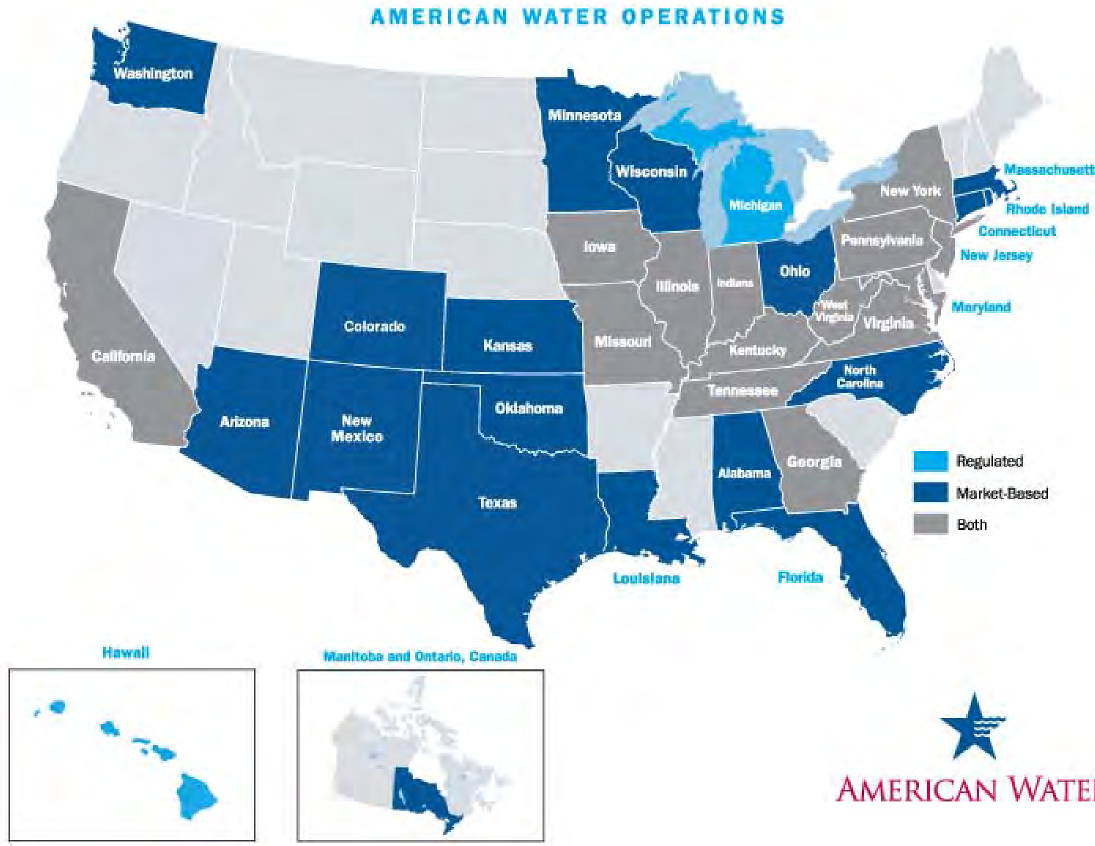
Pennsylvania American Water

Who Is American Water

We are the largest publicly traded water and wastewater service provider in the United States

- Provides services to approx. 14 million people in more than 30 states and parts of Canada

- Treat and delivers more than one billion gallons of water daily



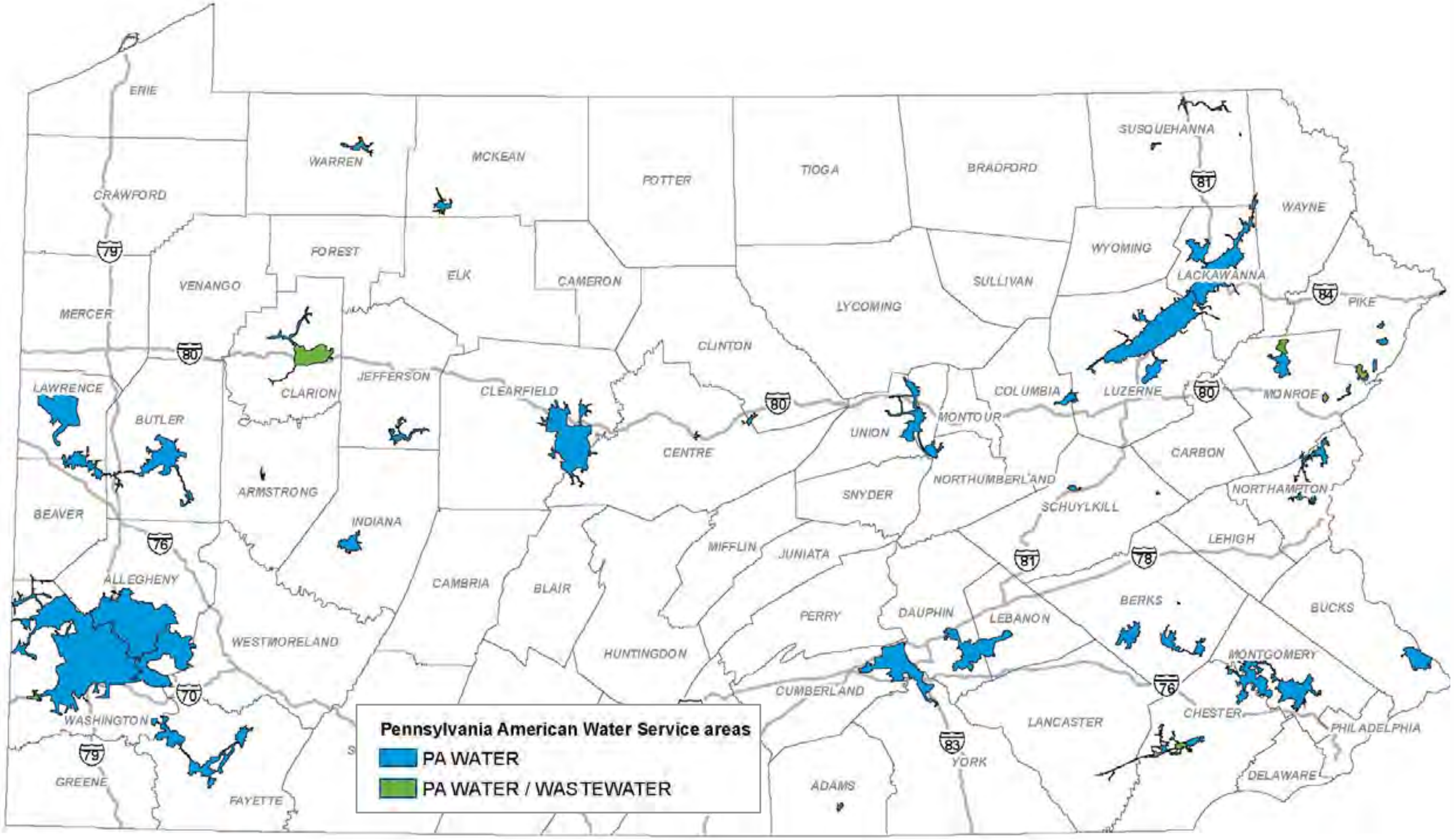
AMERICAN WATER

Our Company

- **Subsidiary of American Water Works Co. Inc.**
- **Roots date back to early 1800s, Incorporated in 1904**
- **Largest regulated water and wastewater service provider in PA**
- **Serving approximately 2.2 million people in 36 counties**
- **More than 1,000 employees**
- **Customer base:**
  - 640,000 water customers
    - 92% residential
    - 7% commercial
    - 1% industrial/other
  - 17,000 wastewater customers

PENNSYLVANIA AMERICAN WATER

Pennsylvania American Water Service Area



Serving 17 percent of the Commonwealth's population

Presentation Overview

I. The Case for Pump Efficiency
II. Case Study Approach
III. Methodology
IV. Case Study #1
V. Case Study #2
VI. Case Study #3
VII. Conclusions
VIII. Recommendations

I. The Case for Pump Efficiency

- **Drinking water pumping systems – 20% of world's electrical demand**
- **Footprint of a water utility includes:**
  - Energy use (power)
  - Fossil fuels (natural gas, fuel, oil)
- **Carbon footprint – the total set of greenhouse gas (GHG) emissions**
- **Carbon footprint reduction – measured in terms of the amount of carbon dioxide removed from the environment**
  - 6.8956×10^{-4} metric tons CO_2 / KWh
    - 1.52 lbs CO_2 / KWh
- **Increasing efficiency leads to decrease in GHGe, increased sustainability and decreased operational costs**

I. The Case for Pump Efficiency

Pennsylvania American Water

- **850+ facilities billed for electricity**
  - Treatment plants, office buildings, pump stations
- **Vast majority of electrical use is for pumping (97%)**
- **Estimated 90% of GHGe are due to pumping**
- **Identified 10 largest 'facilities' - account for 60% of the state energy usage**
- **Water pumping comprises majority of energy usage at facilities**

II. Case Study Approach

- Test efficiencies of pumps at top 10 facilities
  - Wire-to-Water Testing

- Refurbish or replace pumps to obtain better operating efficiencies
  - Reduces energy use
  - Reduces carbon footprint
  - Saves operating expenses

II. Case Study Approach

- Wire-to-Water Testing
  - Considers overall efficiency of the motor and pump
  - Is a measure of the pumping power produced by a unit of electrical power
  - Wire-to-Water Efficiency = Water HP / Wire HP

II. Case Study Approach

- Wire-to-Water Testing
  - Wire Horsepower (HP)
    - Electrical power applied to the motor
    - Wire HP = (Volts x Amps x Power Factor) / 431
  - Power Factor
    - Measure of how the voltage leads or lags the amperage
    - Power factor = Active Power (W) / Apparent Power (VA)
  - Water HP
    - Power transferred to the water by the pump
    - Water HP = [Flow (gpm) x Head (ft)] / 3960
  - Note: Wire-to-water tests indicate the efficiency of the pump and motor; not just the pump

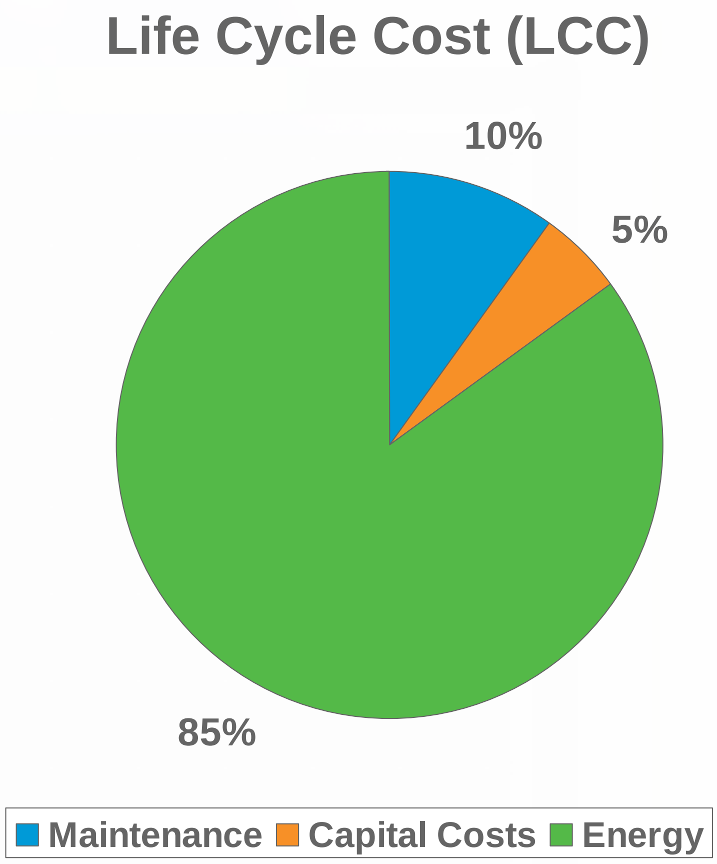
II. Case Study Approach

Motor Data					Flow Data				Pump Data					
Voltage & FLA		HP	Efficiency	PF	Flow Meter	Range	Span	% Error			Design Flow		Design head	
460/230		200	0.9		Venturi	0 - 6944.4	6944.4	1.00	1770		2100		240	
Test Date	% Test Flow	Voltage volts (avg.)	Current amps (avg.)	Power Factor	Flow gpm	Suction** Measure Ft of top of water to pressure gauge	Discharge psi	Total Head	Wire hp	Water hp	BHP	W/W Eff.	Pump Eff.	Gallons per KWH
05/25/10	0	495	137	0.60	0	16.1	109	268.31	94	0				
	50	495	163	0.71	1217	16.1	98	242.43	133	75	119	56%	62%	737
	75	496	181	0.75	1796	16.4	91	226.56	156	103	140	66%	73%	928
	100	495	198.00	0.77	2395	16.0	76	191.59	175	116	158	66%	74%	1100
Device accuracy		0.25	0.10	0.50					0.85	2.90	0.85	2.07	2.07	2.07

- Example Wire-to-Water Input
  - Nameplate data
    - Motor
    - Pump
  - Actual (field) data
    - Motor
    - Pump
    - Electrical

II. Case Study Approach

- Typical bowl efficiency of new, high efficiency pumps: 83-88%
- Typical wire-to-water efficiency (assuming 95% motor efficiency): 79-84%
- The capital cost of a pump installation is a small percentage of the Life Cycle Cost (LCC)
  - Energy: 85%
  - Maintenance: 10%
  - Capital cost: 5%



II. Case Study Approach

- **Define top energy systems we plan to engage with efficiency improvements**
  - Top 10 systems = 60% of company's energy usage
  - Top 4 systems = 40% of company's energy usage
  - All of the top systems are large pumping facilities (finished water pumping encompasses 75%+ of the energy usage at those facilities)

- **Current operating finished water pump efficiencies**
  - 50-80% (based on wire-to-water testing)

- **Potential finished water pump efficiencies**
  - 80-85%

II. Case Study Approach

- Develop a metric and baseline to compare future and past
  - Energy Unit Index (EUI)
    - Energy Used (MWh) / Water Pumped (MG)
  - Example:
    - Pump requires 100 MWh to pump 25 MG
    - EUI = 4.00
    - More efficient pump requires 75 MWh to pump 25 MG
    - EUI = 3.00

II. Case Study Approach

- Evaluate current hydraulics and flow of each system
- View current pump sizing and design
- Analyze cost effectiveness to refurbish vs. replace pumps
- Capital cost and payback analysis
- Comparison of final and initial EUI

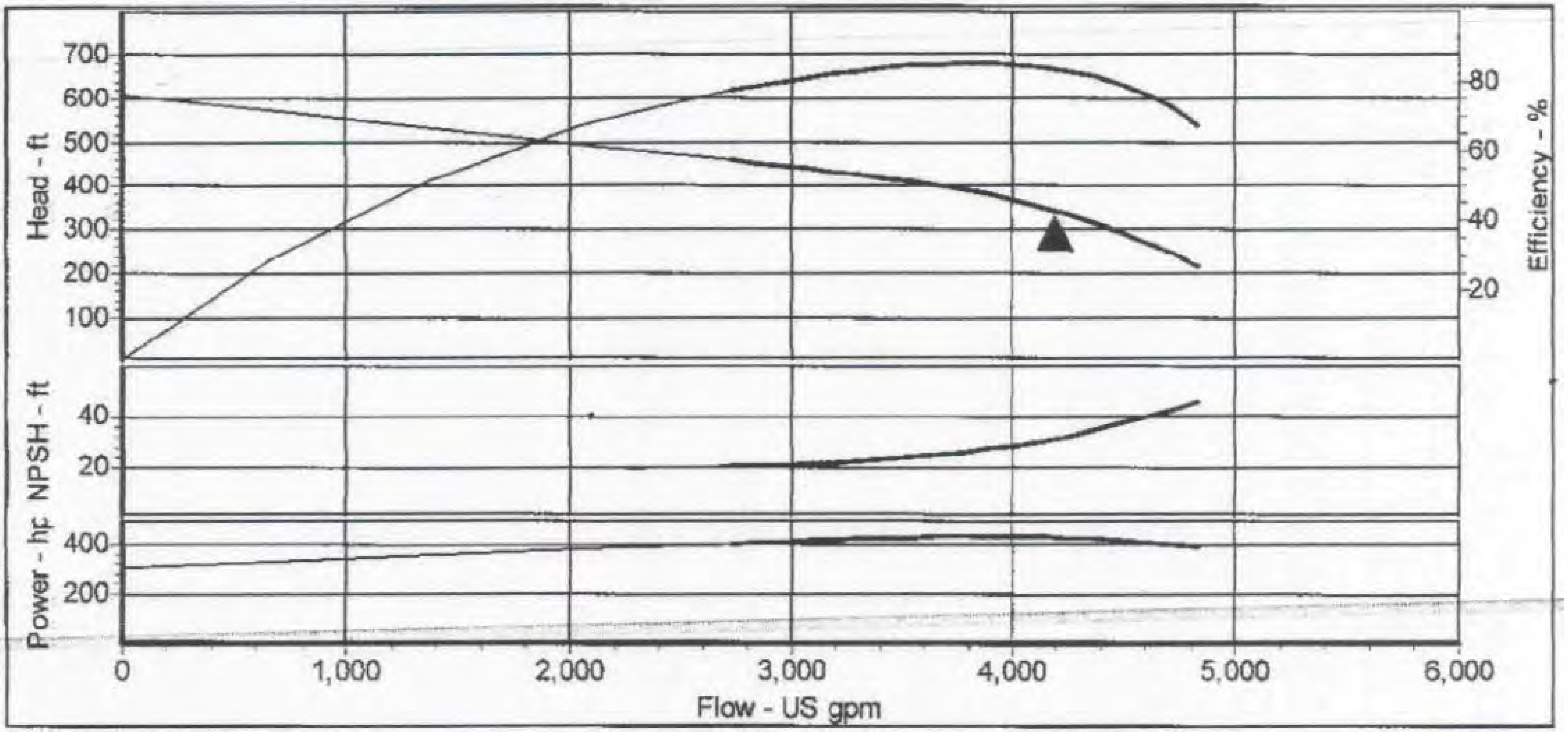
III. Methodology

- **Preferred operating range (POR):**
  - Select pumps that operate within 10% of the best efficiency point (BEP)
    - Average demand and TDH requirements should be near BEP design
- **Pump sizing**
  - What are the demand characteristics?
  - How are pumps operated?
  - Able to still pump maximum flow (MF) and worst-case pressure conditions

III. Methodology

- **Listen**
  - Cavitation (cracking sound)
  - Vibration
- **Look**
  - Excessive leaking (seals)
- **Vibration Analysis**
  - Accelerometers mounted to pump; software is used to compare to baseline (new pump) data
- **Thermography (Infrared Scanning)**
  - For early detection of ‘hot spots’ – deteriorating motor windings, hot running bearings, etc.
- **Evaluate Current Pump Curve**
  - Created from wire-to-water
  - Compare to new/factory pump curve

III. Methodology



III. Methodology

- **Options for Improving Pump Efficiencies**
  - **Mechanical rehabilitation**
    - Pump: replace wear rings, seals, sleeves, gaskets, bearings
    - Motor: rewind motor windings
  - **Sandblast and recoat**
    - Removes tuberculation and roughness
    - Reduces friction losses through pump
    - Coating adds efficiency and longevity
  - **Install VSD**
    - Vary flow at set hydraulic conditions (TDH)
    - Can replace throttled valve
    - Inherent 2-5% loss in efficiency
    - What pump flows/efficiencies will the VSD run at?

III. Methodology

- **Options for Improving Pump Efficiencies (cont.)**
  - **Replace pump (and motor)**
    - Pump not operating near BEP at ADF
    - TDH/Flow requirements changed
    - Cost of rehabilitation >/= replacement
    - New pump/motor more efficient
  - **Trim or replace impeller**

IV. Case Study #1

- **Treatment plant**
  - 6 MGD Plant Capacity
  - 3 MGD ADD

- **3 High Service Pumps (75%+ of plant energy usage)**
  - Vintage 1968 – Pump and motors (200 hp)
  - Pump #2 utilized inefficient fluid hydraulic drive

- **Pumps designed at 2100 gpm, 240 ft, 82% efficiency**

IV. Case Study #1

- **Original wire-to-water efficiencies**
  - #1: 74%
  - #2: 70%
  - #3: 67%

- **Findings**
  - TDH/Flow requirements changed
  - Pumps were not operating efficiently on factory curve
  - VSD was needed to maintain adequate service to customers efficiently

IV. Case Study #1

- **Pumps replaced**
  - Replace pumps with correctly-sized pumps
  - Replace motors with premium efficiency 150 hp motors
  - Add electrical VSDs to 2 of 3 pumps

- **Current wire-to-water efficiencies**
  - #1: 80%
  - #2: 80%
  - #3: 81%
  - Original wire-to-water efficiencies – 67%-74%
- **Pumps designed at 2150 gpm, 215 ft, 84% efficiency**
- **Now properly sized – operating more efficiently**

IV. Case Study #1

	Energy (MWh)	Flow (MG)	EUI
2011 (Jan – Dec)	1,447	1,030	1.41
2012 (Jan – Dec)	1,312	1,022	1.28

- EUI reduction: 9%
- KWh savings (2011 - 2012): 135,000
- Cost savings: $15,200
- Cost of pump: $36,000
- Payback: ~ 2.5 years

V. Case Study #2

- **Relay pump station**
  - 35 MGD ADD

- **Five relay pumps (>95% of location energy usage)**
  - Vintage pumps and motors (1960s)
  - Three 10 MGD pumps
  - Two 20 MGD pumps

- **10 MGD Pumps designed at 7000 gpm, 360 ft, 87% efficiency**

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V. Case Study #2

- **Original Wire-to-Water Efficiencies (10 MGD)**
  - #1: 65%
  - #2: 65%
  - #3: 63%

- **Findings**
  - Normal pump wear reduced efficiencies
  - Pumps were not operating efficiently on factory curve
  - Pumps designed correctly for application

V. Case Study #2

- **2012-2014 pumping refurbishment projects**
  - Refurbish pumps
  - Replace motors with premium efficiency motors
  - Project ongoing from 2012-2014
- **Current wire-to-water efficiency**
  - #3: 85%
- **Pumps designed at 7000 gpm, 360 ft, 87% efficiency**
- **Pumps now running more efficiently and effectively**

V. Case Study #2

	Energy (MWh)	Flow (MG)	EUI
2011 (Jan – Dec)	12,512	12,973	0.96
2012 (Mar – Dec)	11,801	12,630	0.93

- **EUI Reduction: 3%**
- **KWh savings (2011 – 2012): 711,500**
- **Cost savings: $21,200**
- **Cost of pump: $150,000**
- **Payback: ~7 years**
  - Pump in service ¾ of year

VI. Case Study #3

- **Treatment Plant**
  - 50 MGD Plant Capacity
  - 35 MGD ADD

- **5 Potable Water Pumps (90%+ of location energy usage)**
  - Vintage pumps and motors (1960s)
  - Three, 10 MGD pumps
  - Two, 20 MGD pumps

- **10 MGD Pumps designed at 7000 gpm, 420 ft, 87% efficiency**

VI. Case Study #3

- **Original Wire-to-Water Efficiencies (10 MGD)**
  - #1: 70%
  - #2: 59%
  - #3: 77%

- **Findings**
  - Normal pump wear reduced efficiencies
  - Pumps were not operating efficiently on factory curve
  - Pumps designed correctly for application
  - Refurbishment of pumps would cost more than replacement

VI. Case Study #3

- **2012-2014 pumping replacement projects**
  - Replace pumps
  - Replace motors with premium efficiency motors
  - Project ongoing from 2012-2014

- **Current wire-to-water efficiency**
  - #3: 83%

- **Pumps designed at 7000 gpm, 420 ft, 85% efficiency**
- **Pumps now running more efficiently and effectively**

VI. Case Study #3

	Energy (MWh)	Flow (MG)	EUI
2011 (Jan – Dec)	27,771	12,973	2.14
2012 (Mar – Dec)	26,610	12,630	2.11

- **EUI Reduction: 2%**
- **KWh savings (2011 – 2012): 1,161,500**
- **Cost savings: $80,000**
- **Cost of pump: $200,000**
- **Payback: ~2.5 years**
  - Pump in service ¾ of year.

VII. Conclusions

- **Primary factors that can impact pump efficiency**
  - Incorrect design
  - Changes in hydraulic conditions
  - Normal wear
  - Cavitation
  - Chemical contact
  - Mechanical issues – Seals, bearings, degradation of impeller, vibration
  - Inefficient VSD - Eddy current drives, magnetic drives, hydraulic clutch drives, fluid drives
  - Hydraulic – Tuberculation / Corrosion
  - Motor efficiency

VIII. Recommendations

- **Identify your largest energy users**
- **Determine your efficiencies/costs**
- **Recognize that each system is different**
  - Confirm pump is designed with BEP at ADF
  - Make sure the VSD operates effectively
  - Know hydraulic conditions will vary EUI
    - Higher TDH requires more energy to move water
- **Work towards goal systematically**
- **Consider pump coatings - can increase a pumps efficiency and time between repair**
- **Monitor pump efficiency continuously**
  - Real-time wire-to-water
  - SCADA integration

Questions