Kennedy/Jenks Consultants

Engineers & Scientists

Pump Station Design: How Low Can You Go?

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Introduction

Distribution Requirements

Pressure Reducing Valves

Treatment

Pipe Fittings

Reservoir Levels

Conveyance

VFDs

End-Use

Electrical

Reservoir Elevations

Motors

Transformers

Lighting

HVAC

Operating Strategy

Building Support

Pump Control Valves

Hydraulic Energy Calculation

$$HP = \frac{(GPM) \times (Feet)}{3{,}956 \times Eff}$$

$$kW \cdot hr = 0.746 \times HP \times hr$$

HP = horsepower
GPM = gallons per minute
Eff = efficiency
kW = kilowatt
hr = hour

General Assumptions:

- Pump efficiency = 80%
- Pumps run 4,380 hours per year (half time)
- Cost of electricity $0.08 per kW-hr

Example:

- 3,000 gpm pump, 400 feet TDH
- HP = (3,000) (400) / 3956 /.80 = **380 HP**
- Energy = (380) (.746) (4,380)
  = 1,240,000 kW-hr / year
- 65,500 * $0.08 = **~$100,000**

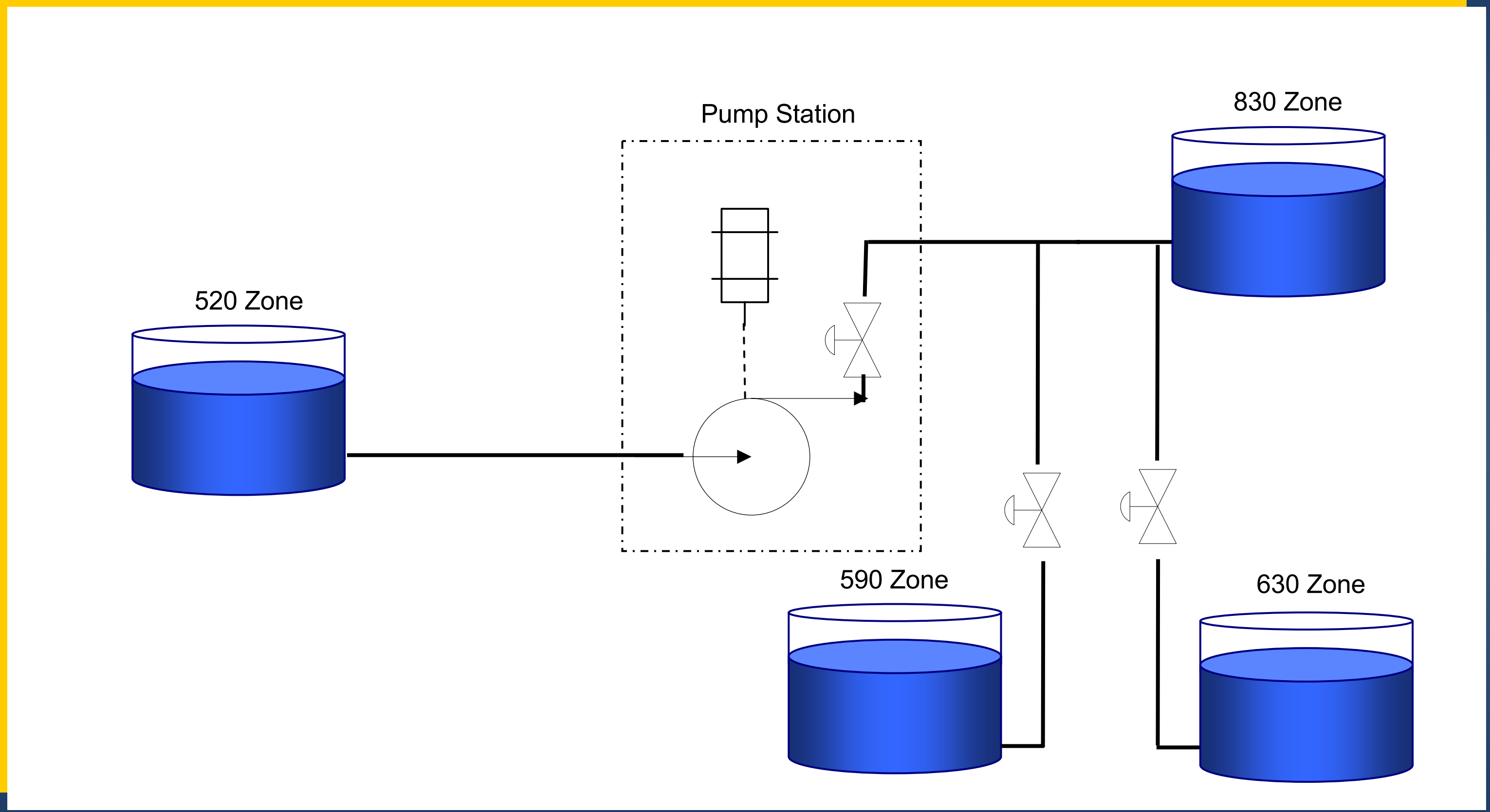
STATE WATER

Comparison of Two Pump Stations

District A	District B
▾290 million gallons per year	▾2.4 billion gallons per year
▾30,000 customers	▾132,000 customers
▾Upgrading a booster station that handles ~20% of the flow	▾Upgrading a pump station that handles most of the flow
▾Pumps to distribution system	▾Pumps directly to reservoirs
▾PS Current Energy Cost - $35,000/year	▾PS Current Energy Cost - $200,000 /year

Pump Station A

- 4 Pumps Total
- 1,800 gpm
- 380 feet TDH
- ~490 kW-hr/yr



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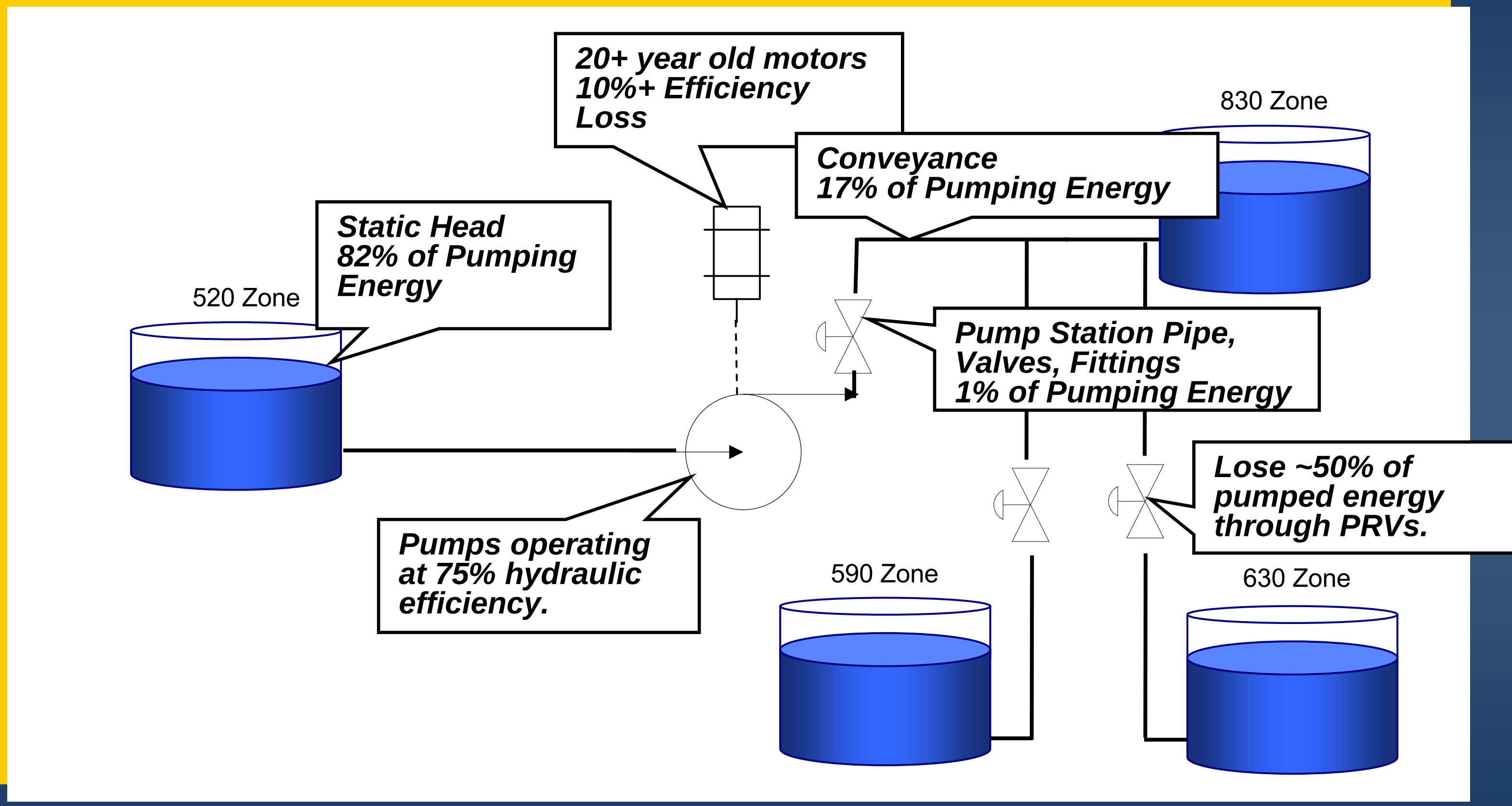

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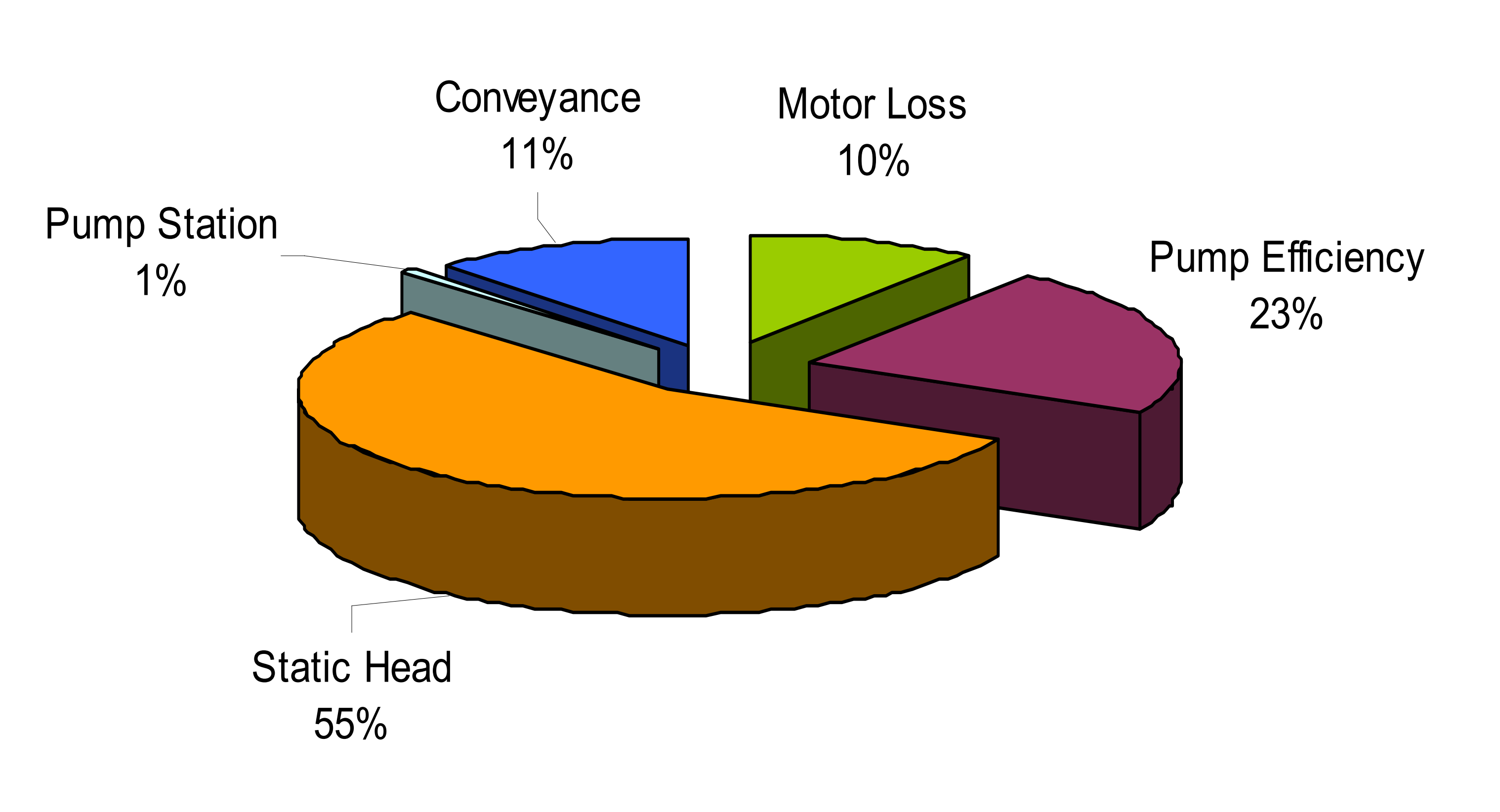

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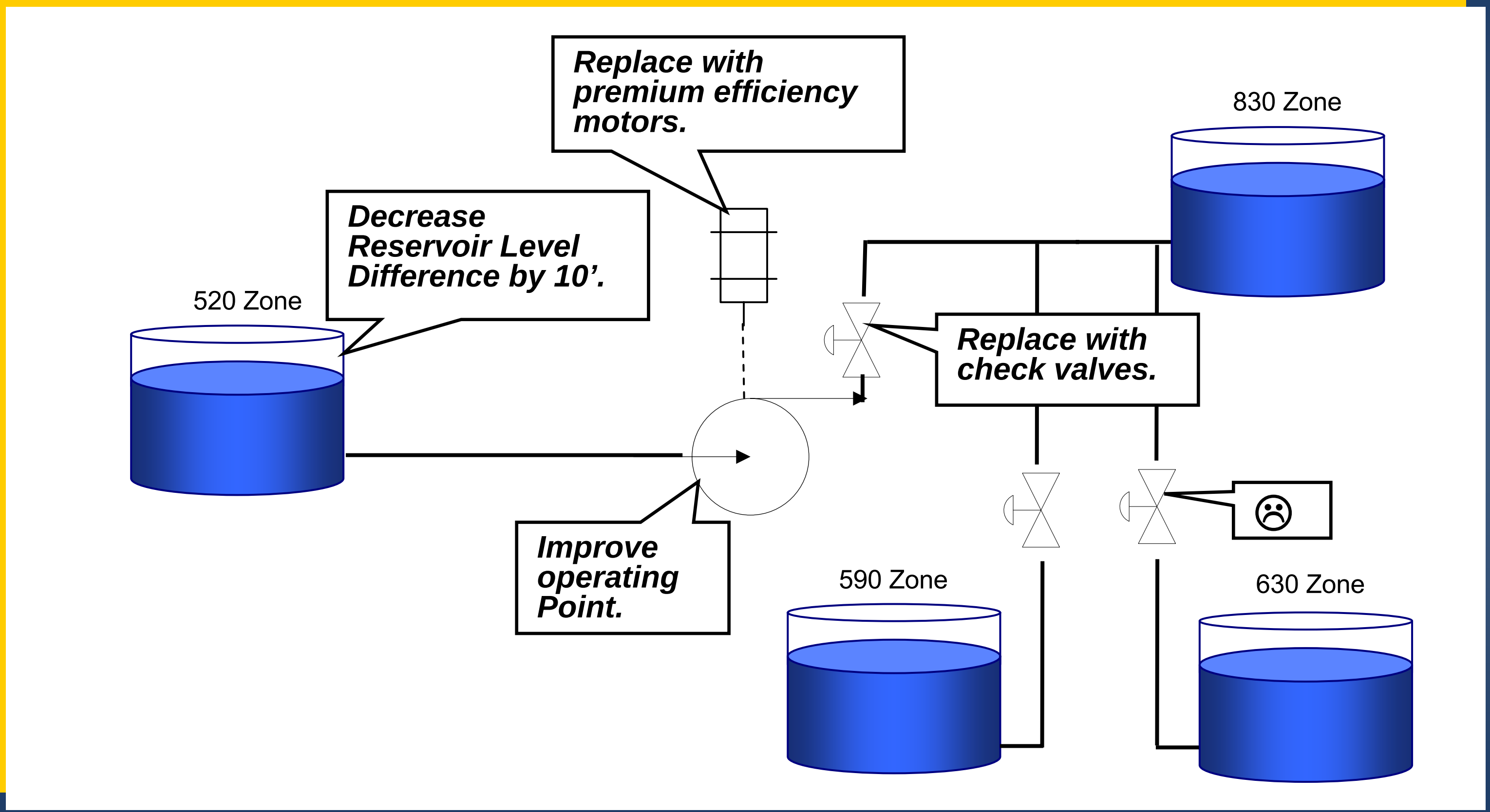

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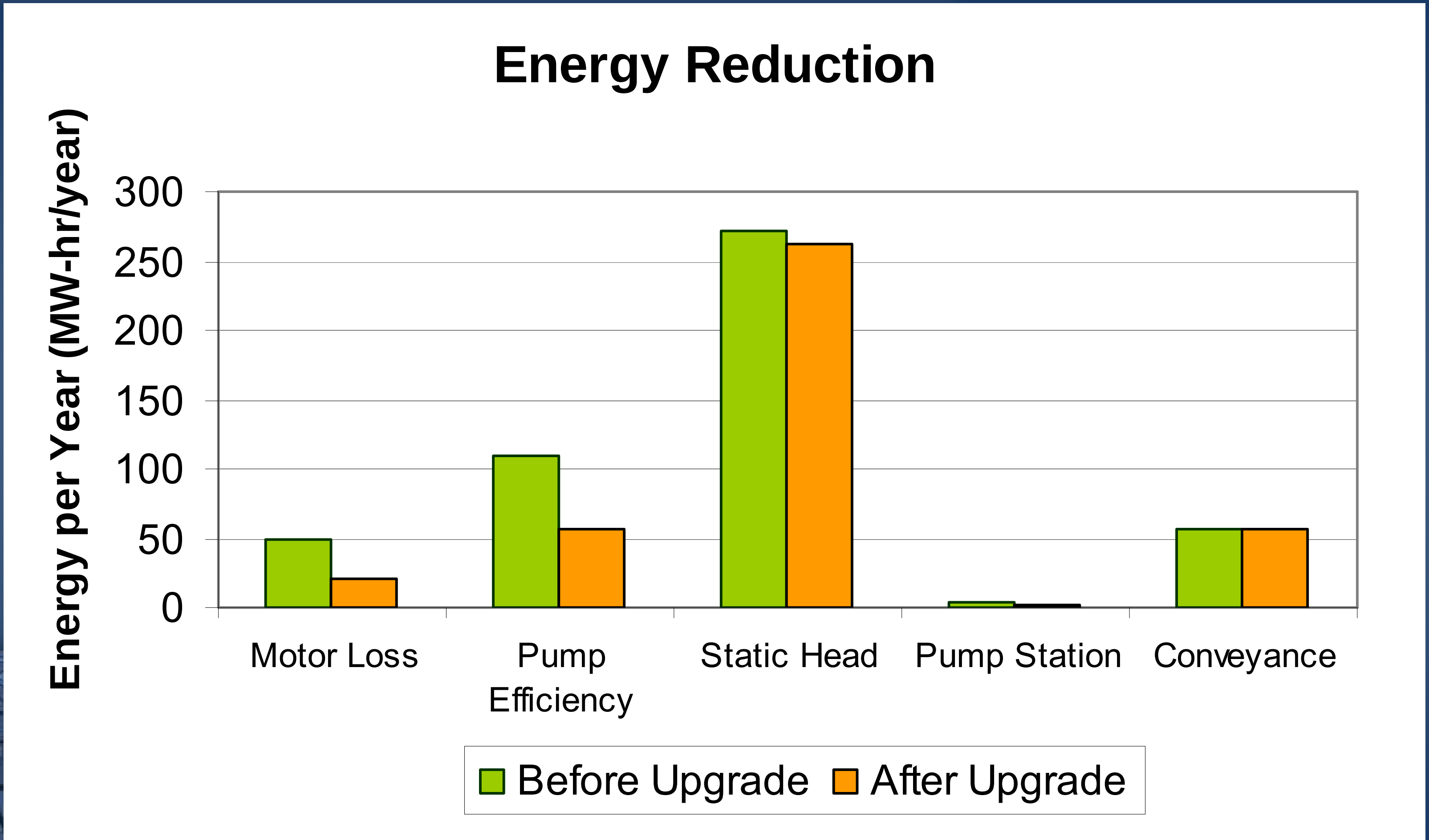

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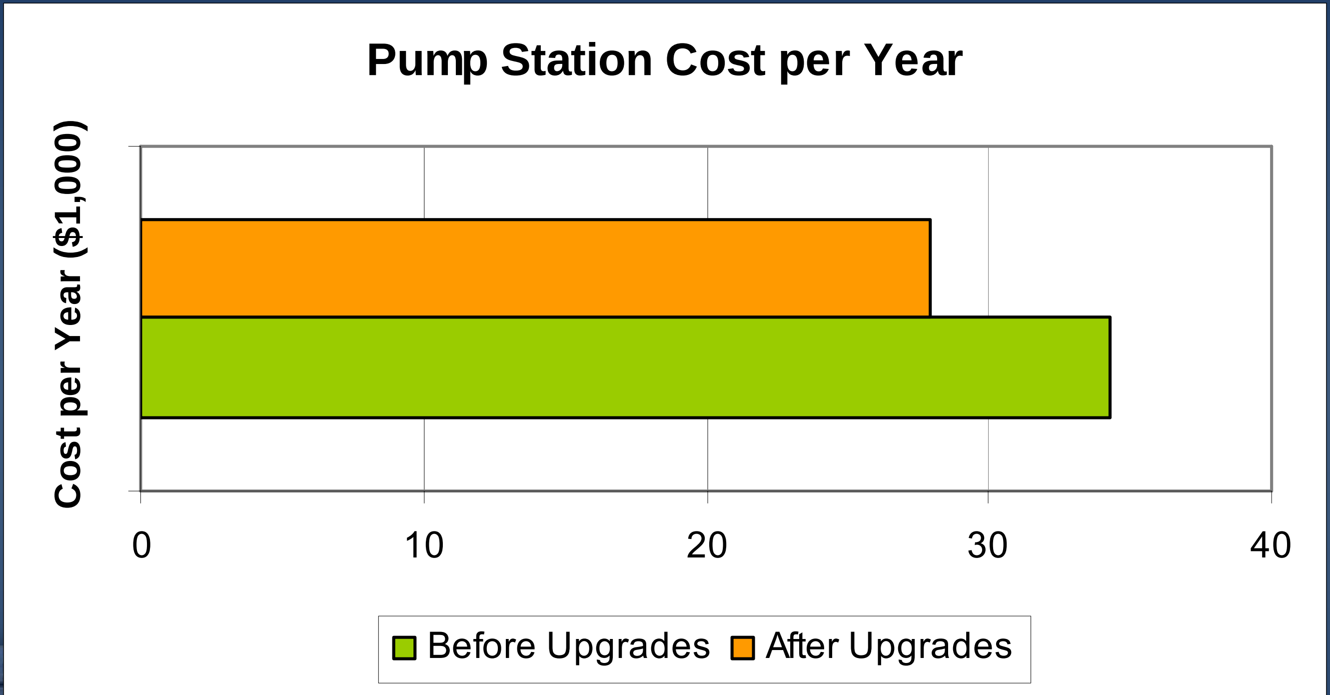
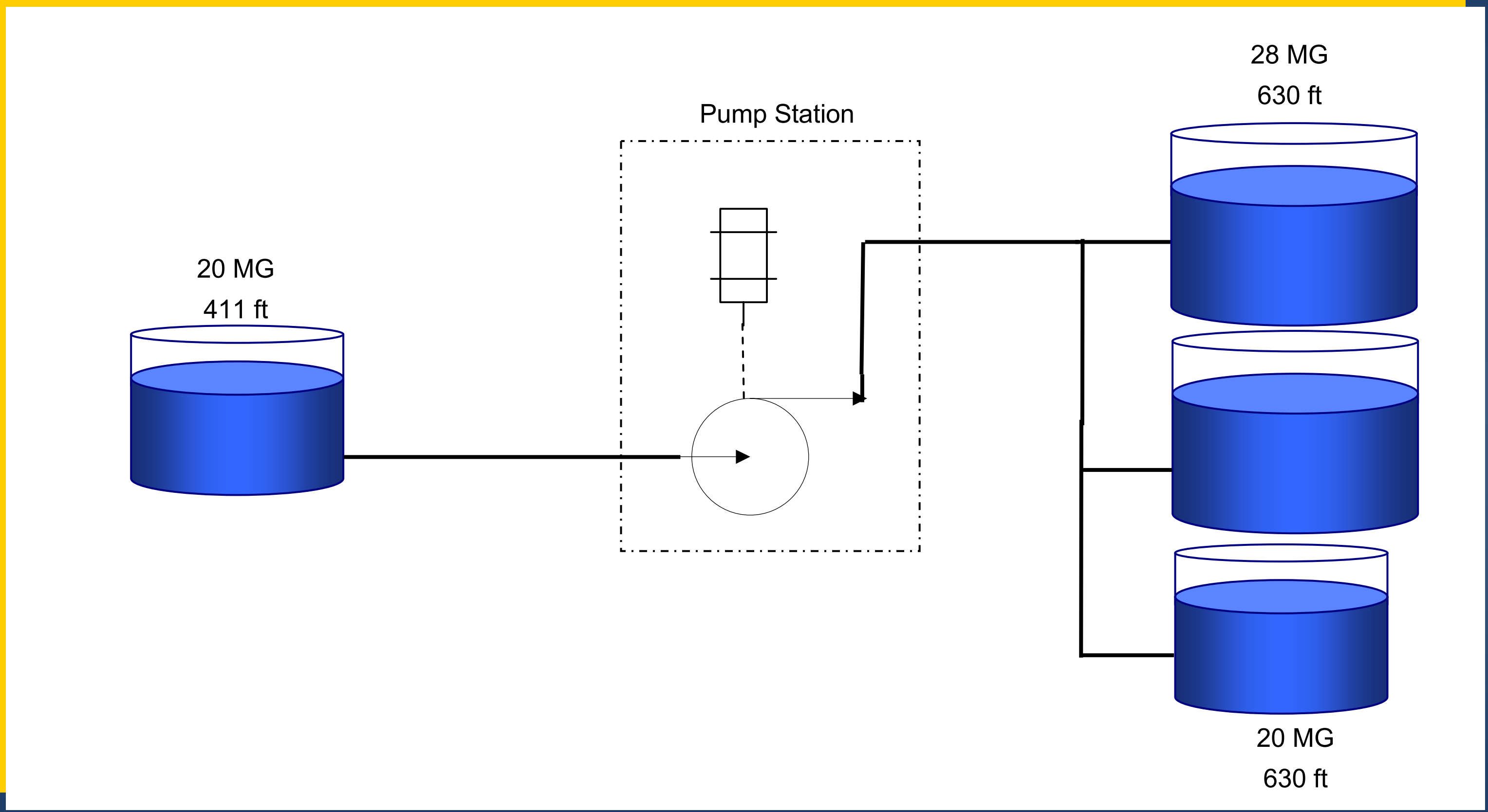


15-20% reduction in operating costs

Pump Station B

- 5 Pumps Total
- 30 MGD
- 350 feet TDH
- ~2.8 MW-hr/yr



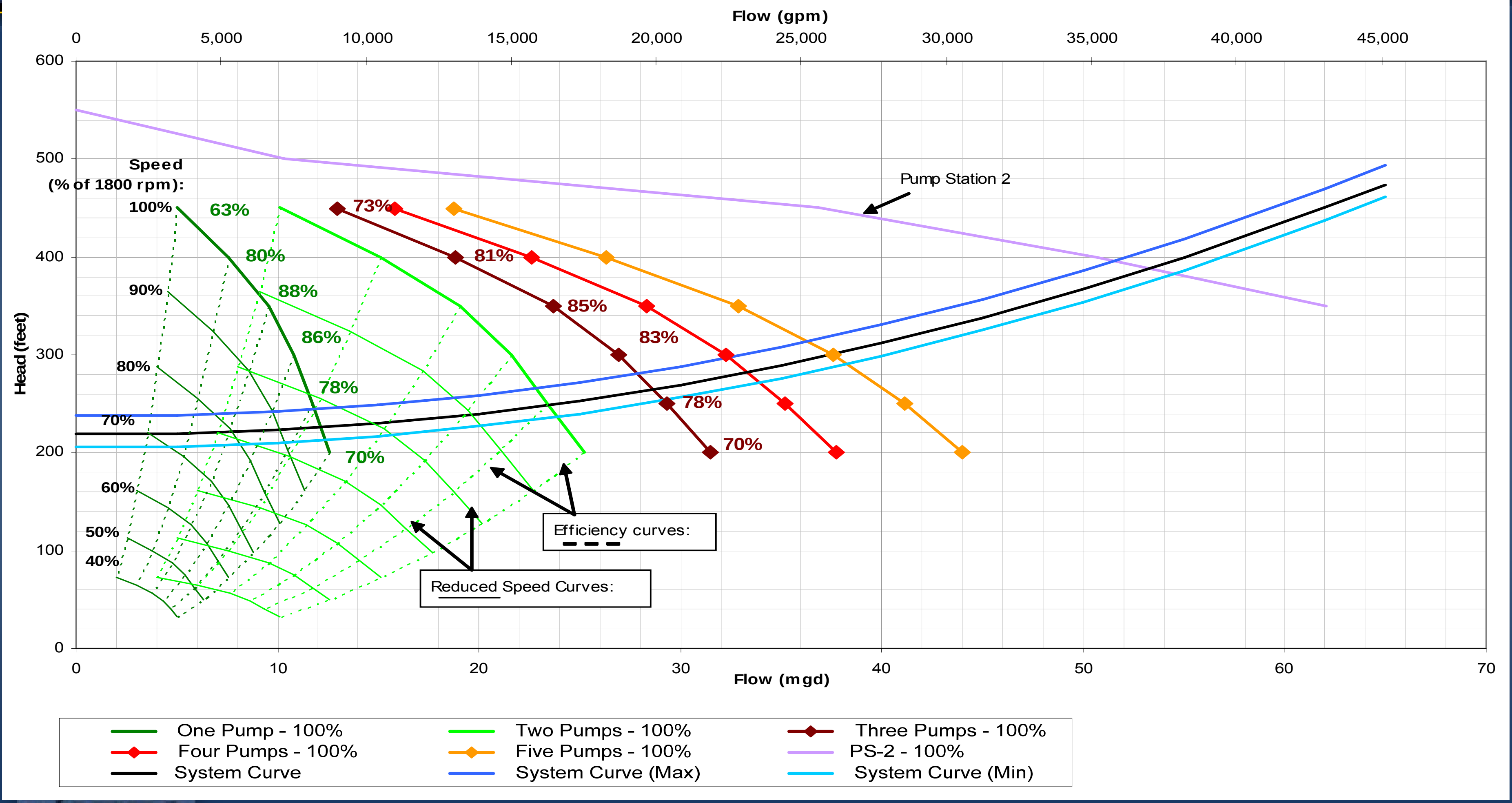
Pumping System Options Control Strategies Overview

- Pump Sizing
  - Five Small Pumps
  - Two Large Pumps, Three Small Pumps
  - Five Large Pumps
- VFDs vs No VFDs
  - No VFDs (all 5)
  - VFDs on just the large pumps (2), No VFDs on small pumps (3)

Operating Strategy

- Assumed Operating Strategy for Two Primary Pumps (VFDs) and Three Secondary Pumps (No VFDs)
  - Primary Pumps would operate first and adjust speed as needed.
  - Secondary Pumps would turn on successively; Primary pumps would adjust speed.

Pump Curves



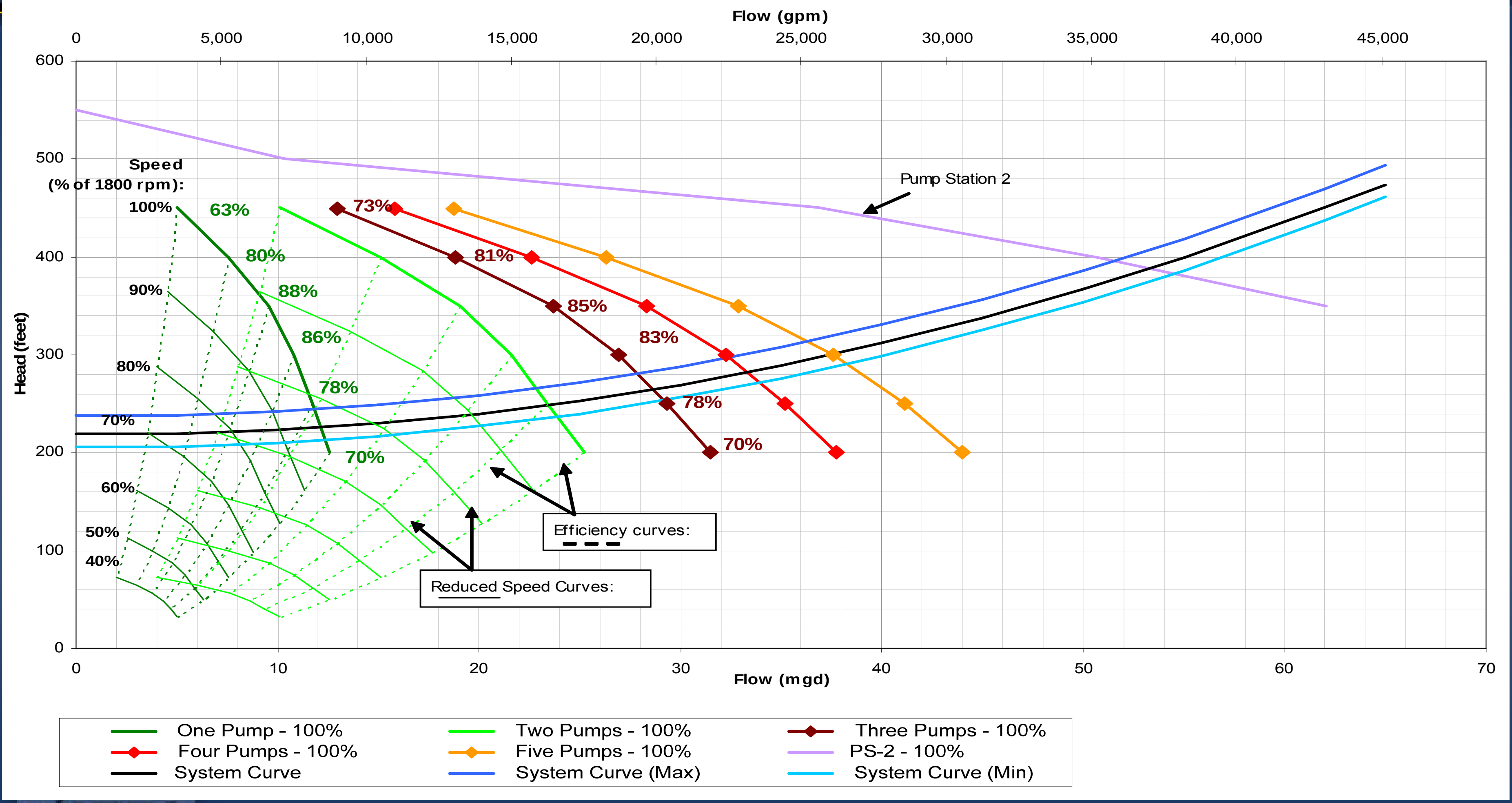
Flow (gpm)
0
5,000
10,000
15,000
20,000
25,000
30,000
35,000
40,000
45,000
Head (feet)
600
500
400
300
200
100
0
Speed
(% of 1800 rpm):
100%
90%
80%
70%
60%
50%
40%
63%
80%
88%
86%
78%
70%
73%
81%
85%
83%
78%
70%
Pump Station 2
Efficiency curves:
Reduced Speed Curves:
Flow (mgd)
0
10
20
30
40
50
60
70
One Pump - 100%
Two Pumps - 100%
Three Pumps - 100%
Four Pumps - 100%
Five Pumps - 100%
PS-2 - 100%
System Curve
System Curve (Max)
System Curve (Min)

Analysis

- Look at range the range of flow rates
- Solve for the operating scheme at a particular flow rate
- Solve for the efficiency at that flow
- Calculate the power requirement

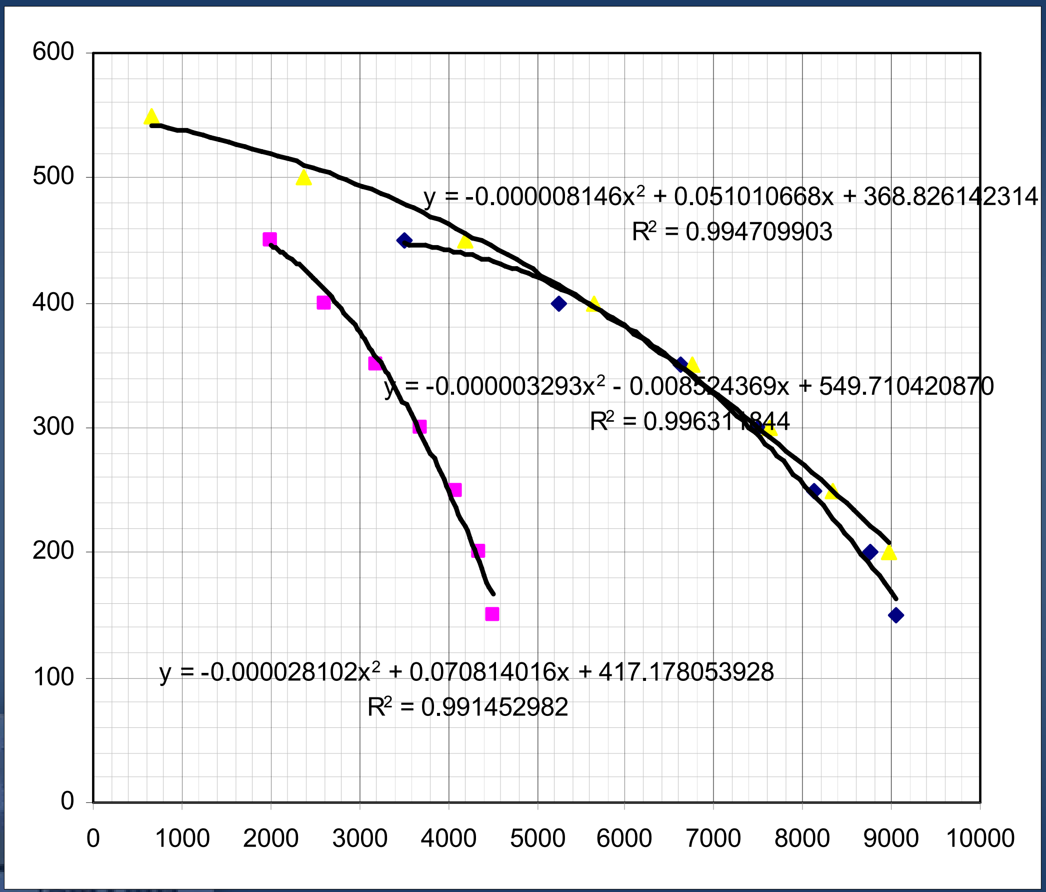
STATE WATER

Pump Curves



WATER

Pump Curves



Curve Fits

$$h = aQ^2 + bQ + c$$

$$Q = \frac{-b - \sqrt{b^2 - 4a(c-h)}}{2a}$$

Analysis

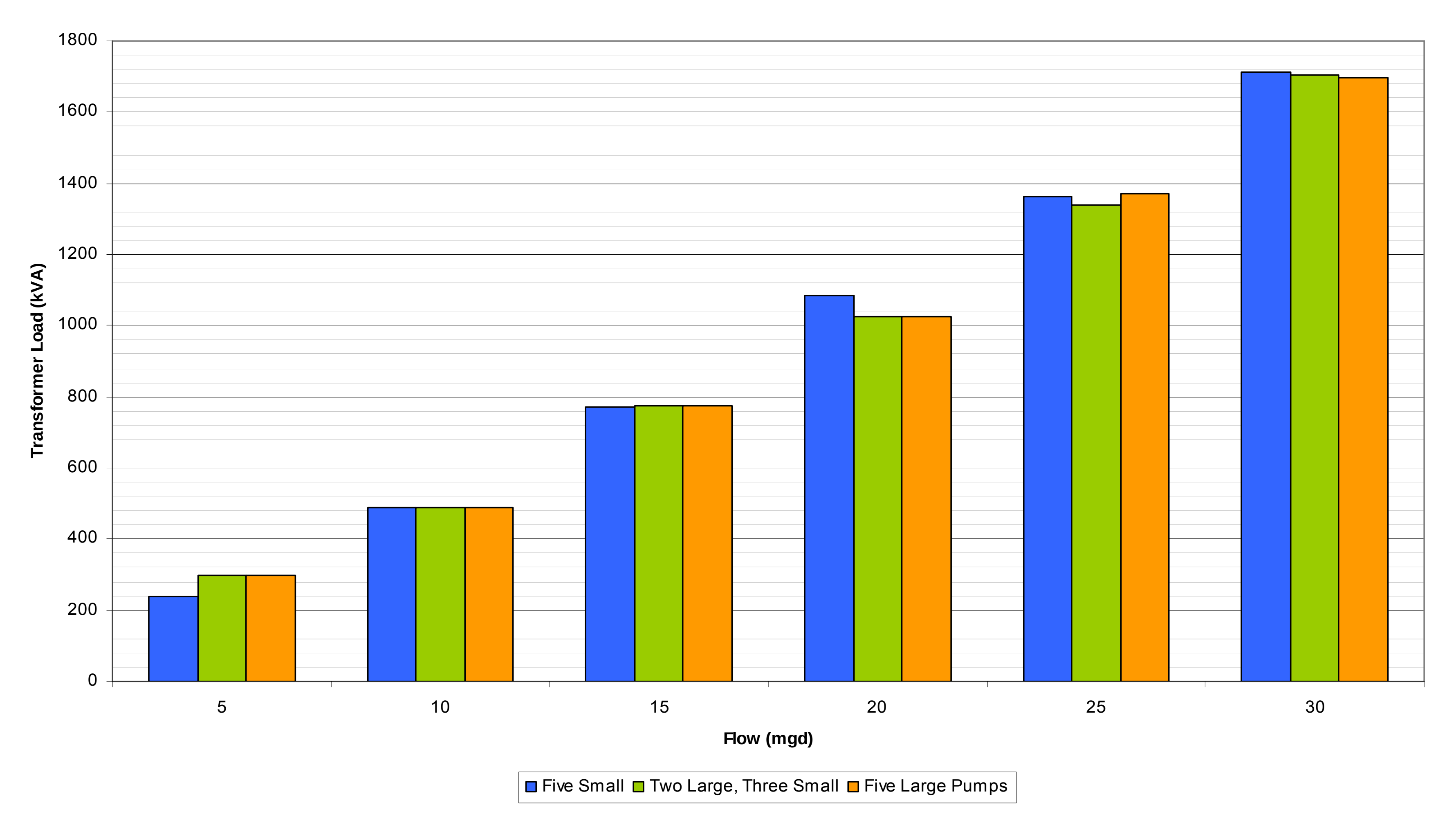
- An automated solving tool…

```
maxflow = Worksheets("Alt-2 Analysis").Cells(8, 5).Value

'To solve for Q = x, use quadratic equation solution (head = y):
'y = a*x^2 + b*x + c
'x = [-b + sqr(b^2 - 4*a*(c-y))]/(2*a)


Worksheets("Alt-2 Analysis").Cells(19, 2).Value = syflow
If syflow > maxflow Then
    exceedscap = syflow - maxflow
    syflow = maxflow
End If

'Finds the required system head at the input flow rate using the curve fit coefficients
syhead = sya * syflow ^ 2 + syb * syflow + syc
'Finds the maximum flow each pump set can pump at the system head using the quadratic so
p1maxflow = (-p1b - Sqr(p1b ^ 2 - 4 * p1a * (p1c - syhead))) / (2 * p1a)
p2maxflow = (-p2b - Sqr(p2b ^ 2 - 4 * p2a * (p2c - syhead))) / (2 * p2a)
ps2maxflow = (-ps2b - Sqr(ps2b ^ 2 - 4 * ps2a * (ps2c - syhead))) / (2 * ps2a)



'Pump 1 Operation
'p1op = the required number of p1 pumps
'p1op is by default the number of pumps in the P1 set.  If the system flow rate does not
'the 'for loop', that means it exceeds the maximum flow rate and all the P1 pumps must b
p1op = np1
For m = 1 To np1
    If syflow > p1maxflow * (m - 1) And syflow < p1maxflow * m Then
```

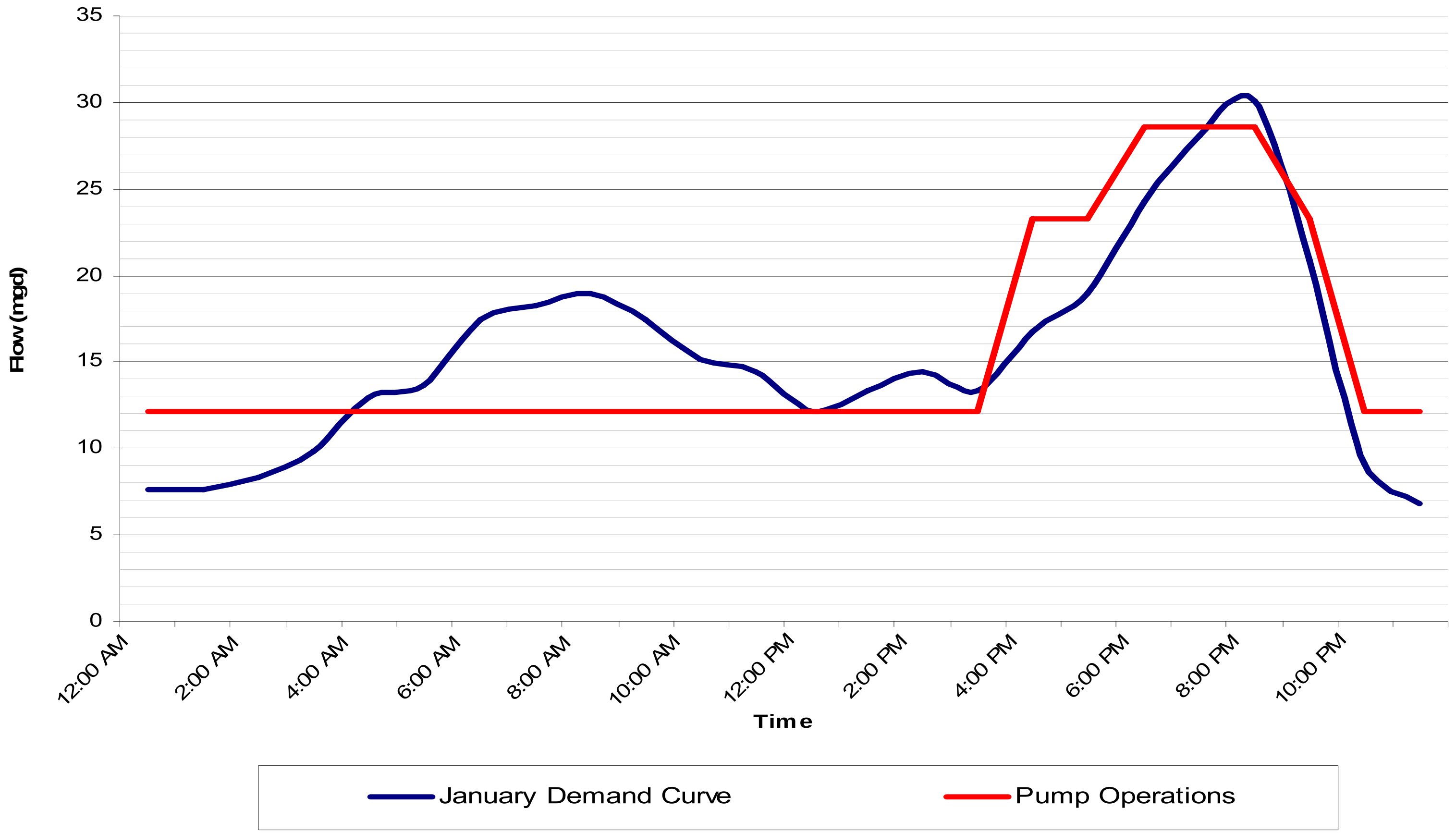
Analysis

mgd		Number of Pumps Operating	% Speed	Efficiency	Flow Rate per Pump (gpm)	Velocity in Can (fps)	Velocity in Suction Pipe (fps)	BHP per Pump	Total kVa per PS
5	PS 1 Primary	1	72%	67%	3472	1.91	4.37	289	
	PS 1 Secondary	0			0	0.00	0.00	0	298
	PS 2	0			0	n/a	n/a	0	0
10	PS 1 Primary	1	90%	83%	6944	3.82	8.75	472	
	PS 1 Secondary	0			0	0.00	0.00	0	488
	PS 2	0			0	n/a	n/a	0	0
15	PS 1 Primary	2	80%	81%	5208	2.87	6.56	375	
	PS 1 Secondary	0			0	0.00	0.00	0	774
	PS 2	0			0	n/a	n/a	0	0
20	PS 1 Primary	2	91%	85%	6944	3.82	8.75	497	
	PS 1 Secondary	0			0	0.00	0.00	0	1026
	PS 2	0			0	n/a	n/a	0	0
25	PS 1 Primary	2	91%	86%	6687	3.68	8.42	496	
	PS 1 Secondary	1	100%	79%	3985	4.74	8.30	321	1340
	PS 2	0			0	n/a	n/a	0	0
30	PS 1 Primary	2	92%	87%	6540	3.60	8.24	514	
	PS 1 Secondary	2	100%	81%	3876	4.61	8.07	327	1704
	PS 2	0			0	n/a	n/a	0	0
35	PS 1 Primary	2	94%	87%	6544	3.60	8.24	550	
	PS 1 Secondary	3	100%	83%	3739	4.45	7.79	331	2112
	PS 2	0			0	n/a	n/a	0	0
40	PS 1 Primary	2	88%	86%	4884	2.69	6.15	448	
	PS 1 Secondary	3	100%	83%	3569	4.25	7.43	337	1919
	PS 2	1	100%	86%	7301	n/a	n/a	669	657
45	PS 1 Primary	2	88%	72%	3758	2.07	4.73	445	
	PS 1 Secondary	3	100%	84%	3359	4.00	6.99	341	1922
	PS 2	2	100%	86%	6828	n/a	n/a	678	1332
50	PS 1 Primary	2	91%	78%	3327	1.83	4.19	394	
	PS 1 Secondary	3	100%	82%	3094	3.68	6.44	352	1851

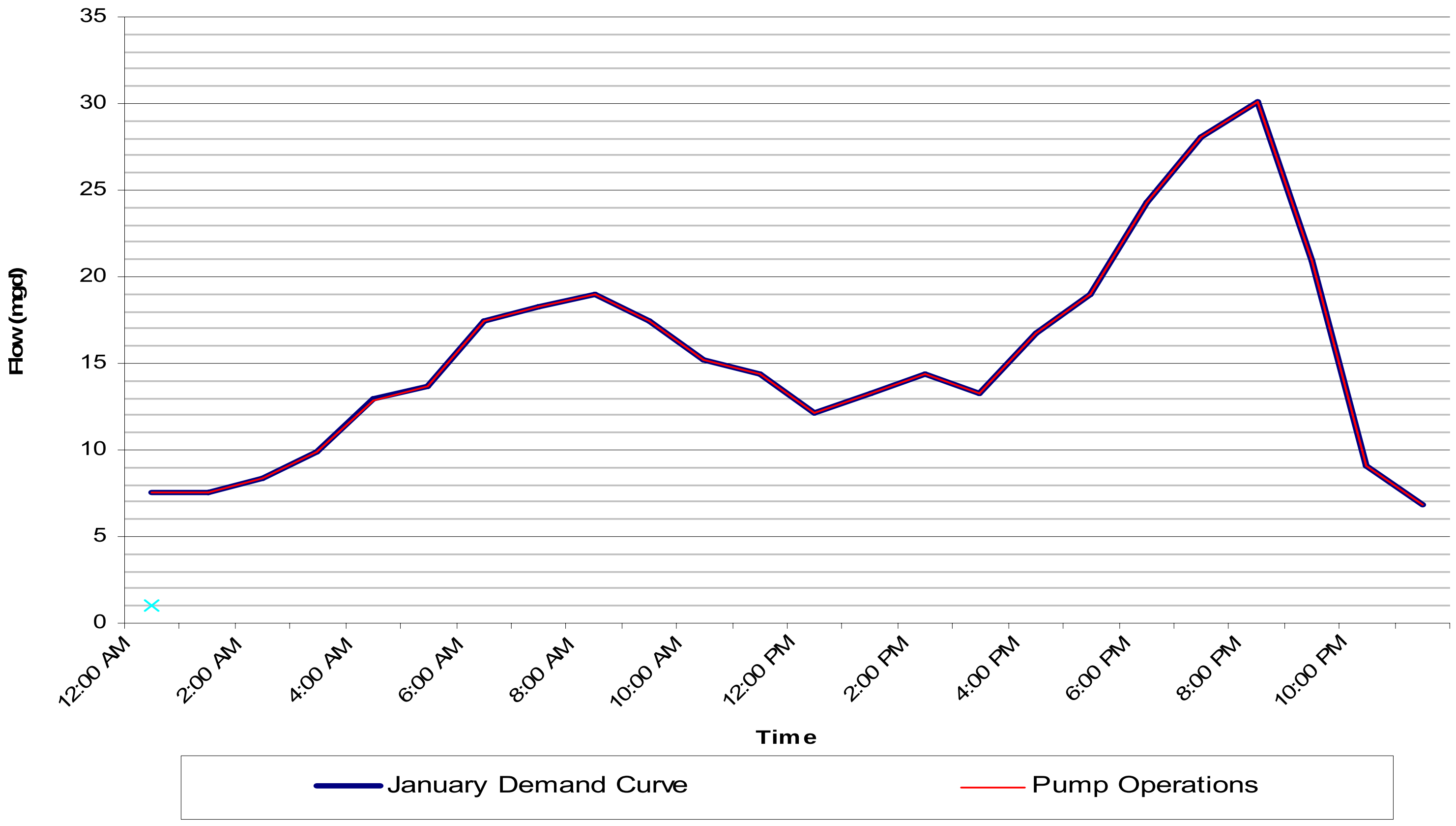
Pump Size Comparison



Pump Operation – No VFDs



Pump Operation – Two VFDs



No VFD vs VFDs Comparison

	No VFDs	Two VFDs	All VFDs
Average Power (kW)	830	770	760
Average Efficiency	72%	78%	79%
Total Project Cost	$550,000	$1,280,000	$2,210,000
Pumping Energy Cost	$503,000	$471,000	$465,000
Net Operating Costs (20-Years)	$9,500,000	$9,000,000	$9,100,000
Total Present Worth	$10,000,000	$10,200,000	$11,100,000

Summary

- Small Pumping Systems
  - Benefits of replacing with high efficiency motors
  - Benefits of operating at best efficiency point
- Large Pumping Systems
  - Analyze different operating scenarios
  - Even a couple percentage points can save $Ks