Water Distribution System Energy Efficiency Optimization

May 10, 2013

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RH2 Engineering

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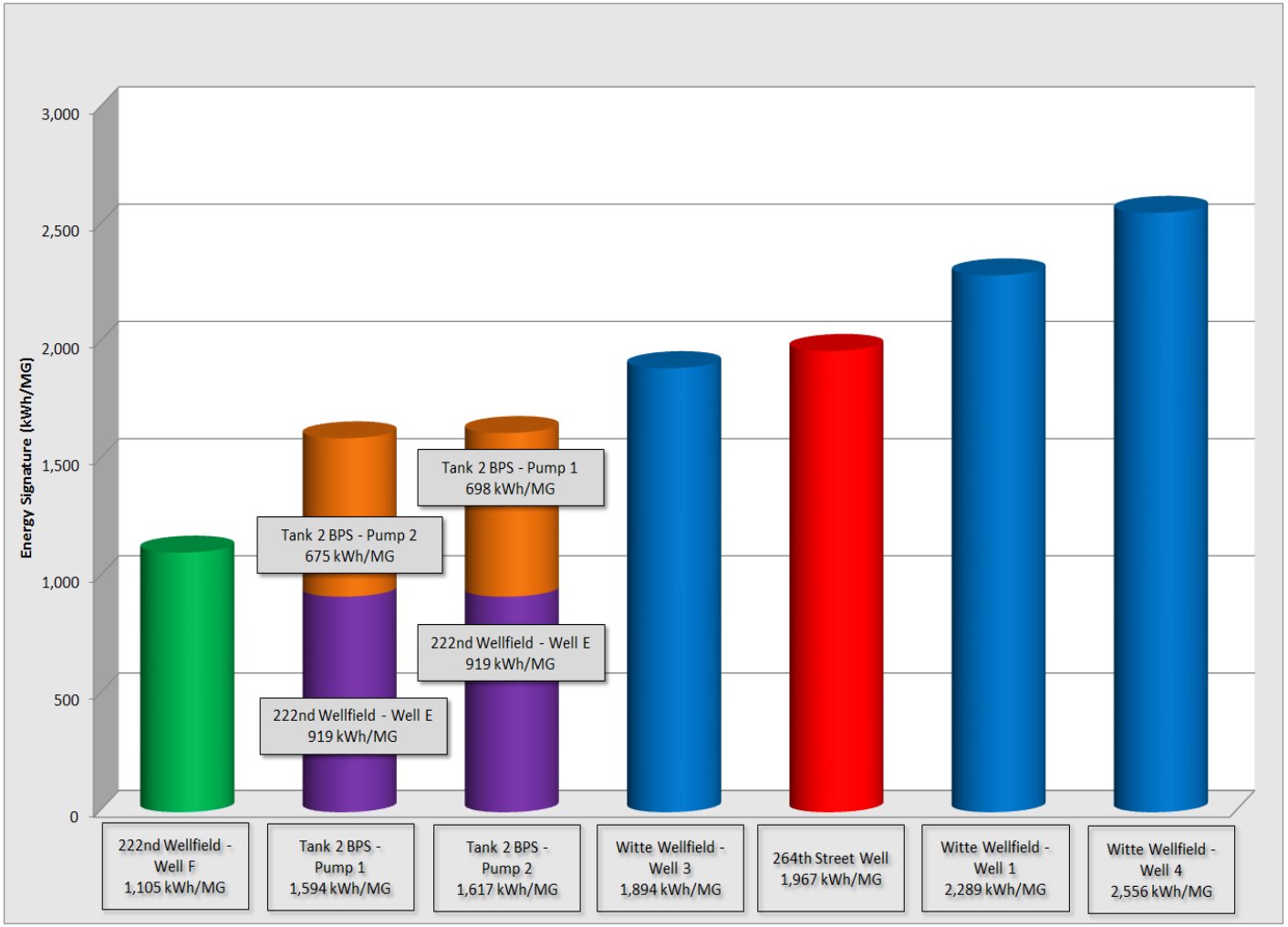
What is Energy Signature?

- Metric for measuring pump energy consumption
- Measured in kWh/MG
- Function of:
  - System demand
  - Discharge HGL
  - Suction HGL
  - Mechanical and electrical equipment efficiency
- No direct correlation to pump/motor efficiency

Energy Signature

$$\text{ES (kWh/MG)} = \frac{\text{Measured Power (kW)} \times 1{,}000{,}000}{\text{Measured Flow (gpm)} \times 60}$$

What is Energy Signature?



How is Energy Signature Evaluated?

TAP Booster Pump Station

- Two 50 hp pumps
- Two 125 hp pumps w/VFDs
- 125 hp pumps alternate as lead
- One 125 hp pump is underperforming

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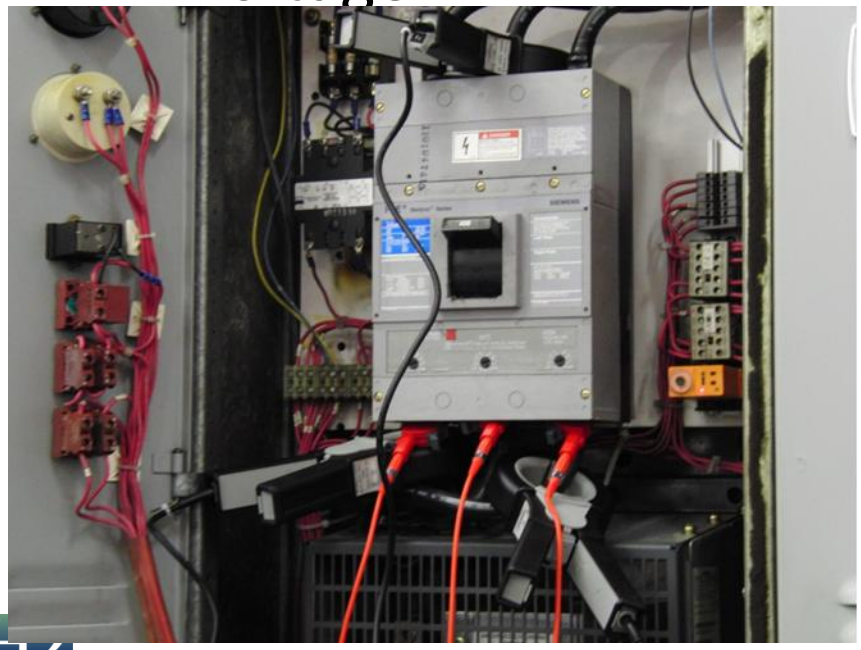
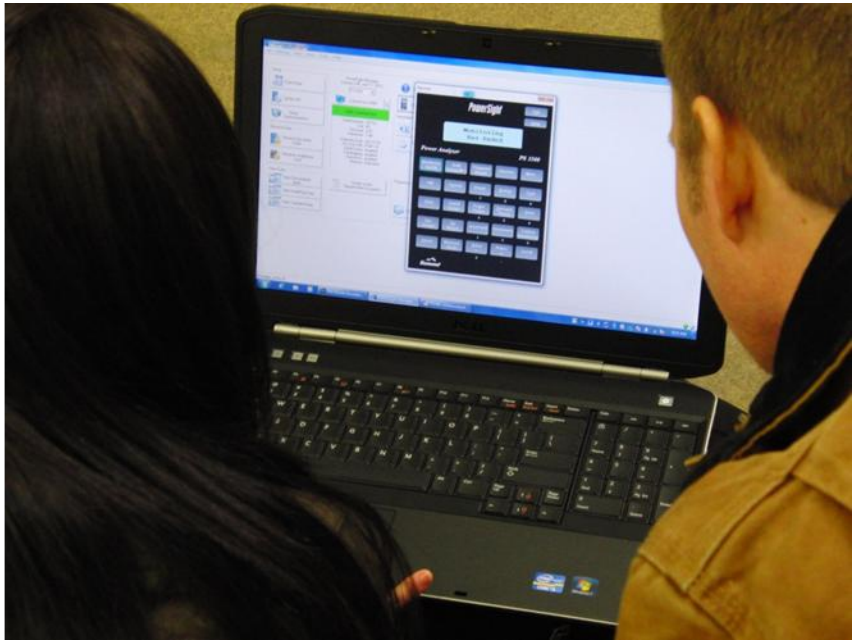
Data Collection

- Mechanical Data
  - Suction pressure (booster pumps)
  - Groundwater level (wells)
  - Discharge pressure
  - Flow rate

Data Collection

- Electrical Data
  - Power usage
  - Voltage
    - Current
    - Power Factor



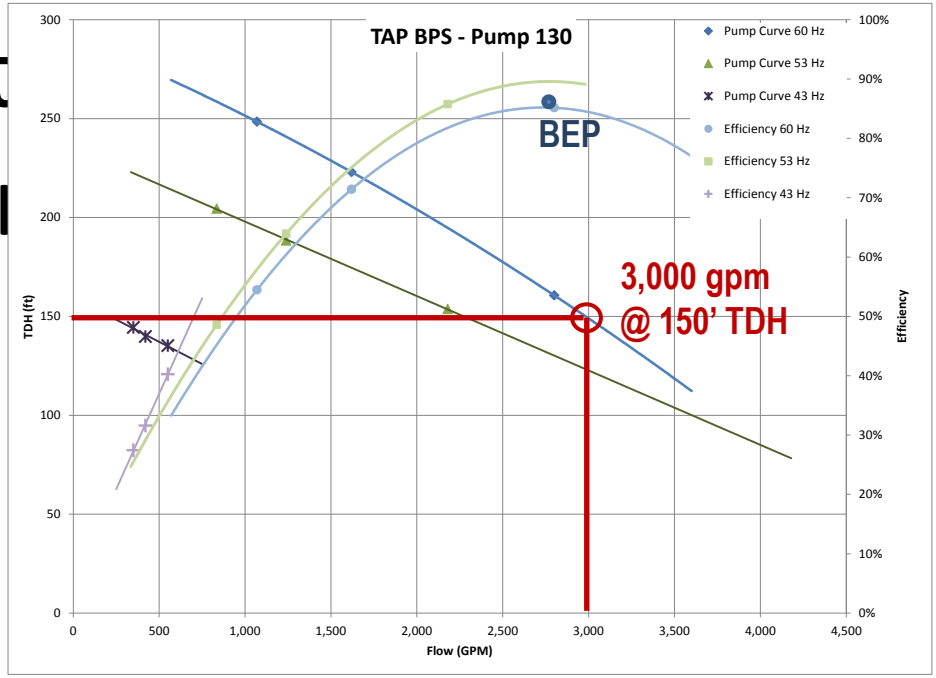


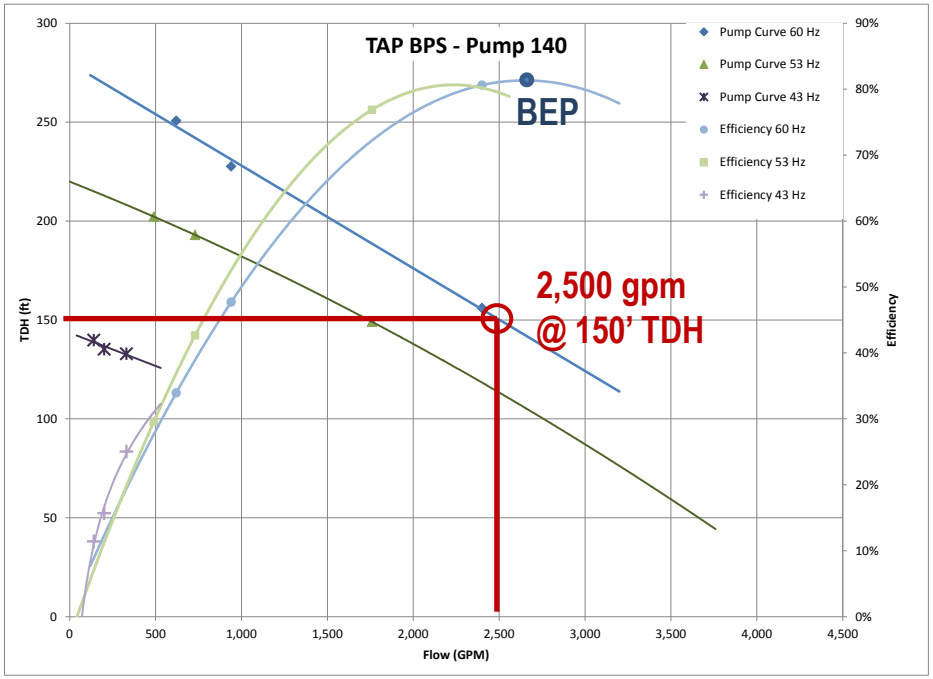
Data Collection Inaccuracies

Poor pressure gage location

Inadequate
length of straight pipe
downstream of meter

Dat
Pu





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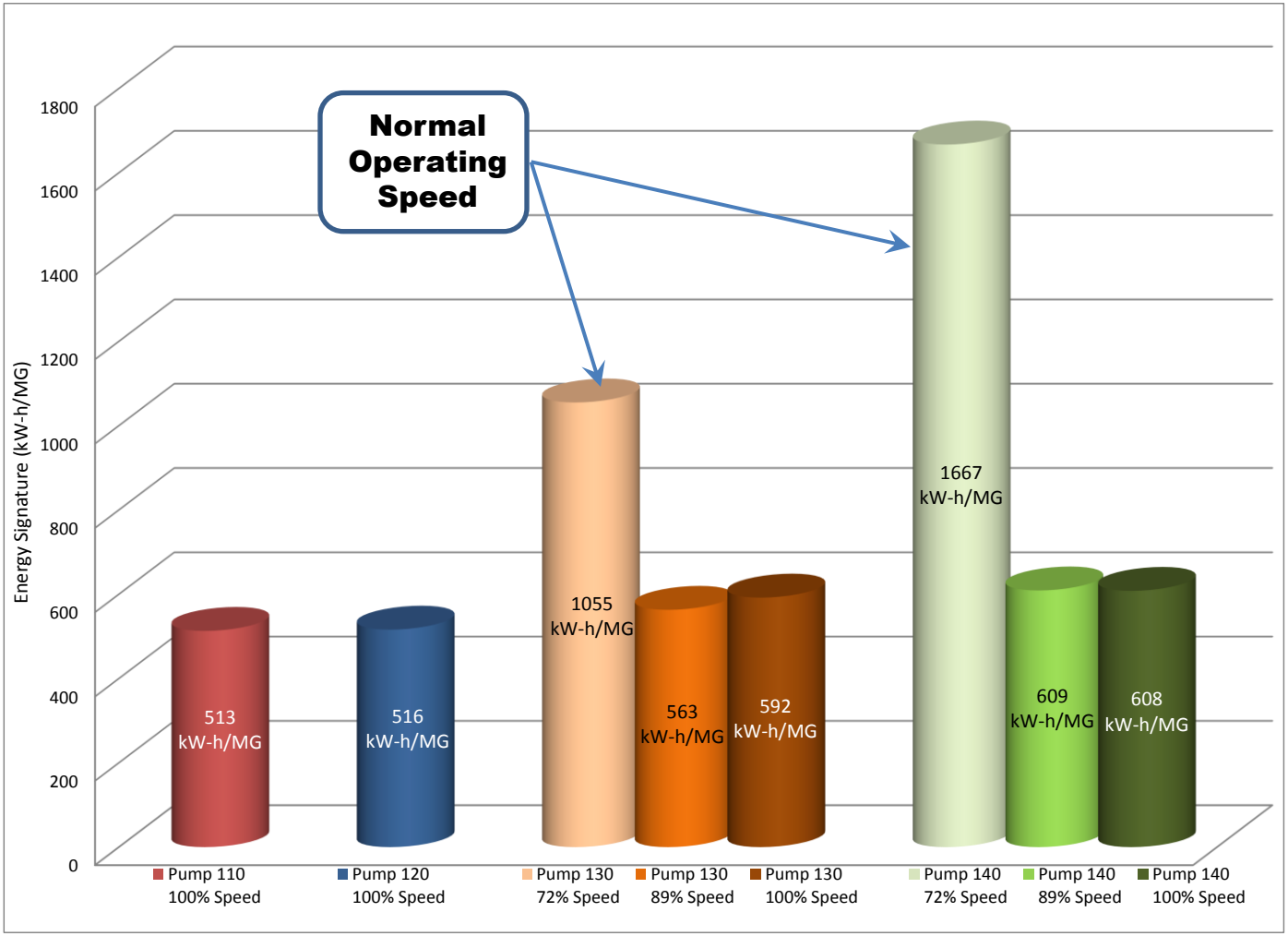
Data Analysis: Energy Signature



Data Analysis: Energy Signature

NEW CHARGES - 08/12	UNITS	COST PER UNIT	CHARGE
Basic Charge - 3P Sec Delivery	105 kw		67.00
Load Size Charge - 3p Sec Del	105 kw	0.4500000	47.25
Demand Charge Sec - Min 15 Kw	78 kw	4.3900000	342.42
Delivery Charge Secondary	38,880 kwh	0.0058500	227.45
Supply Enrgy Sec 1St 20000 Kwh	20,000 kwh	0.0587100	1,174.20
Supply Enrgy Sec > 20000 Kwh	18,880 kwh	0.0571200	1,078.43
Public Purpose		0.0300000	88.10
Energy Conservation Charge	38,880 kwh	0.0020500	79.70
Low Income Assistance	38,880 kwh	0.0005000	19.44

Description	Annual Baseline	Annual Proposed	Annual Savings	Percent Savings
Energy and Demand Costs ($)	$27,754	$20,584	$7,170	26%
Energy Consumption (kWh)	333,257	252,044	81,213	24%
Peak Power Demand (kW)	105	73	32	30%

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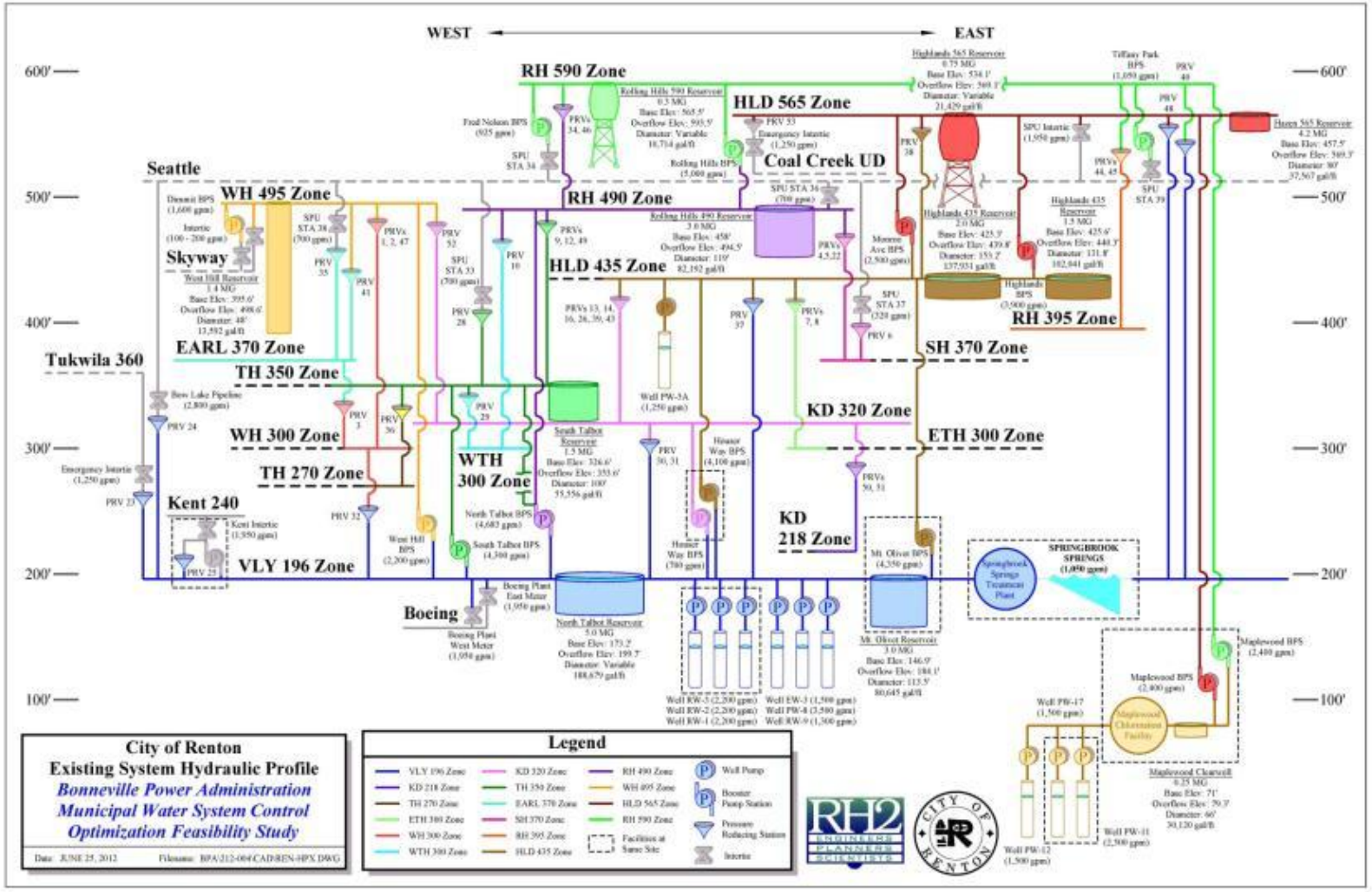
System-Wide
Energy Signature Analysis



Bonneville Power Administration Study

- Grant funding provided by Bonneville Power Administration
- Studied 4 water systems of various size
- Visited 87 sites
- Collected data and evaluated 170 different pumps

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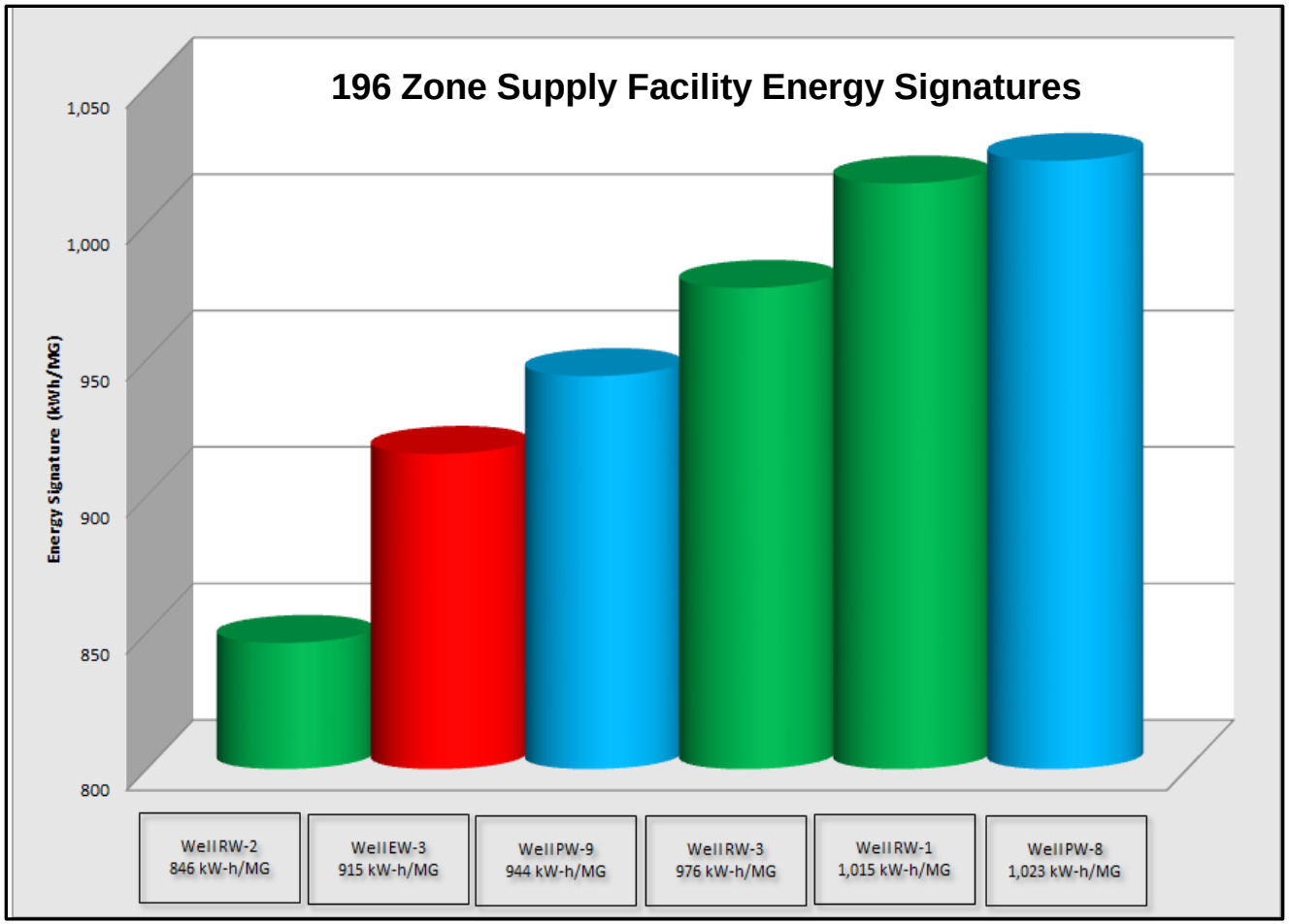
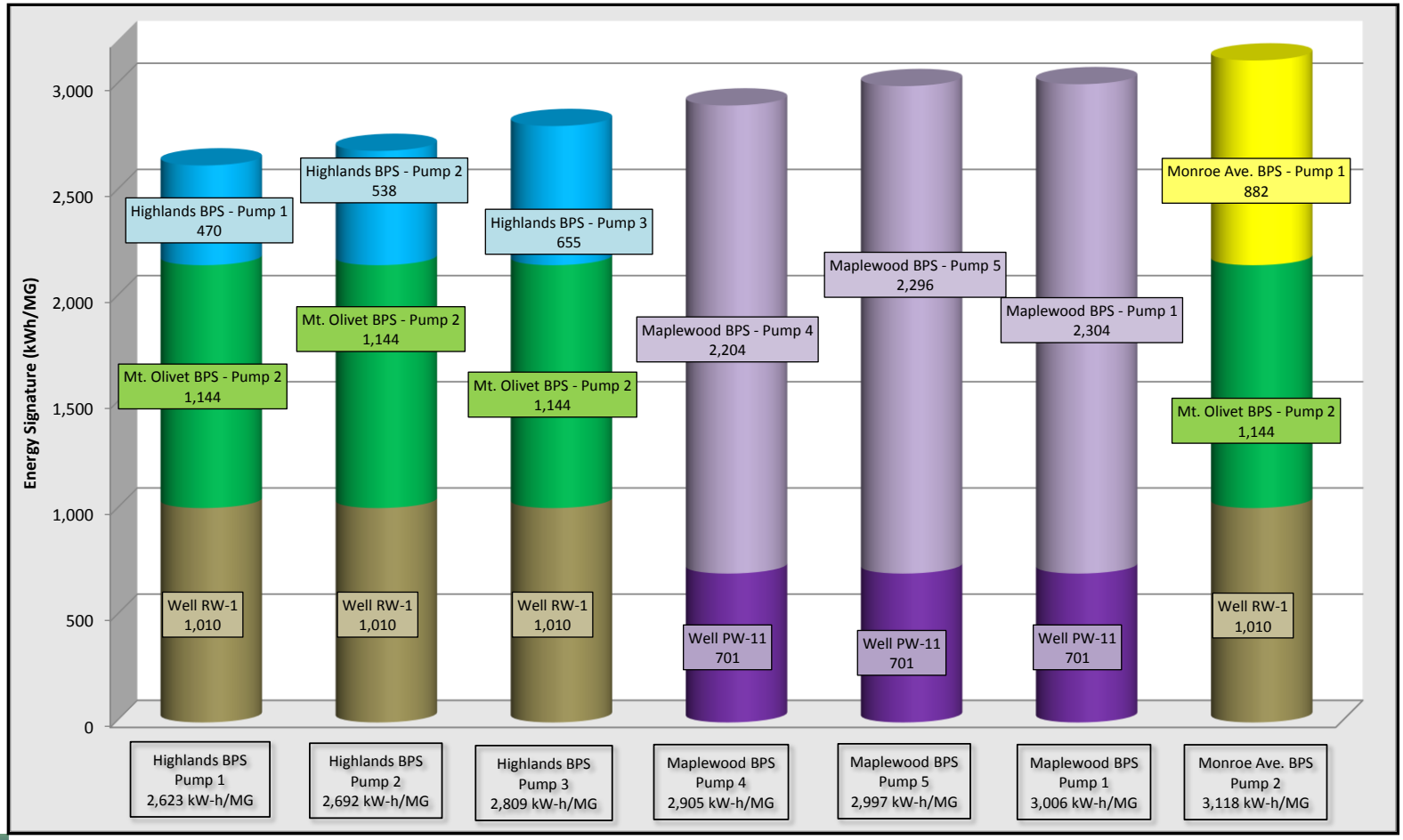
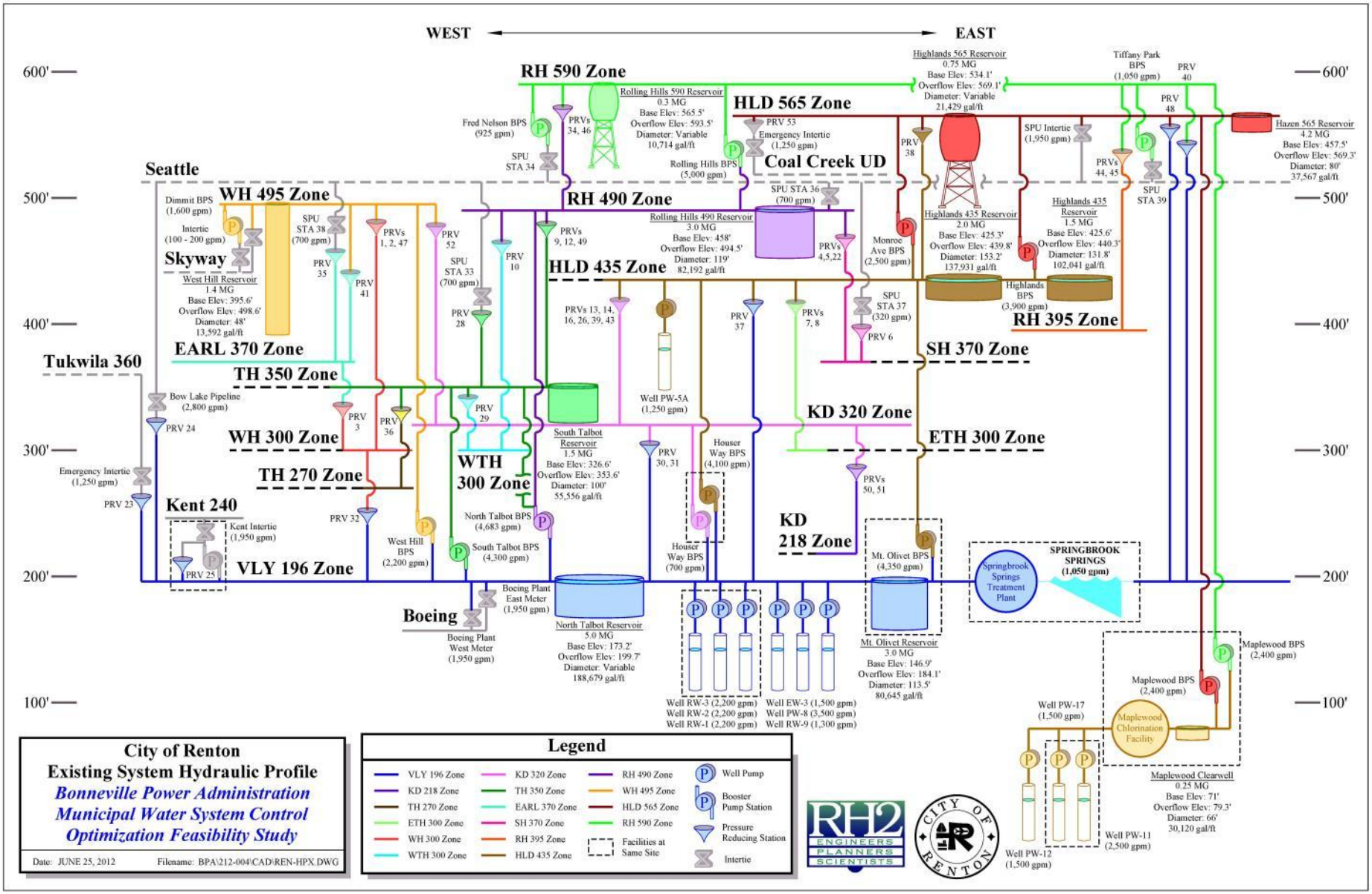
Optimizing Pump Sequencing for Pressure Zones



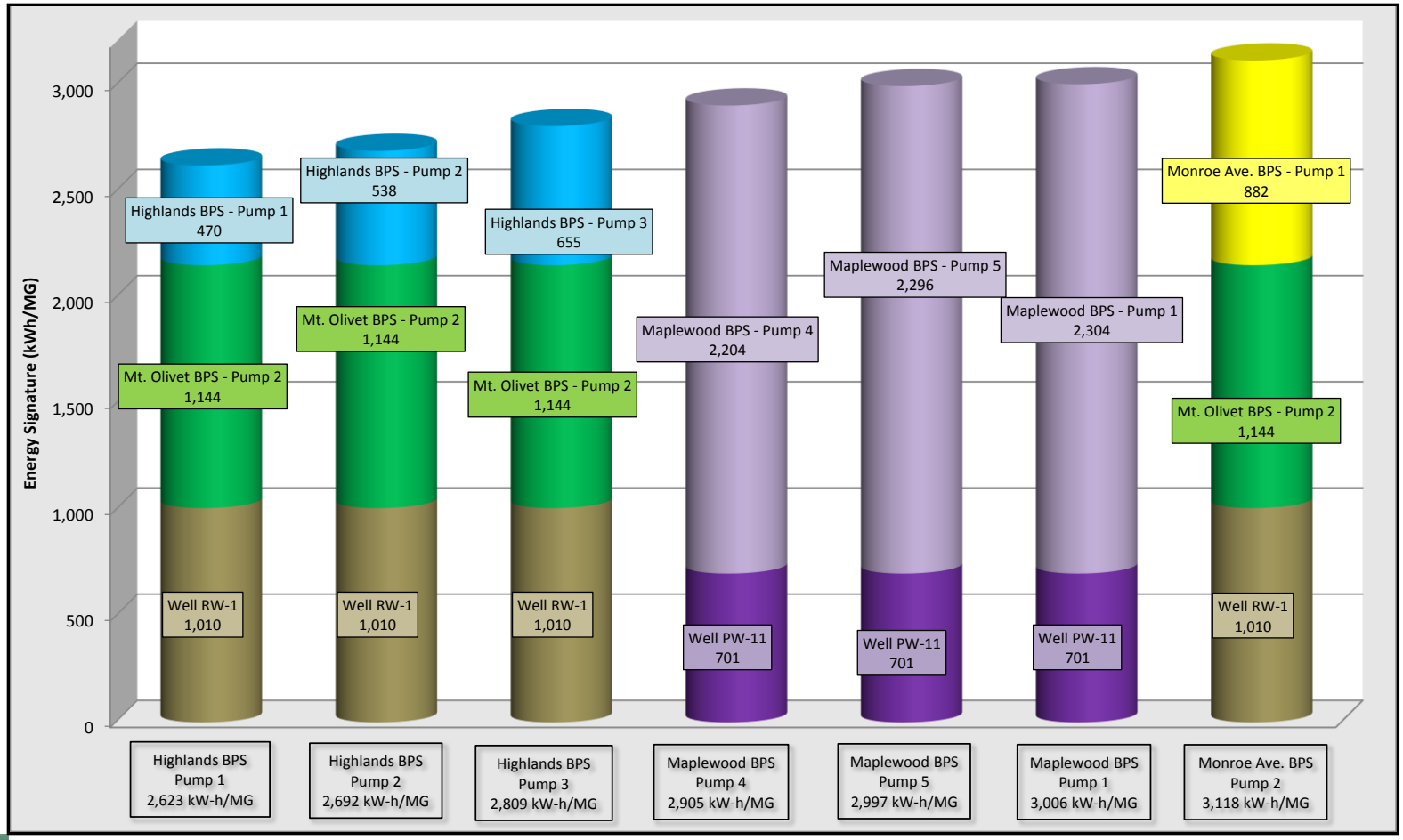
Compounding Pressure Zones



Compounding Pressure Zones



Compounding Pressure Zones



Annual System-Wide Energy Savings with Optimum Pump Sequencing

Description	Baseline System-Annual	Proposed System-Annual	Total Annual Savings	Percent Savings
Energy and Demand Costs ($)	$337,253	$299,591	$37,662	11%
Energy Consumption (kWh)	4,822,452	4,383,681	438,771	9%
Peak Power Demand (kW)	1,745	1,436	309	18%

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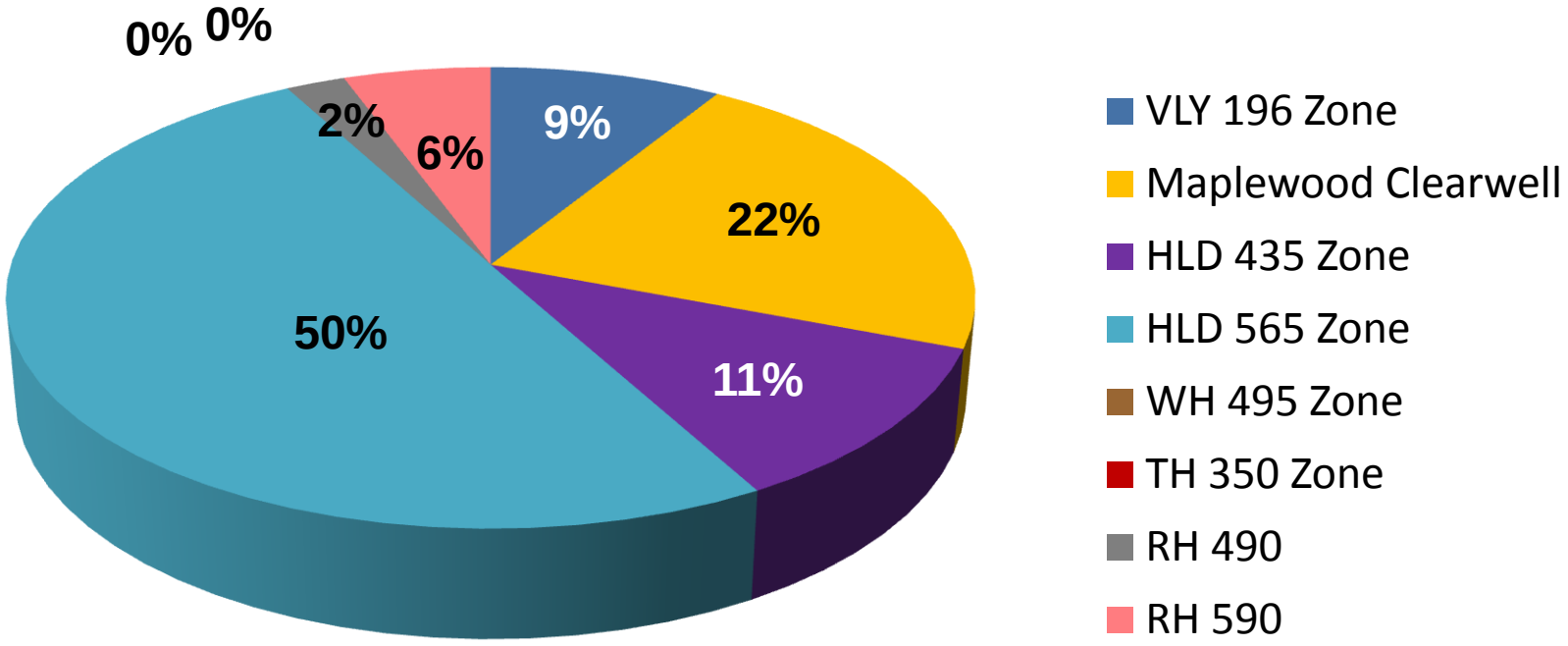
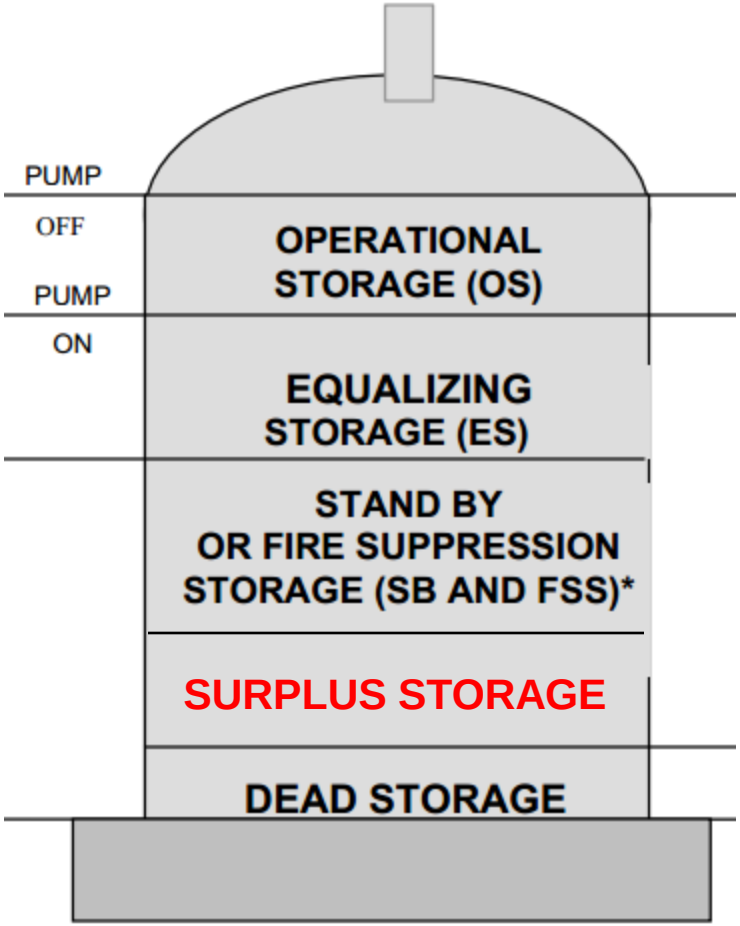
Annual Cost Savings by Zone



Pressure Optimization



Annual System-Wide Energy Savings with Pressure Optimization

Description	Baseline System-Annual	Proposed System-Annual	Total Annual Savings	Percent Savings
Energy and Demand Costs ($)	$61,225	$56,492	$4,733	8%
Energy Consumption (kWh)	526,494	485,903	40,491	8%
Peak Power Demand (kW)	3,100	2,773	327	11%

Summary of Potential Savings Found in BPA Study

Water System	Approximate Population Served	Projected Annual Energy Cost Savings ($)	Projected Annual Energy Cost Savings (%)
1	62,000	$ 40,333	11.8 %
2	49,000	$ 57,400	18.9 %
3	38,000	$ 19,250	31.4 %
4	14,000	$ 7,287	13.1 %

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Implementation

3 options

1. Manual sequencing
2. SCADA and PLCs use to calculate energy signatures and optimum sequences
3. SCADA and PLCs monitor actual real-time energy signatures and changing prioritization

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Implementation

1. Manual Sequencing

- No cost
- Operators can change lead/lag pumps in existing SCADA system
- Energy signatures not monitored
- Not optimal

Implementation

2. Using Calculated Energy Signatures

- Moderate cost
- Energy signatures estimated by the PLC
  - If flow, suction, and discharge pressures are monitored by the SCADA system
  - Estimate based on field data
  - Update the HMI at each PLC

Implementation

3. Actual Real-Time Energy Signatures

- Highest first cost
- Data from all 3 power phases to monitor power data digitally
- Communication to the PLC via a serial connection
- Energy signatures vary based on system conditions- prioritization changes as a result
- Monitor pump or motor over time to see if it is in need of maintenance or overhaul prior to failure
- Eligible for incentive/grants

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Other Uses for Energy Signature Analysis

- Track pump performance over time
- Identify problems before failure/gets expensive
- Prioritize pump maintenance/overhaul

Questions?

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Energy Signature vs. Wire to Water Efficiency

City of Renton
2011 System Control Optimization
Field Data Collection

1,000 gpm rated flow

1,500 gpm rated flow

		Test Information/Pump Data												Hydraulic Data						
																Pumps				
Site - Pump #	Pump Test No.	Date (mm/dd/yy)	Time	Well or BPS?	Suction Zone HGL (ft)	Discharge Zone HGL (ft)	Pump MFG	Pump Model No.	Motor MFG	Motor Model No.	Rated Pump Flow (gpm)	Rated Pump TDH (ft)	Rated Motor Size (hp)	Static (ft)	Pumping Depth to Groundwater Level (ft)	Suction Pressure (psi)	Suction Pressure Gauge Height Above Floor (ft)	Discharge Pressure (City Gauge) (psi)	Discharge Pressure (Other) (psi)	Discharge Pressure Gauge Height Above Floor (ft)	Flow Meter Reading (gpm)
Highlands BPS - Pump 1	1	02/29/12	7:40 AM	BPS	435	565	BJ	14GM2ST			1,500	124	60					49		2.0	1,560
Highlands BPS - Pump 1	2	02/29/12	7:49 AM	BPS	435	565	BJ	14GM2ST			1,500	124	60					51		2.0	1,470
Highlands BPS - Pump 1	3	02/29/12	7:53 AM	BPS	435	565	BJ	14GM2ST			1,500	124									
Highlands BPS - Pump 2	1	02/29/12	7:20 AM	BPS	435	565	BJ	10GH-3ST			600	124									
Highlands BPS - Pump 2	2	02/29/12	7:26 AM	BPS	435	565	BJ	10GH-3ST			600	124									
Highlands BPS - Pump 2	3	02/29/12	7:29 AM	BPS	435	565	BJ	10GH-3ST			600	124	50								
Highlands BPS - Pump 3	1	02/29/12	6:51 AM	BPS	435	565	BJ	10GH-3STG													
Highlands BPS - Pump 3	2	02/29/12	7:08 AM	BPS	435	565	BJ	10GH-3STG										70		2.0	1,260
Highlands BPS - Pump 3	3	02/29/12	7:12 AM	BPS	435	565	BJ	10GH-3STG										75		2.0	1,000
Monroe BPS - Pump 1	1	02/29/12	8:59 AM	BPS	435	565	Westinghouse			12CM-3STG	1,000	154	50			75	2.0	93	100	2.0	850
Monroe BPS - Pump 1	2	02/29/12	9:05 AM	BPS	435	565	Westinghouse			12CM-3STG	1,000	154	50			75	2.0	91	100	2.0	750
Monroe BPS - Pump 1	3	02/29/12	9:16 AM	BPS	435	565	Westinghouse			12CM-3STG	1,000	154	50			75	2.0	91	100	2.0	670
Monroe BPS - Pump 2	1	02/29/12	8:30 AM	BPS			Westinghouse				1,500	154	75			44	2.0	94		2.0	1,100
Monroe BPS - Pump 2	2	02/29/12	8:34 AM	BPS			Westinghouse				1,500	154	75			44	2.0	103		2.0	875
Monroe BPS - Pump 2	3	02/29/12	8:37 AM	BPS			Westinghouse				1,500	154	75			46	2.0	108		2.0	680
Houser Way BPS - Pump 1	1	02/29/12	11:16 AM	BPS	196	320	Fairbanks Morse	12L			700	150	40			70	3.0	141		3.0	400
Houser Way BPS - Pump 1	2	02/29/12	11:21 AM	BPS	196	320	Fairbanks Morse	12L			700	150	40			70	3.0	141		3.0	330
Houser Way BPS - Pump 1	3	02/29/12	11:25 AM	BPS	196	320	Fairbanks Morse	12L			700	150	40			70	3.0	141		3.0	195
Houser Way BPS - Pump 2	1	02/29/12	11:37 AM	BPS	196	435	Fairbanks Morse	13H			2,050	282	200			65	3.0	190		3.0	2,000
Houser Way BPS - Pump 2	2	02/29/12	11:44 AM	BPS	196	435	Fairbanks Morse	13H			2,050	282	200			65	3.0	184		3.0	1,320
Houser Way BPS - Pump 2	3	02/29/12	11:42 AM	BPS	196	435	Fairbanks Morse	13H			2,050	282	200			65	3.0	182		3.0	960
Houser Way BPS - Pump 3	1	02/29/12	11:55 AM	BPS	196	435	Fairbanks Morse	13H			2,050	282	200			65	3.0	190		3.0	1,980
Houser Way BPS - Pump 3	2	02/29/12	11:58 AM	BPS	196	435	Fairbanks Morse	13H			2,050	282	200			65	3.0	187		3.0	1,640
Houser Way BPS - Pump 3	3	02/29/12	12:01 PM	BPS	196	435	Fairbanks Morse	13H			2,050	282	200			65	3.0	184		3.0	1,250
Well PW-9	1	03/02/12	12:14 PM	Well			BJ	12MQH-3STG			1,250	223	100	34.9	3.2			68	71	3.0	1,210
Well PW-9	2	03/02/12	12:30 PM	Well			BJ	12MQH-3STG			1,250	223	100	34.9	6.7			76	79	3.0	1,090
Well PW-9	3	03/02/12	12:26 PM	Well			BJ	12MQH-3STG			1,250	223	100	34.9	8.2			79	82	3.0	1,020
Well PW-12	1	03/06/12	9:54 AM	Well			J-Line Pump Co	512HC-7STG			1,500	364	175		241.0			18		4.0	1,735
Well PW-12	2	03/06/12	9:54 AM	Well			J-Line Pump Co	512HC-7STG			1,500	364	175		241.0			31		4.0	1,630
Well PW-12	3	03/06/12	9:55 AM	Well			J-Line Pump Co	512HC-7STG			1,500	364	175		241.0			38		4.0	1,580
South Talbot BPS - Pump 1	1	03/02/12	6:59 AM	BPS			BJ	8GL10STG		5K254QNM3005			15			64	2.0	134		2.0	200
South Talbot BPS - Pump 1	2	03/02/12	7:02 AM	BPS			BJ	8GL10STG		5K254QNM3005			15			64	2.0	141		2.0	195
South Talbot BPS - Pump 1	3	03/02/12	7:04 AM	BPS			BJ	8GL10STG		5K254QNM3005			15			64	2.0	151		2.0	160
South Talbot BPS - Pump 2	1	03/02/12	6:40 AM	BPS			BJ	12GL5STG		6229-U06U094R041M			40			64	2.0	136		2.0	570
South Talbot BPS - Pump 2	2	03/02/12	6:46 AM	BPS			BJ	12GL5STG		6229-U06U094R041M			40			64	2.0	139		2.0	475
South Talbot BPS - Pump 2	3	03/02/12	6:49 AM	BPS			BJ	12GL5STG		6229-U06U094R041M			40			64	2.0	142		2.0	440
Fred Nelson BPS - Pump 1	1	03/02/12	7:29 AM	BPS			Cornell	10AC-5STG		5K6236X41			10			61	1.3	114		1.3	250
Fred Nelson BPS - Pump 1	2	03/02/12	7:32 AM	BPS			Cornell	10AC-5STG		5K6236X41			10			61	1.3	119		1.3	202
Fred Nelson BPS - Pump 1	3	03/02/12	7:35 AM	BPS			Cornell	10AC-5STG		5K6236X41			10			61	1.3	123		1.3	154
Fred Nelson BPS - Pump 2	1	03/02/12	7:39 AM	BPS			Cornell	12BC-2STG		5K6246XCZUA			25			61	1.3	116		1.3	525
Fred Nelson BPS - Pump 2	2	03/02/12	7:41 AM	BPS			Cornell	12BC-2STG		5K6246XCZUA			25			61	1.3	123		1.3	275
Fred Nelson BPS - Pump 2	3	03/02/12	7:43 AM	BPS			Cornell	12BC-2STG		5K6246XCZUA			25			61	1.3	119		1.3	430
Rolling Hills BPS - Pump 1	1	03/02/12	8:26 AM	BPS			Flowserve				2,500	115	100			17	-5.0	64	64	3.0	2,475
Rolling Hills BPS - Pump 1	2	03/02/12	8:31 AM	BPS			Flowserve				2,500	115	100			16	-5.0	67	67	3.0	2,130
Rolling Hills BPS - Pump 1	3	03/02/12	8:34 AM	BPS			Flowserve				2,500	115	100			16	-5.0	72	72	3.0	1,740
Rolling Hills BPS - Pump 2	1	03/02/12	8:45 AM	BPS			Flowserve				2,500	115	100			16	-5.0	65		3.0	2,390
Rolling Hills BPS - Pump 2	2	03/02/12	8:50 AM	BPS			Flowserve				2,500	115	100			16	-5.0	68		3.0	2,160
Rolling Hills BPS - Pump 2	3	03/02/12	8:53 AM	BPS			Flowserve				2,500	115	100			16	-5.0	71		3.0	1,840
Rolling Hills BPS - Pump 3	1	03/02/12	10:38 AM	BPS			Flowserve				1,000	110	40			16	-5.0	61	61	3.0	900
Rolling Hills BPS - Pump 3	2	03/02/12	10:49 AM	BPS			Flowserve				1,000	110	40			16	-5.0	65		3.0	730
Rolling Hills BPS - Pump 3	3	03/02/12	10:46 AM	BPS			Flowserve				1,000	110	40			16	-5.0	70		3.0	585
Rolling Hills BPS - Pump 4	1	03/02/12	10:57 AM	BPS			Flowserve				1,000	110	40			16	-5.0	63	64	3.0	920
Rolling Hills BPS - Pump 4	2	03/02/12	11:01 AM	BPS			Flowserve				1,000	110	40			16	-5.0	73	74	3.0	700
Rolling Hills BPS - Pump 4	3	03/02/12	11:03 AM	BPS			Flowserve				1,000	110	40			16	-5.0	80	81	3.0	500

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Energy Signature vs. Wire to Water Efficiency

760 gpm average measured flow

885 gpm measured flow

14 percent average.

40 percent average.

51 percent average

59 percent average

1,910 average KWH/MG

1,567 average KWH/MG
~20 percent savings

City of Renton
2011 System Control Optimization
Field Data Collection

Site - Pump #	Test No.	Leg A (amps)	Leg B (amps)	Leg C (amps)	Power Leg A (kW)	Power Leg B (kW)	Power Leg C (kW)	Total Power (kW)	Factor	VFD Only	Head Loss Between Pump and Gauges (ft)	Q (gpm)	TDH (ft)	Wire-to-Water Efficiency	Horsepower (hp)	Theoretical Head (ft) Zone	Average I (amps)	Measured % of
Highlands BPS - Pump 1	1	72	66	72	80	11	11	33	0.36		0.0	1,560	115	103%	44			
Highlands BPS - Pump 1	2	72	66	71	317	478	15	11	41	0.39	0.70		0.0	1,470	120	81%	55	130	321	
Highlands BPS - Pump 1	3	71	64	70	325	489	167	11	39	0.31	0.79		0.0	1,280	129	80%	52	130	327	
Highlands BPS - Pump 2	1	74	65	72	481	210	316	19	50	0.82	0.90	0.16	0.0	1,550	131	77%	67	130	70	336
Highlands BPS - Pump 2	2	73	65	70	480	208	315	19	12	50	0.82	0.91	0.32	0.0	1,390	127	66%	64	130	69	334
Highlands BPS - Pump 2	3	71	63	70	482	208	315	18	12	18	0.81	0.91	0.29	0.0	1,275	138	69%	71	130	68	33
Highlands BPS - Pump 3	1	72	65	70	484	487	487	20	18	20	0.89	0.92	0.0	1,485	136	66%	78	130	69	
Highlands BPS - Pump 3	2	70	63	67	481	483	486	21	18	17	56	0.91	0.0	1,260	164	69%	75	130	66	
Highlands BPS - Pump 3	3	73	66	71	481	483	485	19	17	16	51	0.90	0.90	0.0	1,000	175	65%	68	130	70
Monroe BPS - Pump 1	1	53	52	54	486	487	487	14	14	14	45	0.20	0.75	4.6	850	46	16%	60	130	487
Monroe BPS - Pump 1	2	53	53	54	485	485	486	15	15	15	45	0.21	0.74	0.99	3.6	750	41	13%	54	130	485
Monroe BPS - Pump 1	3	52	51	52	487	486	490	15	14	15	44	0.22	0.73	0.96	2.7	670	40	11%	53	130	488
Monroe BPS - Pump 2	1	74	74	74	485	485	485	21	21	22	64	0.76	0.76	0.76	7	1,100	123	40%	86	0	74
Monroe BPS - Pump 2	2	71	73	75	484	485	485	20	20	20	60	0.78	0.78	0.78	4.6	875	141	39%	80	73
Monroe BPS - Pump 2	3	71	72	72	486	488	489	15	15	15	46	0.74	0.75	0.74	2.7	680	146	41%	62	72
Houser Way BPS - Pump 1	1	31	31	29	483	481	481	7	7	7	23	0.86	0.84	0.84	0.0	400	164	54%	31	124
Houser Way BPS - Pump 1	2	28	29	27	486	483	484	7	7	7	19	0.84	0.82	0.81	0.0	330	164	54%	25	124	484
Houser Way BPS - Pump 1	3	24	25	24	485	483	483	6	6	6	16	0.82	0.79	0.78	0.0	195	164	38%	14	124	484
Houser Way BPS - Pump 2	1	216	216	211	487	486	486	53	52	51	156	0.87	0.86	0.87	10.7	2,000	299	72%	209	239	214
Houser Way BPS - Pump 2	2	199	200	196	487	485	486	48	48	47	143	0.87	0.86	0.86	4.5	1,320	279	49%	192	239	196
Houser Way BPS - Pump 2	3	180	182	177	487	486	485	51	51	49	151	0.86	0.85	0.85	2.4	960	273	33%	202	239	180
Houser Way BPS - Pump 3	1	214	213	209	484	484	483	53	52	51	155	0.87	0.86	0.87	9.5	1,980	298	72%	208	239	212
Houser Way BPS - Pump 3	2	211	210	206	484	484	482	52	51	50	153	0.87	0.86	0.87	6.4	1,640	288	58%	205	239	209
Houser Way BPS - Pump 3	3	194	194	189	487	487	486	47	46	45	138	0.86	0.85	0.86	3.9	1,250	279	48%	185	239	192
Well PW-9	1	93	93	96	480	481	480	23	23	23	69	0.89	0.89	0.89	0.3	1,210	164	54%	92	3	94
Well PW-9	2	91	91	93	480	482	480	22	22	23	67	0.89	0.88	0.89	0.2	1,090	185	57%	90	7	92
Well PW-9	3	89	89	91	481	482	481	22	22	22	66	0.89	0.88	0.89	0.2	1,020	194	56%	88	8	90
Well PW-12	1	228	223	233	470	470	474	56	45	53	154	0.82	0.78	0.88	0.0	1,735	286	61%	207	241	228
Well PW-12	2	228	223	232	472	471	475	56	46	53	154	0.81	0.78	0.88	0.0	1,630	317	63%	207	241	228
Well PW-12	3	228	222	232	471	470	474	56	45	52	154	0.81	0.78	0.88	0.0	1,580	333	65%	206	241	227
South Talbot BPS - Pump 1	1	16	16	16	485	485	484	3	3	3	10	0.76	0.76	0.75	0.0	200	162	61%	13	0	
South Talbot BPS - Pump 1	2	16	16	16	484	484	483	3	3	3	10	0.76	0.76	0.75	0.0	195	177	65%	13	0	484
South Talbot BPS - Pump 1	3	15	16	16	484	484	482	3	3	3	10	0.77	0.77	0.75	0.0	160	201	61%	13	0	483
South Talbot BPS - Pump 2	1	42	44	43	258	487	229	10	5	10	25	0.34	0.45	0.99	0.1	570	166	72%	33		
South Talbot BPS - Pump 2	2	42	43	43	257	486	229	10	5	10	25	0.34	0.45	0.99	0.1	475	173	63%	33		42
South Talbot BPS - Pump 2	3	41	43	42	258	486	229	10	5	10	25	0.34	0.44	0.99	0.1	440	180	61%	33		42
Fred Nelson BPS - Pump 1	1	14	14	14	477	478	478	3	3	3	8	0.66	0.66	0.66	0.0	250	122	75%			14
Fred Nelson BPS - Pump 1	2	14	14	13	478	477	478	3	3	3	7	0.64	0.64	0.64	0.0	202	134	72%		0	13
Fred Nelson BPS - Pump 1	3	13	13	13	478	477	478	2	2	2	6	0.60	0.59	0.60	0.0	154	143			0	
Fred Nelson BPS - Pump 2	1	27	27	27	474	475	474	6	6	6	18	0.82	0.82		0.1						
Fred Nelson BPS - Pump 2	2	23	24	23	478	477	477	5	5	5	15	0.79	0.79								
Fred Nelson BPS - Pump 2	3	25	26	25	478	478	477	6	6	6	17	0.81	0.80								
Rolling Hills BPS - Pump 1	1	108	102	112	477	479	479	26	25	26	76	0.87	0.86								
Rolling Hills BPS - Pump 1	2	103	103	106	480	482	483	25	25	25	75	0.87	0.88								
Rolling Hills BPS - Pump 1	3	96	99	100	481	483	484	24	23	23	70	0.86	0.87								
Rolling Hills BPS - Pump 2	1	104	112	103	477	478	475	26	26	24	76	0.87	0.84	0.85	0.1	2,390	122	72%	102		106
Rolling Hills BPS - Pump 2	2	107	108	102	478	478	476	25	25	24	74	0.86	0.84	0.84							
Rolling Hills BPS - Pump 2	3	103	102	100	482	482	479	24	24	23	71	0.86	0.84	0.85							
Rolling Hills BPS - Pump 3	1	38	36	38	483	485	488	9	9	9	27	0.88	0.86	0.85							
Rolling Hills BPS - Pump 3	2	36	36	38	486	488	490	9	8	9	26	0.86	0.86	0.85							
Rolling Hills BPS - Pump 3	3	34	33	34	485	485	486	8	8	8	24	0.86	0.86	0.84							
Rolling Hills BPS - Pump 4	1	41	42	40	487	485	487	10	10	10	30	86.00	87.00	87.00							
Rolling Hills BPS - Pump 4	2	39	39	37	487	485	488	9	9	9	28	86.00	88.00	86.00							
Rolling Hills BPS - Pump 4	3	36	36	35	483	479	484	9	9	8	25	85.00	87.00	85.00							

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Single Pump	Energy Signature (kWh/MG)[1]	Two-Pump Combo	Energy Signature (kWh/MG)[1]
T2 - 1[1]	1,617	T2 - 1, T2 - 2	2,561
T2 - 2[1]	1,594	T2 - 1, WR 1	3,885
WR 1[2]	2,289	T2 - 1, WR 3	3,543
WR 3[2]	1,894	T2 - 1, WR 4	4,182
WR 4[2]	2,556	T2 - 1, 264	3,514
264	1,967	T2 - 1, 222 F	3,082
222 F[2]	1,105	T2 - 2, WR 1	3,857
		T2 - 2, WR 3	3,513
		T2 - 2, WR 4	4,164
		T2 - 2, 264	3,523
		T2 - 2, 222 F	3,064
		WR 1, WR 3	4,188
		WR 1, WR 4	4,816
		WR 1, 264	4,198
		WR 1, 222 F	3,715
		WR 3, WR 4	4,471
		WR 3, 264	3,834
		WR 3, 222 F	3,372
		WR 4, 264	4,465
		WR 4, 222 F	4,013
		264, 222 F	3,366

(1) The energy signatures of the Tank 2 BPS pumps include the energy signature of the 222nd Wellfield - Well E, which is required to indirectly supply the 770 Zone when the Tank 2 BPS is operating. The energy signature of the Tank 2 BPS Pump 1 is 698 kWh/MG and the energy signature of the Tank 2 BPS Pump 2 is 675 kWh/MG.

(2) The Witte Road Wellfield wells alternate as the lead supply pumps during the summer months, and the 222nd Wellfield - Well F is the lead supply pump in the winter months.

T2 Prefix = Tank 2 BPS
WR Prefix = Witte Road Wellfield
264 Prefix = 264th Street Well
222 Prefix = 222nd Place Wellfield

####	Existing pump sequence for each pump combination (see footnote 2)
####	Most efficient energy signature for each pump combination
####	Existing pump sequence and most efficient energy signature for each pump combination

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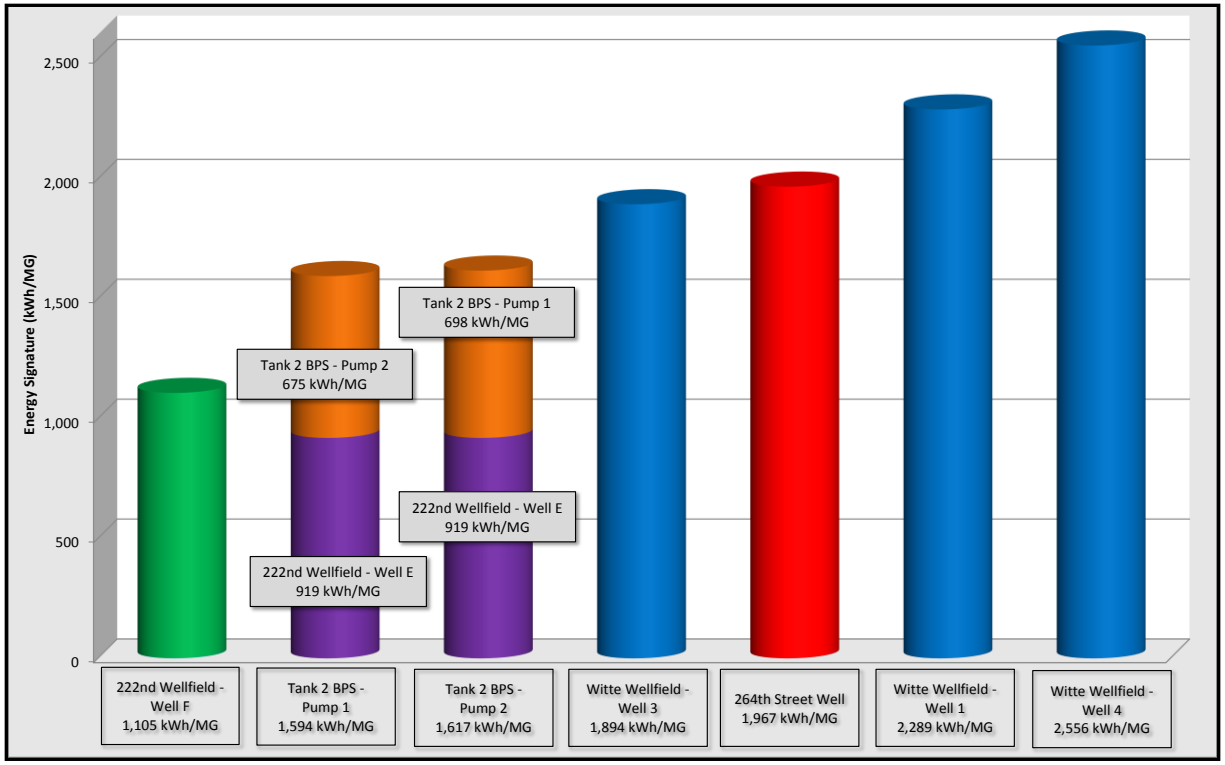
Optimizing Pump Sequencing for Pressure Zones



Description	Annual Baseline	Annual Proposed	Annual Savings	Percent Savings
Energy and Demand Costs ($)	$61,225	$46,708	$14,518	24%
Energy Consumption (kWh)	526,494	456,667	69,827	13%
Peak Power Demand (kW)	3,100	1,942	1,158	37%

Example Well Pump Vibration Data