Shippensburg University

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Central Chilled Water System Evaluation

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June 10, 2010

Shippensburg University
Central Chilled Water System
Evaluation

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Shippensburg University
Central Chilled Water System

1.0 BACKGROUND

In 2008, a Utility Master Plan for Shippensburg University was developed as part of the overall Campus Master Plan. One of the more significant recommendations presented in the Campus Master Plan was to replace the existing residence halls with new, air conditioned buildings constructed over a period of three years. The Campus Master Plan also emphasized the importance of implementing energy and environmentally friendly practices.

The Utility Master Plan then evaluated various strategies for providing heating and cooling to the campus into the future. Several strategies for providing air conditioning to campus buildings into the future were explored, including the following:

<u>Air Conditioning Options</u>

- Continue with "distributed" air conditioning equipment at each building.
- Central chilled water.
- Ground-source heat pumps for heating and cooling the new residence halls.

In the Utility Master Plan, the Central Chilled Water system was presented as the recommended cooling option for the following reasons:

<u>Benefits of Central Chilled Water</u>

- There is economy of scale with larger chilled water equipment. The new residence halls will require substantial cooling equipment which can be more economically installed if it is installed as a central plant rather than cooling equipment installed at each building.
- Building mechanical rooms' size and cost can be reduced in the proposed residence halls. Cooling tower pumps are located at one site versus having plumes all over Campus.
- Equipment noise and vibration from chillers and cooling towers will be located at the central plant, not within the housing area.
- The central chilled water plant will have back-up equipment, and is therefore more reliable.
- The central plant will have very efficient equipment, reducing energy costs and greenhouse gas emissions.
- It is easier to implement electric load limiting or curtailments with central cooling.
- With proper piping design, existing chillers in campus buildings can be connected to the cooling loop to help provide chilled water to other campus buildings.
- With system diversity, the connected cooling equipment in a central cooling system will be less than what would be installed if each building had its own individual chiller.
- With proper planning, future buildings and renovated buildings can be easily connected to the central cooling system for lower cost.
- Thermal storage, an option for moving cooling and electrical load to off-peak periods, can be more easily installed on a central chilled water system.

This study further investigates the feasibility of adding a central chilled water system for the campus. A preliminary design has been prepared to illustrate the recommended system, identify proposed equipment sizes, and develop opinions of probable cost. The option of adding thermal storage is also explored.

2.0 CENTRAL CHILLED WATER SYSTEM CAPACITY

While it is not necessary to install the total central chilled water system at one time, it is important to have a long term plan for which cooling loads will eventually get connected to the system. The main piping system should be installed so that it is large enough to pump the required chilled water around the Campus. Even if buildings with chillers are connected to the Campus pipe loop to help supply chilled water to the Campus, eventually those building chillers may be replaced with a larger central chiller capacity located in the plant.

The following table has been prepared to estimate the potential size of a Campus central chilled water system. A 70% factor has been applied to represent the lower combined cooling load as a result of load diversity.

Building Name	Conditioned Floor Area (SF)	Estimated Cooling Load (tons)	Installed Capacity (tons)	Year Installed
Buildings With Newer Chillers that Remain				
Reisner Dining Hall	71,296	350	350	2004
Heiges	91,634	24	24	2001
Franklin Science/ Shippen/ Dauphin	201,308	700	700	2001
PAC (Performing Arts Center)	92,380	340	340	2004
Shearer/Rowland	42,863	185	185	2006
Kriner Hall	32,611	70	70	2001
Student Rec Center	64,196	192	192	2007
Huber	44,000	90	90	2009
Total	**640,288**	**1,951**	**1,951**	
Total w/70% Diversity		**1,366**		
Buildings With Older Chillers that will be Removed				
Memorial Auditorium	26,375	80	80	1996
Lehman Library	74,108	185	240	1990
MCT Center	39,194	100	100	1995
Grove Hall	69,278	300	300	1995
Old Main (partially cooled)	75,000	140	140	1980
Total	**283,955**	**805**	**860**	
Total w/70% Diversity		**564**		

Building Name	*Conditioned Floor Area (SF)*	*Estimated Cooling Load (tons)*	*Year Installed*
	Buildings to be Connected in the Next 5 Years		
Etter	*9,000*	*20*	*1976*
Stewart	*11,936*	*32*	*2014*
Ceddia Union (CUB) w/expansion	*140,000*	*400*	*2011*
Dorms (Phase 1)	*284,000*	*711*	*2012*
Dorms (Phase 2)	*281,400*	*704*	*2013*
Dorms (Phase 3)	*297,700*	*744*	*2014*
Total	***1,024,036***	***2,611***	
Total w/70% Diversity		***1,818***	

Total Estimated Cooling Load by the Year 2014 = 1,366 + 564 + 1,828 = 3,758 tons.

The total estimated cooling load for buildings that will be connected to the Central Chilled Water System by 2014 is 3,758 tons. Seven of these buildings have chillers that were installed within the past eight years, which can be used to provide chilled water if required. While the total nameplate capacity for these chillers totals 1,951 tons, the Campus can probably rely on 60% of this capacity for Campus use. The remaining capacity is available, but because of the building location, it cannot be delivered efficiently to all the buildings connected to the system.

It is also forecasted that there will be nine buildings requiring additional cooling within the next 5 to 25 years. This future load is estimated to be approximately 1,432 tons.

Buildings to be Connected in 5 years to 25 years	**SF**	**tons**
Old Main (expand cooling)	39,000	240
Building between Dauphin & Franklin	55,600	161
Bldg between Kriner & Henderson	75,600	218
Lehman Library Expansion	78,000	195
Building between Grove & MCT	68,800	200
Building on Naugle Site-1	87,200	252
Building on Naugle Site-1	76,000	220
Heiges (expand cooling)	81,600	233
Henderson	36,250	104
Total	**398,050**	**1,823**
Total w/70% Diversity		**1,276**
Total for Campus	**2,546,329**	**7,245**
Total for Campus w/70% Diversity		**5,072**

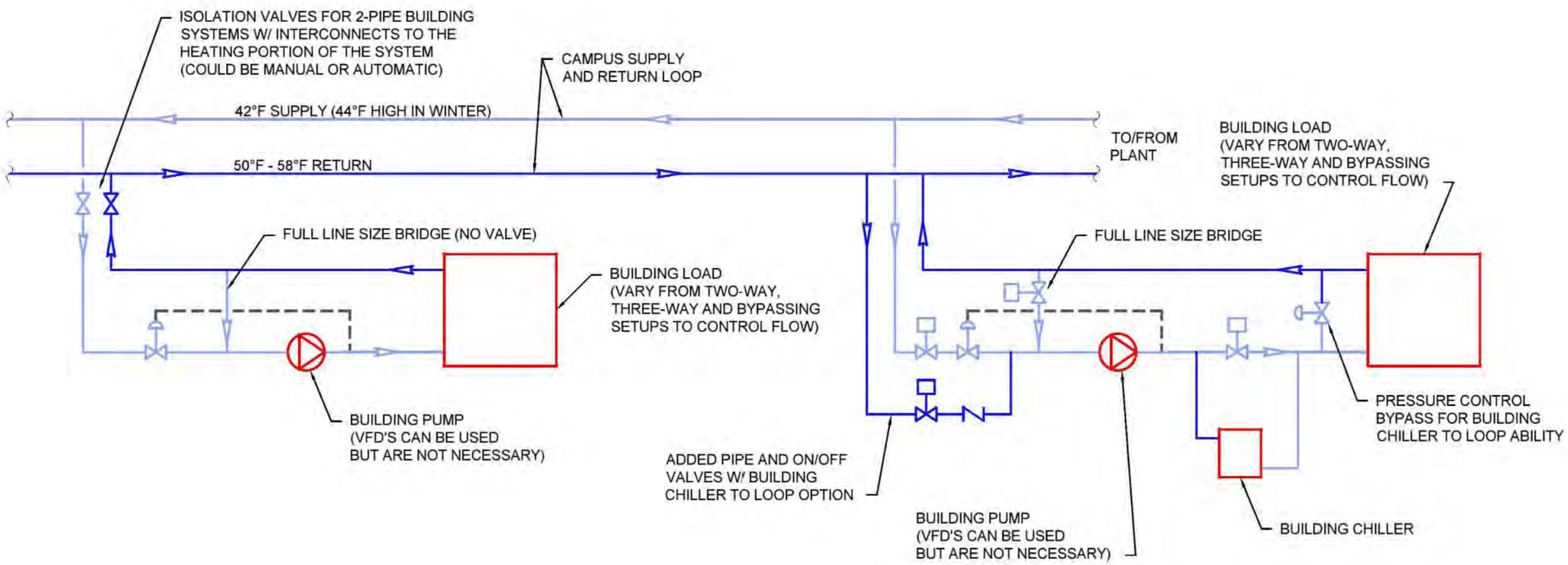
Based on this chilled water load summary, the total Central Chilled Water System should be sized to handle approximately **<u>5,072 tons</u>** (3,744 tons + 1,328 tons). The target sizing for the plant is 4,800 tons with the residual amount to be supported/ offset by Campus building chillers as needed. The mains coming out of the plant are intended to be 20", which can handle approximately 5,000 tons at a 12°F temperature differential and even more at higher ΔT's. If the main chilled water pipe is 20-inch, then the chilled water flow can be as high as 10,000 gpm.

3.0 CONNECTING EXISTING CHILLERS TO THE SYSTEM

With proper piping design, it is possible to connect existing building chillers to the chilled water pipe loop that will be installed on the Campus. In order for a building chiller to be able to supply chilled water to the campus loop, three pipes must be installed between the building and the pipe loop. The simple flow diagram, Figure 1 found on the following page, illustrates a typical bridge arrangement for all the buildings, and it also shows the added third pipe needed to incorporate a building chiller that could "export" chilled water to the central loop.

Because the chilled water supplied by the chillers must enter the Campus supply pipe before it reaches the buildings with the cooling load, it is best to have the building chillers that supply chilled water to the loop be located as close to the central plant as possible. If it is located further away, the equipment cannot be relied upon to provide the total chiller capacity to other buildings where the cooling load is located.

The CUB chiller is not included on this list. Because the timing on the Central Chilled Water System is close to the completion of the CUB Renovation Project, a new 500 ton air-cooled chiller is being installed at CUB on a temporary basis until the central plant is operational. The CUB chiller can then be relocated to the Central Chilled Water Plant. The CUB chiller will be an air cooled chiller that can later provide the smaller amount of chilled water needed during periods of colder weather when tower freezing is a problem for water cooled chillers.



<u>TYPICAL BUILDING SETUP</u>
<u>(2-PIPE TO LOOP)</u>

<u>TYPICAL BUILDING SETUP</u>
<u>W/ CHILLER (3-PIPE TO LOOP)</u>

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CENTRAL CHILLED WATER PLANT
TYPICAL BUILDING SCHEMATIC

FIGURE 1

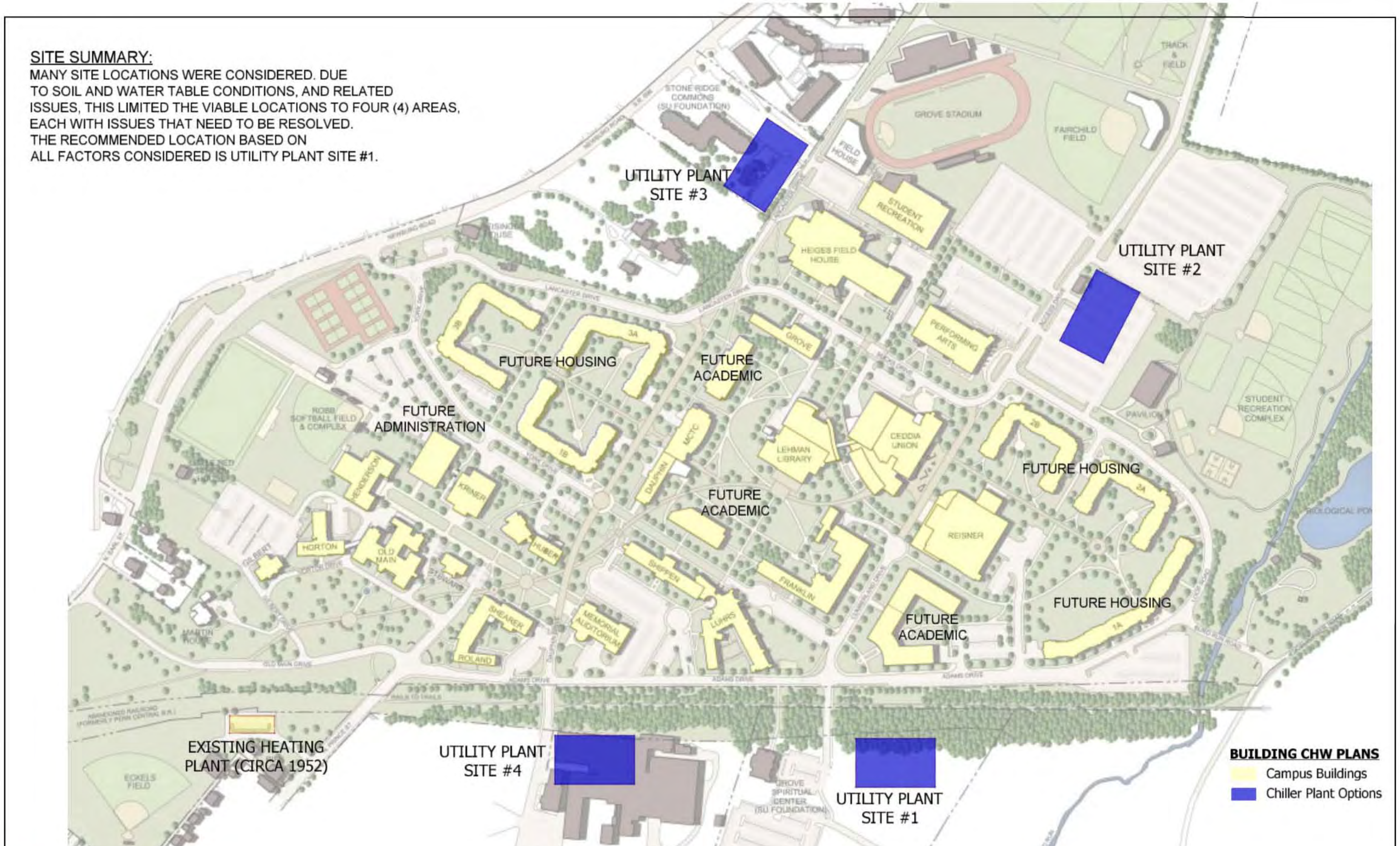
4.0 CENTRAL PLANT LOCATION

Various site locations for the proposed Central Chilled Water Plant have been evaluated. The central plant will contain the main chillers and pumps for the system. Factors that must be considered when selecting a plant location are as follows:

- The plant should be located as close to the Campus chilled water loads as possible in order to reduce piping costs and minimize pumping costs.
- Because the plant will contain large, noisy equipment, it should be located away from other buildings as much as possible.
- There are benefits if the chilled water plant is located adjacent to the Campus heating plant. The existing plant is not ideal from a distance standpoint, and would add significant construction costs, and of course add to the pumping costs. The existing plant does not have the space to accommodate chillers and construction in the area is limited. If together, the plant operators could more easily supervise both heating and cooling operations. Also, building spaces (shops, storage, chemical storage, loading/unloading, etc.) can serve both heating and cooling operations rather than having duplicate spaces if the operations are split.
- Because the plant will require truck traffic (plant deliveries, maintenance trucks, etc) it is better to locate the facility outside of the Campus, away from heavy pedestrian traffic.
- There must be sufficient space to locate cooling towers. As discussed later in this report, there is also an opportunity to use thermal storage for the chilled water system. Consequently, there must be space to be able to erect a large, pad-mounted storage tank.
- The site must be available for this function.

A number of possible plant locations were evaluated on campus. The possible plant locations investigated are shown in Figure 2 on the following page. However, based on the factors described above, the recommended location for the central plant is on the wooded area located across from the Spiritual Center. This land is presently owned by the Foundation.

The site plan on the next page, Figure 3, identifies the preferred building location. Figure 4 is the same area layout with a thermal energy storage (TES) tank.



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CENTRAL CHILLED WATER PLANT
CAMPUS UTILITY PLANT LOCATIONS

FIGURE 2

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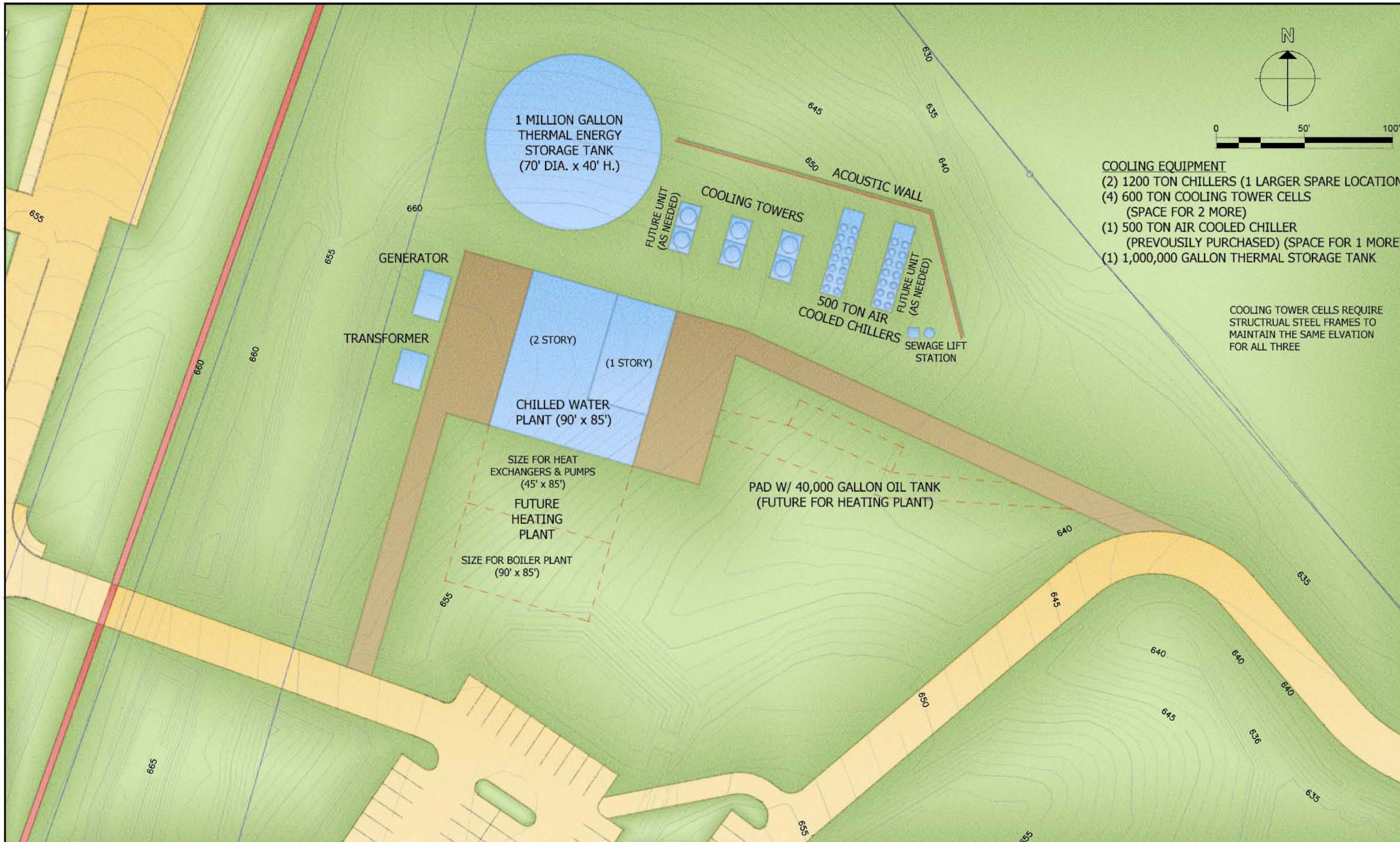
CENTRAL CHILLED WATER PLANT
PROPOSED SITE PLAN - UTILITY PLANT SITE #1

FIGURE 3



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CENTRAL CHILLED WATER PLANT
PROPOSED SITE PLAN WITH THERMAL STORAGE - UTILITY PLANT SITE #1

FIGURE 4

5.0 PROPOSED CAMPUS CHILLED WATER LOOP

With a central chilled water system, a system of underground chilled water supply and return pipes must be installed around the Campus. If project funding is limited, some of the piping can be installed in later phases. However, if funding levels permit, it is best to complete the main distribution loop in the first phase.

The proposed pipe routing is illustrated on the site. The following design criteria was used when developing the proposed pipe route.

- Locate the pipe underground, away from congested areas with other underground utilities.
- Where possible, stay away from roadways and sidewalks to reduce restoration costs.
- Stay away from areas known to have significant underground rock, implying roads may be a better choice in some areas.
- Develop a loop around the Campus core. With a properly designed loop, sections of pipe can be taken out of service to make repairs without taking the total system out of service. The loop also can provide more efficient pumping.
- Target a pipe loop differential temperature designed for 14ºF ΔT and 5,100 tons cooling load. This is a long term goal, not an immediate requirement.
- Maximum pipe velocity = 12 ft./sec for 6" and larger diameters. Below 6", the recommended criteria is a loss of 8'/100' of piping.
- Chilled water supply temperature in loop = 42ºF to allow 45ºF supply in buildings.
- New building HVAC system designs should target 15ºF ΔT's.
- Pipe should be Schedule 40 welded steel pipe with foam insulation covered by an HDPE jacket. In other installations, pipe materials such as PVC or ductile iron have been used, and many times these lines have not been insulated in order to reduce costs. However, we do not recommend reducing quality on pipe materials and insulation for such an important system. There are newer products such as flexible tubing that may be considered for connections to buildings with smaller loads, but welded steel is our recommendation.

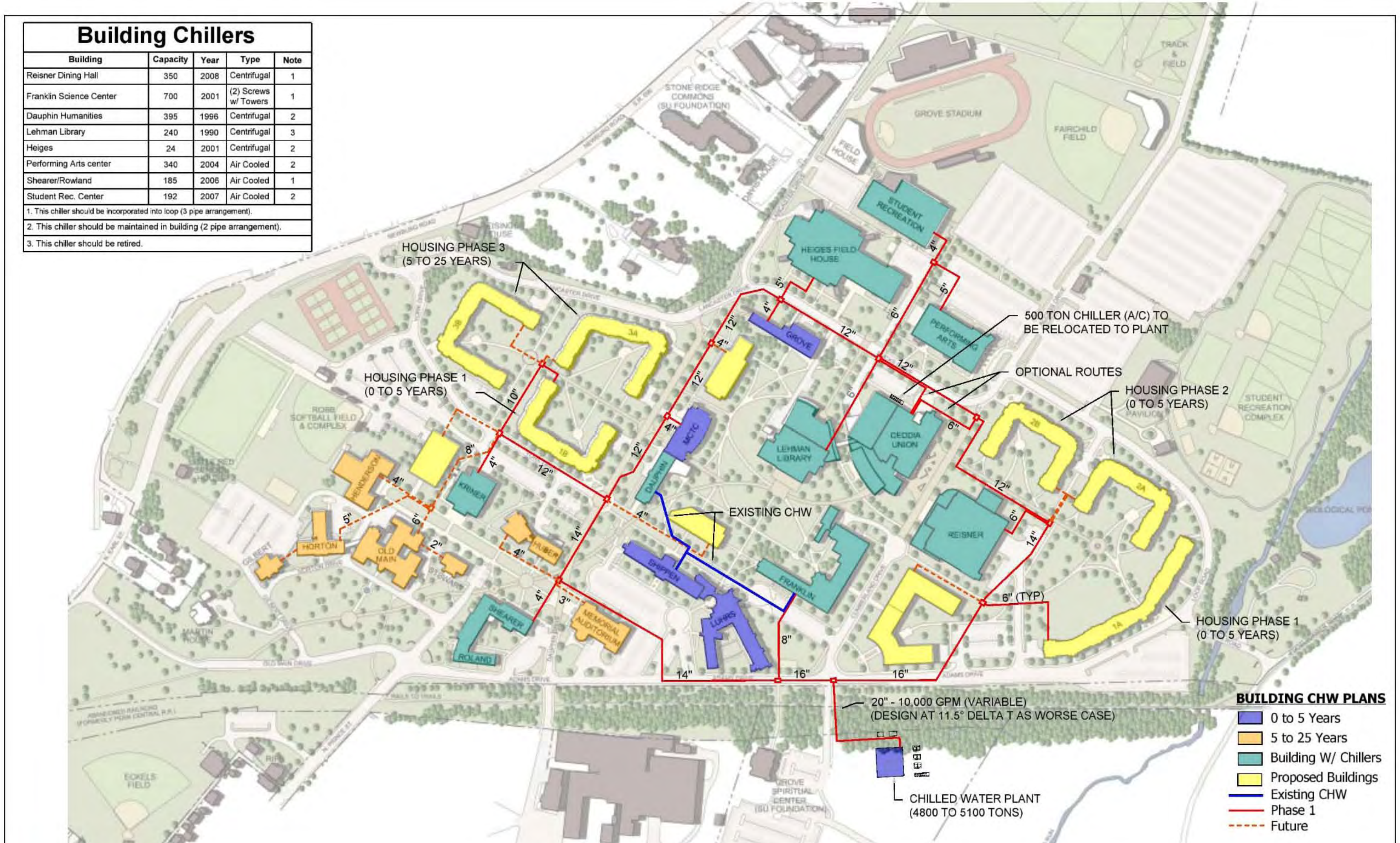
Using the criteria described above, a preliminary pipe layout for the Campus has been developed. The suggested pipe routing is shown on the site plan found on the following page in Figure 5. The plan identifies buildings that should maintain their chillers to help with Campus cooling during hot days. It also shows buildings that can be added to the system whenever an HVAC renovation project adds or replaces air conditioning in a building.

The chilled water loop should have primary pumping in the central plant with a variable frequency drive to vary the flow based on cooling load. A recirculation pump should be installed in each building connected to the central chilled water system. The chilled water supply from the campus loop should connect to the pump with a temperature control valve. The building return should have a "bridge" between the building pump and the temperature control valve. Refer to the diagram in Figure 1, previously shown, that schematically depicts how this building hookup connection should be piped.

Building Chillers

Building	Capacity	Year	Type	Note
Reisner Dining Hall	350	2008	Centrifugal	1
Franklin Science Center	700	2001	(2) Screws w/ Towers	1
Dauphin Humanities	395	1996	Centrifugal	2
Lehman Library	240	1990	Centrifugal	3
Heiges	24	2001	Centrifugal	2
Performing Arts center	340	2004	Air Cooled	2
Shearer/Rowland	185	2006	Air Cooled	1
Student Rec. Center	192	2007	Air Cooled	2

1. This chiller should be incorporated into loop (3 pipe arrangement).
2. This chiller should be maintained in building (2 pipe arrangement).
3. This chiller should be retired.



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CENTRAL CHILLED WATER PLANT
CAMPUS CHILLED WATER PIPE ROUTING

FIGURE 5

The proposed concept incorporates existing underground PVC piping between the Franklin and Shippen/Dauphin buildings. It is assumed that the existing piping is capable of handling 150 psig pressure and this piping should be hydrotested at some point to confirm this.

The campus building automation system (BAS) can be expanded to control the chilled water operations. With a web based BAS, the system can be monitored and controlled from almost any location. In most buildings, there should be a central panel for monitoring temperature and flows so Btu's can be measured at each building. In this time where energy efficiency is critical, measuring energy consumption is vital. If chilled water storage is implemented, understanding and predicting chilled water use and matching it to the chilled water available in the tank will be necessary.

6.0 CHILLED WATER PLANT REQUIREMENTS

Should the University proceed with constructing a new heating plant, the building for the central chilled water plant should be combined with the new heating plant building. However, it is possible to construct the chilled water plant as a stand-alone facility. The building should include the following:

- Three electrical driven chillers with space for a fourth (future) chiller. The total plant capacity should be sized for an eventual 4,800 to 5100 tons of cooling. Water cooled centrifugal chillers will see some variable flow.
- Relocate the 500 ton air-cooled chiller from CUB to a pad located outside the chiller building. This will be a lower load, winter use chiller that would likely be brought on last otherwise.
- Space should be provided for an additional 500 ton air-cooled chiller to provide additional cooling in the future.
- The plant should use variable, primary pumping. Primary/secondary piping is more traditional, but not necessary with today's chillers and control schemes with VFD's on pumps and chillers.
- Use cooling towers with VFD's on the tower fans. The towers can be mounted on the building roof or on a slab on-grade. Towers with corrosion resistant materials should be used. Provisions for controlling tower noise should be implemented. VFD's on condenser water pumps are not necessary.
- The building should include the following:

    - Sound attenuation
    - Overhead doors to access and replace large equipment, such as chillers
    - Control room
    - Water treatment room
    - Chemical storage
    - Maintenance area
    - Parts storage
    - Lunch/conference room
    - Rest rooms
    - Structure sized to handle plant piping
    - Electric switchgear room

- The building size required is estimated to be approximately 12,000 SF, including second floor offices, etc.
- The electrical distribution service must be upgraded to serve both the new residence halls and the chiller plant. The present plan described in the campus master plan calls for Feeders 1201 and 1202 to be relocated outside of the footprint of the new buildings and the older cable replaced with larger cable to serve the new residence halls and the chiller/boiler plant. The total electric feeder upgrade cost is estimated to be $1.8 million. $1 million is portioned into the cost estimates for the new chiller plant at this time.

7.0 CHILLER PLANT OPTIONS

Two options for constructing the first phase of the proposed chilled water plant have been evaluated. The first option is to construct a standard chilled water plant. The second option is to construct a chiller plant with a thermal storage tank. The chillers will produce chilled water during off-peak periods at night when the electric rates are lower and the chiller and cooling tower operate more efficiently. During the day, the tank helps supply chilled water to the campus. In periods of milder weather, it may be possible to provide most of the chilled water from the thermal storage tank during the day.

Option 1 – Standard Chiller Plant

- Two (2) 1,200 ton centrifugal chillers.
- One (1) 500 ton air-cooled chiller (relocated from CUB).
- Space for one future 1,500 ton chiller.
- Space for one future 500 ton air-cooled chiller.

Option 2 – Chiller Plant with Thermal Storage

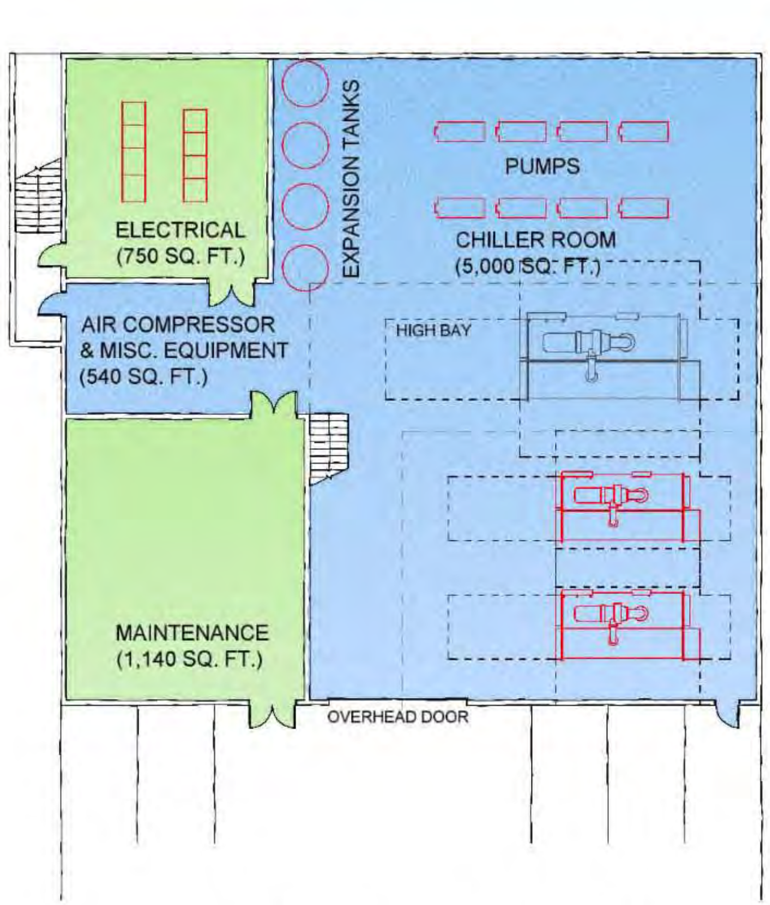
- Two (2) 900 ton centrifugal chillers.
- One (1) 500 ton air-cooled chiller (relocated from CUB).
- One (1) 1 million gallon thermal storage tank (800-1,000 ton equivalent).
- Space for one future 1,500 ton chiller inside the building.
- Space for one future 500 ton air-cooled chiller.

CENTRAL CHILLED WATER SYSTEM EVALUATION
GENERATION SUMMARY

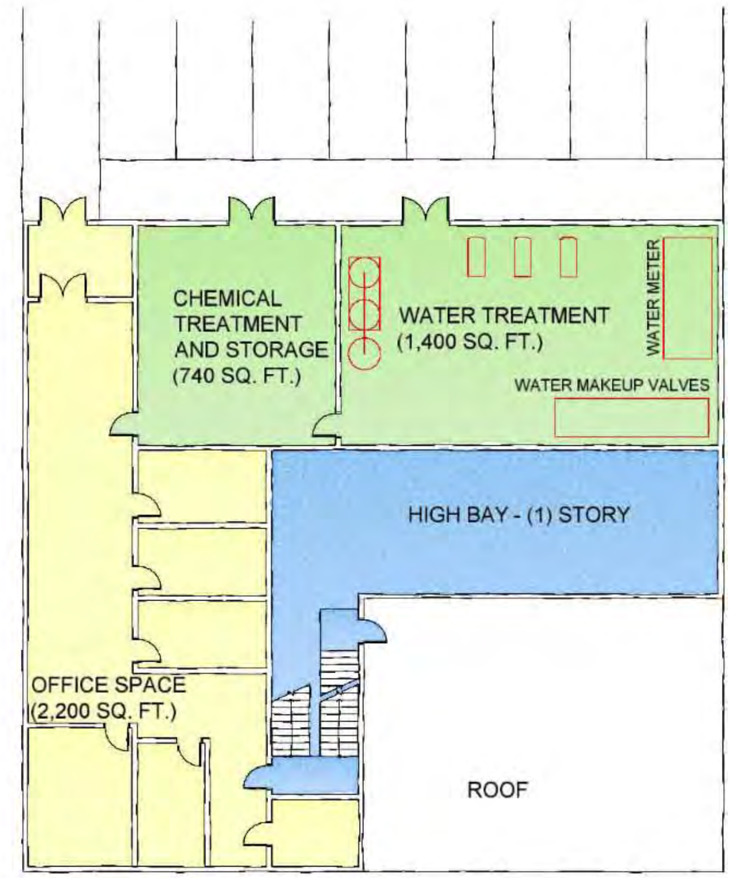
Unit	Number	Capacity	Total
Option 1 – Standard Chiller Plant			
Centrifugal Chiller	2	1200	2400
Air Cooled Chiller	1	500	500
Current Chillers			1170
Total			4070

Unit	Number	Capacity	Total
Option 2 – Chiller Plant with Thermal Storage			
Centrifugal Chiller	2	900	1800
Air Cooled Chiller	1	500	500
Current Chillers			1170
Thermal Storage Equivalent Capacity	1	1 Mil Gal	800
Total			4270

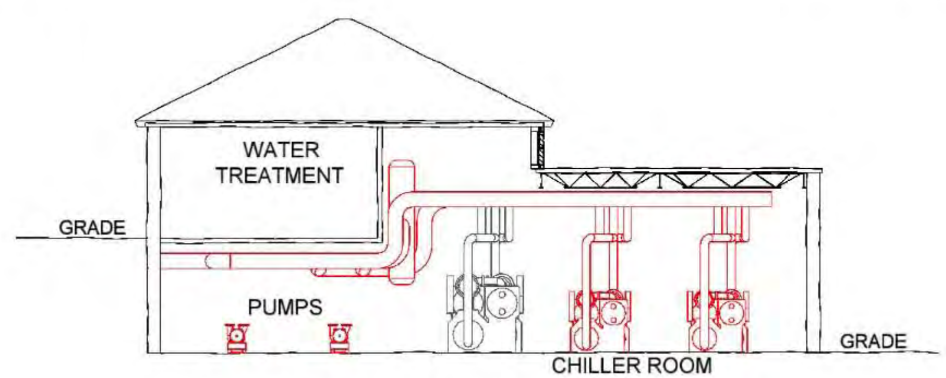
Note: Provide space for future 1500 ton chiller inside building with each alternative.
A preliminary floor plan on the following page has been developed to illustrate a recommended plant arrangement and to prepare a project budget. The proposed floor plan and elevation for the plant is shown in Figure 6. The plant schematic, Figure 7, on the next page depicts the recommended basic schematic for the plant, including the TES tank.



LOWER FLOOR PLAN



UPPER FLOOR PLAN



BUILDING SECTION

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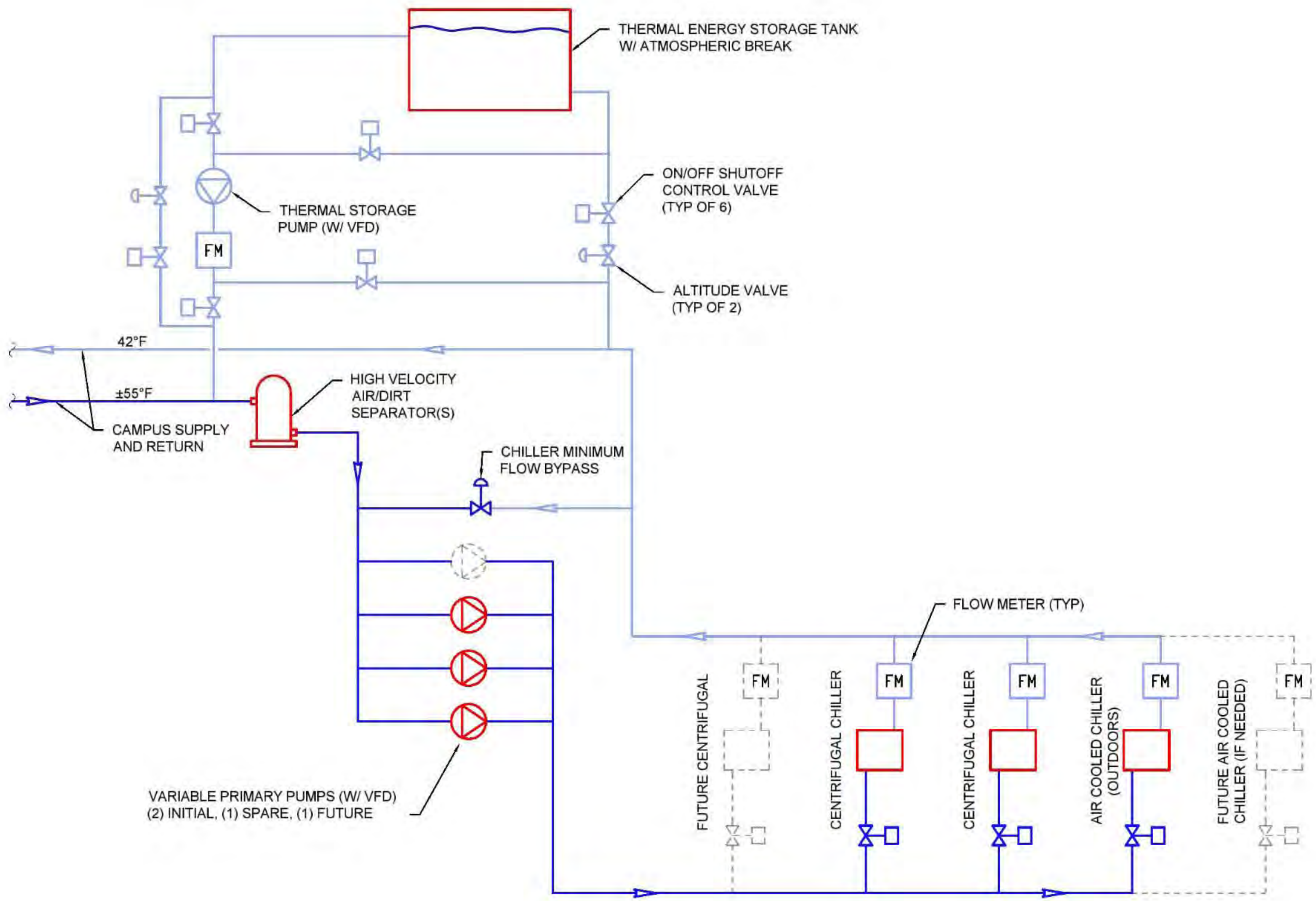
SHIPPENSBURG UNIVERSITY
CENTRAL CHILLED WATER PLANT
BUILDING LAYOUT

FIGURE 6



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CENTRAL CHILLED WATER PLANT
PLANT SCHEMATIC (W/ THERMAL STORAGE TANK)

FIGURE 7

8.0 THERMAL STORAGE

As described above, thermal storage is the process of using chillers to produce chilled water during off-peak periods and storing it for use during the day when electric rates are higher. Cooling can be stored in the form of ice or as chilled water stored in a large tank. Generally, it is cost effective to use ice storage for smaller systems and use chilled water storage in larger systems. For a central chilled water system at Shippensburg University, a large chilled water storage tank is recommended. The size of the tank depends on the rate chilled water is used throughout the day, and with the large increase in Campus air conditioning planned, a proven chilled water demand profile has yet to be established. However, if a 1 million gallon insulated storage tank is installed with a 14ºFΔT, it can provide approximately 800 tons of cooling over a 12 hour period, or 1,000 tons for up to a 10 hour period. It will be possible to supply higher amounts of cooling, but for a shorter duration. The tank can handle higher peaks or cooling spikes.

With a thermal storage tank, the size of the chillers, towers and other associated plant equipment initially installed can be decreased from 1,200 tons each to at least 900 tons each.

The benefits of thermal storage include the following:

- The chillers and towers, electrical, etc. can be smaller.
- Energy costs decrease because less expensive off-peak electricity is used.
- Energy costs decrease because the cooling towers operate more efficiently at night when air temperature decreases.
- During the winter, spring and autumn months, the chilled water storage system will be able to provide most of the Campus cooling with off-peak cooling.
- Thermal storage can be used to take advantage of utility load curtailment incentives.
- The storage tank allows short-term back-up for chilled water supply to the campus.
- The chilled water tank can be used to “smooth” out chiller operation and campus electric demand.

9.0 THERMAL STORAGE COST SAVINGS

As mentioned above, the thermal storage tank allows the campus chillers to shift some of the load to night time periods when electric rates are lower and ambient temperatures cooler. By maximizing the use of the thermal storage tank, we estimate the billing demand will be reduced as follows:

Month	kW Reduction
January	0
February	0
March	200
April	500
May	1,000
June	1,000
July	1,000
August	1,000
September	1,000
October	1,000
November	500
December	200
Total	**7,400**

After the rate caps are eliminated in 2011, we estimate the billing demand charge will be approximately $8.30/kW. At this cost rate, the demand savings is expected to be $61,420. The chillers will also operate at night when the tank is being recharged. Because the condensers are operating at a cooler temperature, we expect a 15% improvement in efficiency. Over the course of the year, we estimate the performance improvement will decrease electric consumption by approximately 300,000 kWh/yr. Using a projected electric rate of $0.104/kWh after the rate caps are removed, the savings will be $31,650. Therefore, the total electric savings in the first year will be $93,000 ($61,000 + $ 32,000). With electric power deregulation in Pennsylvania, the University will have more opportunity for reducing its electric bill by controlling power consumption using techniques such as thermal storage. It is anticipated the cost savings using the storage tank will increase, perhaps significantly, in coming years, and the payback period will decrease.

10.0 SCHEDULE AND PHASING

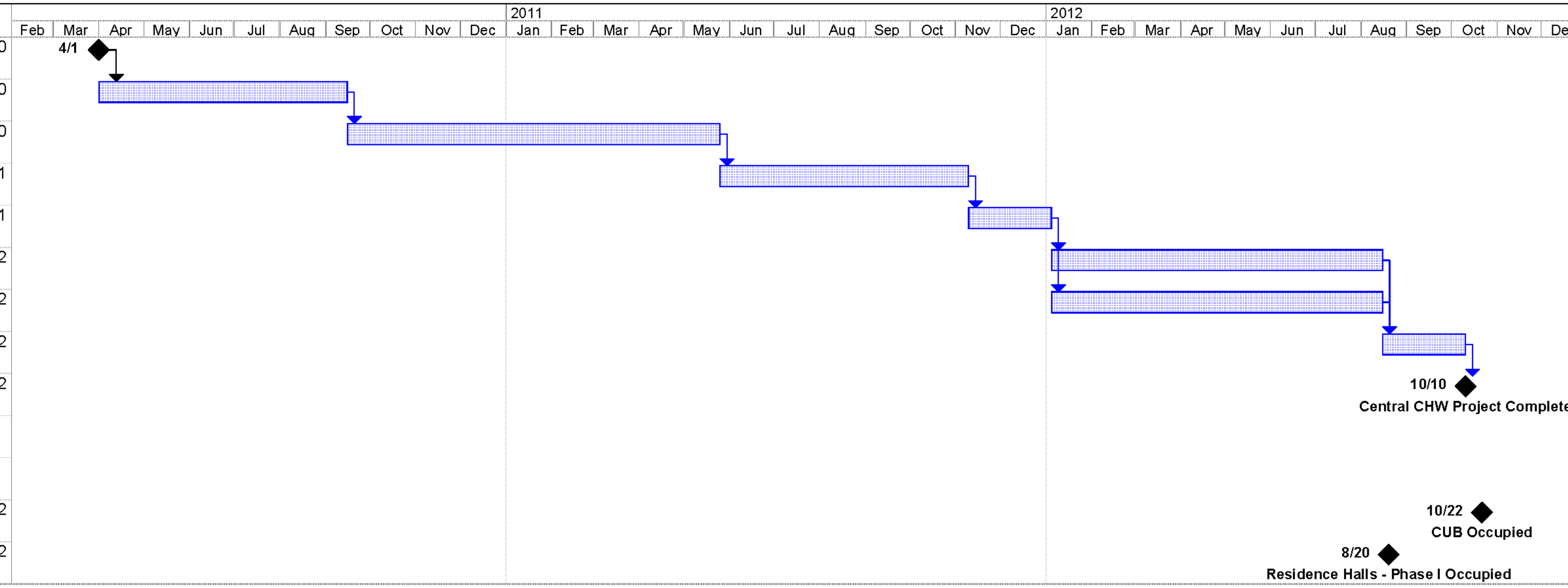
A preliminary project schedule shown on the following page has been prepared, and shows an anticipated completion date of October 10, 2012. This date is important since it must be coordinated with other building construction projects on Campus that are occurring around the same time. New buildings and renovated buildings will not need a chiller and cooling tower because they can be connected to the central chilled water loop.

The Ceddia Union Building (CUB) is being expanded and renovated. This project is expected to be completed by October 2012. CUB is designed to have a 500 ton air-cooled chiller, pad mounted outside the building. When the new central chilled water plant is completed the following year, the building will then be connected to the central system, and the air-cooled chiller will be moved to the central plant. This chiller will then provide cooling for peaking and back-up at the central plant. Because it is air-cooled, this chiller may operate better during periods of cold weather.

The new residence halls should also be connected to the central chilled water system. The Phase 1 buildings are scheduled to be completed by August 2012, which is prior to the scheduled completion of the chilled water project. Therefore, a temporary chiller/tower must be installed for August-October 2012 at these buildings. The estimated cost for a three month period is $30,000 to $50,000 depending on how much prep and hookup work is needed. The project cost estimate should have the ability to cover the cost for equipment rental included. Provisions for the required power for temporary chillers should be included in the building project.

Shippensburg University
Central Chilled Water Plant System Project

ID	Task Name	Duration	Start
1	Project Start	0 days	Thu 4/1/10
2	Design Professional Selection	6 mons	Thu 4/1/10
3	Project Design	9 mons	Thu 9/16/10
4	Bid and Award Const Contracts	6 mons	Thu 5/26/11
5	Shop Drawing Review	2 mons	Thu 11/10/11
6	Central Plant Construction	8 mons	Thu 1/5/12
7	Pipe Distribution Construction	8 mons	Thu 1/5/12
8	Commissioning	2 mons	Thu 8/16/12
9	Central CHW Project Complete	0 days	Wed 10/10/12
10			
11			
12	CUB Occupied	0 days	Mon 10/22/12
13	Residence Halls - Phase I Occupied	0 days	Mon 8/20/12



Project: CHW Plant Schedule.mpp
Date: Thu 1/21/10

Task		Progress		Summary		External Tasks		Deadline	
Split		Milestone		Project Summary		External Milestone			

11.0 COST ESTIMATES

Cost estimates for the proposed central chilled water system are provided on the following pages. The estimates are in current cost rates and include 10% contingency and 8% professional fees. The cost to relocate the CUB chiller is included, as is the cost for rental chillers for the Phase 1 residence halls. Piping modifications within the existing buildings is included.

A summary is as follows:

Option 1 – Central Chilled Water Plant with (2) 1,200 Ton Units

Central Chilled Water Plant	$ 8.2 million
Distribution Pipe	$10.2 million
	$18.4 million

Chilled Water Plant Cost Summary:

Description	Cost
Mobilization, Site Prep and Building Construction	$ 2,200,000
Chillers and Towers, including a 500 Ton Air Cooled Unit moved from CUB and chiller rental for Phase 1 Residence Halls	$ 1,450,000
Plant Chilled Water/Condenser Water Piping, Pumps and Controls	$ 900,000
Plant and Site Plumbing, including a Sewage Lift Station	$ 250,000
Building HVAC, including Exhaust Fans and Louvers	$ 70,000
Electrical for Plant and Site	$ 800,000
Misc. Site Prep, Impacts and Fees	$ 1,100,000
Contingency (10%)	$ 680,000
Architectural/Engineering/Support Fees (10%)	$ 750,000
Total	**$ 8,200,000**

Chilled Water Piping and Building Hookup Cost Summary:

Description	Cost
Mobilization, Misc, Damage Costs, and Site Trenching/Backfill/Restoration	$ 3,100,000
Underground Piping	$ 3,300,000
Manholes/Manhole Piping/Valves	$ 1,000,000
Building Connections and System Hookup within Buildings (20 Buildings)	$ 1,000,000
Contingency (10%)	$ 850,000
Architectural/Engineering/Support Fees (10%)	$ 930,000
Total	**$ 10,180,000**

Note: for either Option, the University will require an upgrade of the campus electrical distribution. There is an ongoing study to determine the electrical and communications upgrades needed for the new chiller plant, new dorms, and future building and additions.

Option 2 – Central Chilled Water Plant with (2) 900 ton Units and Thermal Storage

Central Chilled Water Plant	$10.02 million
Distribution Pipe	$10.18 million
	$20.2 million

Chilled Water Plant Cost Summary:

Description	Cost
Mobilization, Site Prep and Building Construction (slightly smaller Building, but more rock removal for tank)	$ 2,200,000
Chillers and Towers, including a 500 Ton Air Cooled Unit moved from CUB and chiller rental for Phase 1 Residence Halls	$ 1,280,000
Thermal Energy Storage (TES) Tank	$, 1,400,000
Plant Chilled Water/Condenser Water Piping, Pumps and Controls	$ 950,000
Plant and Site Plumbing, including a Sewage Lift Station	$ 250,000
Building HVAC, including Exhaust Fans and Louvers	$ 70,000
Electrical for Plant and Site	$ 800,000
Misc. Site Prep, Impacts and Fees	$ 1,315,000
Contingency (10%)	$ 830,000
Architectural/Engineering/Support Fees (10%)	$ 910,000
Total	**$ 10,020,000**

Chilled Water Piping and Building Hookup Cost Summary:

Description	Cost
Mobilization, Misc, Damage Costs, and Site Trenching/Backfill/Restoration	$ 3,100,000
Underground Piping	$ 3,300,000
Manholes/Manhole Piping/Valves	$ 1,000,000
Building Connections and System Hookup within Buildings (20 Buildings)	$ 1,000,000
Contingency (10%)	$ 850,000
Architectural/Engineering/Support Fees (10%)	$ 930,000
Total	**$ 10,180,000**

For funding purposes, the cost for this project can be shared with other projects. For example, the cost for the new Residence Halls will be significantly reduced if they are connected to the Central Chilled Water System. Building chillers, cooling towers, water treatment, electric distribution, and building space and structure to house the equipment will no longer be required. Also, the electric duct bank upgrade is necessary even if the Central Chilled Water Plant is not installed.

12.0 CONCLUSION

Because the University is proceeding with a large residence hall building project that requires air conditioning, there is a great opportunity to construct a central chilled water plant for the campus. This type of system will more efficiently provide chilled water for air conditioning to all the campus buildings. The system should be more reliable, easier to maintain than distributed equipment, and remove large equipment from campus buildings.

Two options have been presented in this study which should provide flexibility as the campus continues to grow and change. The second option uses thermal storage, a technology which should provide many benefits as the energy market continues to change. The information contained in this report will help guide the University if this project is implemented. Many factors will determine the final design and layout of the system. In the end, the campus should have the infrastructure for providing reliable cooling to the campus for many years.

ATTACHMENT 1

Detailed Cost Estimates

CONSTRUCTION COST ESTIMATE	DATE PREPARED 06/10/10	SHEET 1 OF 1
PROJECT Shippensburg Boiler Plant Study - Project 2184.32	BASIS FOR ESTIMATE	
LOCATION Shippensburg Univeristy	[ ] CODE A (NO DESIGN COMPLETED) [ ] CODE B (PRELIMINARY DESIGN) [X] CODE C (FINAL DESIGN) [ ] OTHER (SPECIFY)_______________	
ARCHITECT ENGINEER Entech Engineering, Inc. file: plant-jed-2-1200		
Project Estimated: ***CHW Plant w/(2)1200 ton units*** ESTIMATOR JED	CHECKED BY JCE	

All contracts	QUANTITY NO. UNITS	UNIT MEAS.	MATERIAL PER UNIT	MATERIAL TOTAL	LABOR PER UNIT	LABOR TOTAL	TOTAL COST
MOBILIZATION (all contracts plus trailers, etc	1	LS	$50,000	$50,000	$50,000	$50,000	$100,000
chilled water plant building:							
site prep	1	LS	$30,000	$30,000	$70,000	$70,000	$100,000
building construction	12000	FT2	$90	$1,080,000	$70	$840,000	$1,920,000
chilled water plant equipment:							
1200 ton centrifugal chiller w/VFD	2	EA	$350,000	$700,000	$50,000	$100,000	$800,000
600 ton cooling tower (SS)	4	EA	$100,000	$400,000	$50,000	$200,000	$600,000
dirst/air separator	1	EA	$50,000	$50,000	$15,000	$15,000	$65,000
expansion tanks	3	EA	$15,000	$45,000	$12,500	$37,500	$82,500
CHW plant controls	1	LS	$150,000	$150,000	$100,000	$100,000	$250,000
CHW plant piping and valves	1	LS	$225,000	$250,000	$100,000	$100,000	$350,000
Condenser pumps (constant - 60 HP)	3	EA	$12,000	$36,000	$4,000	$12,000	$48,000
Chilled Wtr pumps (VFD - 125 HP)	3	EA	$25,000	$75,000	$6,000	$18,000	$93,000
chemical treatment tanks, controls & pumps	1	LS	$40,000	$40,000	$20,000	$20,000	$60,000
Relocate 500 ton air cooled from CUB	1	LS	$30,000	$30,000	$30,000	$30,000	$60,000
piping, etc. for 500 A/C unit	1	LS	$50,000	$50,000	$20,000	$20,000	$70,000
Misc. mech/plumb items:							
plumbing	1	LS	$40,000	$40,000	$30,000	$30,000	$70,000
HVAC (heating/cooling/ventilation)	1	LS	$40,000	$40,000	$20,000	$30,000	$70,000
Electrical equipment, lighting, data, etc.							
electrical equipment	1	LS	$250,000	$250,000	$125,000	$125,000	$375,000
power conduit and cable	1	LS	$75,000	$75,000	$50,000	$50,000	$125,000
lighting (plant)	12000	FT2	$3	$36,000	$3	$36,000	$72,000
misc. wiring and conduit	12000	FT2	$2	$24,000	$3	$36,000	$60,000
site lighting and distribution (adder)	1	LS	$50,000	$50,000	$25,000	$25,000	$75,000
site power and distribution to local manholes	1	LS	$40,000	$40,000	$40,000	$40,000	$80,000
Site Development:							
stormwater	1	LS	$30,000	$30,000	$50,000	$50,000	$80,000
sewage w/lift station	1	LS	$100,000	$100,000	$40,000	$40,000	$140,000
communication	1	LS	$50,000	$50,000	$50,000	$50,000	$100,000
water	1	LS	$20,000	$20,000	$20,000	$20,000	$40,000
permits, fees, studies, planning, etc.	1	LS	$0	$0	$50,000	$50,000	$50,000
Damage/interference	1	LS	$30,000	$30,000	$50,000	$50,000	$80,000
Shoring	1	LF	$10,000	$10,000	$5,000	$5,000	$15,000
Rock Removal	1000	CY	$40	$40,000	$200	$200,000	$240,000
Excavation/Backfill (building only)	1	LS	$50,000	$50,000	$50,000	$50,000	$100,000
flowable fill & other Karst geology affects	1	LS	$100,000	$100,000	$150,000	$150,000	$250,000
screen for towers and A/C chilers	1	LS	$100,000	$100,000	$40,000	$40,000	$140,000
SUBTOTAL				$4,071,000		$2,689,500	$6,760,500
CONTINGENCY	10%			$407,100		$268,950	$676,050
Sub-sub Total				$4,478,100		$2,958,450	$7,436,550
Arch/Eng fees (10%)							$594,924
TOTAL THIS SHEET							**$8,031,474**

CONSTRUCTION COST ESTIMATE	DATE PREPARED 06/10/10	SHEET 1 OF 1

PROJECT
Shippensburg Boiler Plant Study - Project 2184.32
LOCATION
Shippensburg Univeristy
ARCHITECT ENGINEER
Entech Engineering, Inc.

BASIS FOR ESTIMATE
[ ] CODE A (NO DESIGN COMPLETED)
[ ] CODE B (PRELIMINARY DESIGN)
[X] CODE C (FINAL DESIGN)
[ ] OTHER (SPECIFY)________________

H:\2184.32\Ss\[chilled water piping - Base Bid.xls]CHW piping -Base Bid

Project Estimated: ***Chilled Water Piping*** | ESTIMATOR: JED | CHECKED BY: JCE

MECHANICAL CONTRACT	QUANTITY		MATERIAL		LABOR		TOTAL
	NO. UNITS	UNIT MEAS.	PER UNIT	TOTAL	PER UNIT	TOTAL	COST
MOBILIZATION	1	LOT	$0	$0	$15,000	$15,000	$15,000
chilled water UG piping				$0		$0	$0
2"	0	LF	$15	$0	$30	$0	$0
3"	0	LF	$18	$0	$35	$0	$0
4"	1500	LF	$22	$33,000	$45	$67,500	$100,500
6"	4500	LF	$30	$135,000	$55	$247,500	$382,500
8"	1600	LF	$44	$70,400	$65	$104,000	$174,400
12"	6350	LF	$70	$444,500	$85	$539,750	$984,250
14"	3650	LF	$80	$292,000	$100	$365,000	$657,000
16"	2340	LF	$100	$234,000	$115	$269,100	$503,100
18"	1200	LF	$100	$120,000	$115	$138,000	$258,000
chilled water UG fittings				$0		$0	$0
2"	0	EA	$265	$0	$250	$0	$0
3"	0	EA	$328	$0	$300	$0	$0
4"	8	EA	$331	$2,648	$350	$2,800	$5,448
6"	14	EA	$497	$6,958	$400	$5,600	$12,558
8"	10	EA	$973	$9,730	$450	$4,500	$14,230
12"	16	EA	$1,615	$25,840	$550	$8,800	$34,640
14"	6	EA	$1,895	$11,370	$600	$3,600	$14,970
16"	6	EA	$2,000	$12,000	$650	$3,900	$15,900
18"	4	EA	$2,200	$8,800	$700	$2,800	$11,600
chilled water UG valves				$0		$0	$0
2"	0	EA	$500	$0	$300	$0	$0
3"	0	EA	$750	$0	$400	$0	$0
4"	12	EA	$1,000	$12,000	$500	$6,000	$18,000
6"	24	EA	$1,500	$36,000	$700	$16,800	$52,800
8"	10	EA	$2,000	$20,000	$750	$7,500	$27,500
12"	16	EA	$2,500	$40,000	$800	$12,800	$52,800
14"	6	EA	$3,000	$18,000	$900	$5,400	$23,400
16"	4	EA	$3,300	$13,200	$950	$3,800	$17,000
18"	2	EA	$3,500	$7,000	$1,000	$2,000	$9,000
Trenching/Backfill/Restoration	10000	LF	$100	$1,000,000	$100	$1,000,000	$2,000,000
Manhole Installation	16	EA	$10,000	$160,000	$5,000	$80,000	$240,000
Manhole Piping	16	EA	$20,000	$320,000	$10,000	$160,000	$480,000
Anchors	25	EA	$3,000	$75,000	$1,500	$37,500	$112,500
Building Hookup	60	EA	$2,300	$138,000	$1,500	$90,000	$228,000
Damage/interference	1	LS	$30,000	$30,000	$40,000	$40,000	$70,000
Shoring	10000	LF	$3	$30,000	$5	$50,000	$80,000
Rock Removal	4000	CY	$25	$100,000	$200	$800,000	$900,000
expansion compensation (impact)	1	LS	$80,000	$80,000	$40,000	$40,000	$120,000
				$0		$0	$0
changes for buildings w/CHW pumps	15	EA	$15,000	$225,000	$10,000	$150,000	$375,000
changes for buildings w/o CHW pumps	5	EA	$60,000	$300,000	$30,000	$150,000	$450,000
				$0		$0	$0
				$0		$0	$0
SUBTOTAL				$4,010,446		$4,429,650	$8,440,096
CONTINGENCY	10%			$401,045		$442,965	$844,010
sub-sub total				$4,411,491		$4,872,615	$9,284,106
Arch/Eng Fees	10%			$441,149		$487,262	$928,411
TOTAL THIS SHEET				$4,852,640		$5,359,877	***$10,212,516***

CONSTRUCTION COST ESTIMATE

DATE PREPARED 06/10/10

SHEET 1 OF 1

PROJECT
Shippensburg Boiler Plant Study - Project 2184.32

LOCATION
Shippensburg Univeristy

ARCHITECT ENGINEER
Entech Engineering, Inc.

file: plant-jed-3-900&tank

BASIS FOR ESTIMATE
[ ] CODE A (NO DESIGN COMPLETED)
[ ] CODE B (PRELIMINARY DESIGN)
[X] CODE C (FINAL DESIGN)
[ ] OTHER (SPECIFY)________________

Project Estimated: **CHW Plant w/(3)900's & Tank**

ESTIMATOR JED

CHECKED BY JCE

All contracts	QUANTITY NO. UNITS	QUANTITY UNIT MEAS.	MATERIAL PER UNIT	MATERIAL TOTAL	LABOR PER UNIT	LABOR TOTAL	TOTAL COST
MOBILIZATION (all contracts plus trailers, etc	1	LS	$20,000	$20,000	$40,000	$40,000	$60,000
chilled water plant building:							
site prep	1	LS	$30,000	$30,000	$70,000	$70,000	$100,000
building construction	11520	FT2	$90	$1,036,800	$70	$806,400	$1,843,200
chilled water plant equipment:							
900 ton centrifugal chiller w/VFD	3	EA	$300,000	$900,000	$50,000	$150,000	$1,050,000
450 ton cooling tower (SS)	6	EA	$80,000	$480,000	$50,000	$300,000	$780,000
dirst/air separator	1	EA	$50,000	$50,000	$15,000	$15,000	$65,000
expansion tanks	3	EA	$15,000	$45,000	$12,500	$37,500	$82,500
CHW plant controls	1	LS	$150,000	$150,000	$75,000	$75,000	$225,000
CHW plant piping and valves	1	LS	$225,000	$225,000	$100,000	$100,000	$325,000
Condenser pumps (constant - 60 HP)	3	EA	$12,000	$36,000	$4,000	$12,000	$48,000
Chilled Wtr pumps (VFD - 125 HP)	3	EA	$25,000	$75,000	$6,000	$18,000	$93,000
chemical treatment tanks, controls & pumps	1	LS	$40,000	$40,000	$20,000	$20,000	$60,000
1,000,000 thermal storage tank	1	LS	$900,000	$900,000	$300,000	$300,000	$1,200,000
piping and valve impact w/storage tank	1	LS	$100,000	$100,000	$60,000	$60,000	$160,000
Misc. mech/plumb items:							
plumbing	1	LS	$20,000	$20,000	$20,000	$20,000	$40,000
HVAC (heating/cooling/ventilation)	1	LS	$30,000	$80,000	$20,000	$20,000	$100,000
Electrical equipment, lighting, data, etc.							
electrical equipment (adder)	1	LS	$150,000	$150,000	$75,000	$75,000	$225,000
power conduit and cable (adder)	1	LS	$75,000	$75,000	$50,000	$50,000	$125,000
lighting (plant)	11520	FT2	$3	$34,560	$3	$34,560	$69,120
misc. wiring and conduit	11520	FT2	$2	$23,040	$3	$34,560	$57,600
site lighting and distribution (adder)	1	LS	$50,000	$50,000	$25,000	$25,000	$75,000
site power and distribution to local manholes	1	LS	$40,000	$40,000	$40,000	$40,000	$80,000
Site Development:(adders - HW/steam)							
stormwater	1	LS	$20,000	$20,000	$10,000	$10,000	$30,000
sewage	1	LS	$20,000	$20,000	$10,000	$10,000	$30,000
communication	1	LS	$5,000	$5,000	$5,000	$5,000	$10,000
water	1	LS	$10,000	$10,000	$5,000	$5,000	$15,000
natural gas (from plant w/some gas co. help)	1	LS	$0	$0	$0	$0	$0
permits, fees, studies, planning, etc.	1	LS	$0	$0	$50,000	$50,000	$50,000
Damage/interference	1	LS	$5,000	$5,000	$5,000	$5,000	$10,000
Shoring	1	LF	$10,000	$10,000	$5,000	$5,000	$15,000
Rock Removal	1200	CY	$40	$48,000	$200	$240,000	$288,000
Excavation/Backfill (building only)	1	LS	$50,000	$50,000	$50,000	$50,000	$100,000
flowable fill & other Karst geology affects	1	LS	$150,000	$150,000	$200,000	$200,000	$350,000
SUBTOTAL				$4,878,400		$2,883,020	$7,761,420
CONTINGENCY	10%			$487,840		$288,302	$776,142
Sub-sub Total				$5,366,240		$3,171,322	$8,537,562
Arch/Eng fees (10%)							$683,005
TOTAL THIS SHEET							**$9,220,567**