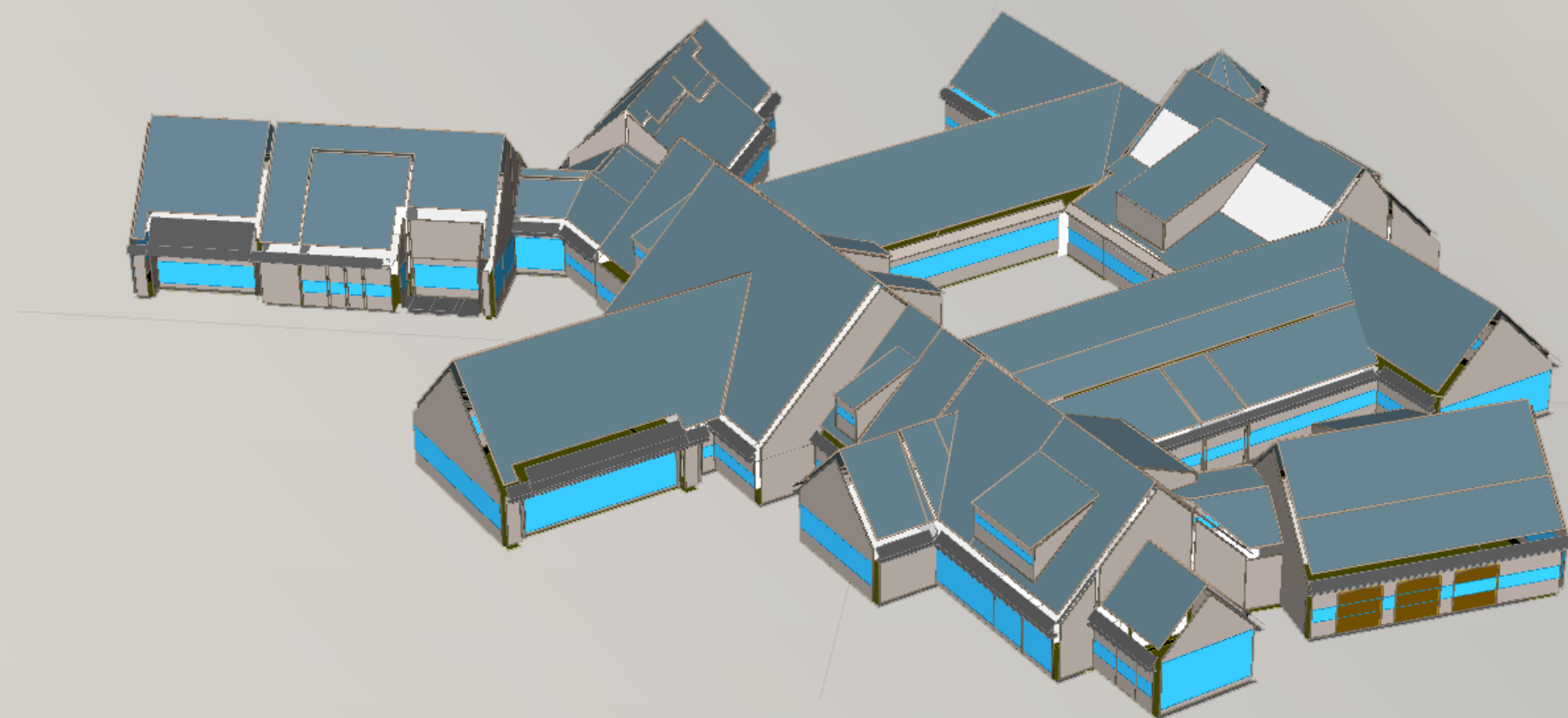


The New RLPS Architects Office Building
Lancaster, PA
Brice Ohl – Mechanical Option
Presented on 4/10/13

Presentation Outline

Project Team

Project Introduction
Existing mechanical systems
Mechanical Depth Study
Construction Breadth Study
Results
Conclusion
Recommendation
Questions



Project Team

Owner & Architects: RLPS Architects Ltd.

General Contractor: Warfel Construction

Mechanical & Electrical Engineers: Reese Engineering Inc.

Structural Engineers: Zug & Associates, Ltd. Structural Engineers.

Civil Engineers: Harbor Engineering

Surveyor: Herbert, Rowland, & Grubic, Inc.

Landscaping: RLPS Architects Ltd.

Presentation Outline

Project Team

Project Introduction

Existing mechanical systems

Mechanical Depth Study

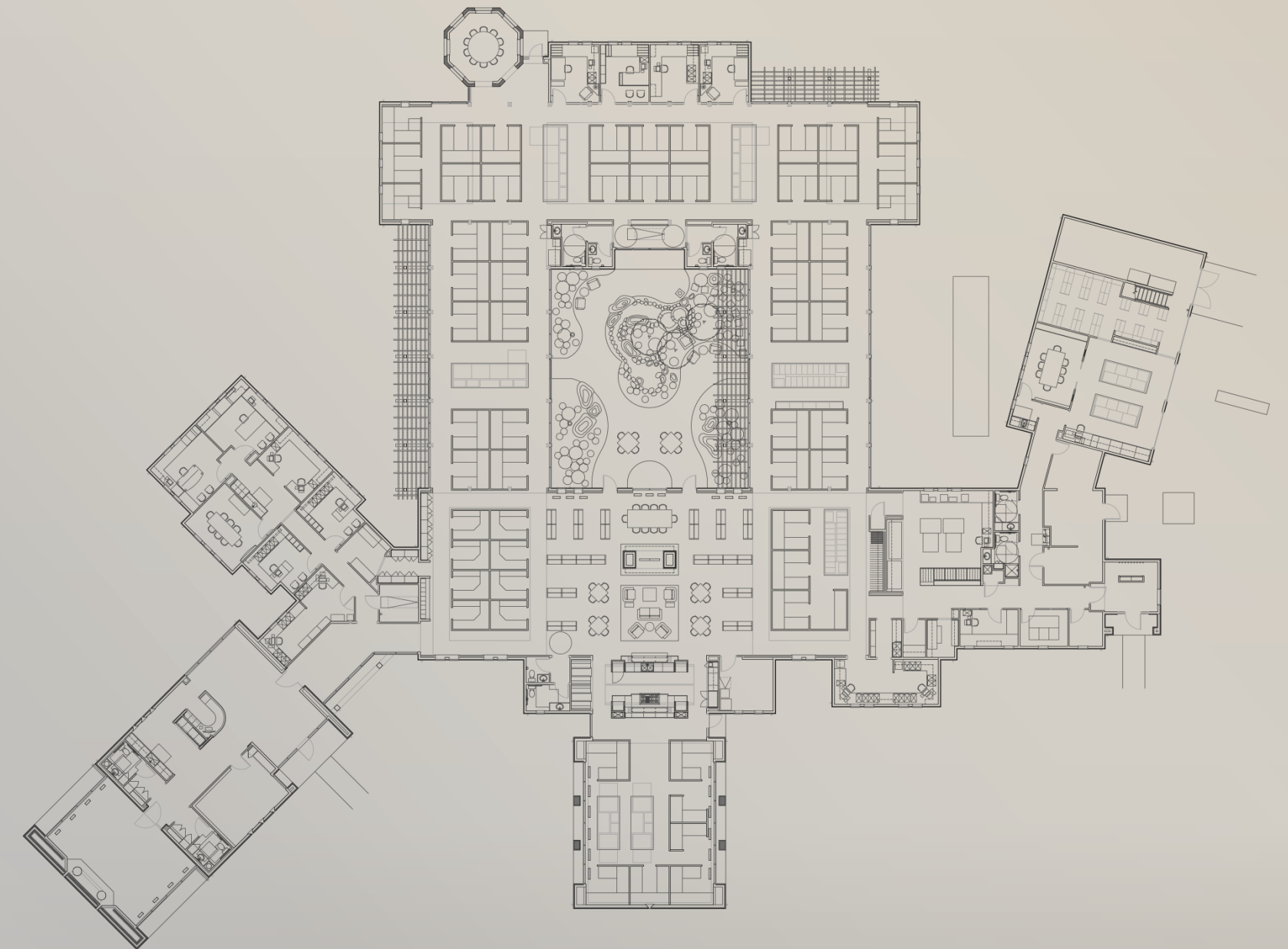
Construction Breadth Study

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Presentation Outline

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- Mechanical Spaces
- Ground Level
- Mezzanine Level
- Well Field Layout
- Summary

Mechanical Depth Study

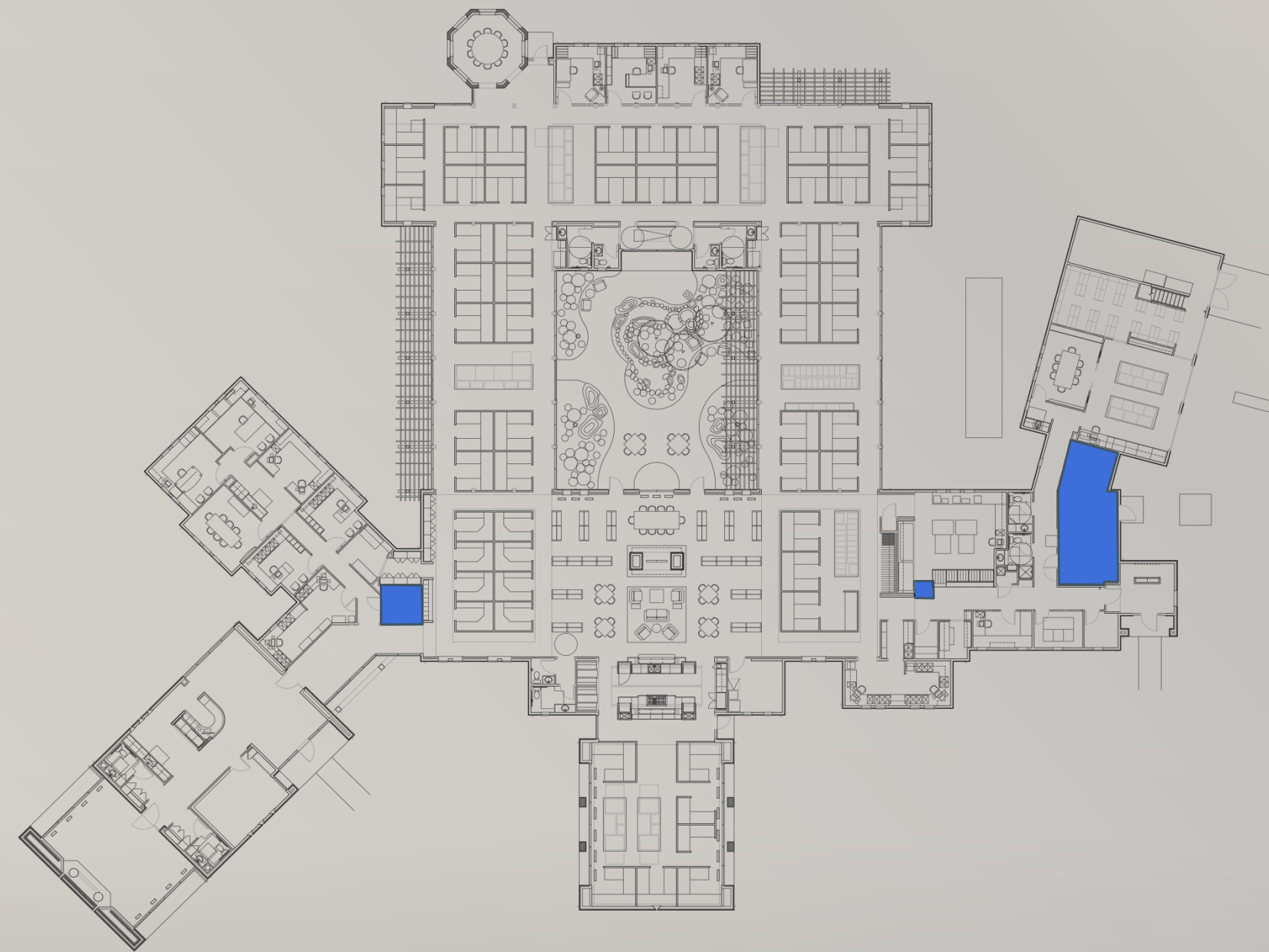
Construction Breadth Study

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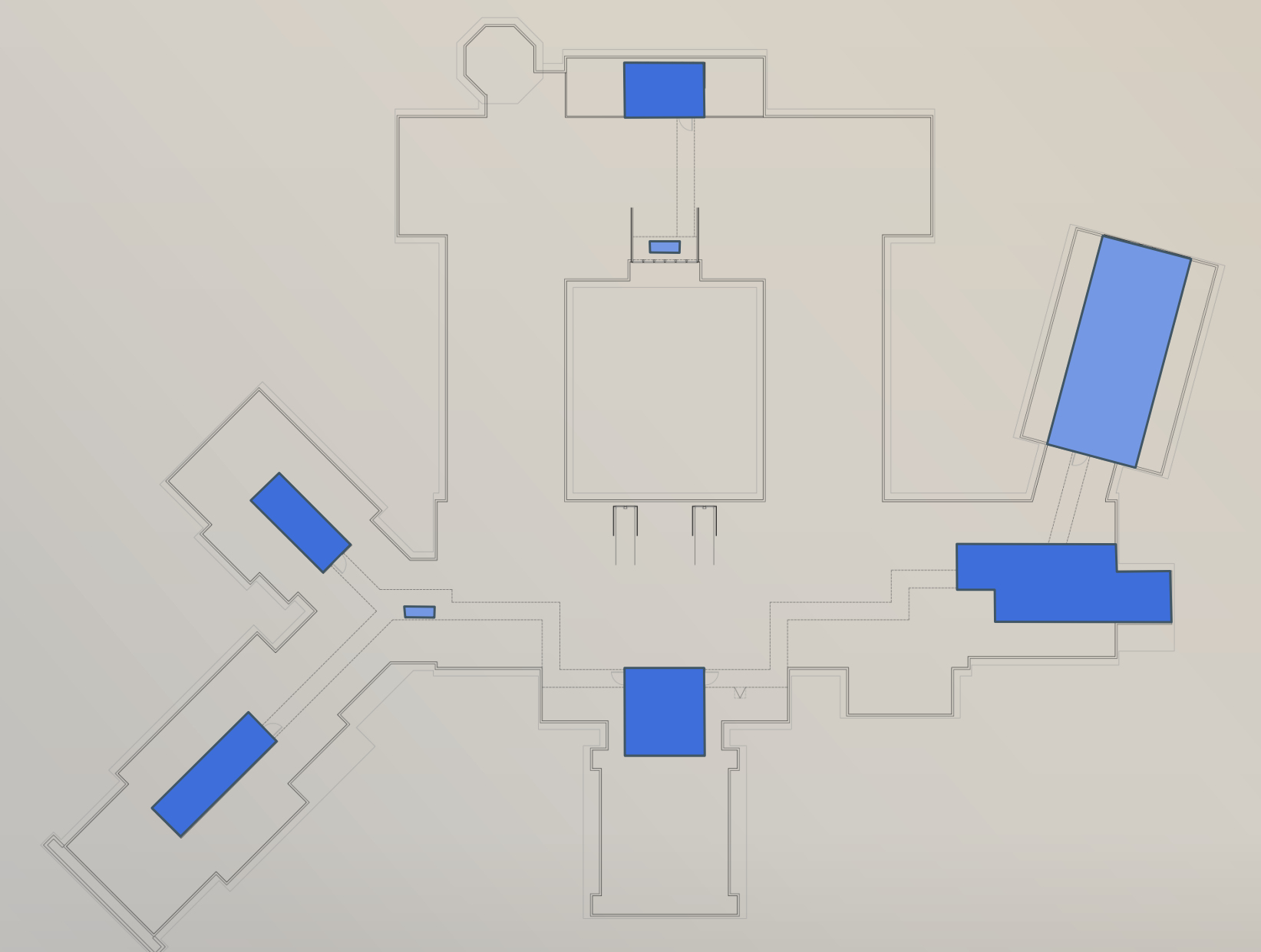
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Ground Level



Mezzanine Level

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- **Ground Level**
- Mezzanine Level
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Mechanical Depth Study

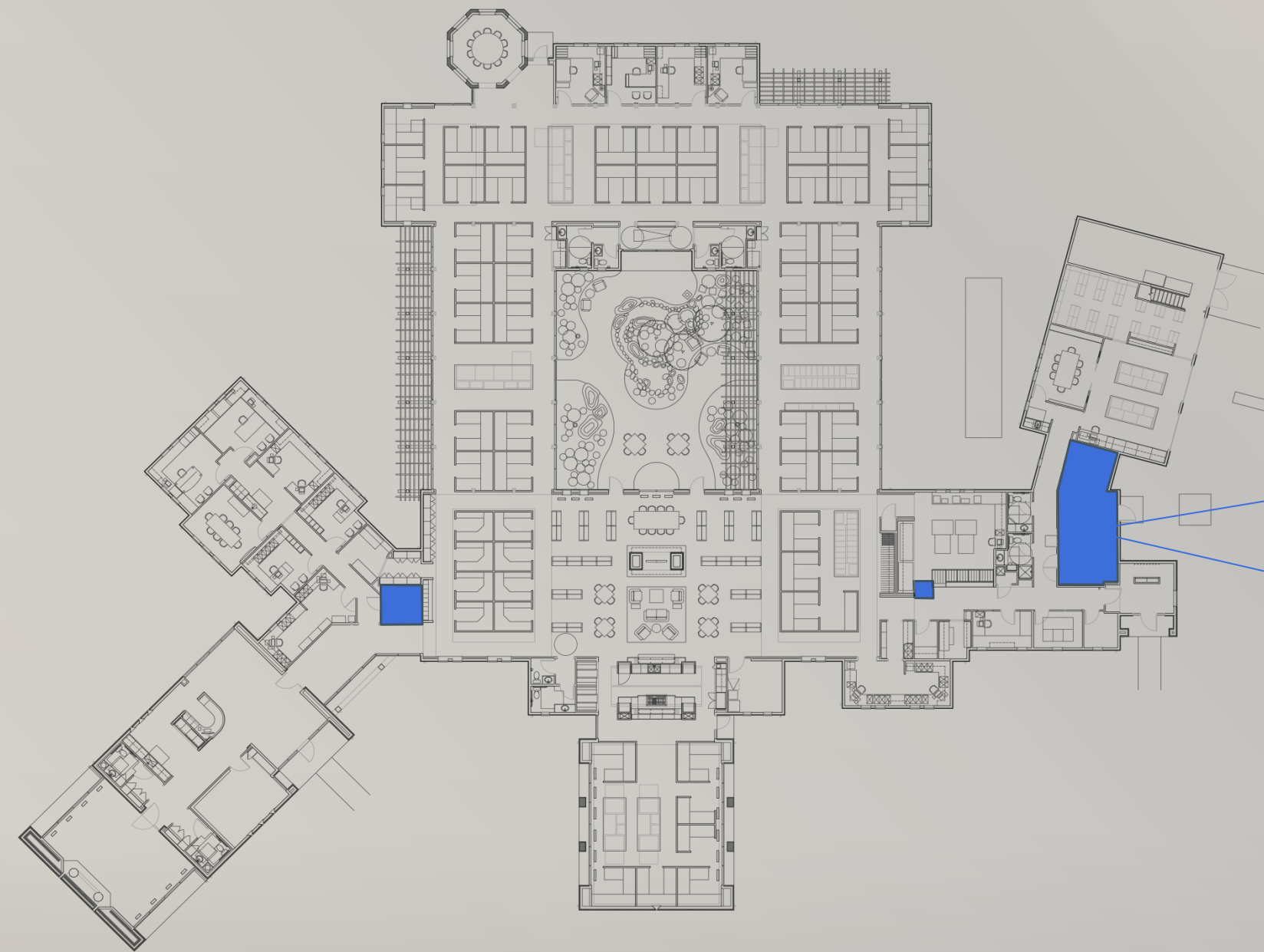
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Ground Level



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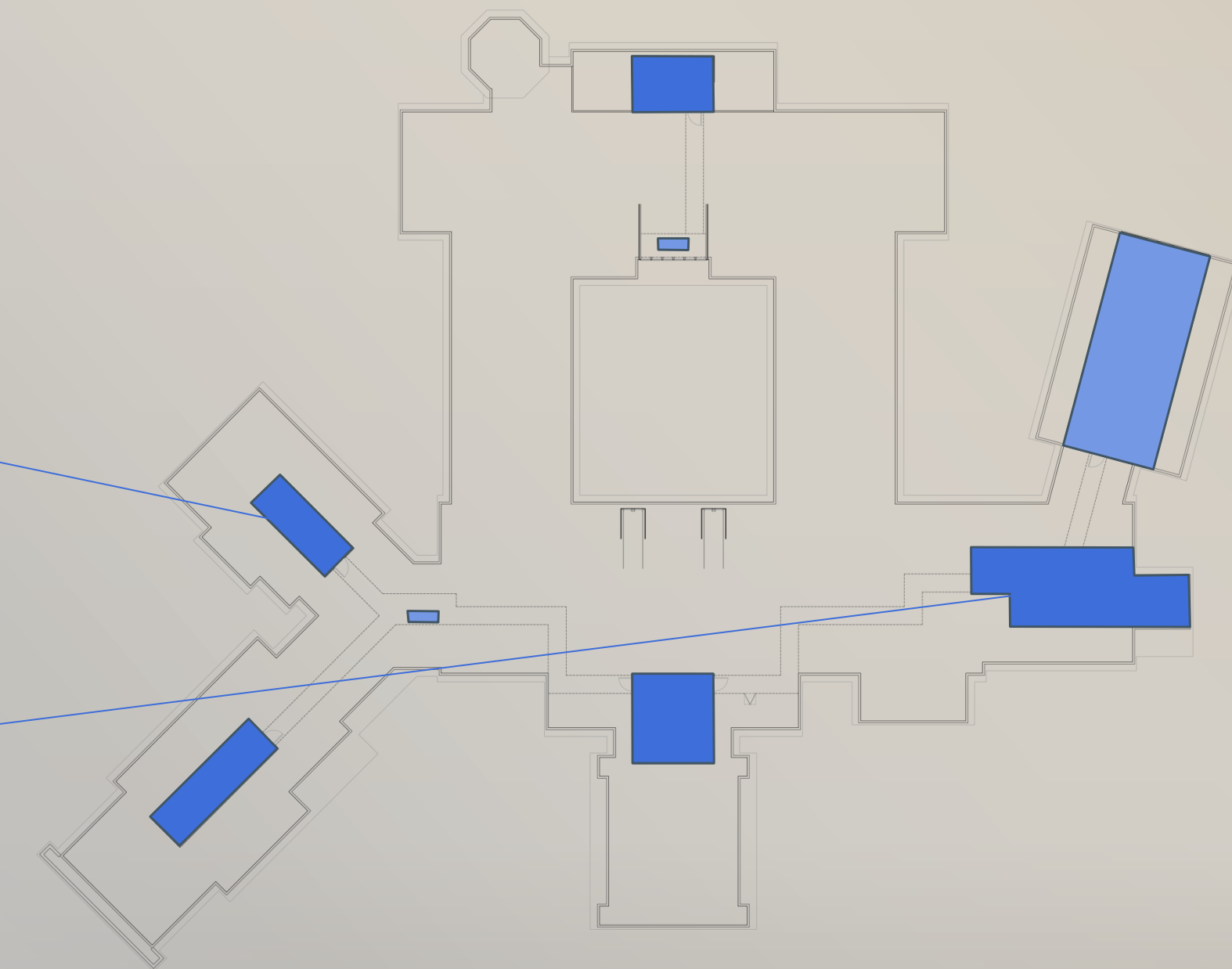
Construction Breadth Study

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Mezzanine Level

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Mechanical Depth Study

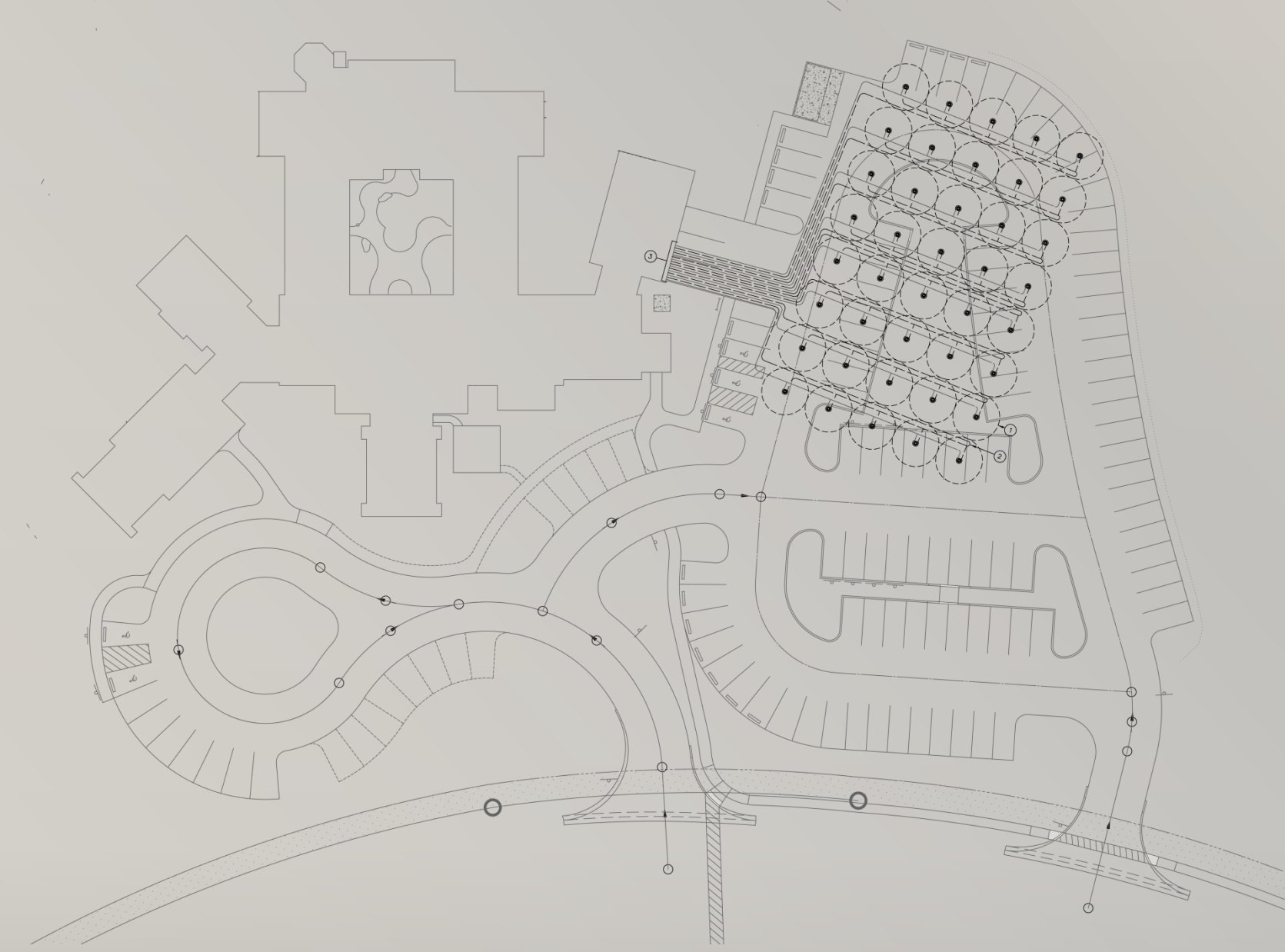
Construction Breadth Study

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Key Mechanical Equipment

- 8 Closed Loop Water Source
- 2 Pumps for heat Pump Loop
- 28 Water Source Heat Pumps
- Condensate Pump for Heat Pump Loop
- Expansion Tank for Heat Pump Loop
- 4 Ventilation Units

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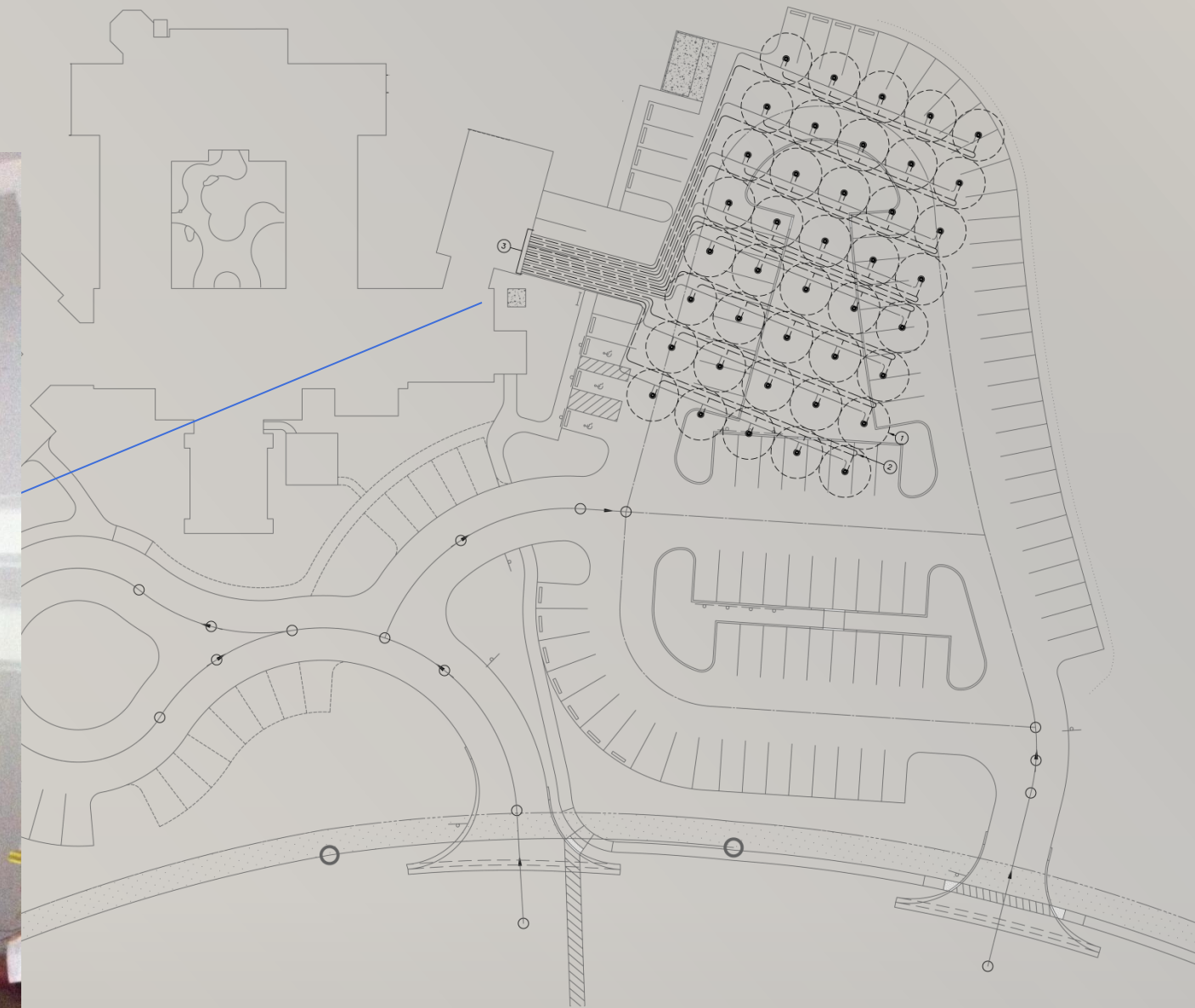
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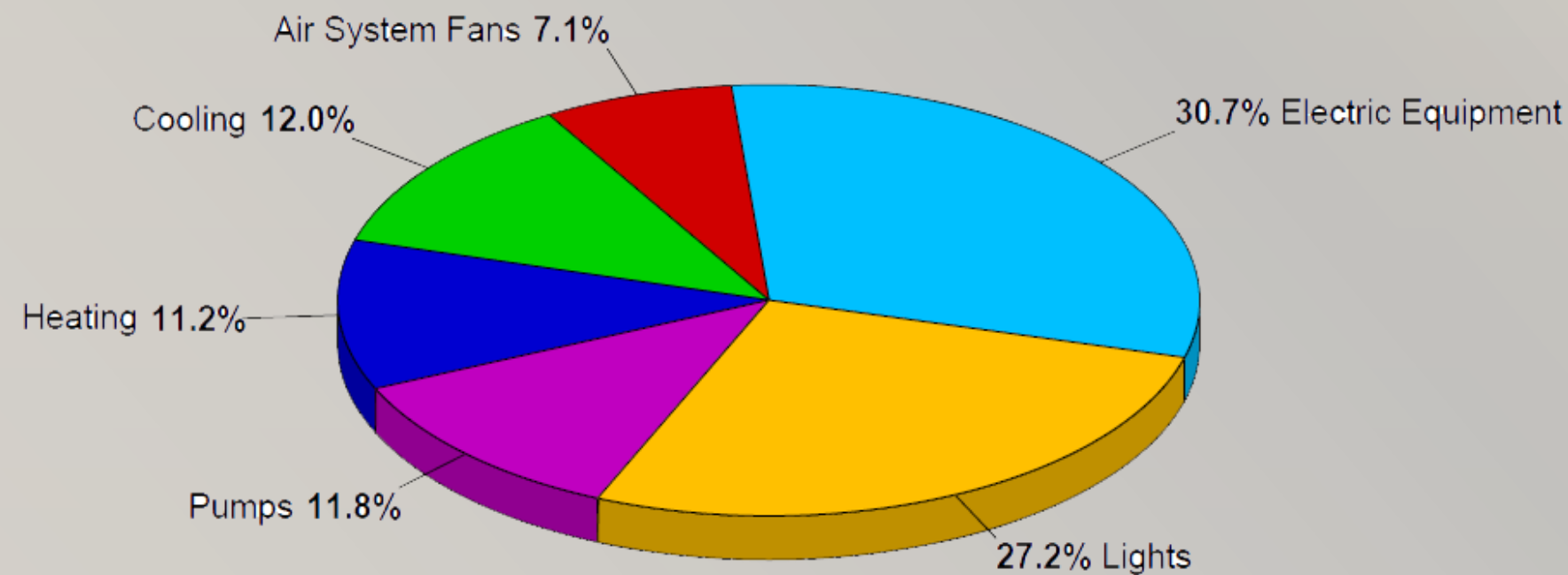
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Units	Model Results
Cooling [tons]	47
Cooling [sf/ton]	460
Cooling [cfm/ton]	N/A
Cooling [Btuh/sf]	26.1
Heating [Btuh/sf]	21
Design air Flow [cfm]	29336
Supply [cfm/sf]	1.36

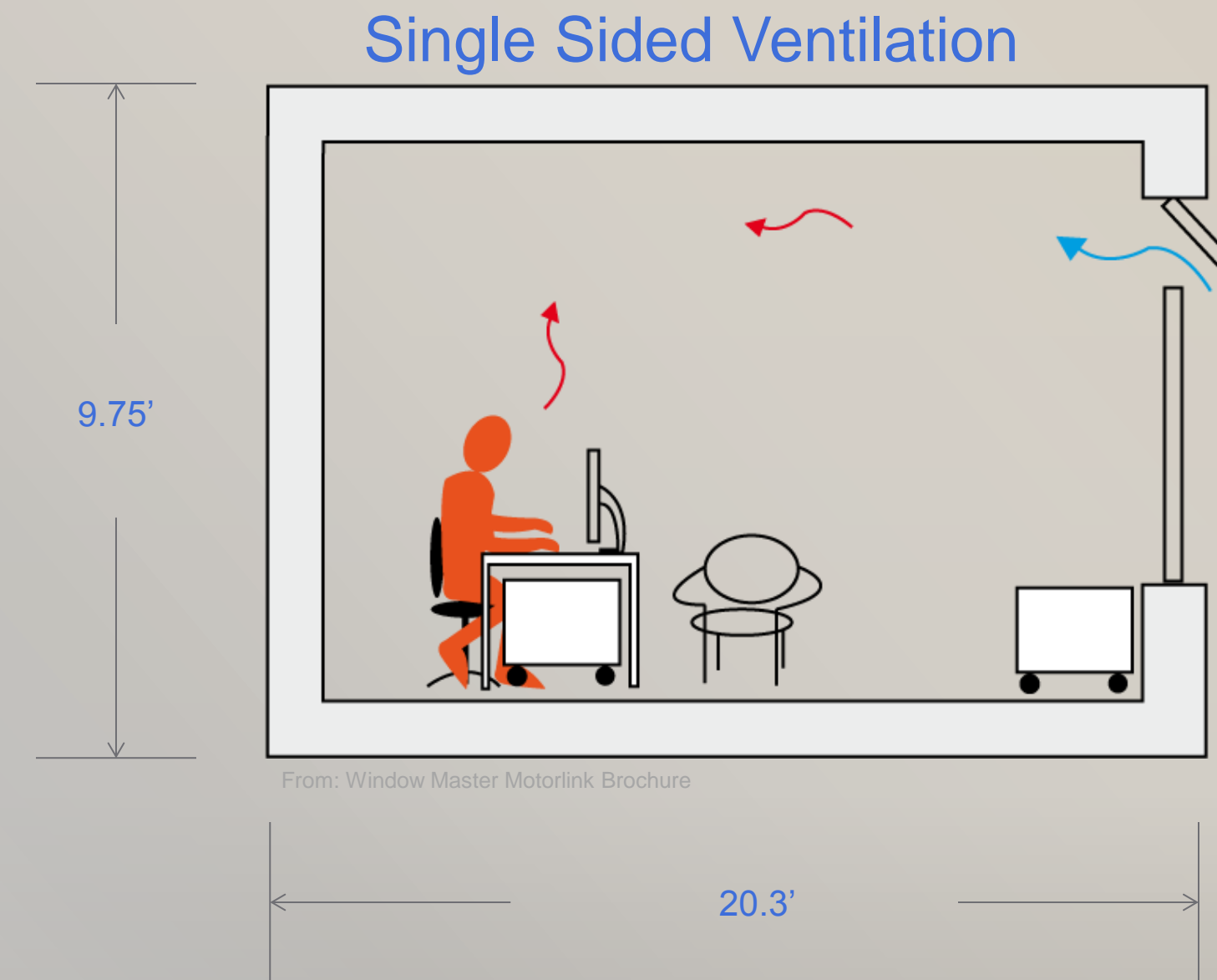
HVAC Components	Cost [\$ /yr]	Cost per area [\$ /sf]	Percent of Total Cost [%]	National Avg. for Office Buildings [%]
Air System Fan	2,274	0.105	7.1	5
Cooling	3,829	0.177	12	9
Heating	3,585	0.166	11.2	25
Pumps	3,765	0.174	11.8	N/A
Lights	8,679	0.402	27.2	29
Electrical Equipment	9,803	0.454	30.7	16
Total	31,931	1.477	100	

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Design Objectives

- Reduce Energy Consumption
- Minimize the Need for Conditioned Air
- Maximize Outdoor Air
- Achieve Single Sided Ventilation



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Proposed Redesign

Hybrid Ventilation System

- Automated Window System

Hybrid Ventilation System with Water Feature

- Automated Window System
- Subgrade Cistern
- Water Feature



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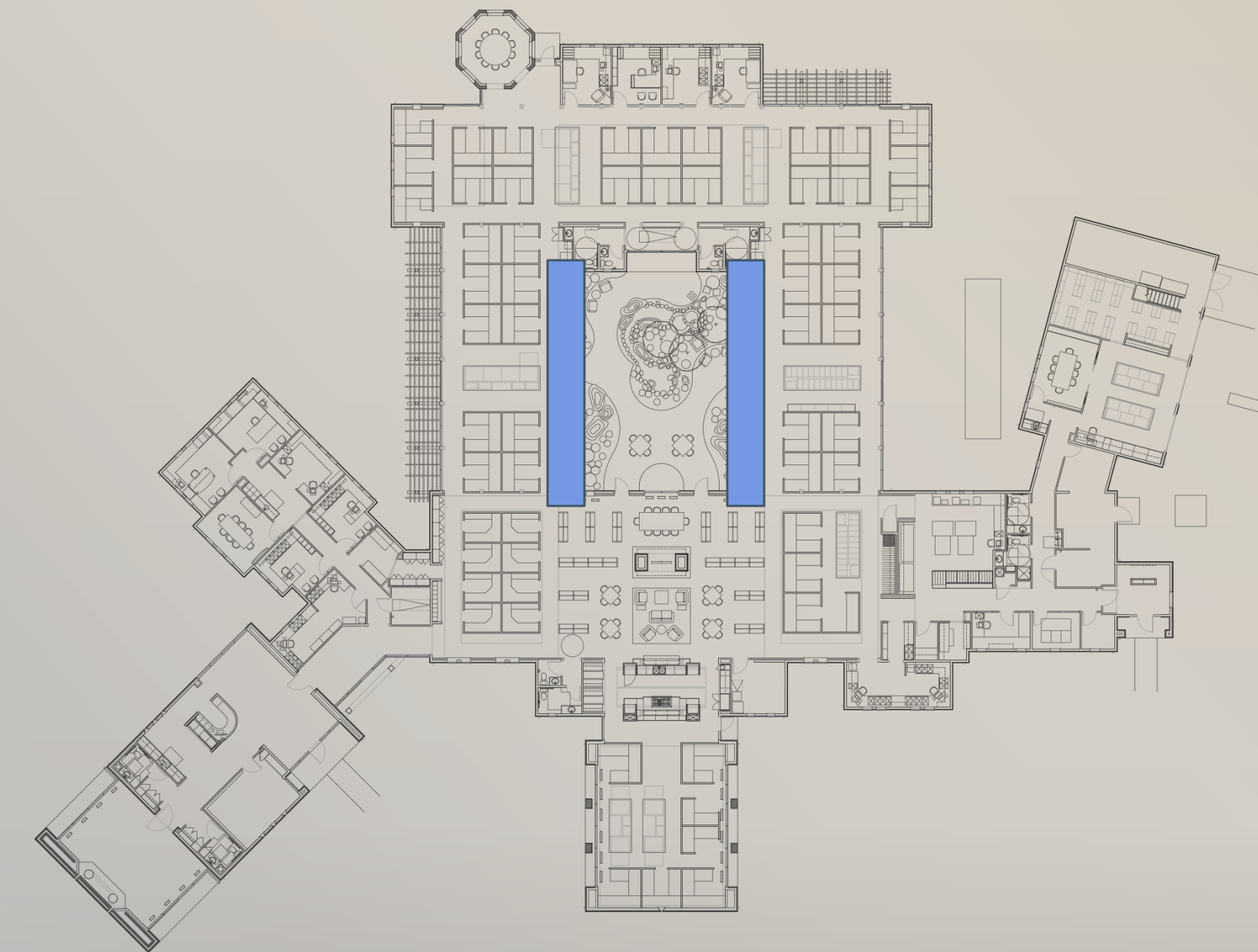
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- **Automated Window System**
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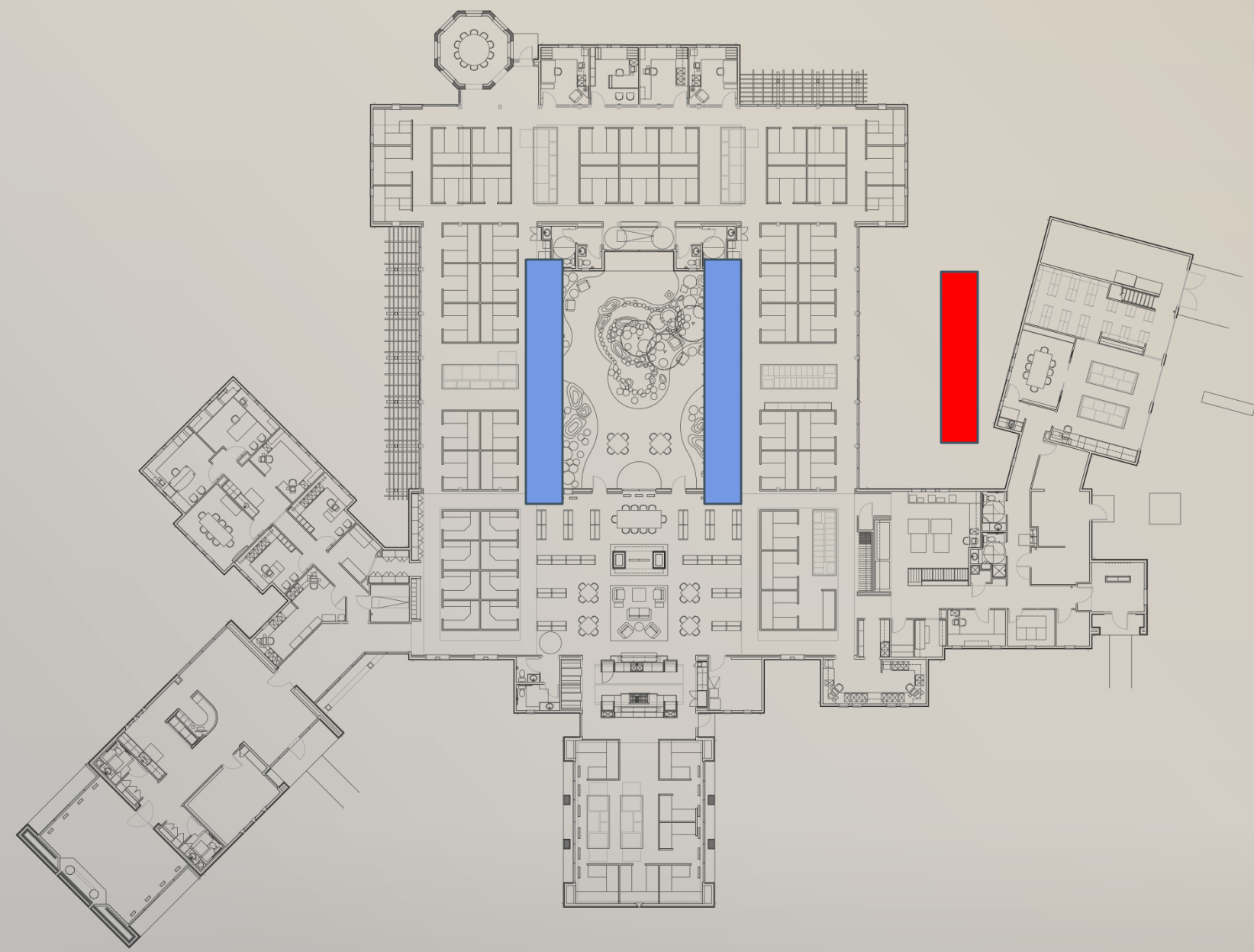


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Proposed Redesign

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 - **Subgrade Cistern**
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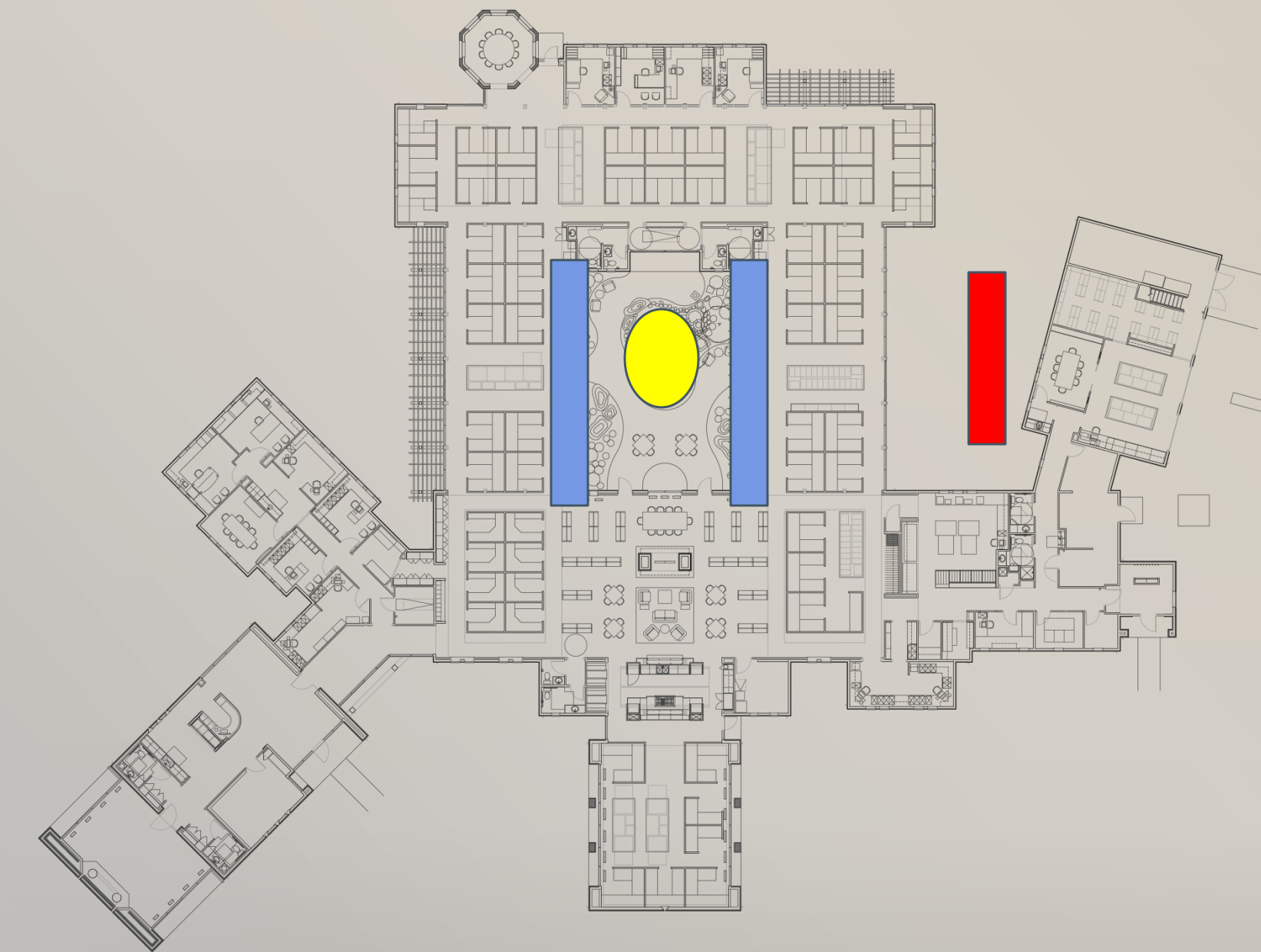
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Method of Modeling

- Weather Data**
- Air Mixing
- Summer/Winter Design Conditions

January	Typical Weather (°F)		Design		Weekday		Saturday		Sunday		Monday	
Hour	OADB	OAWB	Htg (Btuh)	Clg (Tons)	Htg (Btuh)	Clg (Tons)	Htg (Btuh)	Clg (Tons)	Htg (Btuh)	Clg (Tons)	Htg (Btuh)	Clg (Tons)
1	26.4	23.0	-116,135	0.0	-486,626	0.0	-615,895	0.0	-1,212,381	0.0	-1,229,741	0.0
2	25.0	21.7	-22,641	0.0	-522,406	0.0	-551,125	0.0	-1,239,274	0.0	-1,238,140	0.0
3	23.8	20.8	-362,760	0.0	-611,660	0.0	-703,904	0.0	-1,473,735	0.0	-1,473,803	0.0
4	23.0	20.1	-554,347	0.0	-777,558	0.0	-1,124,768	0.0	-1,565,056	0.0	-1,565,055	0.0
5	22.4	19.7	-879,328	0.0	-1,052,921	0.0	-1,287,435	0.0	-1,665,051	0.0	-1,667,647	0.0
6	22.3	19.6	-1,219,895	0.0	-1,339,670	0.0	-1,443,785	0.0	-1,801,830	0.0	-1,802,522	0.0
7	22.8	19.7	-1,408,614	1.0	-1,492,450	65.6	-1,506,146	0.0	-1,851,995	0.0	-1,964,287	61.6
8	24.2	21.3	-4,559,023	4.2	-3,636,904	24.6	-1,557,298	0.0	-1,866,184	0.0	-4,076,044	6.4
9	26.4	23.5	-2,999,091	1.1	-2,802,329	0.0	-1,826,184	0.0	-2,051,708	0.0	-3,046,619	0.3
10	29.0	25.9	-3,085,110	2.1	-2,266,339	0.5	-1,635,882	0.0	-1,833,918	0.0	-2,484,417	0.0
11	31.9	28.1	-3,117,413	2.9	-2,084,587	1.4	-1,474,548	0.0	-1,589,195	0.0	-2,255,169	1.1
12	34.6	30.2	-3,844,407	11.6	-2,384,292	2.1	-1,327,196	0.0	-1,408,142	0.0	-2,597,305	2.0
13	36.8	31.9	-3,551,958	11.2	-2,762,411	2.6	-1,258,003	0.0	-1,333,876	0.0	-2,870,913	2.5
14	38.2	32.5	-3,479,410	17.4	-3,079,451	2.9	-1,233,823	0.0	-1,296,383	0.0	-3,127,808	2.9
15	38.7	32.5	-3,525,801	58.2	-3,158,524	8.6	-1,129,360	0.0	-1,178,761	0.0	-3,211,258	8.5
16	38.5	32.3	-3,552,948	52.8	-3,083,891	10.7	-835,448	0.0	-885,935	0.0	-3,128,298	10.2
17	38.0	32.0	-3,153,969	50.8	-2,998,037	17.5	-908,125	0.0	-973,800	0.0	-3,037,293	12.2
18	37.1	31.8	-1,684,748	73.1	-1,825,752	21.9	-1,347,263	0.0	-1,371,452	0.0	-1,926,232	18.9
19	36.0	31.4	-93,009	18.4	-317,233	0.4	-1,279,340	0.4	-1,302,252	0.4	-453,049	0.4
20	34.6	30.4	-31,952	25.5	-408,326	5.1	-1,251,484	6.2	-1,285,277	6.2	-449,259	4.3
21	33.0	29.2	-379,270	41.4	-339,206	15.7	-1,245,189	15.2	-1,266,302	15.2	-344,238	15.5
22	31.3	27.8	-444,827	43.3	-414,738	30.2	-1,381,500	22.8	-1,399,244	22.7	-435,397	30.0
23	29.6	26.1	-507,189	21.6	-630,463	17.4	-1,335,585	17.4	-1,363,753	17.3	-674,192	17.3
24	27.9	24.4	-384,412	3.5	-418,460	2.1	-1,045,418	2.1	-1,074,812	2.1	-418,563	2.1

Temperature

$$T_{\text{mix}} = (T_{\text{Outdoor}} * Q_{\text{Outdoor}} + T_{\text{Heat Pump}} * Q_{\text{Heat Pump}}) / Q_{\text{Total}}$$

Humidity

$$W_{\text{Mix}} = W_{\text{Outdoor}} + (\dot{m}_{\text{Heat Pump}} / \dot{m}_{\text{Total}}) (W_{\text{Heat Pump}} - W_{\text{Outdoor}})$$

Summer Design Conditions

73-79 F°, 40-60% RH

Winter Design Conditions

68-74 F°, 40-60% RH

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20	34.6	30.4	-31,952	25.5	-408,326	5.1	-1,251,484	6.2	-1,285,277	6.2	-449,259	4.3
21	33.0	29.2	-379,270	41.4	-339,206	15.7	-1,245,189	15.2	-1,266,302	15.2	-344,238	15.5
22	31.3	27.8	-444,827	43.3	-414,738	30.2	-1,381,500	22.8	-1,399,244	22.7	-435,397	30.0
23	29.6	26.1	-507,189	21.6	-630,463	17.4	-1,335,585	17.4	-1,363,753	17.3	-674,192	17.3
24	27.9	24.4	-384,412	3.5	-418,460	2.1	-1,045,418	2.1	-1,074,812	2.1	-418,563	2.1

Temperature

$$T_{mix} = (T_{Outdoor} * Q_{Outdoor} + T_{Heat Pump} * Q_{Heat Pump}) / Q_{Total}$$

Humidity

$$W_{Mix} = W_{Outdoor} + (\dot{m}_{Heat Pump} / \dot{m}_{Total}) (W_{Heat Pump} - W_{Outdoor})$$

Summer Design Conditions

73-79 F°, 40-60% RH

Winter Design Conditions

68-74 F°, 40-60% RH

Presentation Outline

- Project Team
- Project Introduction
- Existing mechanical systems
- Mechanical Depth Study
- Construction Breadth Study**

- Interior Components
- Exterior Components

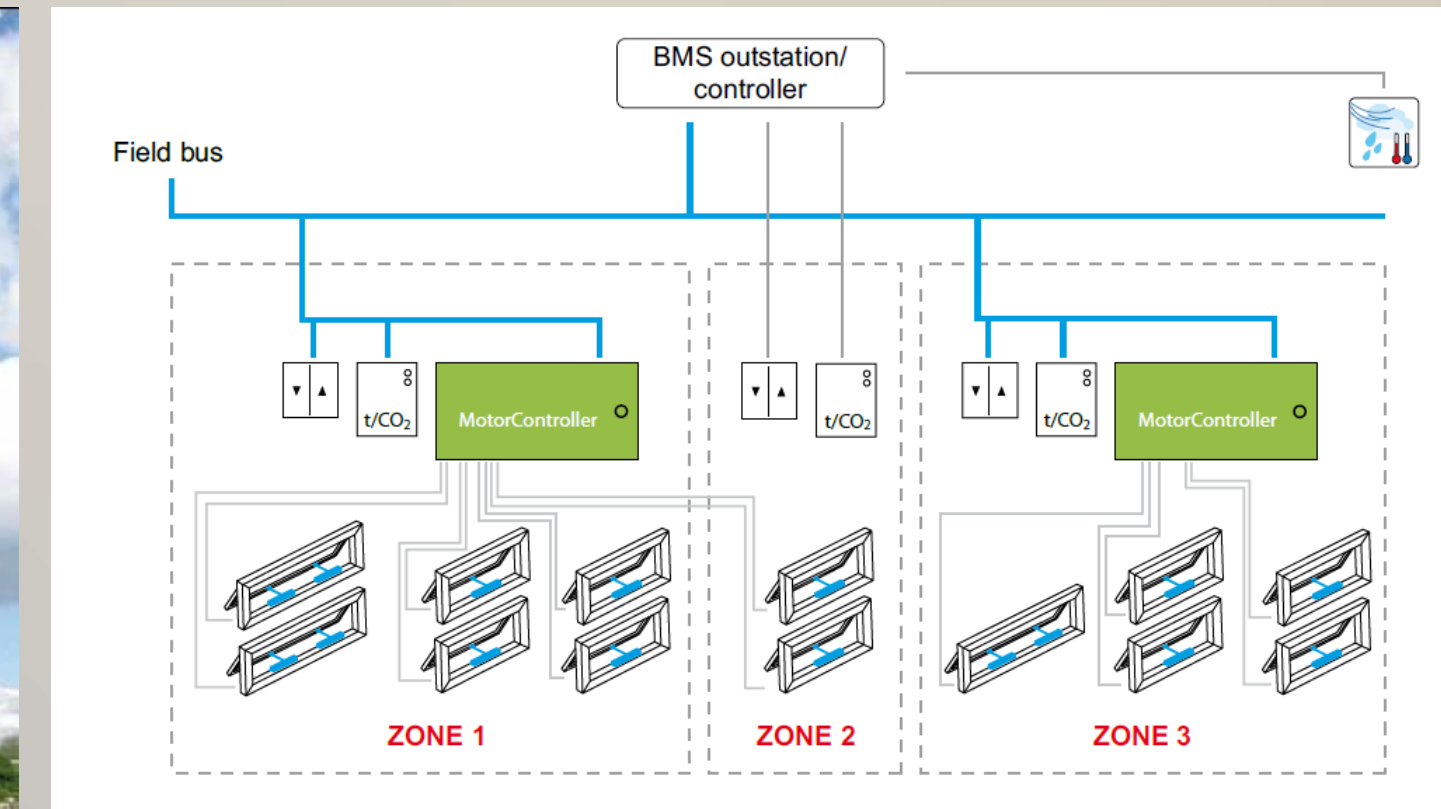
- Results
- Conclusion
- Recommendation
- Questions

Interior Design Components

Item	Unit Details		Labor Details	Cost Details					Misc.
Window Automation	Quantity	Units	Labour Hours	Material	Labor	Equipment	Cost per Unit	Total Cost	Notes
Outstation Controller	2	each	16	945	905	0	1850	3700	
Motor Controller	40	each	0.5	325	28.5	0	353.5	14140	
Temperature Sensor	40	each	0.667	167	37	0	204	8160	
Humidity Sensor	40	each	0.5	385	28	0	413	16520	
CO2 Sensor	40	each	0.5	62	28	0	90	3600	
Window	160	each	0	273	155	0	428	68480	
Window Hardware	160	each	1.4	-	-	-	-	-	Included
Actuator Package	320	each	1	219	56.5	0	275.5	88160	
Control Program	1	each	0	0	0	0	36	36	
Electrical Systems	Quantity	Units					Cost per Unit		Notes
Panelboard	1	each	2.222	147	115	0	262	262	100 Amp
Conduit	145	L.F.	0.08	3.22	4.12	0	7.34	1064.3	1.25"
Wires	1.45	C.L.F.	1.6	124	82.5	0	206.5	299.425	



From: Window Master Motorlink Brochure



From: Window Master Motorlink Brochure

Presentation Outline

- Project Team
- Project Introduction
- Existing mechanical systems
- Mechanical Depth Study
- Construction Breadth Study**
 - Interior Components
 - **Exterior Components**
- Results
- Conclusion
- Recommendation
- Questions

Exterior Components

Item	Unit Details		Labor Details			Cost Details			Misc.
Water Feature Supply	Quantity	Units					Cost per Unit	Notes	
Cistern	1	each	6.4	1600	400	0	2000	12,000 Gal. Tank. Pump Included	
Filtration System	1	each	8	40000	330	39	40369	Grey water filtration	
UV Filtration System	1	each	8	825	330	45	1200	For Legionellosis Prevention	
Water Feature	1	each	8	550	284	0	834	Pump included	
Pipe	70	L.F.	0.101	5.7	4.32	0	10.02	701.4	
Grey Water Collection	Quantity	Units					Cost per Unit	Notes	
Trench excavation	500	L.F.	0.011	0	0.51	0.09	0.6	330	
Pipe	1000	L.F.	0.101	5.7	4.32	0	10.02	11022	
Excavation of Soil	Quantity	Units					Cost per Unit	Notes	
Soil Removal	80	C.F.	0.03	0	1.28	1.11	2.39	191.2	
Trench Excavation	70	L.F.	0.011	0	0.51	0.09	0.6	42	
Pipe Bedding	70	C.F.	0.025	1.69	0.88	2.57	5.14	359.8	
Backfill	5	C.F.	0.01	0	0.43	1.04	1.47	7.35	



From: studio39.com. Landscape Architecture Blog

Presentation Outline

- Project Team
- Project Introduction
- Existing mechanical systems
- Mechanical Depth Study
- Construction Breadth Study**
 - Interior Components
 - **Exterior Components**
- Results
- Conclusion
- Recommendation
- Questions

Exterior Components

Item	Unit Details		Labor Details	Cost Details			Cost per Unit		Misc.
Water Feature Supply	Quantity	Units					Cost per Unit		Notes
Cistern	1	each	6.4	1600	400	0	2000	2000	12,000 Gal. Tank. Pump Included
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Water Feature	1	each	8	550	284	0	834	834	Pump included
Pipe	70	L.F.	0.101	5.7	4.32	0	10.02	701.4	
Grey Water Collection	Quantity	Units					Cost per Unit		Notes
Trench excavation	500	L.F.	0.011	0	0.51	0.09	0.6	330	
Pipe	1000	L.F.	0.101	5.7	4.32	0	10.02	11022	Estimate w. Safety Factor
Excavation of Soil	Quantity	Units					Cost per Unit		Notes
Soil Removal	80	C.F.	0.03	0	1.28	1.11	2.39	191.2	
Trench Excavation	70	L.F.	0.011	0	0.51	0.09	0.6	42	
Pipe Bedding	70	C.F.	0.025	1.69	0.88	2.57	5.14	359.8	
Backfill	5	C.F.	0.01	0	0.43	1.04	1.47	7.35	

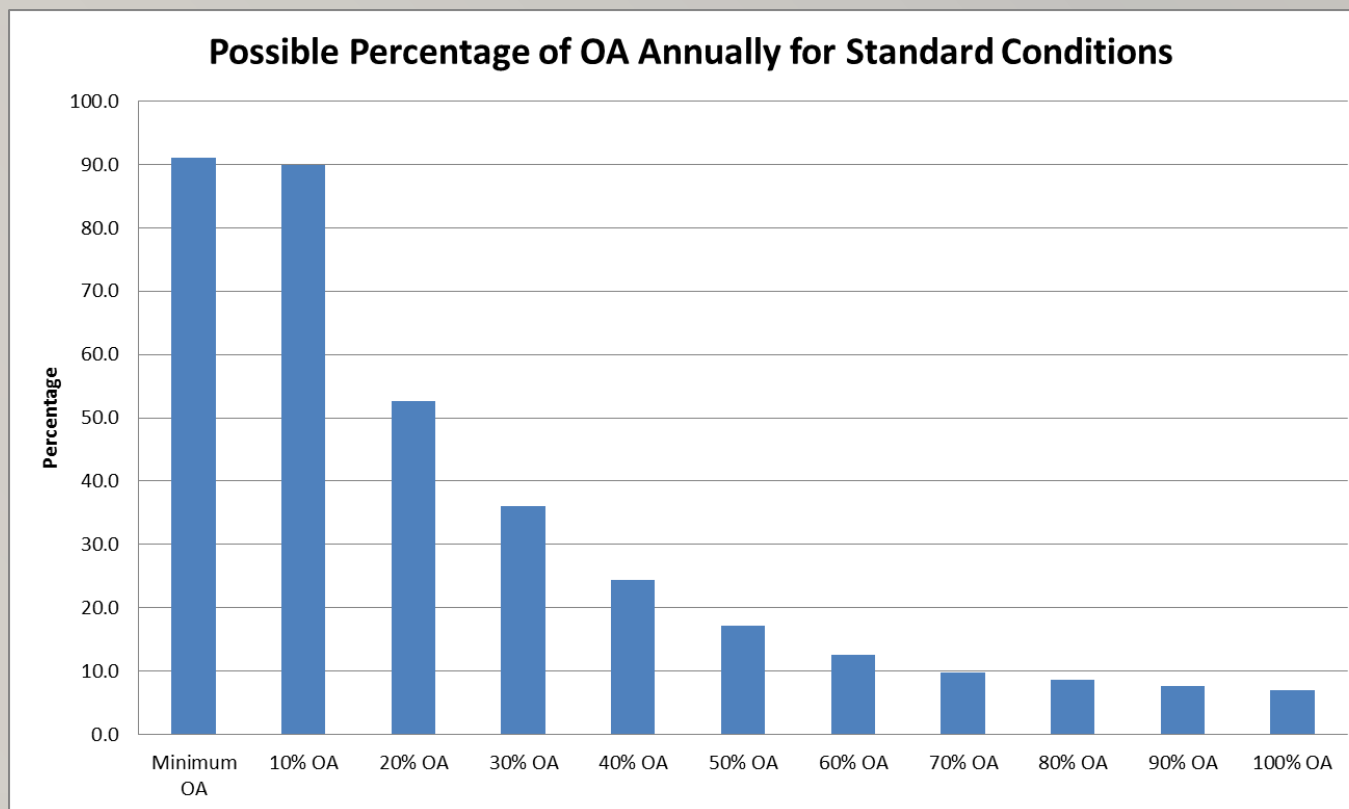


From: studio39.com. Landscape Architecture Blog

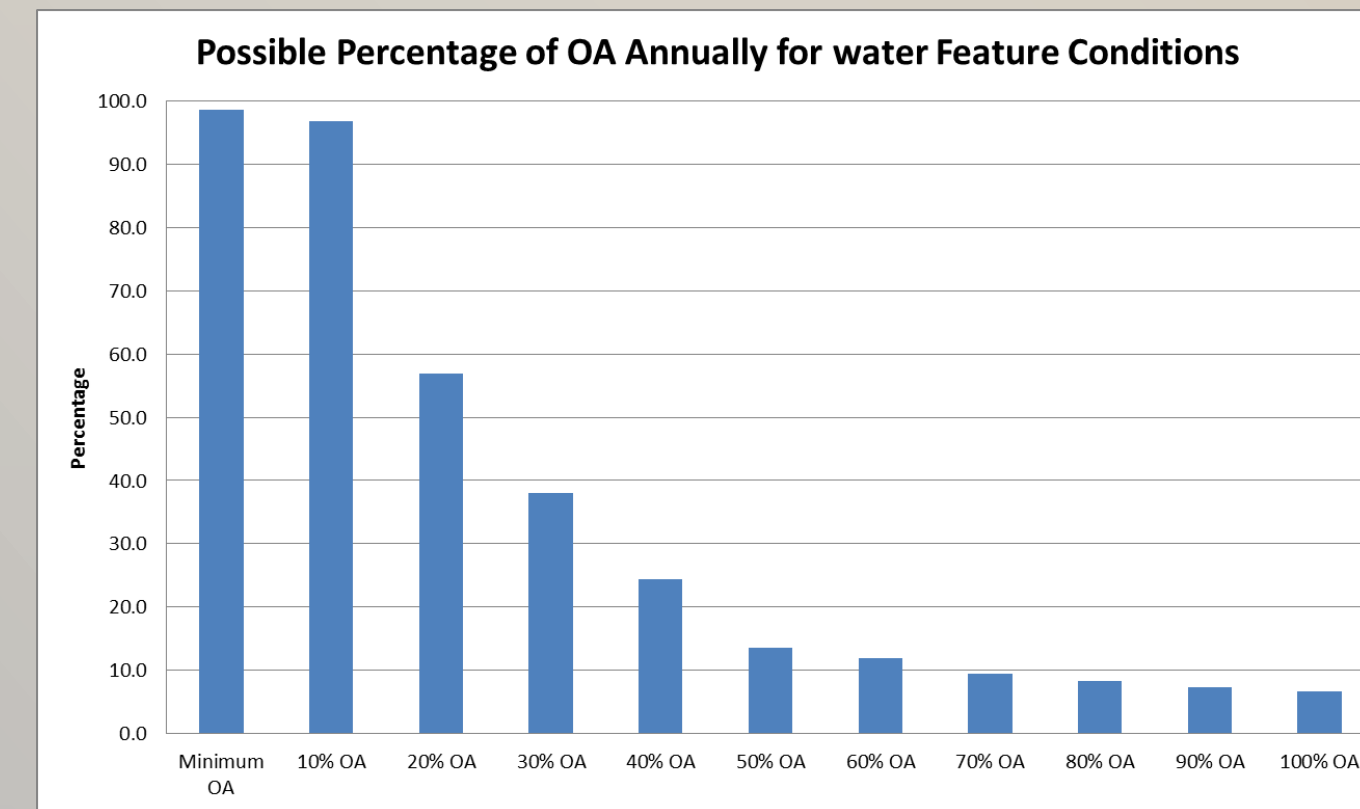
Presentation Outline

- Project Team
- Project Introduction
- Existing mechanical systems
- Mechanical Depth Study
- Construction Breadth Study
- Results**
 - **Hybrid Ventilation For Both conditions**
 - Comparative Results
 - Construction Costs
 - Energy / Cost Savings
- Conclusion
- Recommendation
- Questions

Hybrid Ventilation with Standard Ventilation



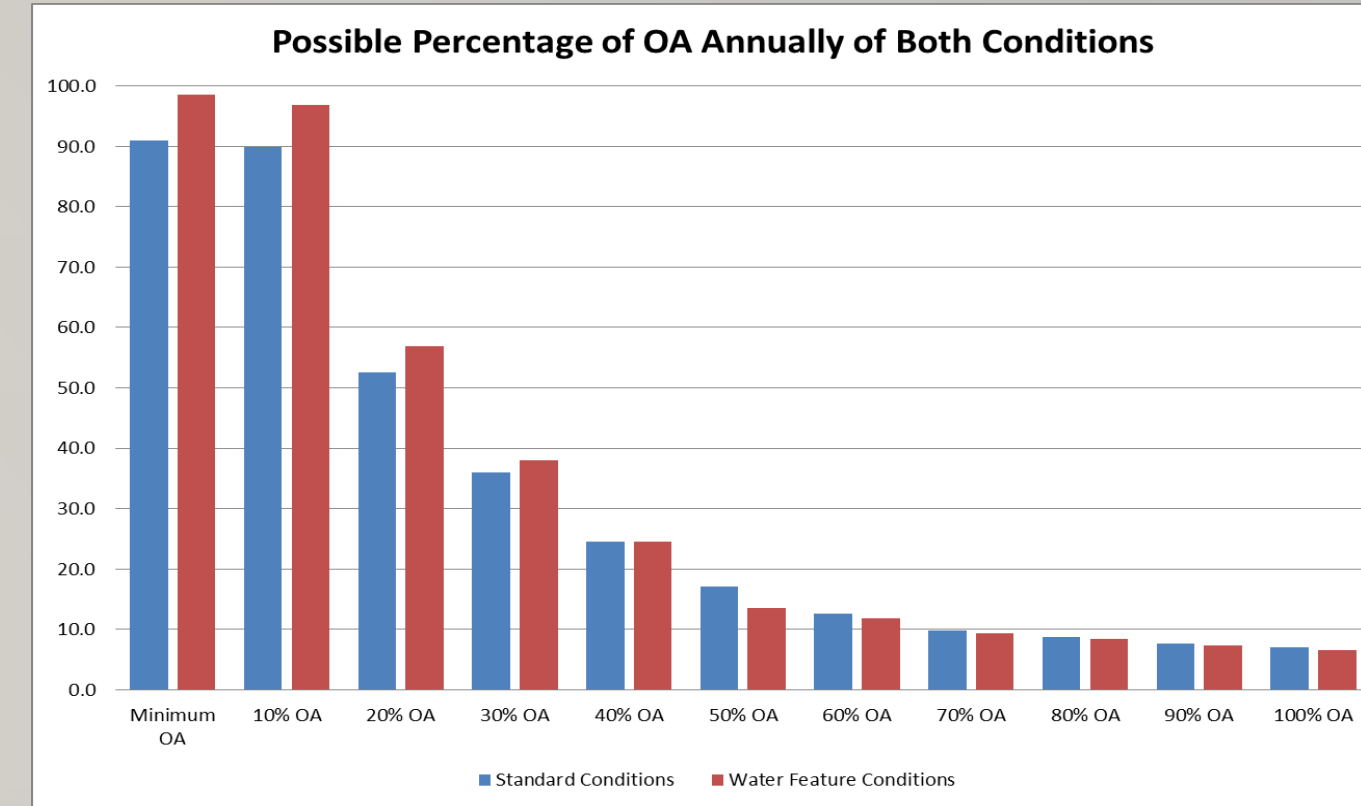
Hybrid Ventilation with Water Feature Conditions



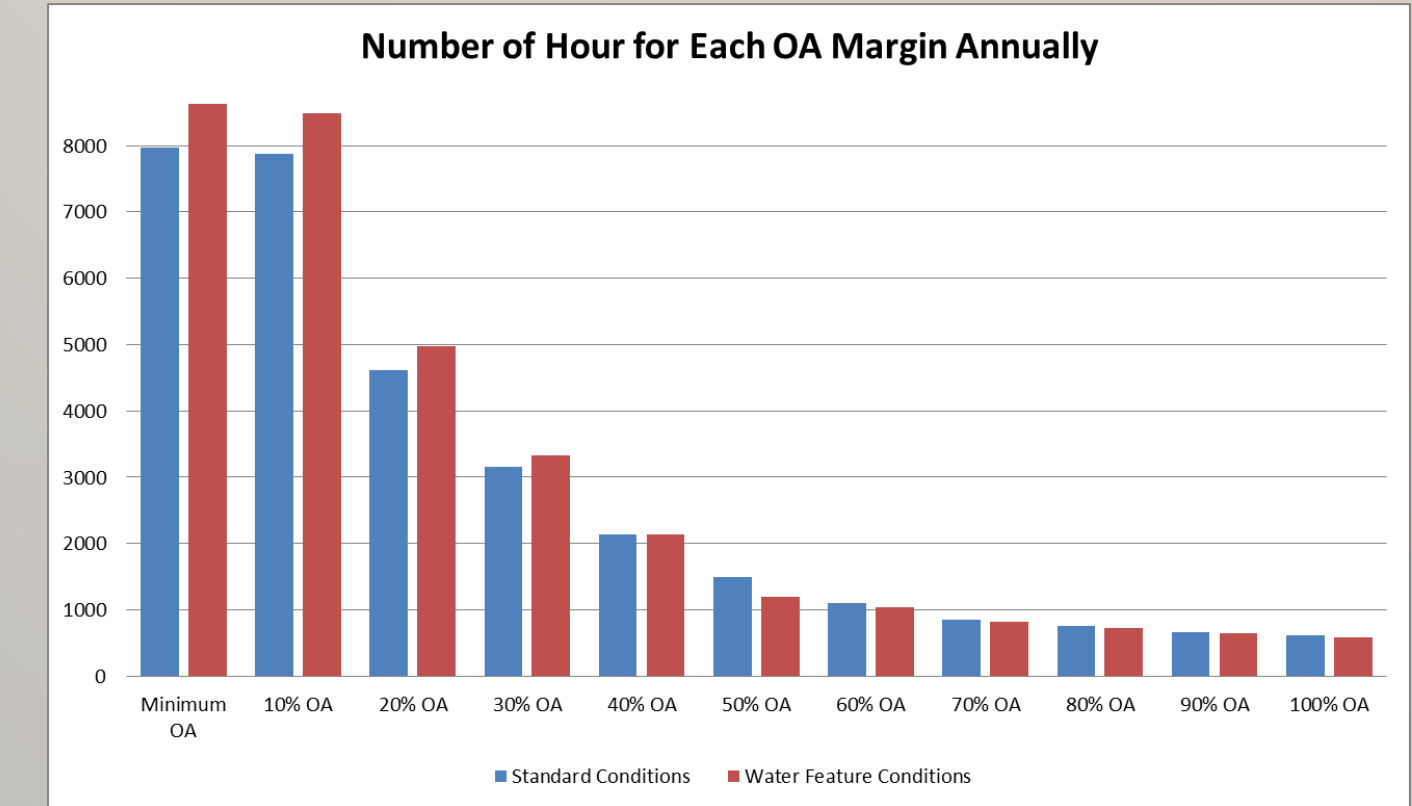
Presentation Outline

- Project Team
- Project Introduction
- Existing mechanical systems
- Mechanical Depth Study
- Construction Breadth Study
- Results**
 - Hybrid Ventilation with Standard Conditions
 - Comparative Results**
 - Construction Costs
 - Energy / Cost Savings
- Conclusion
- Recommendation
- Questions

Percentage of Hours Annually for Each Condition



Number of Hours for Each Condition



Presentation Outline

- Project Team
- Project Introduction
- Existing mechanical systems
- Mechanical Depth Study
- Construction Breadth Study
- Results
 - Hybrid Ventilation with Standard Conditions
 - Comparative Results
 - **Construction Costs**
 - Energy / Cost Savings
- Conclusion
- Recommendation
- Questions

Construction Cost

Item	Unit Details		Labor Details	Cost Details				Misc.		
Window Automation	Quantity	Units	Labour Hours	Material	Labor	Equipment	Cost per Unit	Total Cost	Notes	
Outstation Controller	2	each	16	945	905	0	1850	3700	Included	
Motor Controller	40	each	0.5	325	28.5	0	353.5	14140		
Temperature Sensor	40	each	0.667	167	37	0	204	8160		
Humidity Sensor	40	each	0.5	385	28	0	413	16520		
CO2 Sensor	40	each	0.5	62	28	0	90	3600		
Window	160	each	0	273	155	0	428	68480		
Window Hardware	160	each	1.4	-	-	-	-	-		
Actuator Package	320	each	1	219	56.5	0	275.5	88160		
Control Program	1	each	0	0	0	0	36	36		
Water Feature Supply	Quantity	Units					Cost per Unit			Notes
Cistern	1	each	6.4	1600	400	0	2000	2000	12,000 Gal Tank. Pump Included	
Filtration System	1	each	8	40000	330	39	40369	40369	Grey Water filtration	
UV Filtration System	1	each	8	825	330	45	1200	1200	For Legionellosis Prevention	
Water Feature	1	each	8	550	284	0	834	834	Pump included	
Pipe	70	L.F.	0.101	5.7	4.32	0	10.02	701.4		
Grey Water Collection	Quantity	Units					Cost per Unit		Notes	
Trench excavation	500	L.F.	0.011	0	0.51	0.09	0.6	330		
Pipe	1000	L.F.	0.101	5.7	4.32	0	10.02	11022	Estimated w. Safety Factor	
Electrical Systems	Quantity	Units					Cost per Unit		Notes	
Panelboard	1	each	2.222	147	115	0	262	262	100 Amp	
Conduit	145	L.F.	0.08	3.22	4.12	0	7.34	1064.3	1.25"	
Wires	1.45	C.L.F.	1.6	124	82.5	0	206.5	299.425		
Excavation of Soil	Quantity	Units					Cost per Unit		Notes	
Soil Removal	80	C.F.	0.03	0	1.28	1.11	2.39	191.2		
Trench Excavation	70	L.F.	0.011	0	0.51	0.09	0.6	42		
Pipe Bedding	70	C.F.	0.025	1.69	0.88	2.57	5.14	359.8		
Backfill	5	C.F.	0.01	0	0.43	1.04	1.47	7.35		
			Total Hours	827.8				Total Cost	\$261,478.48	

Presentation Outline

- Project Team
- Project Introduction
- Existing mechanical systems
- Mechanical Depth Study
- Construction Breadth Study
- Results**
 - Hybrid Ventilation with Standard Conditions
 - Comparative Results
 - Construction Costs**
 - Energy / Cost Savings
- Conclusion
- Recommendation
- Questions

Total Mechanical Systems Cost

Mechanical Item	Cost [\$]	Mechanical Item	Cost [\$]
Project Coordination	19,800*	Heating & Cooling Piping	280,456
Temporary Utilities	24,632	Air Handlers	46,037
Fire Protection	153,400	Heat Pumps	137,862
Plumbing Piping	99,736	Duct Work	182,241
Plumbing Specialties	73,642	Fans	24,049
Plumbing Fixtures	70,213	Air Devices	49,654
Plumbing Equipment	39,300	Building Controls	128,765
N/A	N/A	Hybrid Ventilation	261,479
	Total [\$]	1,571,466	
	Total [\$/SF]	69.17	

Total Mechanical Systems Cost

Mechanical Item	Percentage of Cost [%]	Mechanical Item	Percentage of Cost [%]
Project Coordination	-	Heating & Cooling Piping	17.8
Temporary Utilities	1.6	Air Handlers	2.9
Fire Protection	9.8	Heat Pumps	8.8
Plumbing Piping	6.3	Duct Work	11.6
Plumbing Specialties	4.7	Fans	1.5
Plumbing Fixtures	4.5	Air Devices	3.2
Plumbing Equipment	2.5	Building Controls	8.2
		Hybrid Ventilation	16.6
	Total Cost [\$]	1,309,987	

Presentation Outline

- Project Team
- Project Introduction
- Existing mechanical systems
- Mechanical Depth Study
- Construction Breadth Study
- Results**
 - Hybrid Ventilation with Standard Conditions
 - Hybrid Ventilation with Water Feature Conditions
 - Construction Costs
 - **Energy / Cost Savings**
- Conclusion
- Recommendation
- Questions

Energy and Cost Savings

Mechanical Item	Cost [\$]	Mechanical Item	Cost [\$]
Project Coordination	19,800*	Heating & Cooling Piping	280,456
Temporary Utilities	24,632	Air Handlers	46,037
Fire Protection	153,400	Heat Pumps	137,862
Plumbing Piping	99,736	Duct Work	182,241
Plumbing Specialties	73,642	Fans	24,049
Plumbing Fixtures	70,213	Air Devices	49,654
Plumbing Equipment	39,300	Building Controls	128,765
N/A	N/A	Hybrid Ventilation	261,479
Total [\$]		1,571,466	
Total [\$/SF]		69.17	

Components	Current System Energy Use [kWh]	Energy Use with Hybrid Ventilation	[%] of Current System
Cooling Coil Compressor	34919	27351	78.3
Heating Coil Compressor	32717	28496	87.1
Terminal Fan Compressor	20751	15296	73.7
Total	88387	71143	80

Electrical Consumption for HVAC Equipment [kWh]	122,748
Cost Electrical Consumption for HVAC Equipment [\$]	13,449

Electrical Consumption with Hybrid System [kWh]	98,198
Cost of Electrical Consumptionwith Hybrid System [\$]	10,837

Annual Energy Consumptions Savings [kWh]	24,550
Annual Cost Savings [\$]	2,612

Presentation Outline

- Project Team
- Project Introduction
- Existing mechanical systems
- Mechanical Depth Study
- Construction Breadth Study
- Results
- Conclusion
 - Savings vs. Cost
- Recommendation
- Questions

Energy and Cost Savings

Mechanical Item	Cost [\$]	Mechanical Item	Cost [\$]
Project Coordination	19,800*	Heating & Cooling Piping	280,456
Temporary Utilities	24,632	Air Handlers	46,037
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Cost of Electrical Consumption with Hybrid System [\$]	10,837

Annual Energy Consumptions Savings [kWh]	24,550
Annual Cost Savings [\$]	2,612

Cost Above Existing [\$]	211478.48
Payback Period [Years]	81

Construction Costs

Item	Unit Details		Labor Details	Material	Labor	Cost Details		Misc. Notes		
	Quantity	Units	Labour Hours			Equipment	Cost per Unit		Total Cost	
Outstation Controller	2	each	16	945	905	0	1850	3700	Included	
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Backfill	5	C.F.	0.01	0	0.43	1.04	1.47	7.35		
			Total Hours	827.8				Total Cost	\$261,478.48	

Presentation Outline

Project Team

Project Introduction

Existing mechanical systems

Mechanical Depth Study

Construction Breadth Study

Results

Conclusion

Recommendation

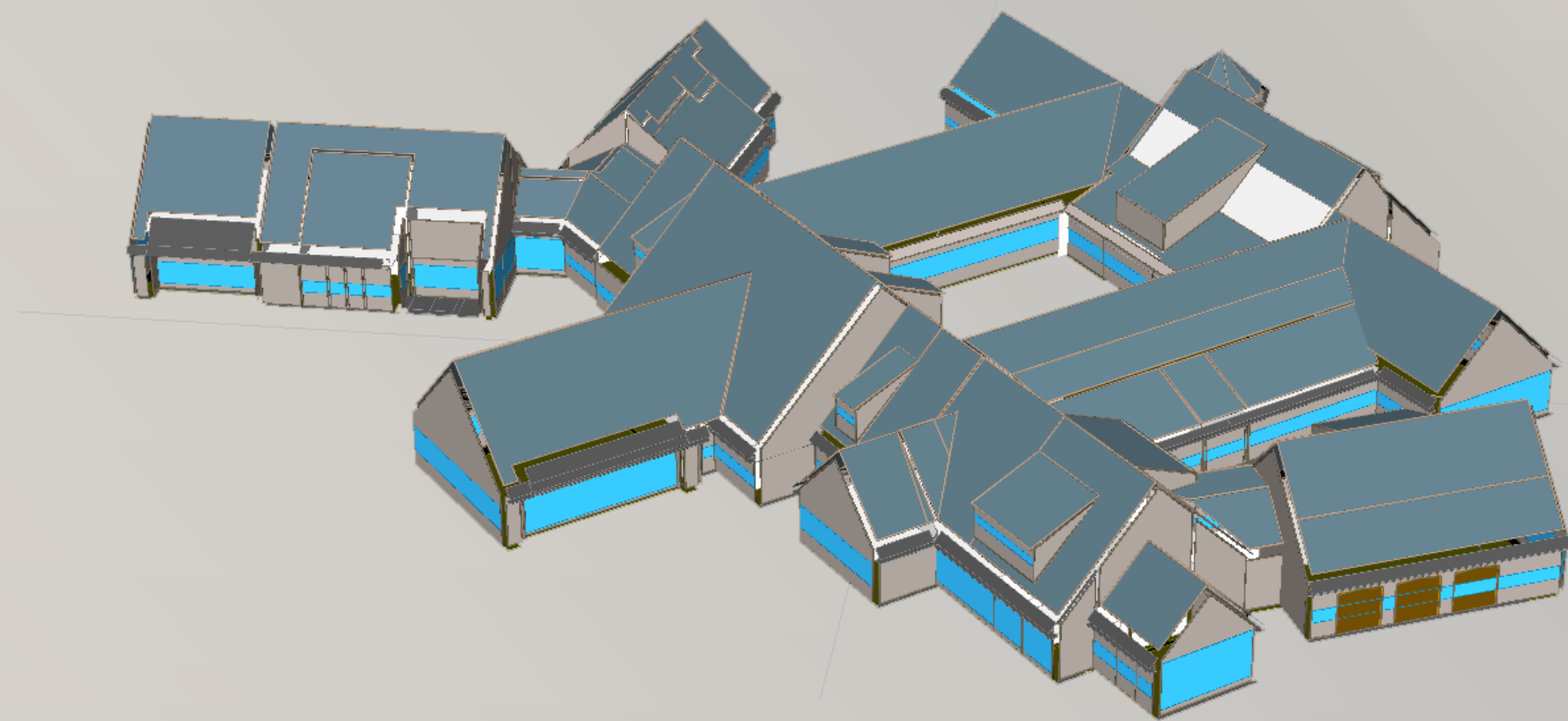
Questions

Recommendation

- There is a great potential for natural ventilation
- Simpler system
- Integrate with existing BAS

Presentation Outline

Project Team
Project Introduction
Existing mechanical systems
Mechanical Depth Study
Construction Breadth Study
Results
Conclusion Recommendation
Questions



Questions?

Special Thanks to:

RLPS Architects
Reese Engineering
Project Engineer: Bryan Smith
Thesis Advisor: S. Treado
PSU AE Department
A,C, D, and the Grandparents