

Presentation Outline

Existing System

Mechanical Depth

- GSHP
- U Tube Design
- Layout
- System Design
- Cost
- OA Study

Electrical

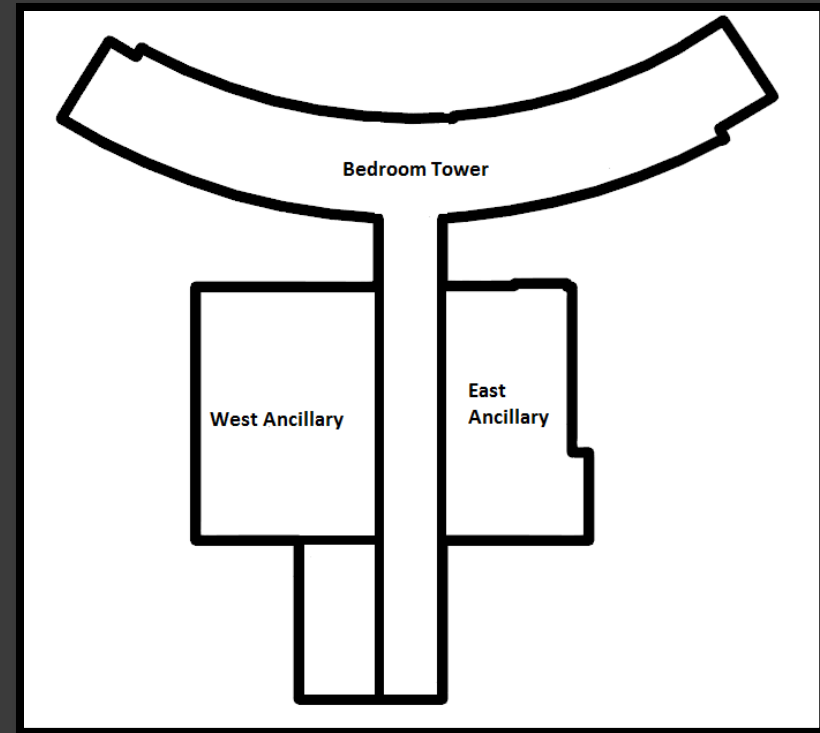
- PV Panels



Virtua Replacement Hospital

-Voorhees NJ

Justin Prior
Mechanical
Advisor – Prof Treado



360 Patient Rooms



Virtua Replacement Hospital

-Voorhees NJ

Size - 690,900 SF

Cost - \$500 million

Owner - Virtua

Architect/Engineer - HGA

CM - Turner Construction

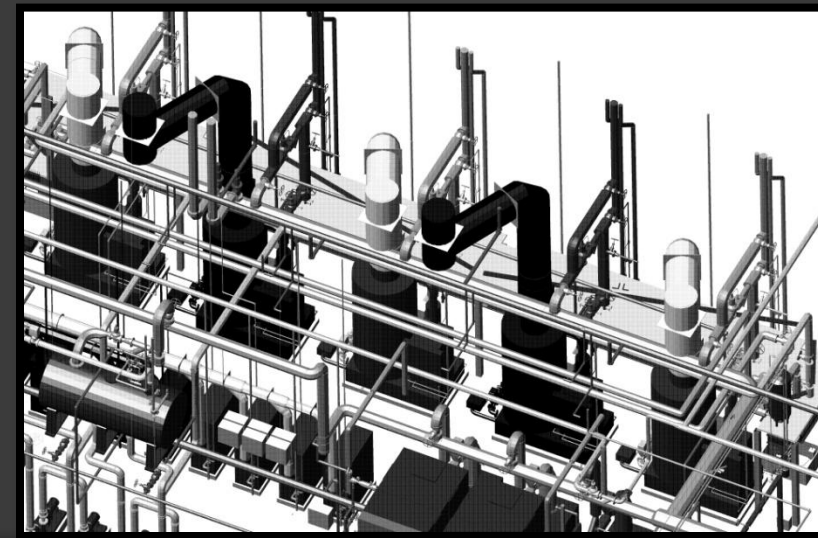
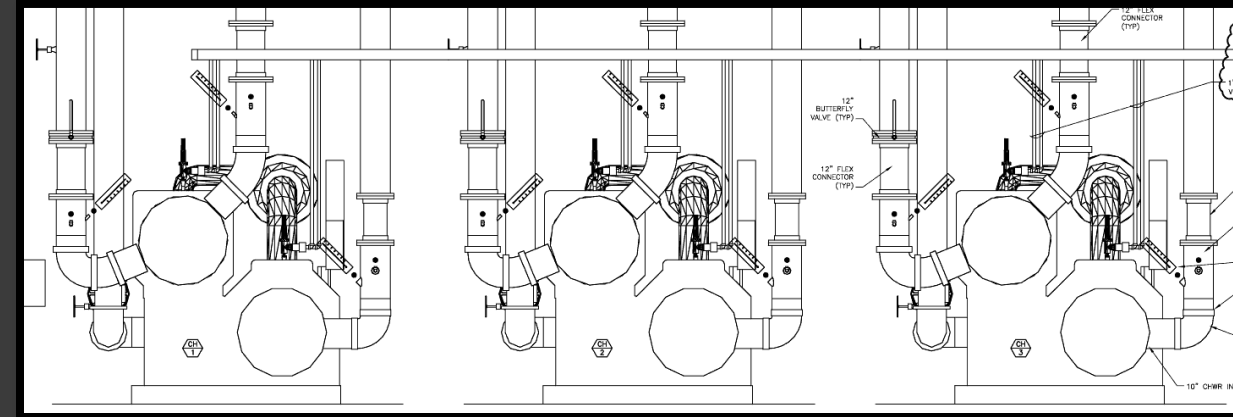
Completion - May 2011



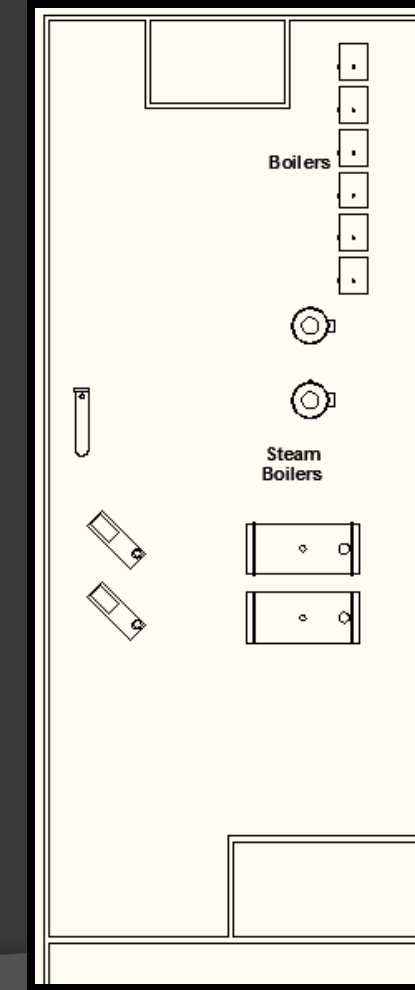
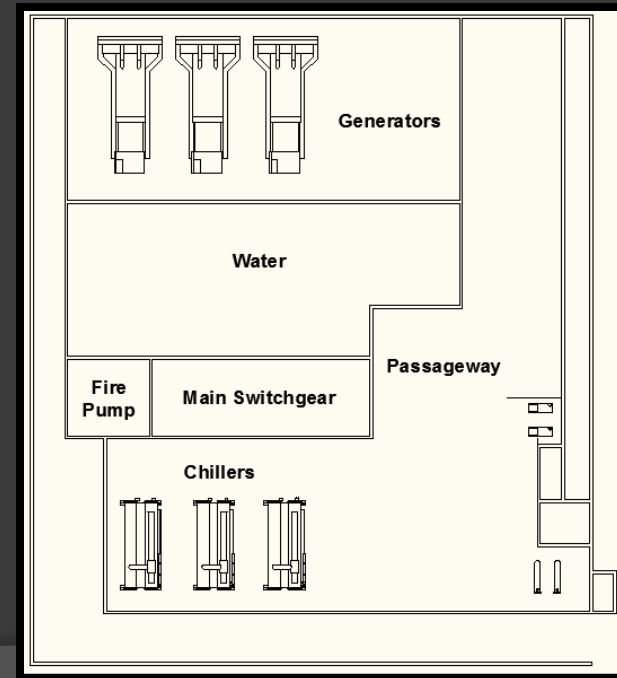
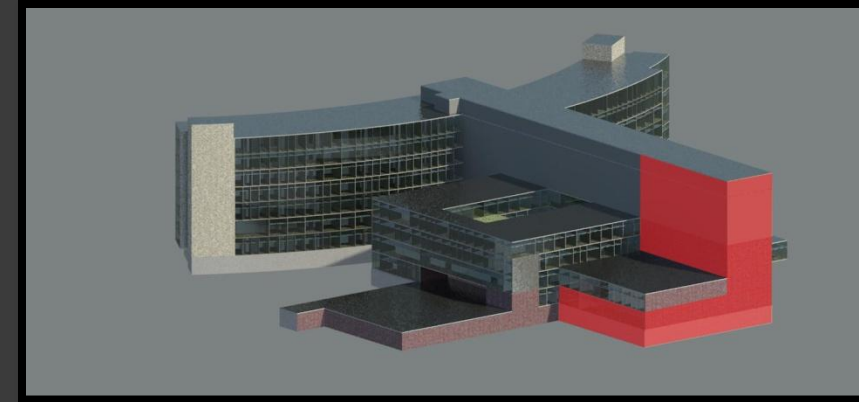
Current System

Central Utility Plant

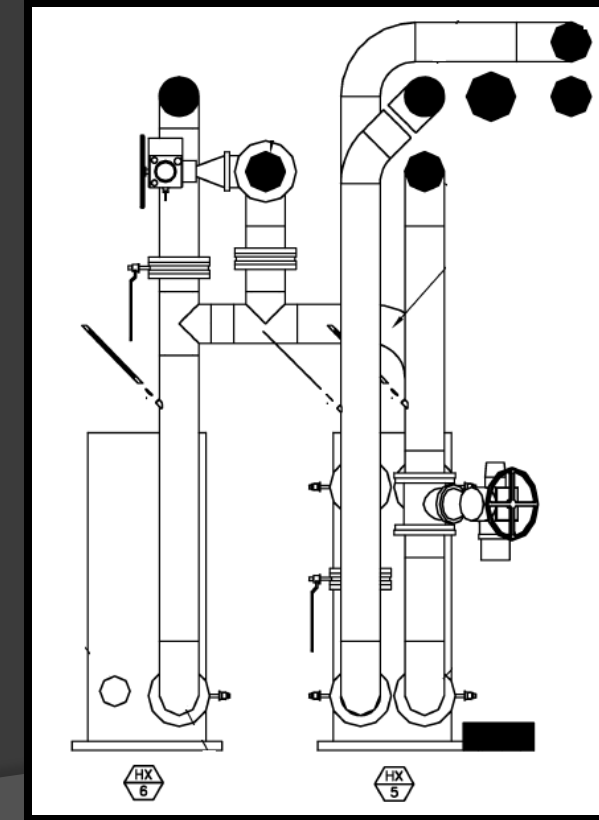
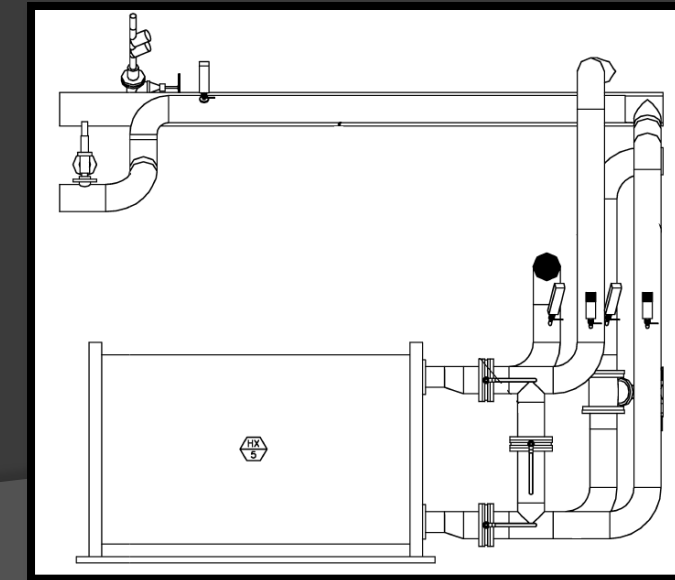
- 3 centrifuge chillers
 - 1000 tons each



- 4 Steam Boilers
 - 2 @ 40 BHP
 - 2 @ 287 BHP

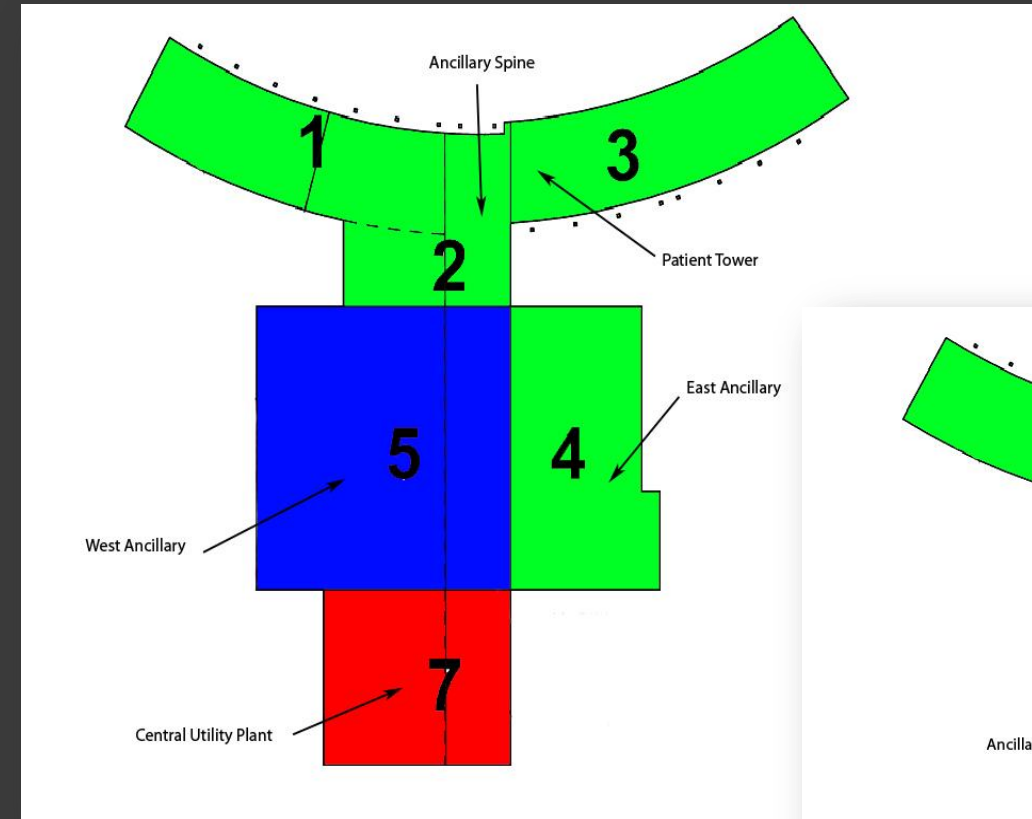
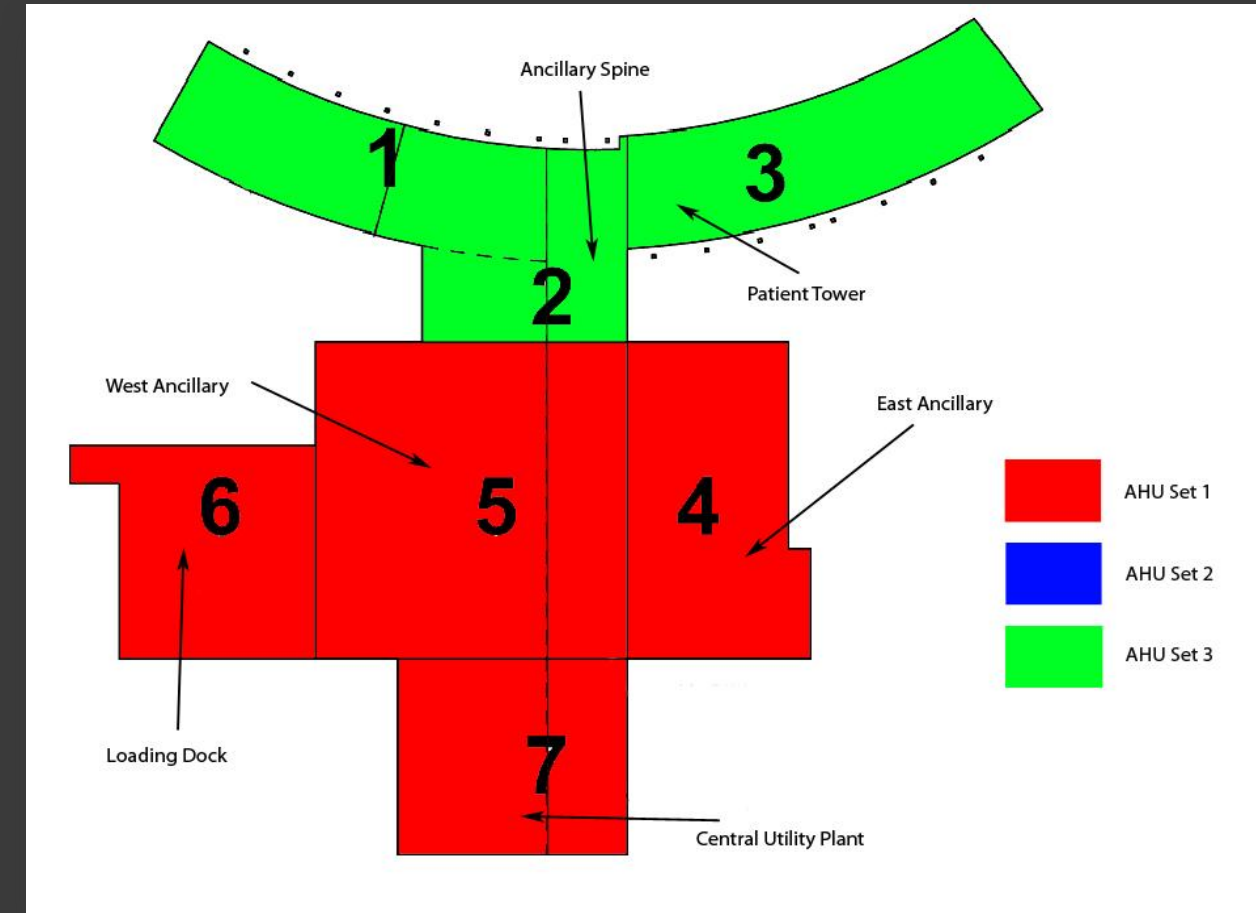


- 6 Heat Exchangers
 - 2 @ 7200 MBH
 - 2 @ 10041 MBH
 - 1 @ 2512 MBH
 - 1 @ 7850 MBH



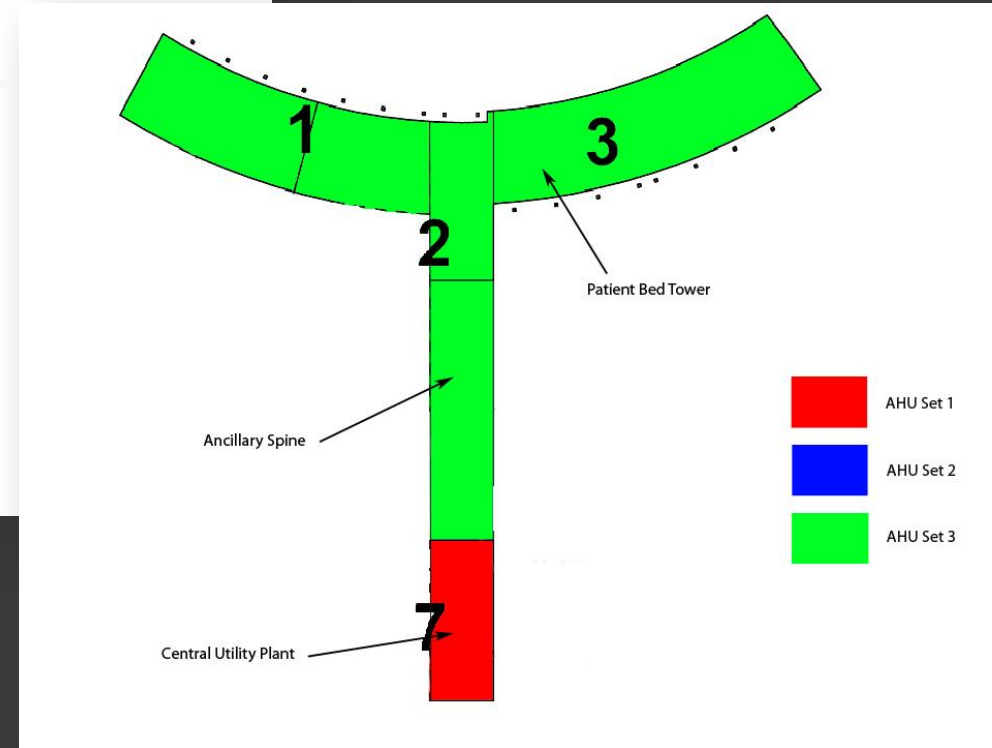
AHU Zones

1st Floor



Floor 2-5

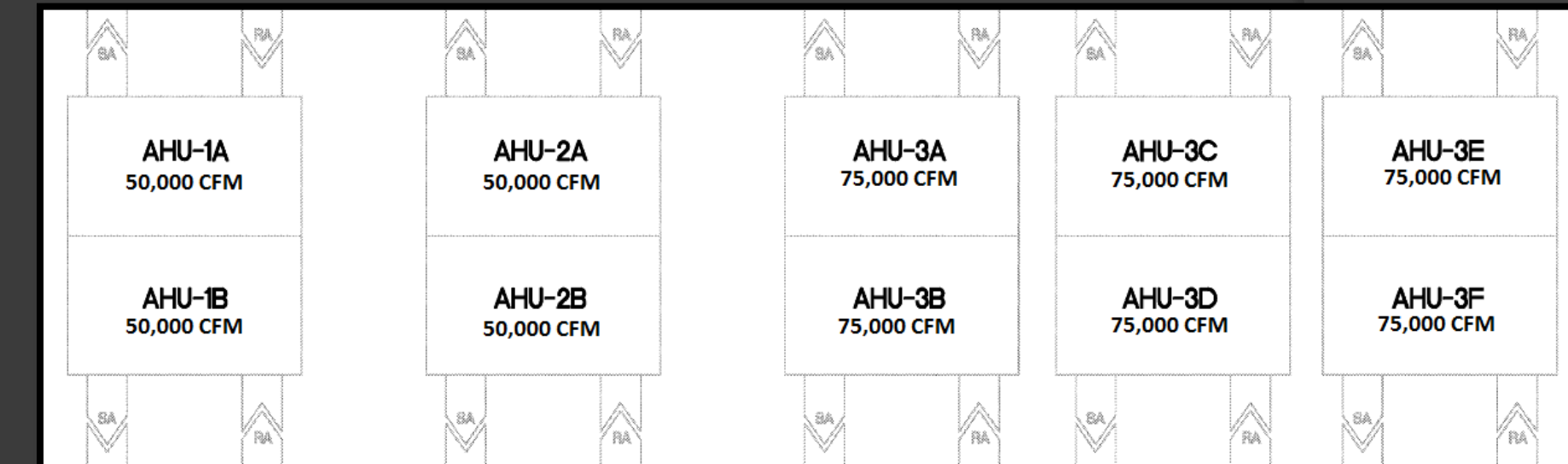
Floor 6-8



- AHU Set 1
 - Non-Patient Care

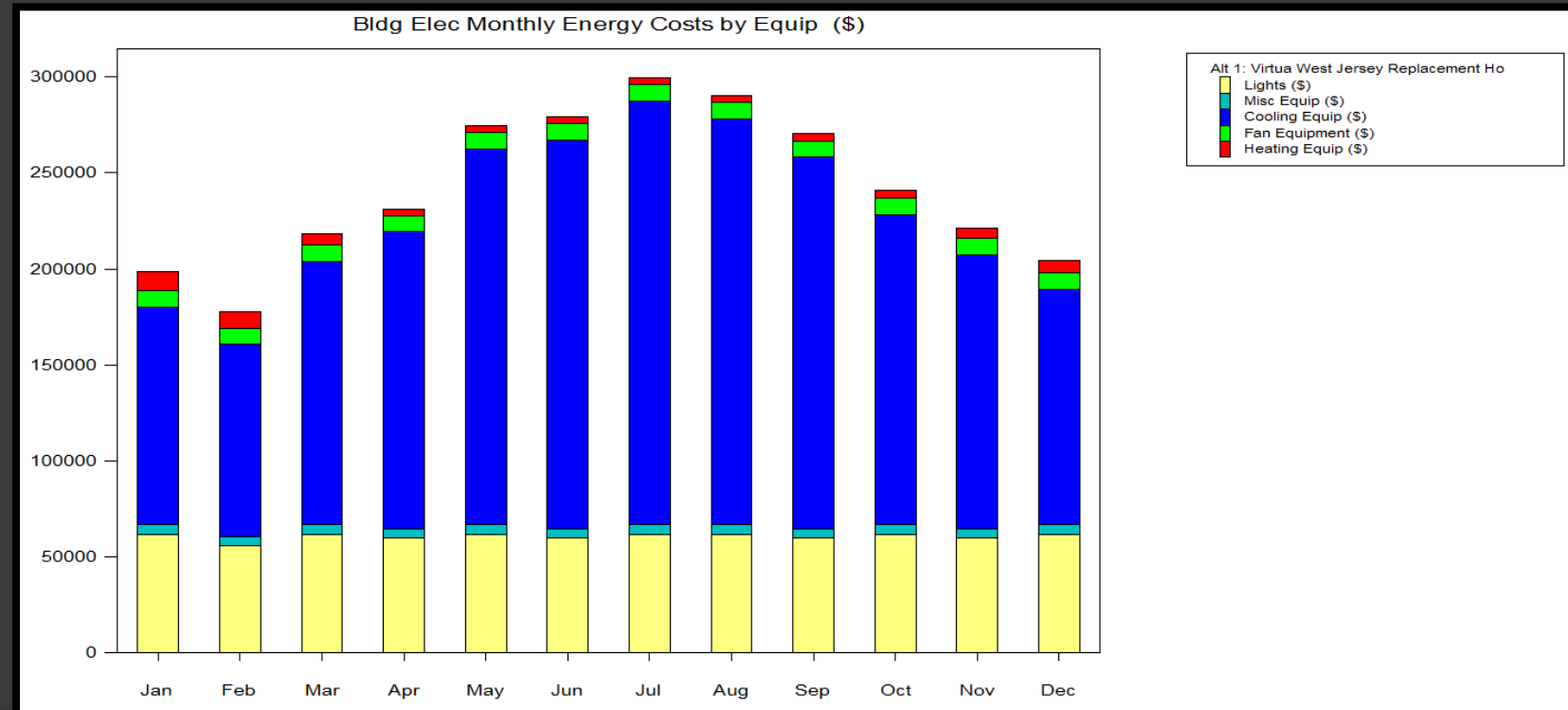
- AHU Set 2
 - Medical Areas

- AHU Set 3
 - Patient Care



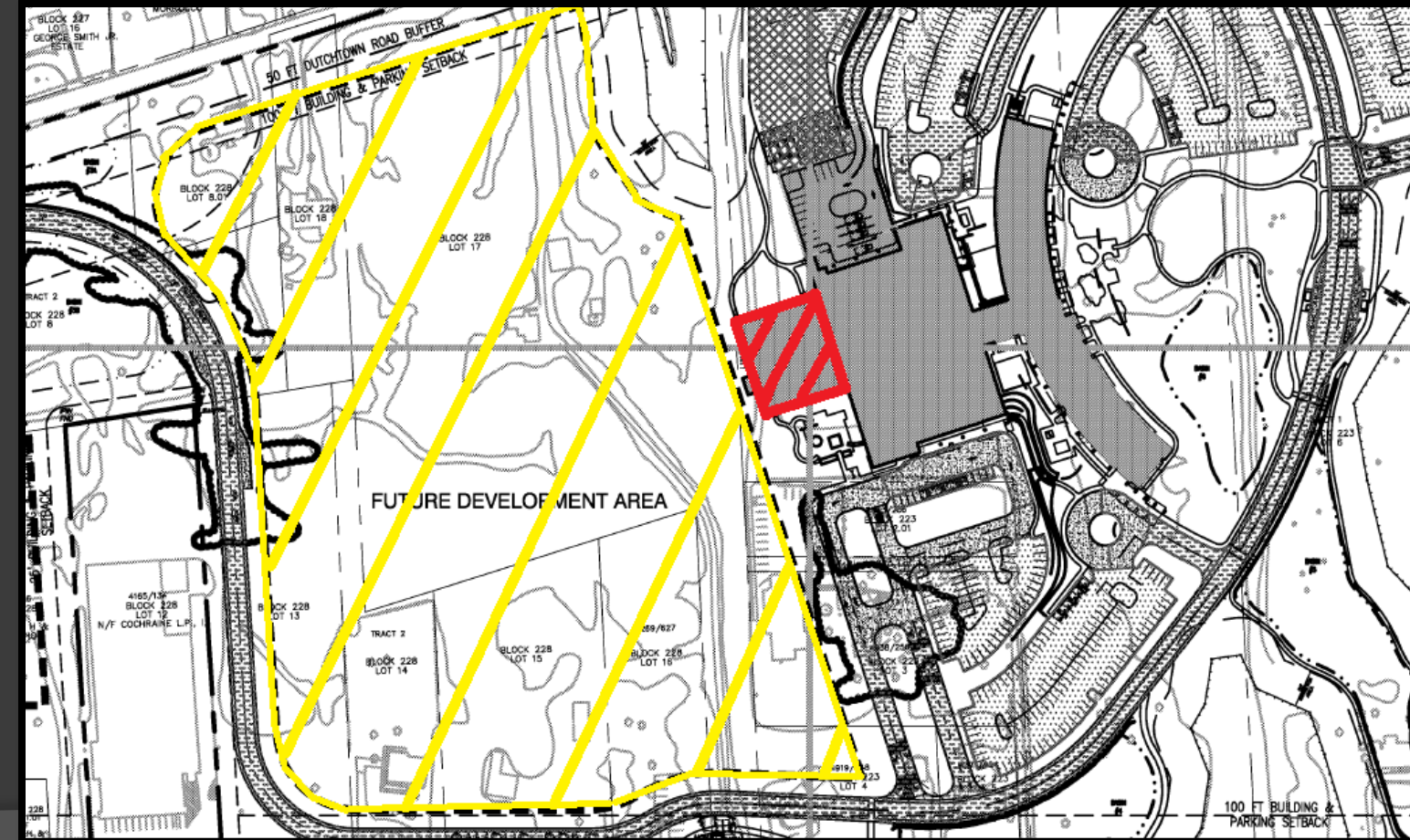
Current Energy Use

Annual Utility Breakdown		
Source	Energy	Cost
Chilling Plant	15,104,376 KWh	\$ 1,963,568.00
Heating Plant	1,503,106 Therms	\$ 1,803,727.00
Total		\$ 3,767,295.00



Ground Source Heat Pump (GSHP)

Proposed Area

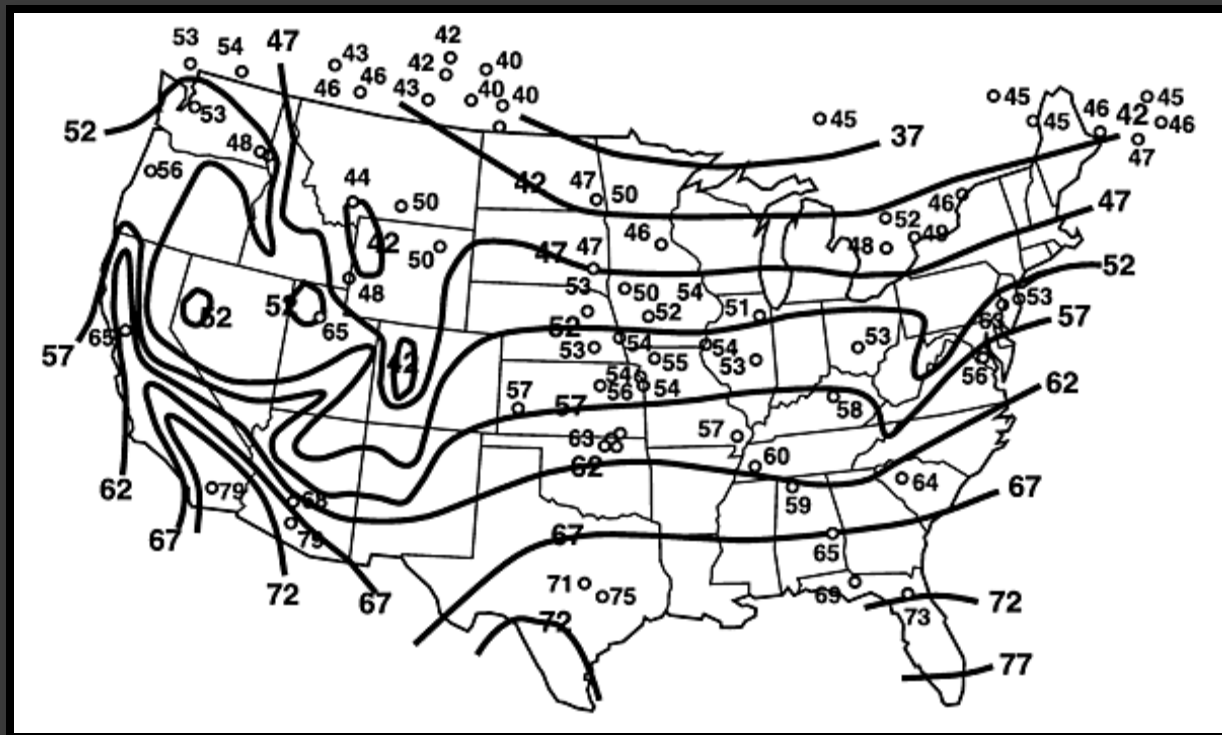


GSHP Goals:

- Low thermal resistance
- Pump Efficiency
- Low Operational Cost
- Low Payback Period



Total Length Calc.



Peak Building Loads	
AHU Set	Load (tons)
1	365
2	696
3	1062

$$L_c = \frac{q_a R_{ga} + (C_{fc} \times q_{lc})(R_b + PLF_m R_{gm} + R_{gd} F_{sc})}{t_g - \frac{t_{wi} + t_{wo}}{2} - t_p}$$

AHU 2 Example

Symbol	Terms	Units	Value
q_a	net annual average heat transfer to ground	Btu/h	-2322324.041
R_{ga}	effective thermal resistance of the ground, annual	h-ft-°F/Btu	0.281690141
q_{lc}	building design cooling block load	Btu/h	-8359650
C_{fc}	power input at design cooling load	W	1.14
R_b	thermal resistance of bore	h-ft-°F/Btu	0.05
PLF_m	part load factor during design month	n/a	0.35
R_{gm}	effective thermal resistance of the ground, monthly	h-ft-°F/Btu	0.281690141
R_{gd}	effective thermal resistance of the ground, daily	h-ft-°F/Btu	0.176056338
F_{sc}	short circuit heat loss factor	n/a	1.01
t_g	undisturbed ground temperature	°F	56
t_{wi}	liquid temperature at heat pump inlet	°F	70
t_{wo}	liquid temperature at heat pump outlet	°F	54
t_p	temperature penalty for interference of adjacent bores	°F	3
L_c	pipe length for cooling	ft	418316.5164

Total Required Length

- AHU 1 = 72,000 ft

- AHU 2 = 418,000 ft

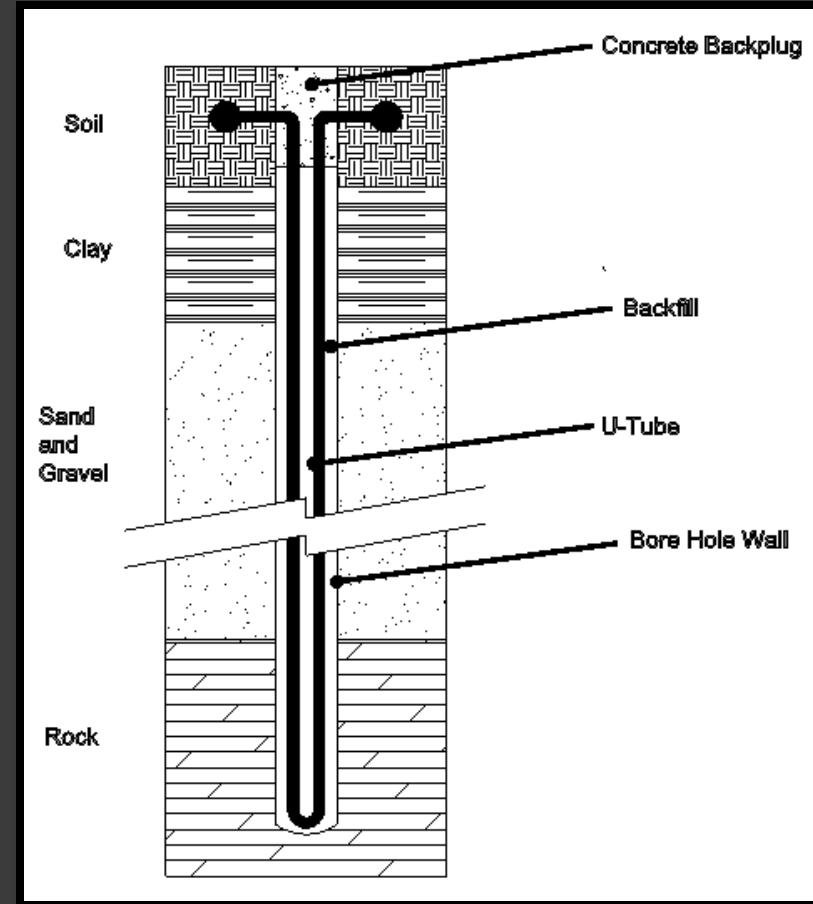
- AHU 3 = 935,000 ft

Thermal Resistance (Rb)		
U-tube Dia.	Pipe	Pipe Resistance
		Water Flows > 2 gpm
1 1/2 "	SDR 11	0.09
	SDR 9	0.11
	Sch 40	0.08

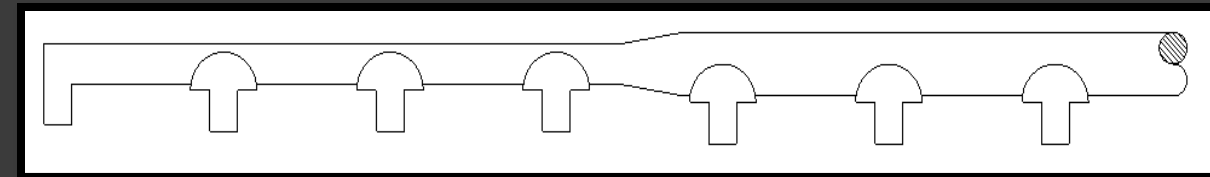
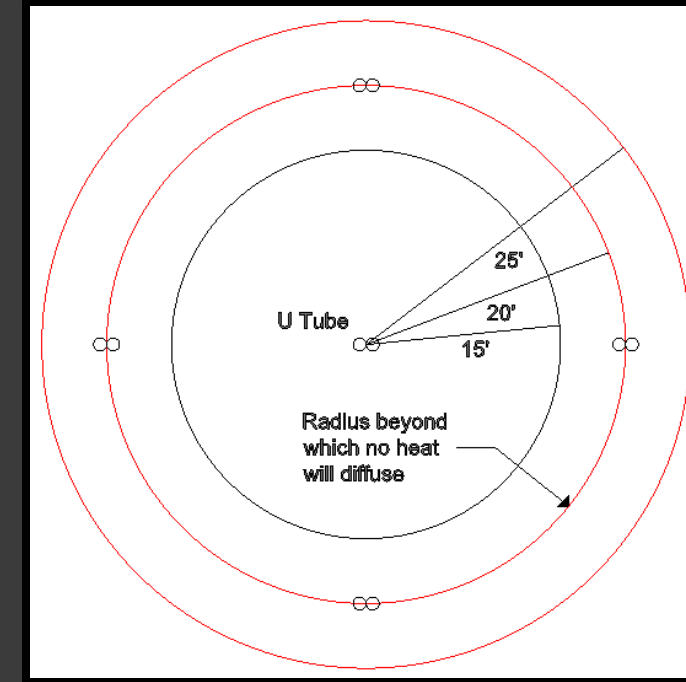
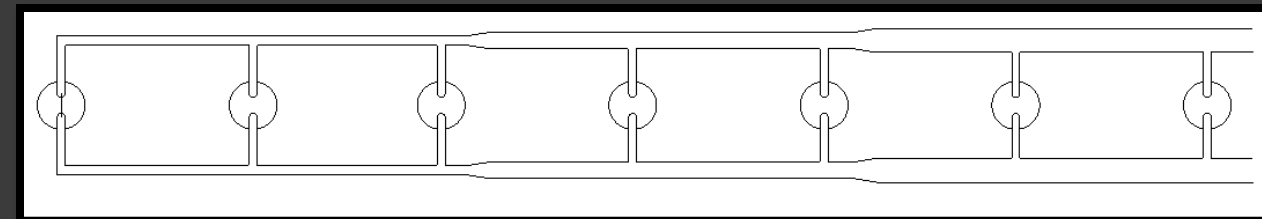
Cooling EER	C_{fc}	Heating COP	C_{th}
11	1.31	3	0.75
13	1.26	3.5	0.77
15	1.23	4	0.8
17	1.2	4.5	0.82
19	1.17		
21	1.14		

U Tube Design

Section



Plan View



5 Options

- AHU 1 @ 300 ft
- AHU 1 @ 600 ft
- **AHU 2 @ 600 ft**
- AHU 2 @ 1000 ft
- AHU 3 @ 1000 ft

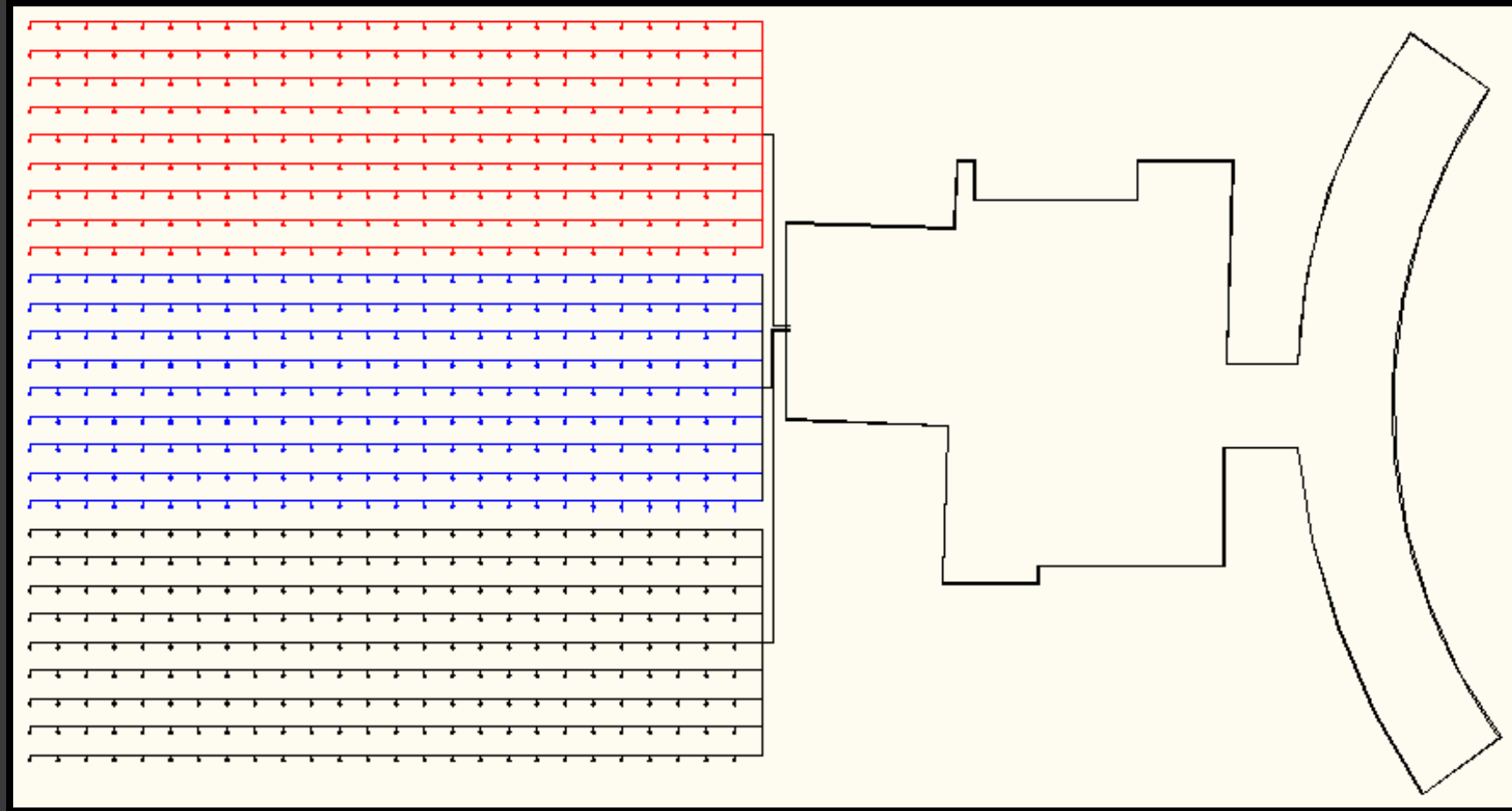
U Tube Dia	Range of Bore Length Per Parallel Circuit		
	Desired Pumping Efficiency		
	High	Adequate	Poor
1/4 in	100-200 ft	up to 250 ft	over 250 ft
1 in	150-300 ft	up to 350 ft	over 350 ft
1 1/4 in	250-500 ft	up to 600 ft	over 600 ft
1 1/2 in	100-600 ft	up to 1000 ft	over 1000 ft



GSHP Layout

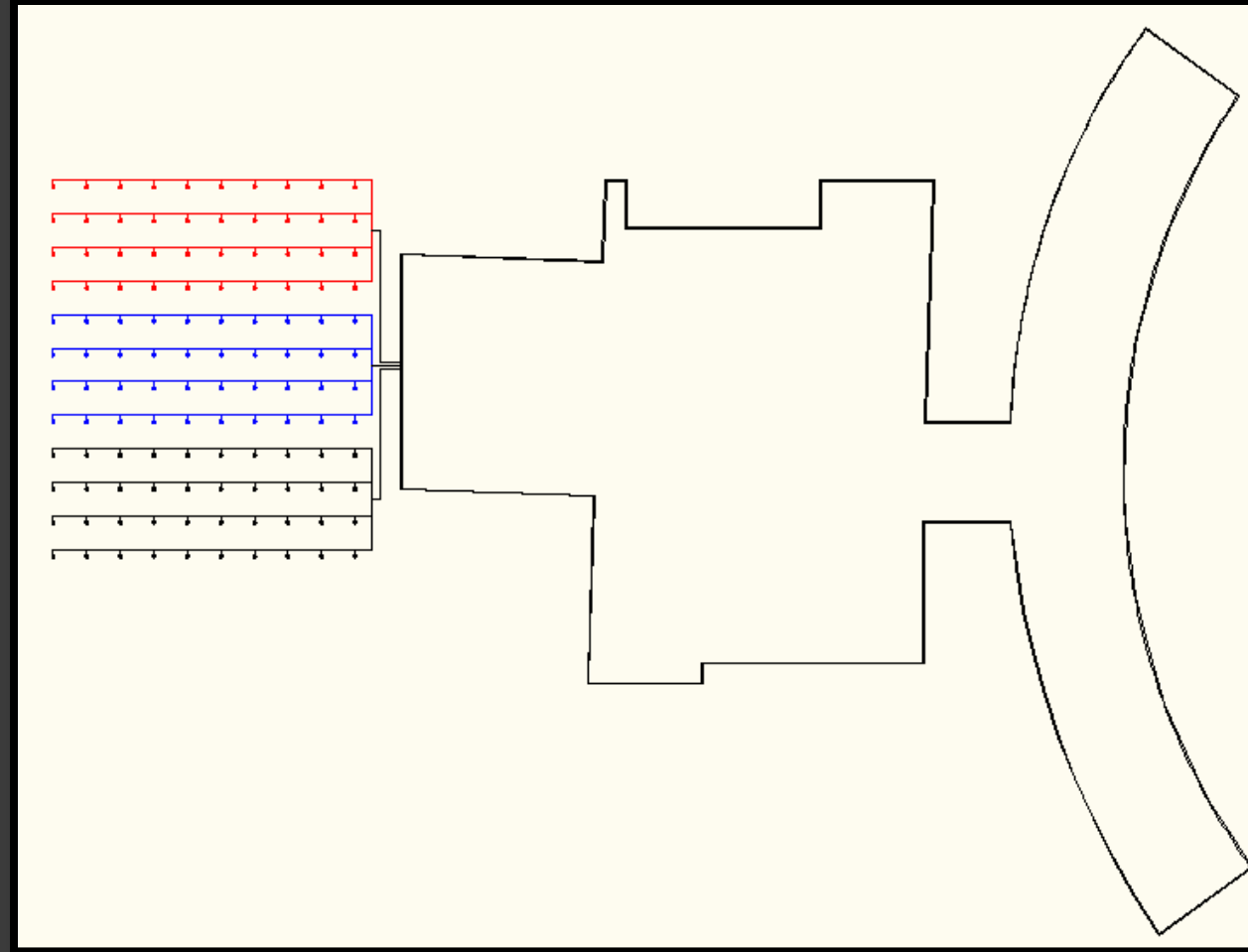
AHU Set 2 @ 600 ft

26 x 27



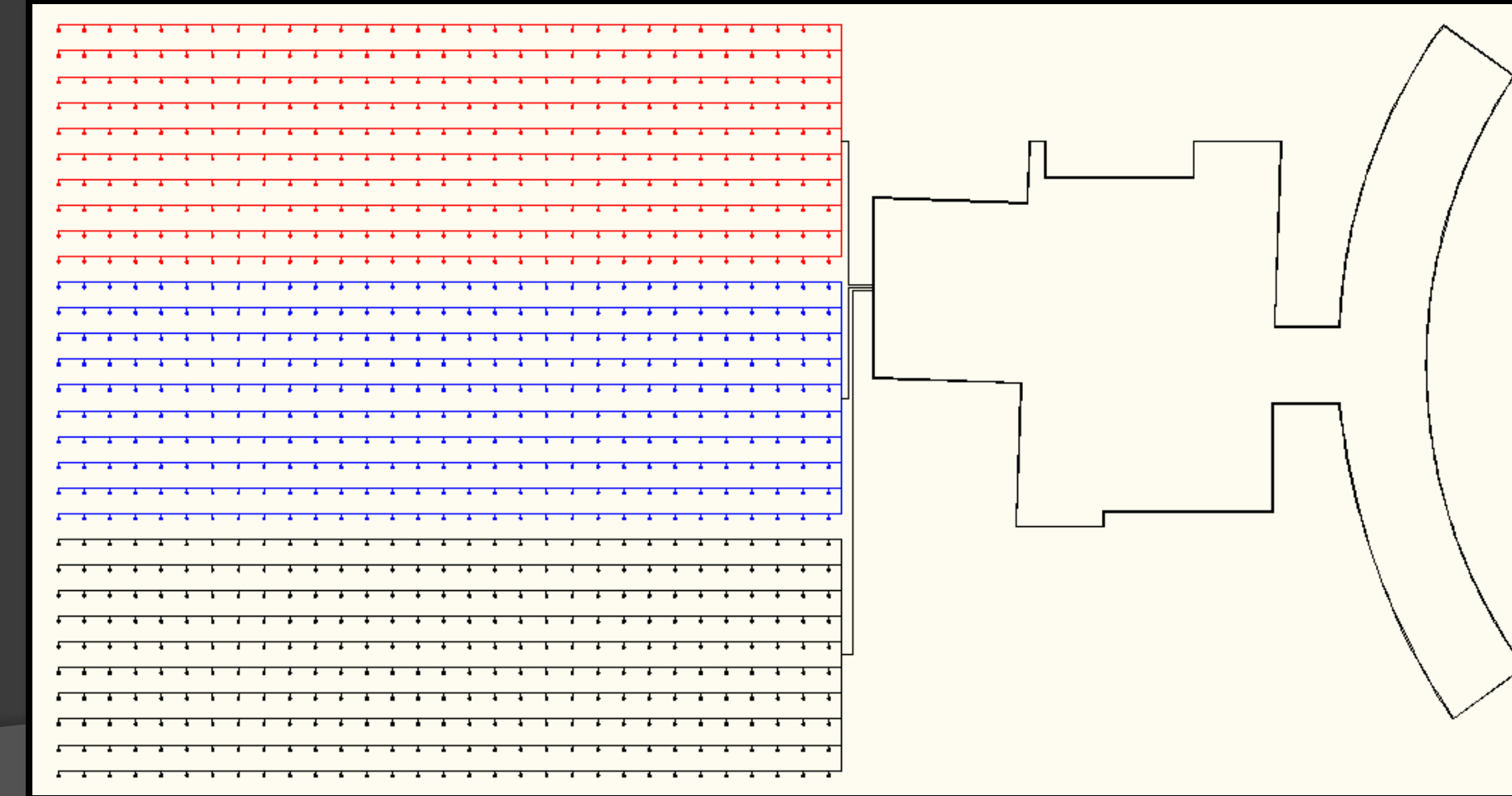
AHU Set 1 @ 600 ft

10 x 12



AHU Set 3 @ 1000 ft

31 x 30



Pump Selection

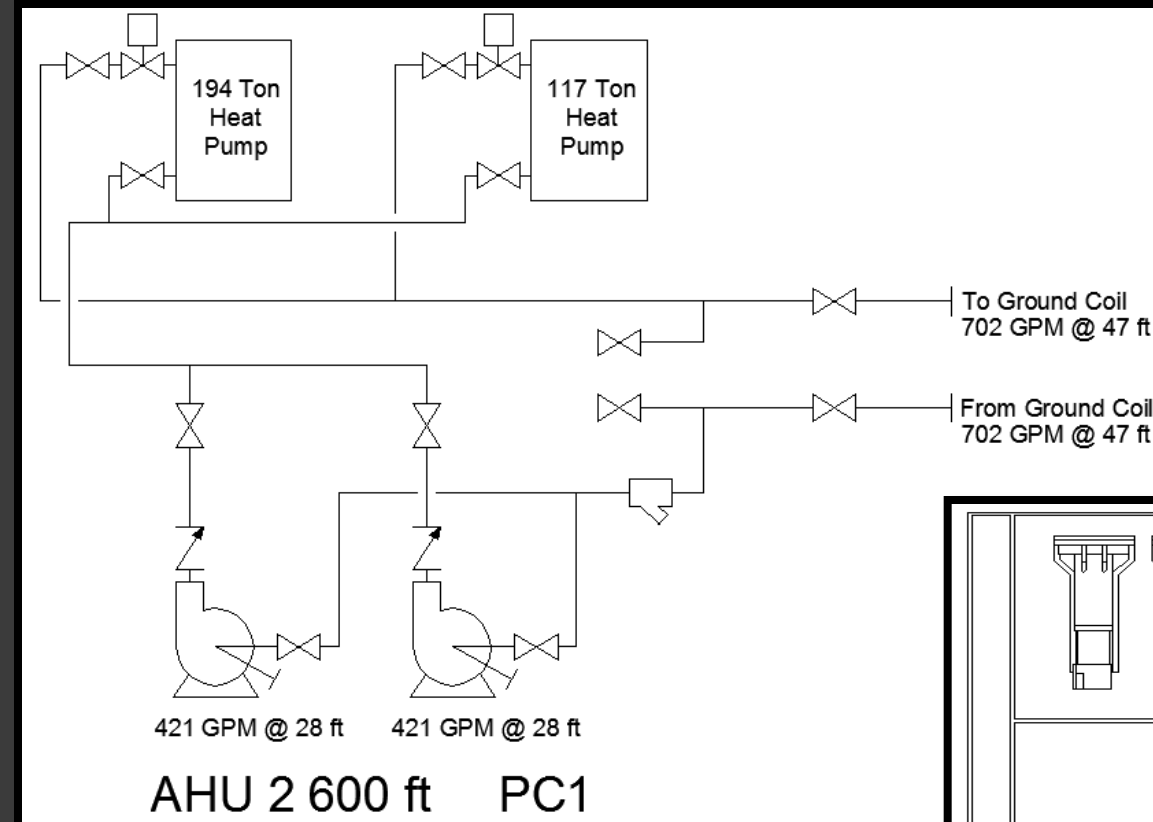
AHU 2 @ 600 ft

AHU 2 600 ft		Pump				
Branch	GPM	Head (ft)	HP	Efficiency	\dot{W}_{pump} (KW)	W (KWh)
1	421	28	5	82.5	4.52	39606
	421	28	5	82.5	4.52	39606
2	421	28	5	82.5	4.52	39606
	421	28	5	82.5	4.52	39606
3	421	28	5	82.5	4.52	39606
	421	28	5	82.5	4.52	39606
Total						237635

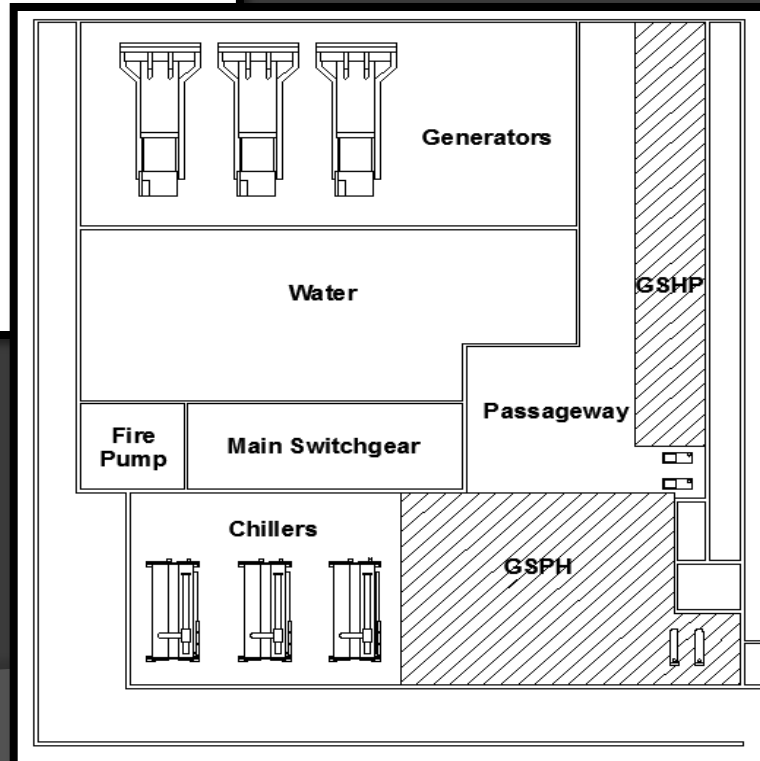
Pumping Efficiency	
W/ton	Grade
50 or less	A - Excellent
50 to 75	B - Good
75 to 100	C - Mediocre
100 to 150	D - Poor
>150	F - Bad

Pump Efficiencies				
	W	Ton	W/ton	Grade
Option 1	6420	365	18	A
Option 2	3420	365	9	A
Option 3	27120	696	39	A
Option 4	17640	696	25	A
Option 5	26940	1064	25	A

System Design



CUP Schematic



CUP

AHU 1

AHU 2

AHU 3

Heat Pump Selection

Heat Pump								
Capacity	COP	EER	Cooling (KW)	hrs	Heating (KW)	hrs	\dot{W}_c (KWh)	\dot{W}_h (KWh)
60	3.4	18.4	38.2	4000	56.5	1400	152800	79100
60	3.4	18.4	38.2	4000	56.5	1400	152800	79100
60	3.4	18.4	38.2	4000	56.5	1400	152800	79100
60	3.4	18.4	38.2	4000	56.5	1400	152800	79100
60	3.4	18.4	38.2	4000	56.5	1400	152800	79100
60	3.4	18.4	38.2	4000	56.5	1400	152800	79100
Total							916800	474600

Heat Pump								
Capacity	COP	EER	Cooling (KW)	hrs	Heating (KW)	hrs	\dot{W}_c (KWh)	\dot{W}_h (KWh)
194	3.5	19.4	120.2	4000	187.2	1200	480800	224640
194	3.5	19.4	120.2	4000	187.2	1200	480800	224640
194	3.5	19.4	120.2	4000	187.2	1200	480800	224640
117	3.4	18.4	76.4	4000	113	1200	305600	135600
Total							1748000	809520

Heat Pump								
Capacity	COP	EER	Cooling (KW)	hrs	Heating (KW)	hrs	\dot{W}_c (KWh)	\dot{W}_h (KWh)
118	3.4	18.4	76.4	4000	113	1200	305600	135600
118	3.4	18.4	76.4	4000	113	1200	305600	135600
118	3.4	18.4	76.4	4000	113	1200	305600	135600
118	3.4	18.4	76.4	4000	113	1200	305600	135600
118	3.4	18.4	76.4	4000	113	1200	305600	135600
118	3.4	18.4	76.4	4000	113	1200	305600	135600
118	3.4	18.4	76.4	4000	113	1200	305600	135600
118	3.4	18.4	76.4	4000	113	1200	305600	135600
118	3.4	18.4	76.4	4000	113	1200	305600	135600
Total							2750400	1220400

Drilling/Pipe

Drilling

Ground Loop Installation Costs / ft bore			
U Tube Dia	Mud Rotary Clay	Mud Rotary Soft Rock	Air Hammer
1 1/2"	\$4.75 - \$6.00	\$5.50 - \$6.75	\$6.00 - \$10.00

Drilling Cost				
	Depth (ft)	# Boreholes	\$/Borehole	Total
AHU 1	300	241	1750	\$ 421,750.00
AHU 1	600	120	3850	\$ 462,000.00
AHU 2	600	802	3850	\$ 3,087,700.00
AHU 2	1000	419	6650	\$ 2,786,350.00
AHU 3	1000	936	6650	\$ 6,224,400.00



Pipe

Pipe Cost	
Pipe	Cost/ft
1"	0.56
1.25"	0.88
1.5"	0.97
2"	1.3
2.5"	2.25
3"	2.65
4"	3.81
5"	4.5
6"	6.69
8"	8.99

Pipe Cost			
Option	System	Depth	Cost
Option 1	AHU 1	300	\$ 94,269.00
Option 2	AHU 1	600	\$ 86,113.00
Option 3	AHU 2	600	\$ 521,334.00
Option 4	AHU 2	1000	\$ 489,465.00
Option 5	AHU 3	1000	\$ 1,081,669.00

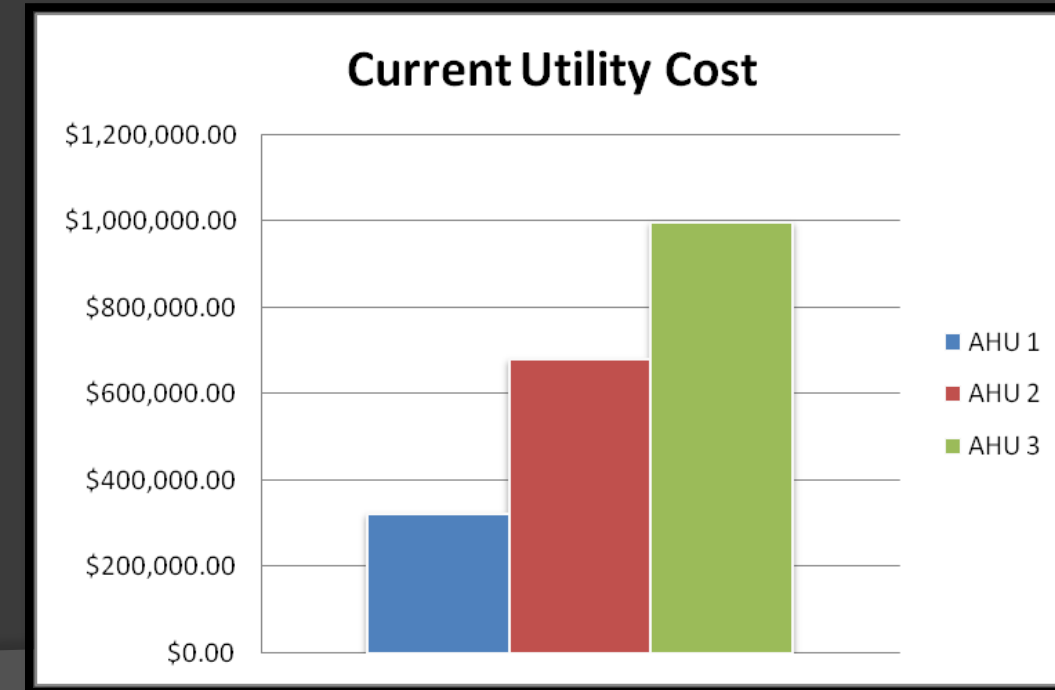


Current Annual Utility Cost

AHU 1 – 1,191,188 KWh / 143,244 therms
-\$325,000 annual utility cost

AHU 2 – 2,382,376 KWh / 286,435 therms
-\$682,435 annual utility cost

AHU 3 – 3,700,000 KWh / 465,500 therms
-\$1,000,000 annual utility cost



GSHP Annual Utility Cost

Option 1 - AHU 1 @ 300 ft

Energy Cost							
Pump			Heat Pump			Total	
W (kWh)	\$/kWh	Cost (\$)	W (kWh)	\$/kWh	Cost (\$)	W (kWh)	Cost (\$)
56014	0.13	7281.82	1391400	0.13	180882	1447414	\$188,163.82

Option 2 - AHU 1 @ 600 ft

Energy Cost							
Pump			Heat Pump			Total	
W (kWh)	\$/kWh	Cost (\$)	W (kWh)	\$/kWh	Cost (\$)	W (kWh)	Cost (\$)
29704	0.13	3861.52	1391400	0.13	180882	1421104	\$184,743.52

Option 3 - AHU 2 @ 600 ft

Energy Cost							
Pump			Heat Pump			Total	
W (kWh)	\$/kWh	Cost (\$)	W (kWh)	\$/kWh	Cost (\$)	W (kWh)	Cost (\$)
237653	0.13	30894.89	2557520	0.13	332477.6	2795173	\$363,372.49

Option 4 - AHU 2 @ 1000 ft

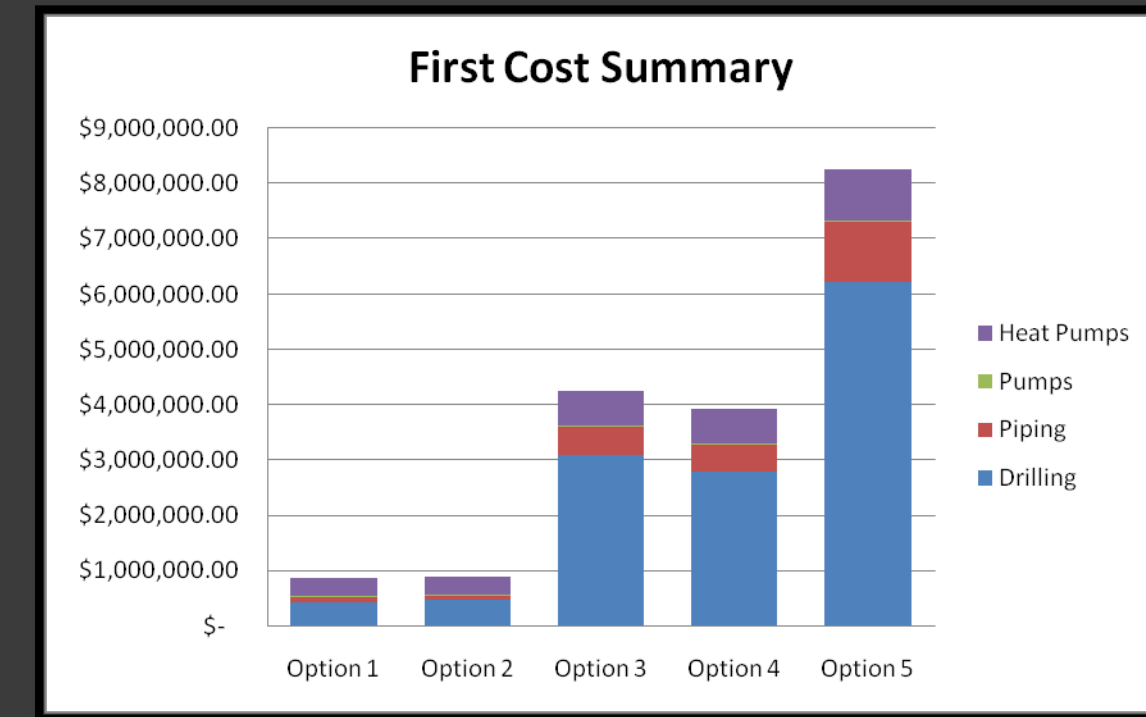
Energy Cost							
Pump			Heat Pump			Total	
W (kWh)	\$/kWh	Cost (\$)	W (kWh)	\$/kWh	Cost (\$)	W (kWh)	Cost (\$)
153453	0.13	19948.89	2557520	0.13	332477.6	2710973	\$352,426.49

Option 5 - AHU 3 @ 1000 ft

Energy Cost							
Pump			Heat Pump			Total	
W (kWh)	\$/kWh	Cost (\$)	W (kWh)	\$/kWh	Cost (\$)	W (kWh)	Cost (\$)
236203	0.13	30706.39	3970800	0.13	516204	4207003	\$546,910.39

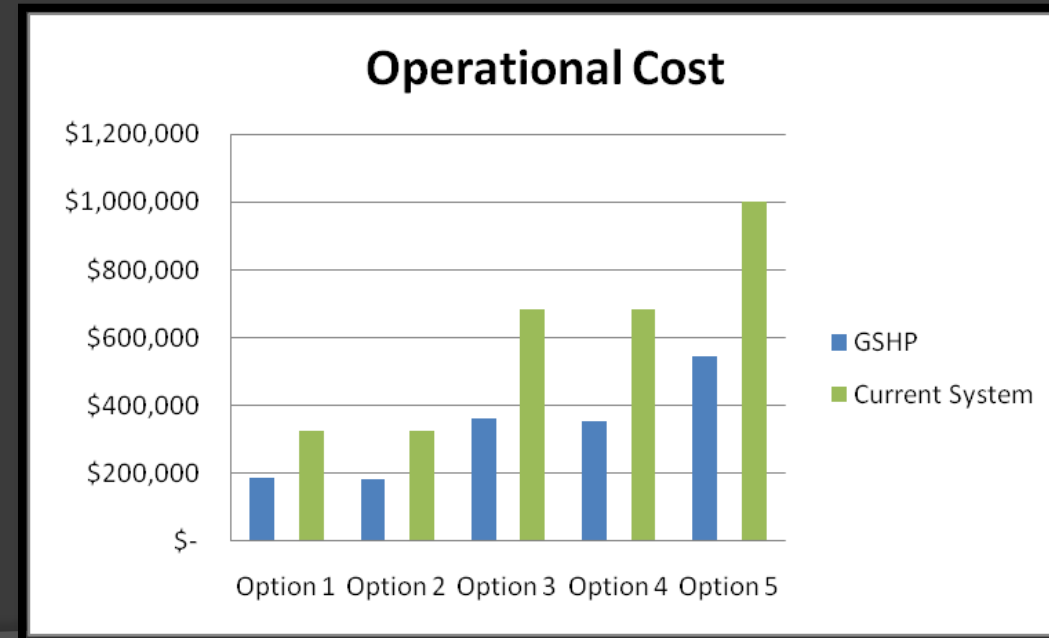
First Cost

Total First Cost					
	Drilling	Piping	Pumps	Heat Pumps	Total
Option 1	\$ 421,750.00	\$ 94,269.00	\$13,398.00	\$324,000.00	\$ 853,417.00
Option 2	\$ 462,000.00	\$ 86,113.00	\$12,000.00	\$324,000.00	\$ 884,113.00
Option 3	\$ 3,087,700.00	\$ 521,334.00	\$14,202.00	\$629,100.00	\$ 4,252,336.00
Option 4	\$ 2,786,350.00	\$ 489,465.00	\$14,202.00	\$629,100.00	\$ 3,919,117.00
Option 5	\$ 6,224,400.00	\$ 1,081,669.00	\$14,202.00	\$947,700.00	\$ 8,267,971.00



Annual Utility Savings

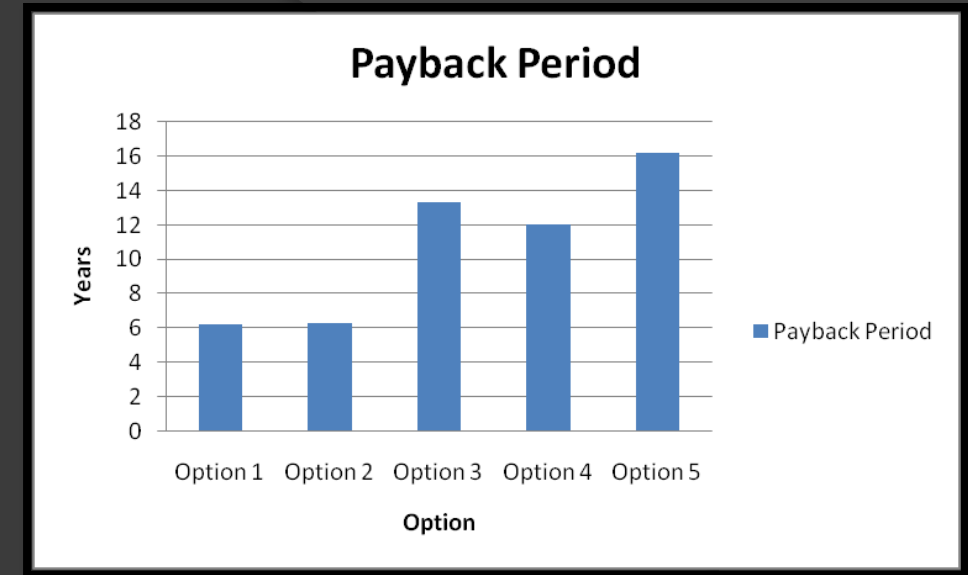
Option 1 AHU 1 @300 ft – \$ 137,000 42%
 Option 2 AHU 1 @600 ft – \$ 140,000 43%
 Option 3 AHU 2 @600 ft – \$ 319,000 47%
 Option 4 AHU 2 @1000 ft – \$ 330,000 48%
 Option 5 AHU 3 @1000 ft – \$ 500,000 50%



Payback Period / Life Cycle

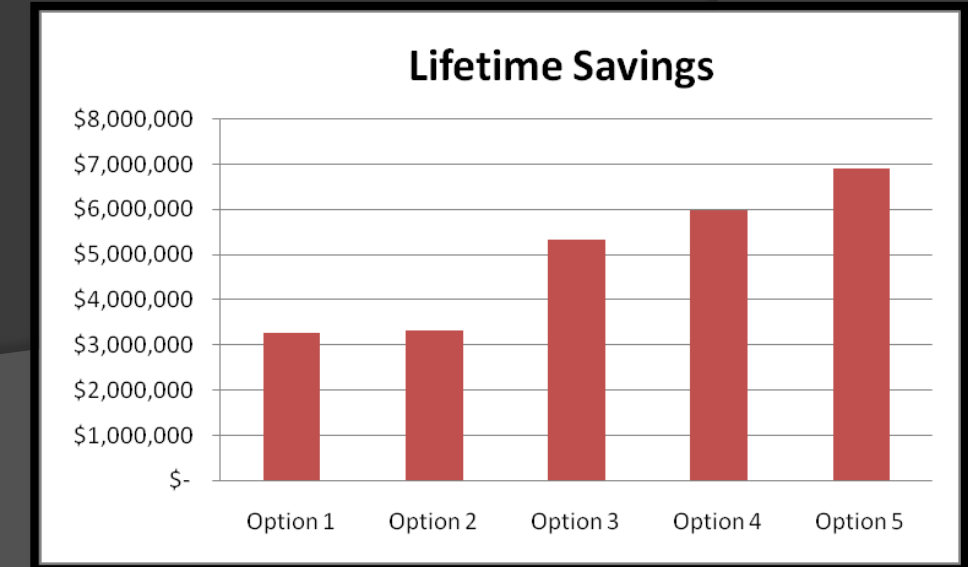
Payback

Option 1 – 6.2 yrs
 Option 2 – 6.3 yrs
 Option 3 – 13.3 yrs
 Option 4 – 12 yrs
 Option 5 – 16.2 yrs



Life Cycle – 30 years

Option 1 – \$3,260,600
 Option 2 – \$3,318,000
 Option 3 – \$5,327,300
 Option 4 – \$6,000,000
 Option 5 – \$6,900,000



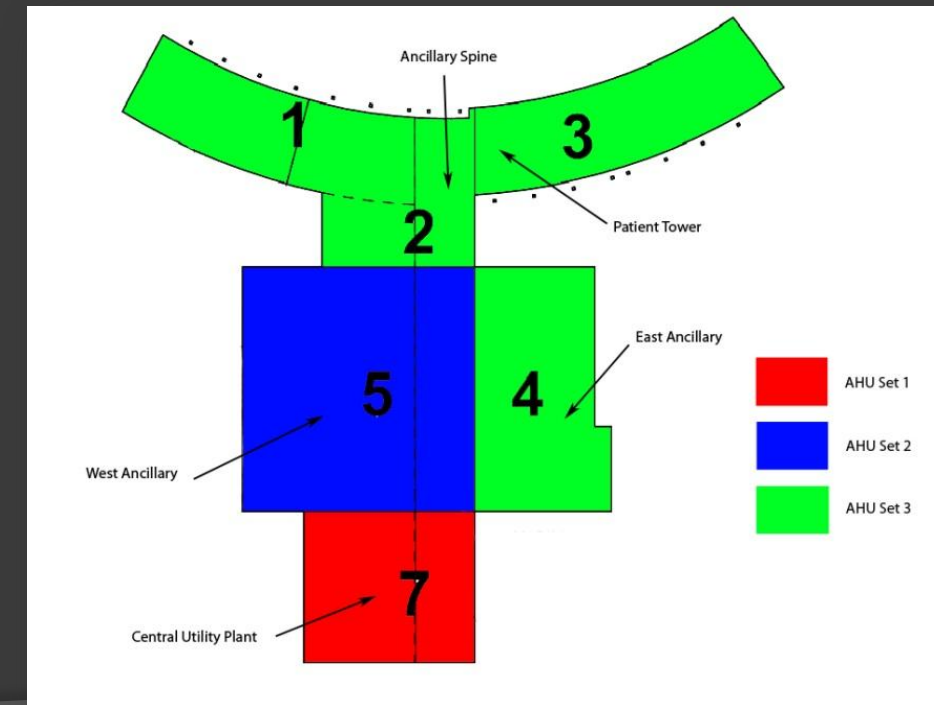
Outdoor Air Study

Outdoor Air Redesign							
Room	Max OA at Max SA	Max SA	OA at Min SA	Min SA	Occupants	Sq Ft	Min ASHRAE OA
MS Dir Office	200	400	100	512	2	138	18
APN Office	40	0	0	0	2	119	17
Consult	60	0	0	0	3	89	20
Asst Nurse Mgr Office	40	0	0	0	2	106	16
Consult	25	75	0	90	3	86	20
Asst Nurse Mng Office	60	600	60	600	3	113	22
PEDS MED Director	40	255	40	255	2	102	16
Tech Work	60	0	0	0	3	193	27
Physician Charting	60	0	0	0	3	108	21
Register Supr Office	40	0	0	0	2	101	16

Total – 172 Rooms

Occupancy – 5cfm/person

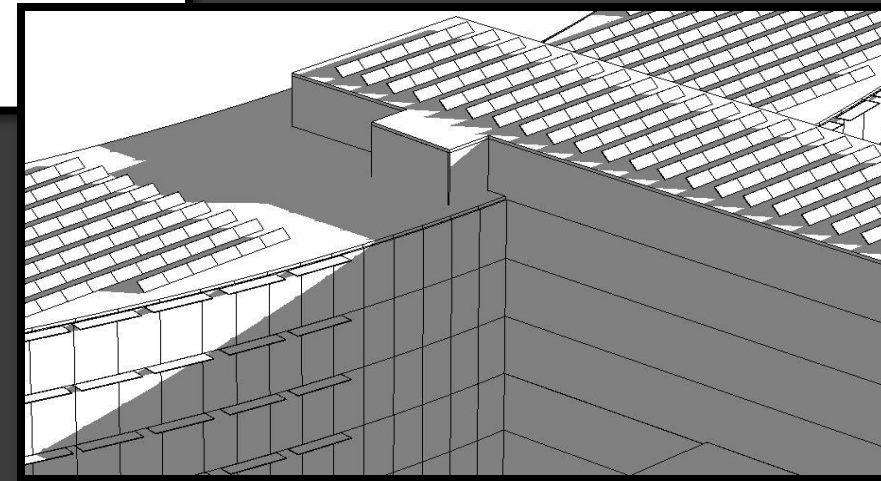
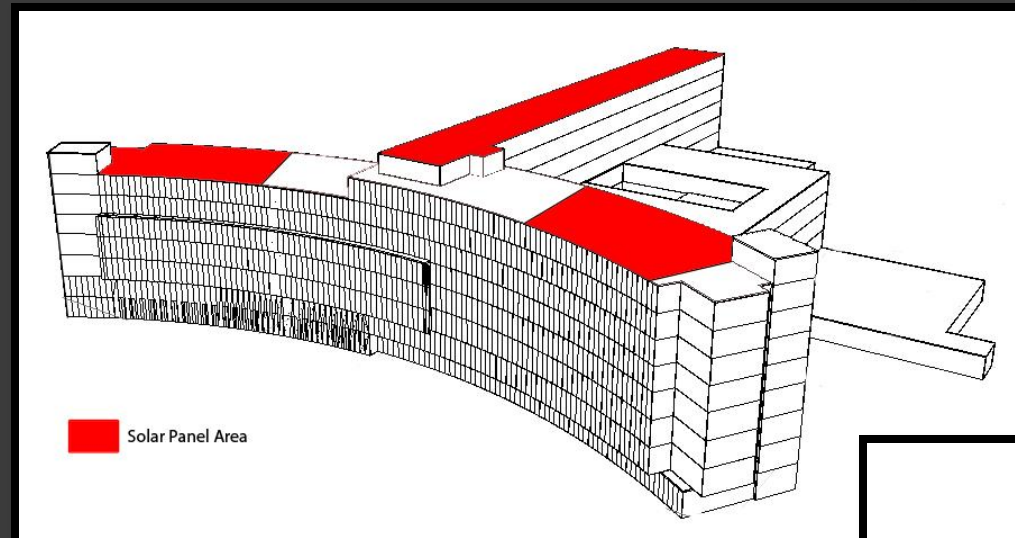
Area - .06 cfm/ft²



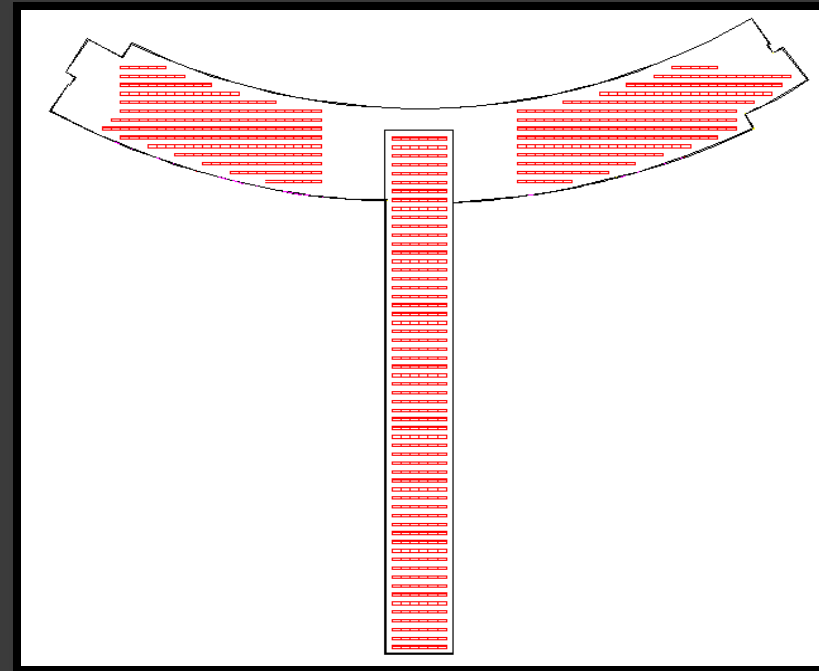
Energy Use			
	KWh	Therms	Savings
IMC	22,212,000	1,533,000	\$20,000.00
ASHRAE	22,199,000	1,533,000	



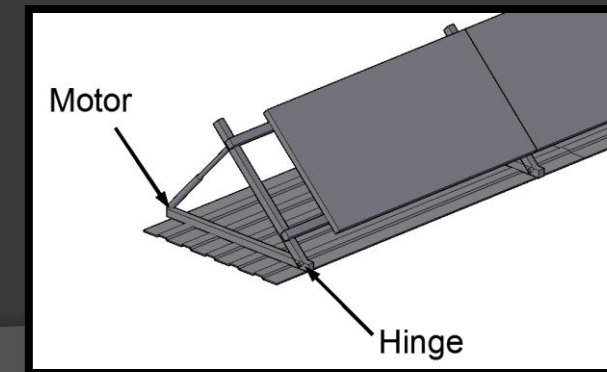
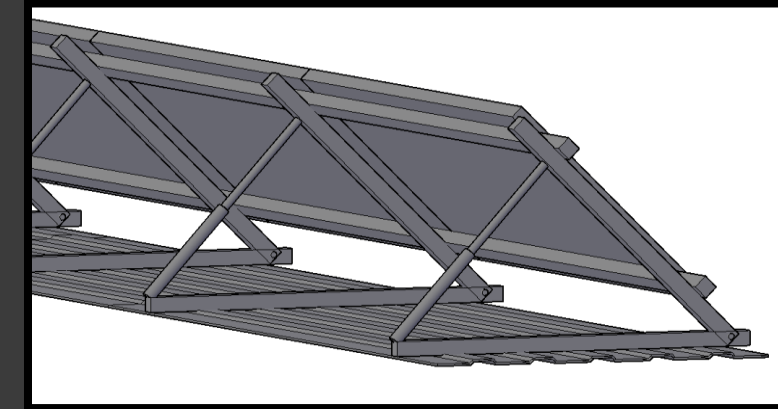
PV Panel Array



PV Panels

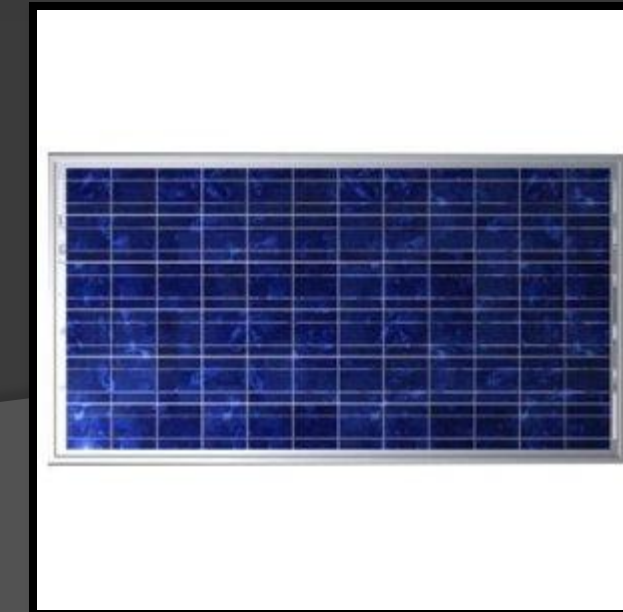


Total Panel Area – 19,400 ft²



	Jan	Feb	Mar	Apr	May	Jun	Units
Solar Energy	3152.64	3233.36	3719.27	3157.11	2507.13	1975.75	KW
	Jul	Aug	Sep	Oct	Nov	Dec	Units
Solar Energy	2233.34	2949.50	3493.59	3685.22	3185.45	3000.70	KW
	Total (KW)						36293.07

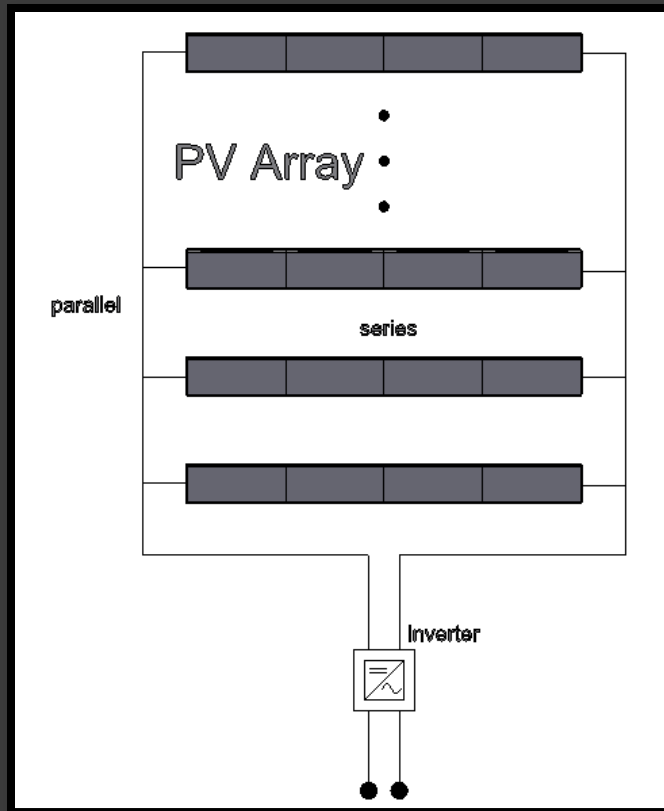
Panel Power	280	W	275	W	270	W	265	W
Efficiency	0.144		0.1417		0.1392		0.1366	
Absorbed Energy	5226.20	KW	5142.73	KW	5051.99	KW	4957.63	KW
Savings	32925.07	\$	32399.18	\$	31827.57	\$	31233.09	\$
Panel Price Total	666436	\$	654160	\$	642668	\$	630292	\$
Payback Period	20.241	yr	20.191	yr	20.192	yr	20.180	yr



Model	Peak Power (Pmp)	Vmp	Imp	Voc	Isc
ET-P672265	265	36.4	7.28	43.63	7.9

PV Panels

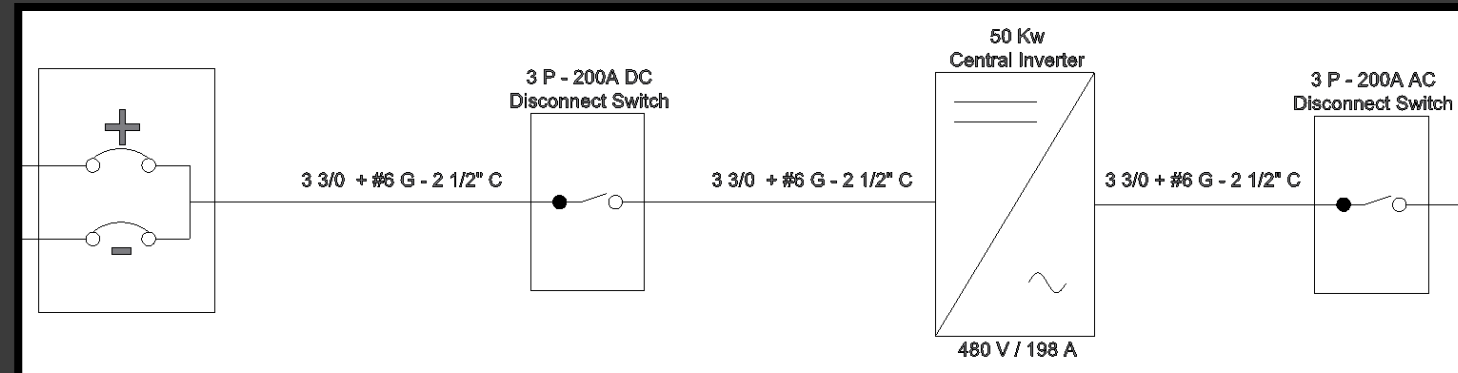
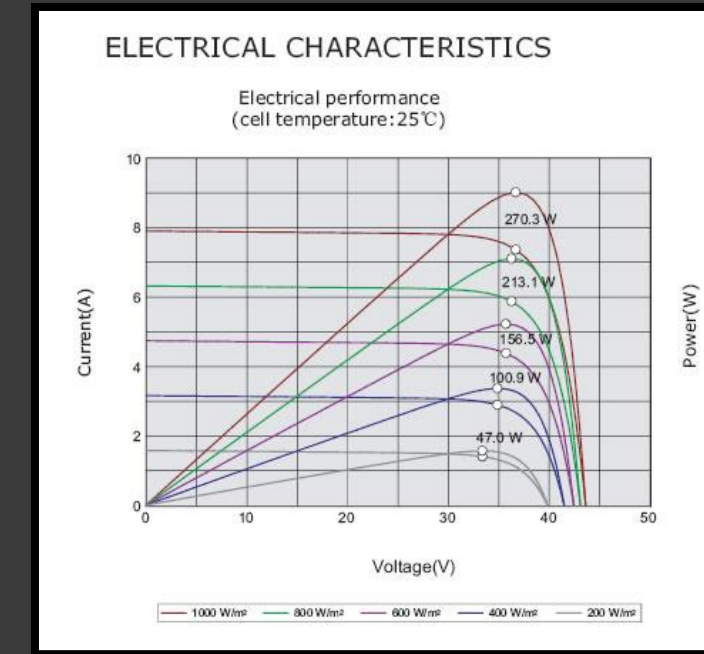
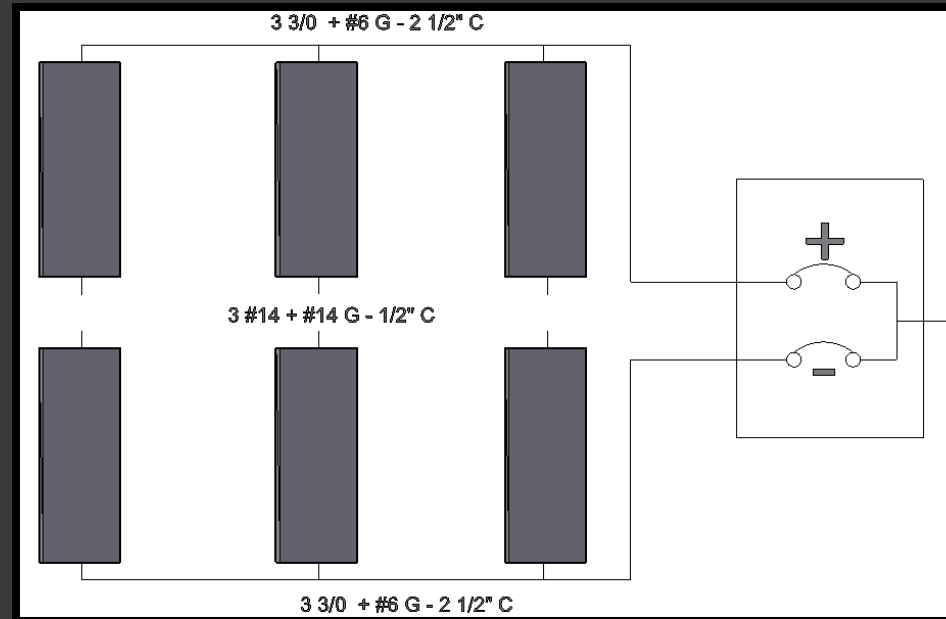
Cost



East Wing		251 Panels				
Panel Properties		Arrangement		Max Conditions		
Voc	Isc	Adjusted Voc	Series	Parallel	Voltage (V)	Current (A)
43.63	7.9	49.7	10	25	497	198
43.63	7.9	49.7	17	15	846	119
43.63	7.9	49.7	11	23	547	182

Main Spine		354 Panels				
Panel Properties		Arrangement		Max Conditions		
Voc	Isc	Adjusted Voc	Series	Parallel	Voltage (V)	Current (A)
43.63	7.9	49.7	12	29	597	229
43.63	7.9	49.7	6	59	298	466
43.63	7.9	49.7	10	36	497	284

West Wing		279 Panels				
Panel Properties		Arrangement		Max Conditions		
Voc	Isc	Adjusted Voc	Series	Parallel	Voltage (V)	Current (A)
43.63	7.9	49.7	12	24	597	190
43.63	7.9	49.7	17	20	846	158
43.63	7.9	49.7	13	23	647	182



Cost - \$713/panel x 884 panels = \$630,292

100 KW Inverter = \$41,000

2 50 KW Inverter = \$52,000

Total First Cost = \$750,000

Federal Incentives = 30%

New First Cost = \$525,000

Annual Energy Savings = \$32,000

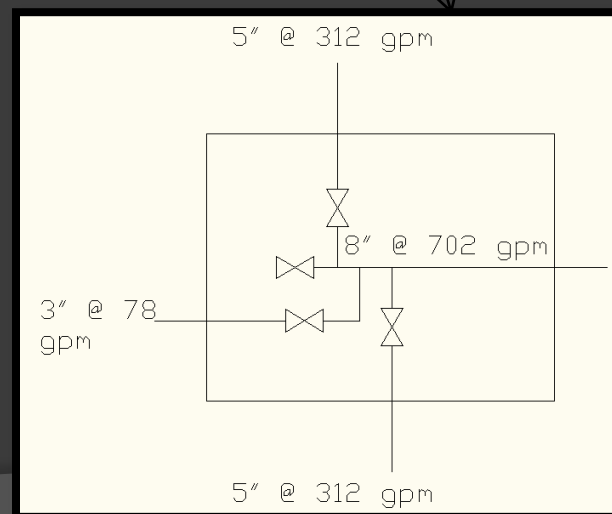
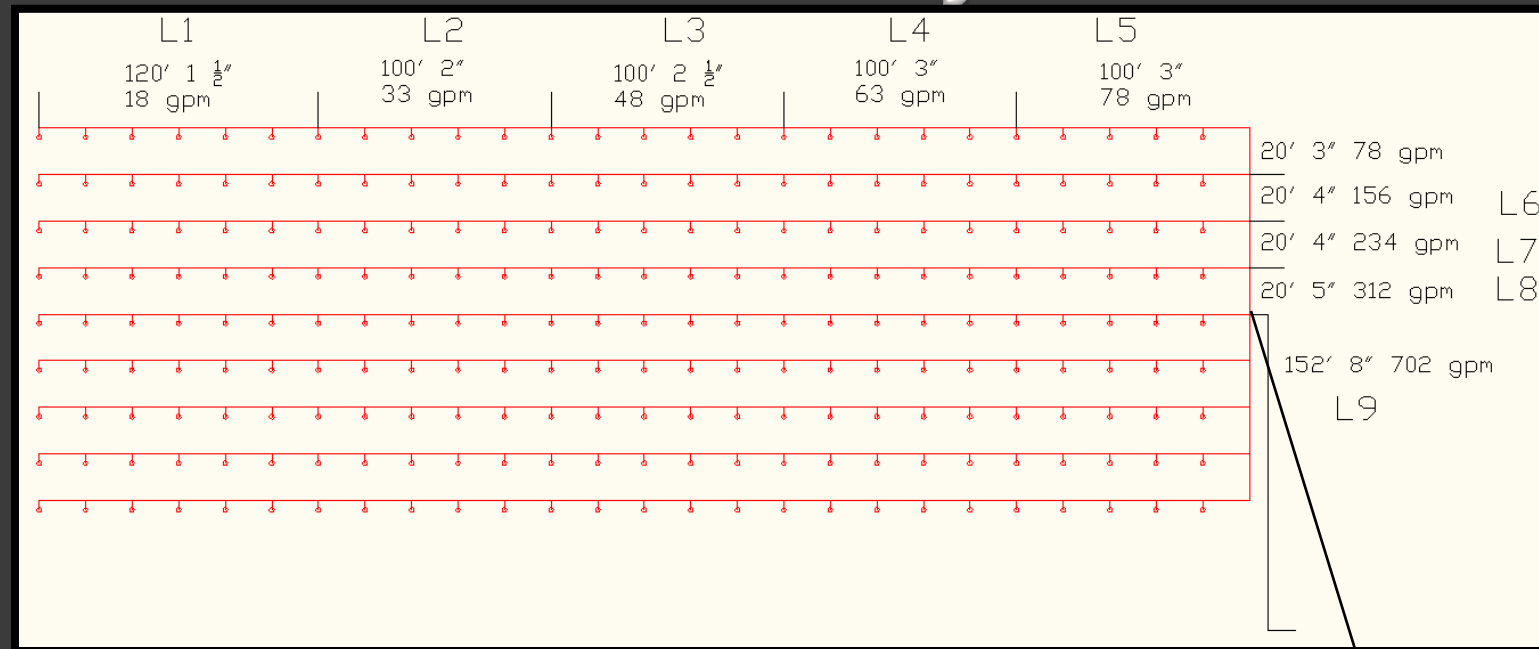
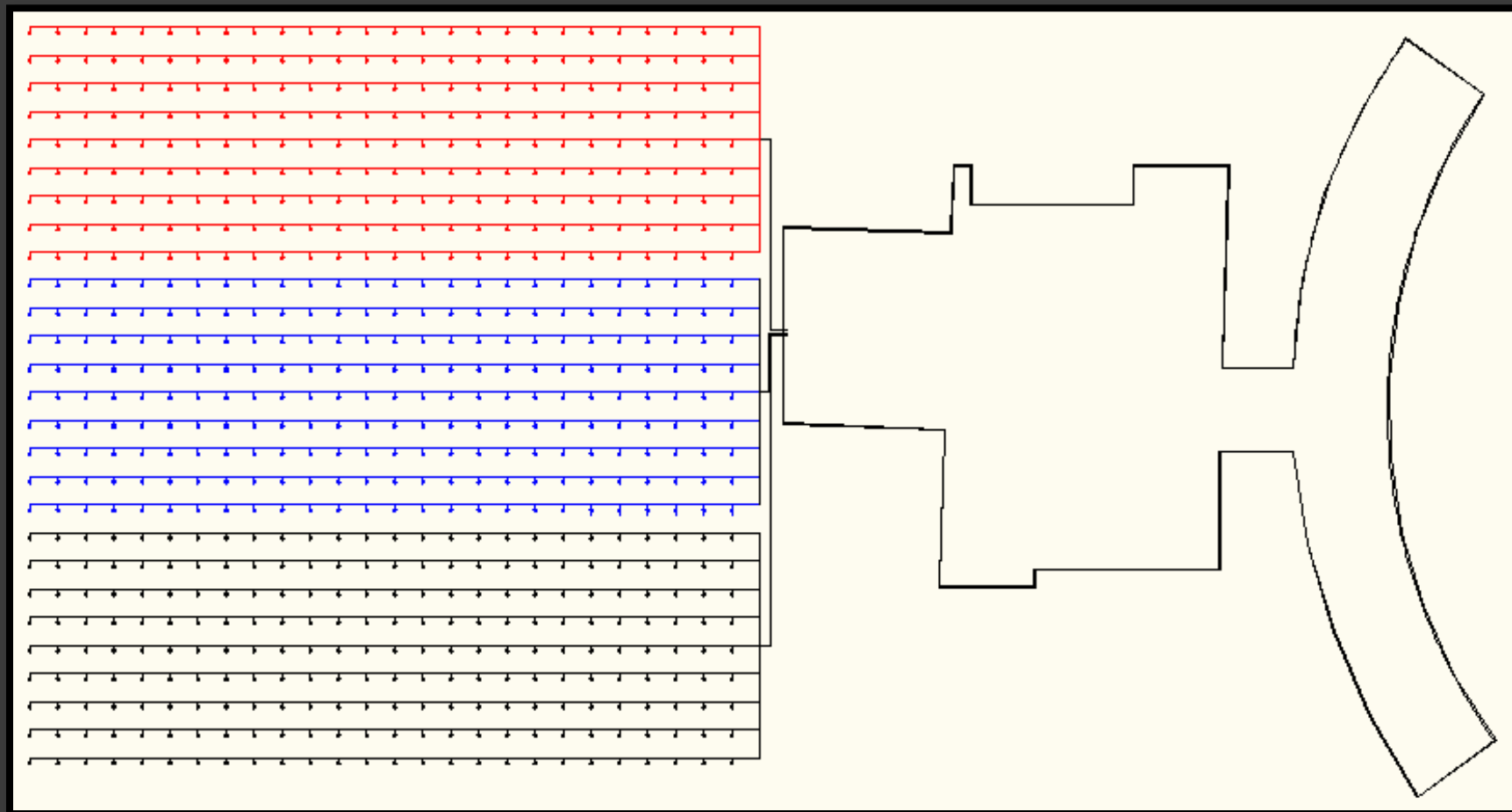
Simple Payback Period = 16 – 17 years

Questions ?



GSHP Layout

AHU Set 2 @ 600 ft
26 x 27



Head Loss Calcs.

Section	Fitting	KF _t	Size	F _t	K	L _{eq}
U tube	-	-	-	-	-	22
L5	90° Bend	30	3	0.018	0.54	16
L6	ST Run	20	4	0.017	0.34	14
L7	ST Run	20	4	0.017	0.34	14
L8	ST Run	20	5	0.016	0.32	18
L8	ST Branch	60	5	0.016	0.96	50
L8	Gate Valve	8	5	0.016	0.128	64
L9	ST Run	20	8	0.014	0.28	28
L9	ST Branch	60	8	0.014	0.84	80
L9	90° Bend	30	8	0.014	0.42	40
L9	90° Bend	30	8	0.014	0.42	40

Section	Length	Size	GPM	Head Loss ft/100 ft	Eq. Length	Head Loss
Utube	1200	1	3	0.7	1222	8.554
L1	240	1.5	18	2.3	240	5.52
L2	200	2	33	1.5	200	3
L3	200	2 1/2	48	1.9	200	3.8
L4	200	3	63	0.9	200	1.8
L5	240	3	78	1.5	256	3.84
L6	40	4	156	1.5	54	0.81
L7	40	4	234	2.7	54	1.458
L8	40	5	312	1.5	172	2.58
L9	304	8	702	0.9	492	4.428
Total						35.79

AHU 1

Heat Pump								
Capacity	COP	EER	Cooling (KW)	hrs	Heating (KW)	hrs	\dot{W}_c (KWh)	\dot{W}_h (KWh)
60	3.4	18.4	38.2	4000	56.5	1400	152800	79100
60	3.4	18.4	38.2	4000	56.5	1400	152800	79100
60	3.4	18.4	38.2	4000	56.5	1400	152800	79100
60	3.4	18.4	38.2	4000	56.5	1400	152800	79100
60	3.4	18.4	38.2	4000	56.5	1400	152800	79100
60	3.4	18.4	38.2	4000	56.5	1400	152800	79100
						Total	916800	474600

Heat Pump								
Capacity	COP	EER	Cooling (KW)	hrs	Heating (KW)	hrs	\dot{W}_c (KWh)	\dot{W}_h (KWh)
105	3.4	18.7	68	4000	100	1400	272000	140000
105	3.4	18.7	68	4000	100	1400	272000	140000
105	3.4	18.7	68	4000	100	1400	272000	140000
52	3.4	18.7	34	4000	50.4	1400	136000	70560
						Total	952000	490560

AHU 2

Heat Pump								
Capacity	COP	EER	Cooling (KW)	hrs	Heating (KW)	hrs	\dot{W}_c (KWh)	\dot{W}_h (KWh)
194	3.5	19.4	120.2	4000	187.2	1200	480800	224640
194	3.5	19.4	120.2	4000	187.2	1200	480800	224640
194	3.5	19.4	120.2	4000	187.2	1200	480800	224640
117	3.4	18.4	76.4	4000	113	1200	305600	135600
						Total	1748000	809520

Heat Pump								
Capacity	COP	EER	Cooling (KW)	hrs	Heating (KW)	hrs	\dot{W}_c (KWh)	\dot{W}_h (KWh)
117	3.4	18.4	76.4	4000	113	1200	305600	135600
117	3.4	18.4	76.4	4000	113	1200	305600	135600
117	3.4	18.4	76.4	4000	113	1200	305600	135600
117	3.4	18.4	76.4	4000	113	1200	305600	135600
117	3.4	18.4	76.4	4000	113	1200	305600	135600
117	3.4	18.4	76.4	4000	113	1200	305600	135600
						Total	1833600	813600

AHU 3

Heat Pump								
Capacity	COP	EER	Cooling (KW)	hrs	Heating (KW)	hrs	\dot{W}_c (KWh)	\dot{W}_h (KWh)
118	3.4	18.4	76.4	4000	113	1200	305600	135600
118	3.4	18.4	76.4	4000	113	1200	305600	135600
118	3.4	18.4	76.4	4000	113	1200	305600	135600
118	3.4	18.4	76.4	4000	113	1200	305600	135600
118	3.4	18.4	76.4	4000	113	1200	305600	135600
118	3.4	18.4	76.4	4000	113	1200	305600	135600
118	3.4	18.4	76.4	4000	113	1200	305600	135600
118	3.4	18.4	76.4	4000	113	1200	305600	135600
118	3.4	18.4	76.4	4000	113	1200	305600	135600
						Total	2750400	1220400