MECHANICAL SYSTEM DESIGN

PROPOSED GOALS, SCOPE & JUSTIFICATION

The Landscape Building will have an estimated yearly utility bill of $3,530,000 once it is completed. This is a direct result of the size of the building as well as the building type. Laboratory spaces have requirements that will directly increase the cost of operation. Providing 100 percent outdoor air to all laboratory spaces will increase fan energy and equipment energy because such a large amount of air must be conditioned and moved throughout the building. Air cannot be recirculated and therefore all of the air in the labs must be exhausted out of the building. Exhaust air contains a large amount of energy that escapes unused into the atmosphere. As stated in a case study of R.W. Johnson Pharmaceutical Research Institute, “Fume hoods are directly responsible for a large amount of fan energy, and they are indirectly responsible for vast amounts of heating and cooling energy because of the volume of conditioned air they continually exhaust from the labs.”

The primary goal is to modify the existing HVAC system to reduce energy consumption and yearly utility costs. As energy consumption is reduced, local and utility emissions will decrease as well. Secondary goals include optimizing the artificial lighting in the laboratory spaces located on the second and third floors as well as resizing affected components of the electrical system.

The system modifications must be done without unfavorably changing the current system. As found with Technical Assignments One and Two, the Landscape Building meets ventilation requirements outlined in ASHRAE Standard 62 and lighting power allowance and building envelope compliance as outlined in ASHRAE Standard 90.1. All changes shall maintain the highest standards of the original design.

The scope of the design process includes the following:

- Modeling the existing laboratory and support spaces.
- Modeling the laboratory and support spaces based on deign requirements.
- Modeling the laboratory and support spaces based on required air changes per hour.
- Determine smallest possible system that meets load and indoor air quality requirements.
- Designing and incorporating a ground-coupled water system.

The laboratory spaces are the prime focus of this design. They make up approximately one third of the building area with mechanical rooms at approximately 50%, and vivarium, offices, and public spaces making up the remainder. It can be said that the laboratory spaces are the dominant load and energy consumer in the Landscape Building due to its 100 percent outdoor air requirement. All comparisons in the design process are in reference to the existing laboratory design only. All other areas and spaces have been excluded.

The results of this thesis provide suggestions for alternative solutions to the design of the Landscape Building at Janelia Farm. All modifications are for academic purposes and do not imply flaws in the original design (old e-studio disclaimer). All modifications are simply alternative solutions which will include one extensive modification to the mechanical system and resulting changes to the other building systems.

CONSIDERED ALTERNATIVES

COGENERATION

Cogeneration systems capture thermal energy that would otherwise be lost to the environment. These systems become increasingly economically feasible as utility rates increase and as energy consumption increases. Such systems are applicable to large facilities with large thermal loads such as the following:

- Assisted Living Facilities
- Nursing Homes
- Senior Housing
- Apartments and Condominiums
- Colleges and Institutions
- Hospitals
- Hotels
- Athletic Clubs
- Industrial and Waste Treatment Facilities
- Laundries

According to the <u>HVAC Systems and Equipment Handbook</u> published by ASHRAE, "the basic components of the cogeneration plant are

- Prime mover and its fuel system.
- Generator.
- Waste heat recovery system.
- Control system.
- Electrical and thermal transmission and distribution system.
- Connections to building mechanical and electrical services.

The design team at Burt Hill considered the feasibility of a cogeneration system to provide power and steam for the Janelia Farm Research Campus. The following three buildings on the campus were incorporated in this study:

- Landscape Building: 546,436 square foot research facility.
- Conference Housing: 42,000 square foot hotel facility with 107 guest rooms.
- Transient Housing: 48-two bedroom apartments for long term visitors.

The conceptual design included a turbine generator with adequate capacity to satisfy the minimum continuous electrical power demand for the campus. The continuous demand ranged from 2.5 to 3.0 mega-watts. The design featured 500kW gas micro-turbines that could be staged on/off to meet demand. The system was more efficient when all the turbines operated continuously. Enough heat could be recovered to operate 1-1200 ton absorption chiller which is equivalent to one of the seven current chillers. The waste heat could have met the majority of the winter heating requirements.

This study concluded an annual savings of $195,640 for the 2.5 mega-watt cogeneration system. The estimated first cost was $4,720,000. Based on this, the simple payback period would be 24 years. This was deemed beyond the limits of a reasonable payback period on such an investment.

A second study utilizing the 3.0 mega-watt system resulted with an annual cost savings of $214,400, system first cost of $7,080,000, and a 33-year pay back period. Again, this is beyond reasonable for a payback period.

Based on these results no further analysis was done. In order for cogeneration to be feasible for the Janelia Farm research campus, equipment and installation costs will have to be greatly reduced.

Note: All dollar values are from 2002.

ENERGY RECOVERY WHEELS

Another energy saving option that the design team considered was the use of enthalpy wheels or desiccant wheels. During cooling mode when outside air is hot and humid, the wheel transfers both heat and humidity from the outdoor air to the exhaust air. This decreases the cooling load on the other mechanical equipment. During the cooling season when outside air is frigid and dry, the wheel transfers heat and humidity to the incoming air from the exhaust air. This decreases the heating load required of the boiler and air handling equipment.

There are two drawbacks to including a wheel in the mechanical system in the Landscape Building. The primary reason is the risk of cross contamination. As the building is a medical research laboratory, there is a always a chance of chemicals, gases, or infectious material becoming air-borne in a space and consequently the mechanical system. One way the system manages this issue is to provide 100 percent outdoor air to all critical spaces and exhausting 100 percent of that air directly out of the building. Energy recovery wheels are able to recover energy and moisture because they are able to effectively mix the exhaust and supply air streams. Given this, contaminants will also transfer between air streams. As a result, the concept of using an enthalpy wheel was not pursed.

Desiccant wheels on the other hand do not transfer air-borne contaminants. The wheel is flushed with supply air that is deflected by a damper in the purging section of the rotor. This further helps reduce the risk of contamination. While this may work well in theory, the chance that the equipment may not work properly was a risk the owner was not willing to take. Using a desiccant wheel was not pursued.

The second more minor drawback is Howard Hughes Medical Institute did not want to pay for the equipment and additional space it would take up in the mechanical rooms.

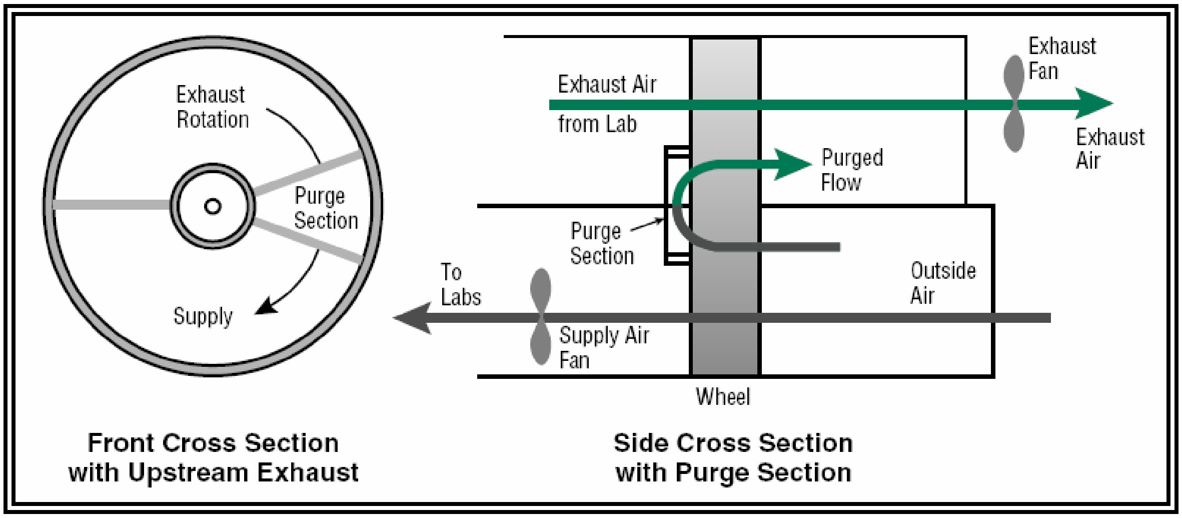

Figure 3 : Desiccant Wheel Schematic

HEAT EXCHANGERS

Two types of heat exchangers will be looked into; air-to-air and a "plate-type" heat exchanger made by ConsERV. Typical air-to-air heat exchangers only let sensible energy pass through a medium from out air stream to the other. As a result, the air streams never directly interact and contamination of the supply air cannot occur. No cross contamination is one of the primary design goals of the original design as well as this redesign. The draw back is the lack of latent energy transfer with an air-to-air heat exchanger. Humidifiers and dehumidifiers (cooling coils) will need to be introduced and sized into the system to ensure adequate humidity levels. This will add to the first cost of the system as well as energy costs.

The integration of a plate-type heat exchanger made by ConsERV will be analyzed for effectiveness and amount of energy saved. As stated in the product description, the exchanger "is a plate-type heat exchanger wherein the plates are constructed of ionomer membranes, such as sulfonated or carboxylated polymer membranes, which are capable of transferring a significant amount of moister from one side of the membrane to the other side." In other words, it is effectively a plate-frame heat exchanger, but instead of using metal or paper, a polymer membrane separates the two air streams. These membranes are able to transfer both sensible and latent energy, but the air streams remain completely isolated from each other. This is the critical feature which makes this a feasible addition to the mechanical system in the Landscape Building. The square box in the left side of Figure 5 below is the actual exchanger in one of the many possible configurations.

It is possible to model both types of heat exchangers in HAP 4.20a with product information found online.

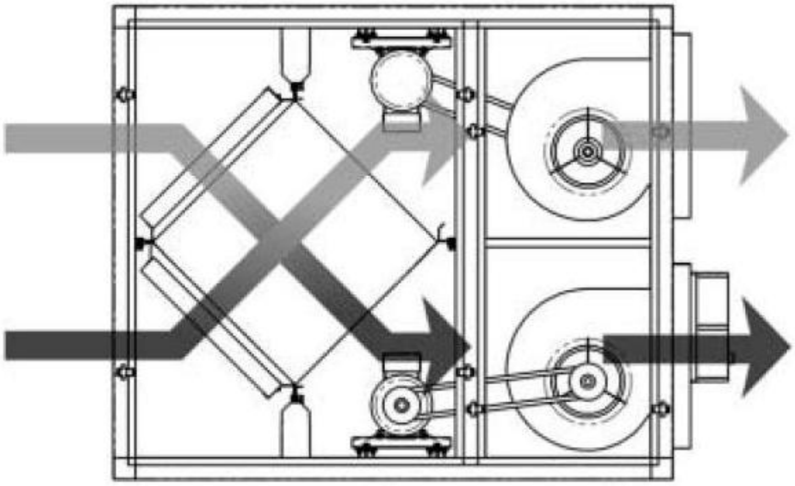

Figure 4 : Membrane Heat Exchanger Schematic

RUN-AROUND COILS

A run-around coil is a system designed to recover heat from the exhaust air stream to the outdoor air plenum and vice versa to pre-heat and pre-cool the incoming air. This is done by a fin tube coil located in the two air streams. According to the Application Team at the Lawrence Berkley Laboratory "A high-performance, run-around energy exchanger can provide a large increase in overall HVAC system effectiveness from 50 percent to nearly 70 percent, large returns on investment, typically 33 percent, and short payback periods of three years. In new building designs and retrofits, a run-around system can reduce peak heating and cooling loads as well as total heating and cooling loads. The run-around system can have a significant impact upon the boiler and chiller capacity in new HVAC designs." The A-Team also states that flow rates greater than 10,000 cfm are good for using this system. The Landscape Building has outdoor air and exhaust air flow rates in excess of 100,000 cfm and the two plenums are located parallel to each other. Installing a run-around coil may be an effective way of reducing the amount of energy needed to condition the air. It is possible to combine the run-around coil loop with the preheat coil to reduce the amount of pressure drop created by the run-around coil (labdesignnews.com). The addition of a run-around heat recovery system can be modeled in HAP 4.20a.

CASE 1 : EXISTING LOAD CALCULATIONS

The first step in the mechanical design is to model the existing laboratory spaces in Carrier's Hourly Analysis Program 4.20 as accurately as possible. The results serve as a benchmark against which all new designs are compared and analyzed.

The data that was needed included the following:

- Room dimensions and orientation.
- Wall, ceiling, and floor assemblies.
- Window and roof characteristics.
- Required supply air flow rate for each room.
- Lighting and equipment loads.
- Air system type and equipment specifications.
- System set points and controls.
- Plant characteristics and configurations.

Information was obtained from the master drawing set, specifications, design calculations, and consultants in the field. All documents were provided by the project manager from Jacobs Facilities, Inc. and a design engineer at Burt Hill.

Results from this model provided helpful information about the current design. Rooms were found to be receiving anywhere from one air change per hour to 47, indicating a great deal of over design. All spaces met ventilation requirements as outlined in ASHRAE Standard 62.1-2004. Please see Table 3 below for basic system information.

Table 3

Case 1 Mechanical System			
Cooling		Heating	
Total Coil Load [ton]	Sensible Coil Load [MBH]	Total Coil Load [MBH]	Peak Load [cfm]
684	4,635	2,602	181,933

CASE 2 : EXISTING SPACE WITH MODIFIED EQUIPMENT LOADS AND AIR CHANGES

Before making alterations to the mechanical system, accurately modeling the existing building was important. It was also important to determine if the assumptions made during the design process were reasonable. According to a research group of scientists and engineers, "Measurements from various laboratories indicate that peak equipment load tends to be overestimated greatly (Mathew, 8). If the air system was oversized, it would be possible to reduce it to the minimum size and therefore decrease equipment size and energy usage.

Existing design documents state 20 W/SF equipment loads for all laboratory and laboratory support spaces. Typically laboratories have an equipment load of 4 W/SF for lab spaces and a range of 6 to 8 W/SF for support spaces depending on the amount of equipment (Mathew, 2).

The design equipment loads and reduced loads were simulated to compare the impact on the mechanical system and energy usage. As a result of the equipment loads for the Landscape Building being unknown, a more conservative 10 W/SF for equipment loads was used. This most likely will result in a larger cooling load and consume more energy than will the actual building. Typically laboratory equipment load schedules were taken from ASHRAE Standard 90.1-1989 because the actual schedules are not known. The occupancy schedules have been taken from the original design calculations as seen below in Table 4.

Table 4

Occupancy Schedule			
Space	**8:00 am to 4:00 pm**	**4:00 pm to 12:00 am**	**12:00 am to 8:00 am**
Open Labs	80%	55%	45%
Lab Support	80%	70%	70%

The results of the reduced load model did not have an effect on the required air flow rate as this is a function of air changes and not the load. One result of this adjustment is less energy is used by equipment than expected. Another good outcome is the room air ΔT can decrease to meet the loads with the same amount of supply air. The room temperature is set at 70°F/50%RH.

$$q = 1.08\text{cfm}\ \Delta T$$

Where q = total cooling load

ΔT = return air temperature – supply air temperature

The required supply air temperature required for the actual design is found to be 34.1°F from the following calculation.

$$8{,}028{,}000 = 1.08(181{,}933)(75 - T_{supply}) \qquad T_{supply} = 34.1^{o}F$$

With the reduced equipment loads, the supply air temperature becomes

$$6{,}276{,}000 = 1.08(181{,}933)(75 - T_{supply}) \qquad T_{supply} = 43.1^{o}F$$

As it can be seen in the short calculation above, reducing the load has a major impact on the room air ΔT. A 21.8% reduction in the load raises the required supply air temperature by nine degrees. Typically, the lower practical limit to supply air temperatures is 40 °F. Therefore, it can be argued that having T_{supply} = 34.1°F is not reasonable.

The hand calculated supply air quantities were combined with the reduced equipment loads to produce the following results. There was a 23.7% reduction in the total coil load and a 21.7% reduction in the annual energy cost. A more comprehensive simulation result can be found in Appendix B.

Table 5

Case 2 Mechanical System			
Cooling		**Heating**	
Total Coil Load [ton]	**Sensible Coil Load [MBH]**	**Total Coil Load [MBH]**	**Peak Load [cfm]**
522	3,534	1,987	138,726

As stated above, after modeling the existing laboratory space it was found that air chances per hour ranged from 1 to almost 48. Having 48 air changes per hour is excessive and a large amount of energy could be saved by downsizing the system. Using the design standards provided by the engineer, required supply air flow rates were determined by hand calculations. Care was taken to ensure the spaces were still sized to create negative pressure using the exhaust hoods.

The owner Howard Hughes Medical Institute typically bases design requirements on The National Institute of Health's (NIH) design standards for their laboratory buildings. In this case, the laboratory spaces called for a minimum of 8 air changes per hour which is greater than the minimum requirement based on NIH design standards. Support spaces have a higher load density and therefore a minimum of 12 air changes per hour should be used.

There are spaces adjacent to the laboratories that were included in this model due to their location. They are not considered lab or support spaces and therefore do not need to be evaluated based on air changes. Instead, ASHRAE Standard 62.1 is applicable. Occupancy classification and internal loads were used to determine the minimum amount of outdoor air needed. In the original design of the building, these spaces were considered laboratory support spaces and therefore were greatly over designed.

CASE 3 : EXISTING SPACE WITH REDUCED LIGHTING LOADS

For the lighting system breath work of this report, the lighting layout and lamp selection was analyzed to determine if the load on the spaces could be reduced. It was concluded that the layout could be improved to provide a more uniform distribution as well as selecting lamps with a better lumen per watt ratio. There was a small decrease in the total coil load. It dropped from 684 tons to 677 tons. The biggest savings can from reducing the electricity use of the lights by 19.4%.For a more detailed explanation, please see Appendix C.

Table 6

Case 3 Mechanical System			
Cooling		Heating	Peak Load [cfm]
Total Coil Load [ton]	Sensible Coil Load [MBH]	Total Coil Load [MBH]	
677	3,222	2,573	181933

CASE 4 : OVERALL IMPACT OF REDUCED LOADS

Case 4 represents combining Case 3 with Case 4. The overall impact of simply designing the system to design standards and not over sizing is fairly significant. It is significant in the fact that resizing the lighting and reducing the equipment loads produced an annual savings of $241,077 which is approximately 25 percent with very little upfront cost to the owner. Comparing the original design in Case 1 to the overall results, the total coil load decreased by 28 percent. This case study clearly demonstrates the importance of knowing the use and loads of each space as much as possible during the design process. The Landscape Building was put out to bid very early in the design process with only approximately 75% of the design completed. The remainder of the design was completed by the contractors on site with the aid of shop and fabrication drawings.

Simulation results can be found in detail in Appendix D.

Table 7

Case 4 Mechanical System

Cooling		Heating	
Total Coil Load [ton]	**Sensible Coil Load [MBH]**	**Total Coil Load [MBH]**	**Peak Load [cfm]**
492	3,337	1,866	138,726

GROUD-COUPLED DESIGN

GROUND-COUPLED SYSTEMS

Ground-Coupled Heat Pumps (GCHPs) are a subset of ground-source heat pumps (GSHPs). GCHPs use a series of plastic piping buried either horizontally or vertically in the ground to discharge or gain energy. The ground may be used as a heat sink due to the relatively constant temperature by either warming the water during the summer or cooling the water in the winter. The benefit of using a GCHP system is the use of free energy which would otherwise have to be produced by mechanicals means. The downside is the large upfront cost of installing the system and the pump energy consumed during operation.

One significant design requirement is an adequate amount of land to install the system. Bores can either be horizontal or vertical. The benefit of vertical bores include a smaller plot of land is required; the soil temperature varies less at larger depths, and require the smallest amount of pipe and pumping energy (Kavanaugh 1). In addition, vertical loops are able to transfer more heat than horizontal loops. The main drawback to vertical fields is the much higher cost as compared to a comparable horizontal field. Howard Hughes Medical Institute owns 669 acres on the Janelia Farm Campus. It is probable that horizontal piping could be used if vertical bores are not necessary. This would result in a lower first cost as vertical drilling can be more expensive.

There are two options for the type of pipe loop designed; closed and open. In a closed loop, water or a refrigerant solution are circulated in a piping loop and then heat is exchanged to or from another piping loop. This prevents any possible contamination from the ground loop to cause problems in the interior piping and equipment. An open loop either uses an open well, stream, or lake as a water source and then can discharge water back. In the case of a well, at least two separate wells are required. Open loops tend to be less expensive on a per-ton basis for large systems and can require no more maintenance than a typical HVAC system is well deigned (Kavanaugh 5). With open systems there is the drawback of environmental issues that stem from dumping possibly contaminated into a nature water source.

Possible configurations include the following:

- Using the water for pre-heating coils in the air handlers.
- Using the water to directly serve the VAV boxes already in the original mechanical system design. This configuration could use the existing piping that serves the VAV boxes. In this system, the branches of the VAV piping will need to be determined as well as location and sizes of heat exchangers.
- A typical heat pump system with a central loop and pump. This application is better suited for smaller buildings. The Landscape Building is too large in size to consider using one pump to serve a system.
- One local loop, multiple heat pumps with pump and check valves on each unit.
- Multiple individual loops, heat pumps, and circulator pumps.
- Multiple units with one local pump that operates when one or more unit is on.

- Multiple units with two-way valves, one local loop, and variable speed pump.
- Heat pumps and water heater on the same loop to balance local load (Kavanaugh 4).

This thesis report will determine the best way to use GCHPs in the Landscape Building to both reduce the amount of energy required to heat and cool the laboratory spaces and reduce the operating costs.

SYSTEM DESIGN

The ground loop is replacing the cooling towers as the means for releasing and absorbing energy to and from the atmosphere, instead of designing a typical ground-coupled heat pump system. The following briefly describes the reasons for this approach:

1) After completing a rough estimate calculation on the size and number of heat pumps that would be required to serve the laboratory spaces, it was determined that too many heat pumps are required. Approximately 300 fairly large heat pumps would need to be located throughout the laboratory spaces. There actually is enough space in the building to do this. The service corridor located behind the occupied areas has 10 feet dedicated to housing MEP system equipment. While being feasibly, it did not seem reasonable to install such a large amount of equipment. The first cost on top of the cost to install the ground loops would have made the system too expensive.

2) The boilers and chiller are used for other applications besides heating and cooling the spaces. The boilers are used to generate steam and hot water that is used by another building on the site as well as supplying a means of sterilizing laboratory equipment in the wash rooms. The chiller is used to meet the loads of the cold rooms and also the data and communication rooms which operate on independent systems from the rest of the building. Therefore, replacing the current system with a heat pump system would eliminate the means to meet the loads of these specialized areas.

3) Using a heat pump system to heat and cool the building requires the heat pumps to be located near the spaces. This in turn means that the piping will travel from the space through the building, to a heat exchanger, and then into the loop in the ground. As the Landscape building is fairly long, this would require loops to be considerably large. This would increase the pressure drop in the pipes thereby requiring larger pumps that consume more energy. In addition, more energy would be lost out of the pipe.

Therefore, it was determined that connecting the ground loop water indirectly into the condenser side of the chiller will be system of choice for this report. The schematic for the system if found below in Figure 5.

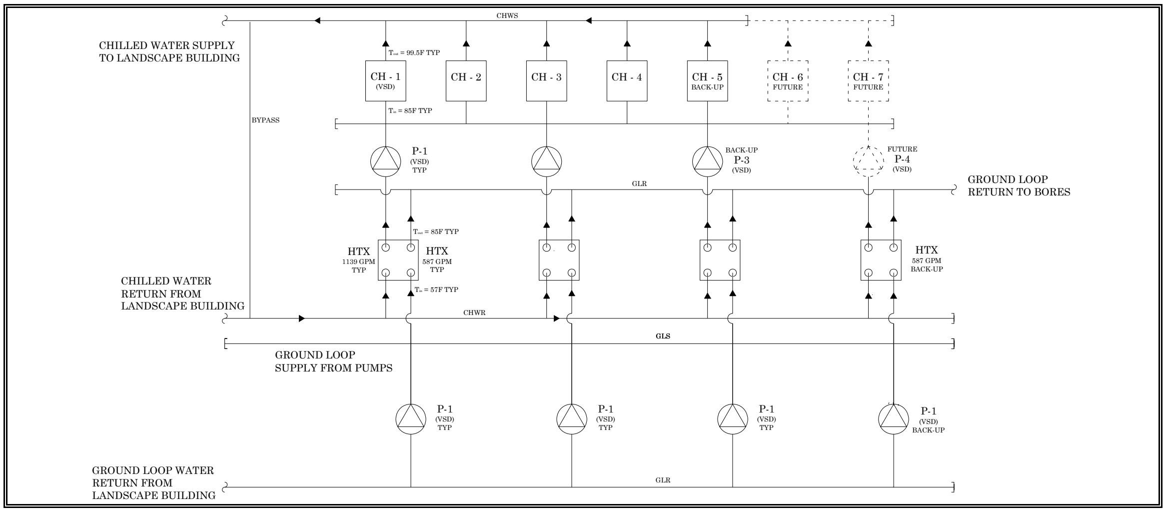

Figure 5 : Condenser Water Schematic

VERTICAL FIELD CONFIGURATIONS

Based on the size of the cooling load, vertical loops will better serve the Landscape Building. Typically, vertical bores need to be located with a minimum of 15 to 20 feet between bores to ensure heat transfer from one bore to another does not occur. It is possible to use two U-tubes per bore. While there is less heat transfer per tube, it may be economically viable due smaller first costs in drilling. An other option is whether to use parallel loops or series loops. "A parallel-piped vertical heat exchanger can utilize U-tubes with smaller diameters than a series-piped vertical heat exchanger, resulting in lower piping costs, lower antifreeze costs, and probably lower labor costs because the smaller pipe is easer to work with." Parallel loops all have the same amount of heat transfer where as the series loops have varying heat transfer depending on the location in the series.

The bore field will be located in the field behind the Landscape Building and then extend east and west of the building. In this location, the piping can extend approximately 60 feet from mechanical room up to the ground surface, drop 120 feet, and then rise 60 feet back to the mechanical rooms. The bores will not extend up as high as the frost line to ensure that freezing is not an issue. Also, the field in which the bores are located is projected by historic preservation acts and therefore nothing substantial will ever be installed there. This ensures that the structural integrity of the soil will also not become an issue.

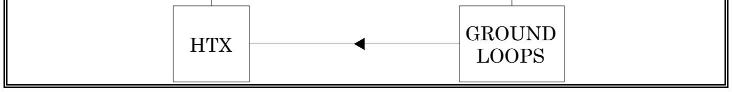

Figure 6 : Ground Loop Diagran

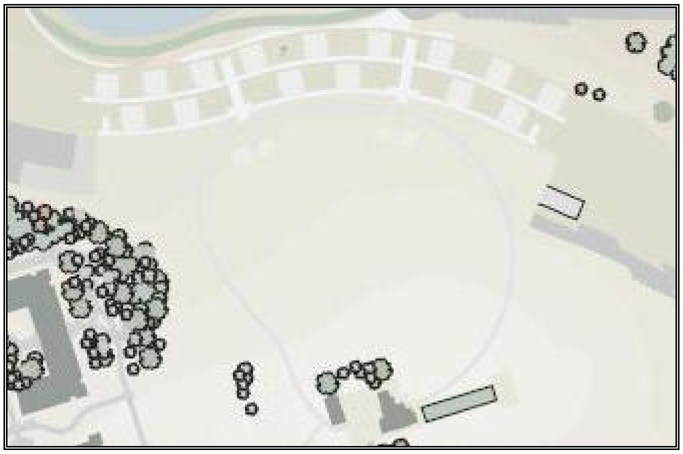

Figure 7 : Ground Loop Proposed Site

Figure 7 above is a rendering of Landscape Building and the surrounding Campus. The building is the series of squares connected by a thin white line. These squares are the office pods located on the second and third floors and are the only part of the building that is exposed. The building and cluster of trees to the left is an existing office building that is currently being used as the trailer for the project manager, architect staff, MEP engineers, and the owner's representative. It is still unknown what plans Howard Hughes Medical Institute has for these buildings. There is a good possibility that they will be demolished after construction is completed. The group of buildings at the bottom center is the Janelia Farm Mansion and out buildings. This building is a historic landmark. The view of Sugarloaf Mountain is protected, meaning nothing can be built that would impair this view. The gray loop seen in the field above is a sidewalk between the two buildings for recreational use. The area that is protected is the wedge that begins at the Mansion and extends upward over the Landscape Building. The boundaries of it are symbolically incorporated into the building as the feature stair cases represented by the two long rectangular shapes which divide the building into thirds.

It is in this area between the Mansion and the Landscape Building that the vertical bore field will be located. As calculated above, the bores will reach a depth of approximately 120 feet below ground. With 61,000 feet of piping to handle the design loads of the building, 510 bores are required. There will be 20 feet between bores in all directions to ensure that heat transfer between bores does not become a problem. A 15 x 34 bore or 300 x 680 ft array will accommodate the number of bores required. The bore array will easily fit within the limits of the field which is well over 210,000 square feet. After sizing three heat exchangers to serve the load of the building, the pipe diameter was found to be 1-1/4" using Table 5.4 found in Ground Source Heat Pumps published by ASHRAE.

All calculations can be found in Appendix E.

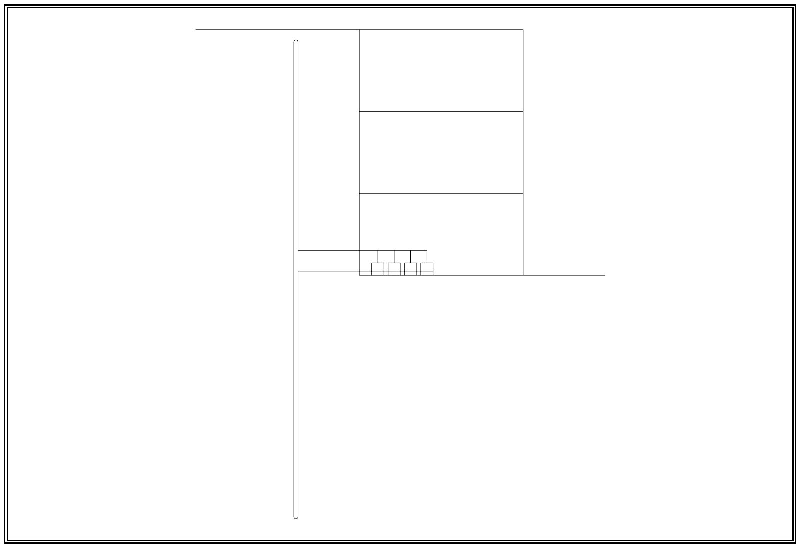

Figure 8 : Bore Diagram

Due to the new system configuration, only pumps on the ground loop side and heat exchangers needed to be sized. There are thee pumps in parallel serving the ground loops and one back-up pump. They are 4030 series variable frequency drive pumps from Armstrong, operating at 3600 rpm. The peak load efficiency is 78%. The heat exchangers were selected using computer software provided by SWEP. There are three heat exchangers in parallel with each other and in series with the pumps. They each have a flow rate of about 570 gpm. Cut sheets and pricing information can be found in Appendix I. The system components have been designed in parallel to continue the practice of allowing for easy maintenance or as a safety in case of failure. This design also connects in well with the current chiller and pump configuration.

POND LOOP CONFIGURATIONS

An alternative configuration is to use the two existing man-made ponds as heat sinks in an open loop system. These ponds are located just north of the Landscape Building and currently serve aesthetic purposes only. Figure 9 below in a rending of the Landscape Building and the two adjacent ponds.

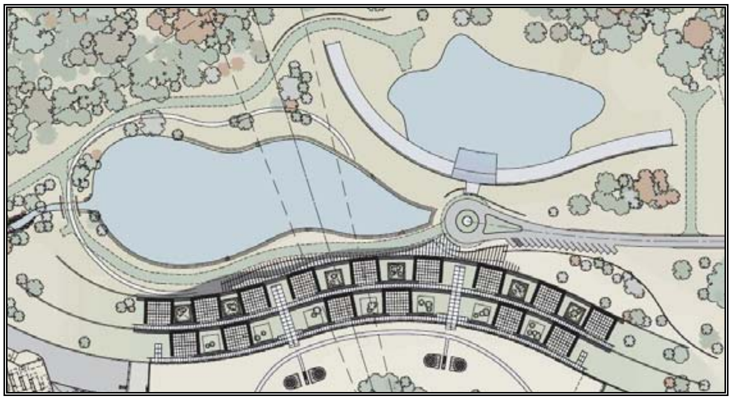

Figure 9 : Existing Ponds

The long arched building is the Conference Housing Building. This building is provides short term housing for visiting scientists and engineers. The Upper Pond is 18 feet deep with the bottom elevation of 240. The pond is 1.1 million square feet in area. The Lower Pond has a bottom elevation at 226 and is 12 feet deep. The pond is slightly smaller than the Upper Pond with an approximate area of 590,000 square feet.

The proposed system will draw water from the Upper Pond, pump in through the heat exchangers in the mechanical room in Zone F, and then be pumped through the service corridor that runs between the two buildings and empty into the Lower Pond. Water will also be pumped at the same rate from the Lower Pond to the Upper Pond to complete the full circle. The pumps that move the water between ponds will be located in existing space in the Conference Housing Building mechanical room. As the ponds are man-made and a great deal of earth work needs to be done for their construction, incorporating a series of pipes into that design is relatively simple and should not incur extra major expenses.

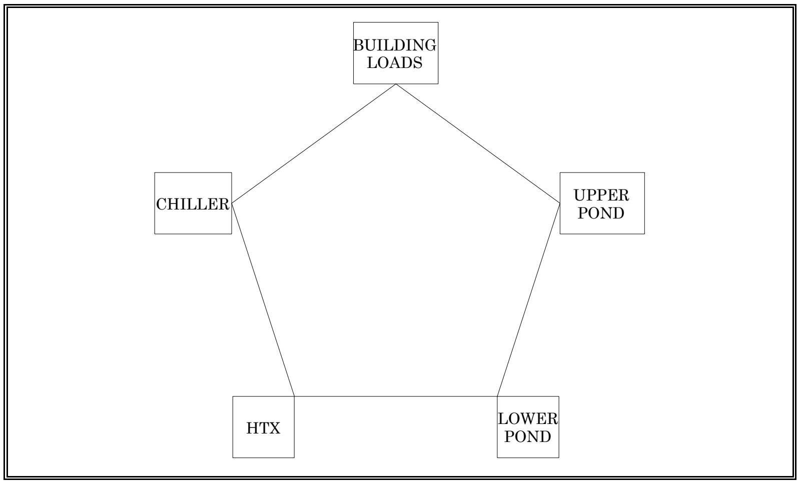

Figure 10 : Pond Loop Diagram

There are 3-1050 series pumps and one back-up pump from Bell & Gossett. They run at 1750 rpm and have a peak load efficiency of about 79%. The pumps are equipped with a VFD bypass to ensure that the heat exchangers will still receive peak load flow when the VFD is not functioning. End suction pumps were selected even though they do not have the best efficiency possible, they do prevent cavitation from occurring. The possibility of having to replace a pump early is more of an economic burden than having to account for a slightly lower efficiency. The pumps that are located between the two ponds have the same features as the pumps in the mechanical room. The only difference is that they are smaller due to small head requirements. Cut sheets can be found in Appendix I.

The ponds have been previously designed to maintain the same water level throughout the year through the use of a make-up water system. In the event that this system is not operational there is a small creek that flows into the Upper Pond. The water discharge and intakes will be located as far apart in each pond to allow the maximum amount of mixing to occur so that constant temperature water is supplied to the building. All pipe inlets and outlets will be located at the bottom of the ponds so as not to diminish their intended aesthetic quality and to provide water that has a more constant temperature. There is no data on the thermal properties of these water sources as they are small man-made ponds and therefore it is assumed that the temperature at the bottom is approximately the same as the ground temperature for calculation purposes.

Pipe is sized to 6” using System Syzer Calculator.

EMISSIONS & FUEL SAVINGS

Emissions and fuel savings is a direct result of smaller loads and more efficient systems. By designing a lighting system with lamps that provide more lumens per watt and more accurately modeling the equipment loads, the building is consuming less energy. Therefore, the operating costs are down as well as emissions rates. Appendix H has complete information on emissions and fuel consumption for each case. Case 7 uses 28.5% less electricity than the actual system. In addition, emissions decreased by approximately 30% as well.