CHILLER PLANT STUDY REPORT

FINAL REVIEW SUBMITTAL

UNIVERSITY OF WISCONSIN
WHITEWATER

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EXECUTIVE SUMMARY

The purpose of this study was to evaluate the technical and economic viability of several options for producing chilled water for future campus loads. In order to evaluate the options an understanding of the campus chilled water load projections along with a campus load profile were developed. The campus chilled water load projections were developed during the 2014 Campus Master Plan project. During the development of the Campus Master Plan it was determined that the campus is currently operating at a cooling deficiency of approximately 79 tons. Based on the estimate load projections there is a projected need for approximately 2000 tons of additional cooling over the next 15 years.

This study set out to review the existing plant space and arrangement to maximize the tonnage of the current plant foot print. During the review process chiller capacities ranging from 2000-2400 tons were utilized to replace the (3) existing 800 ton steam absorption chillers. The proposed chillers were also reviewed based on input energy to operate the chiller whether it's L&S purchased steam, steam produced from the Heating Plant gas fired steam boilers or purchased WE-Energies electricity.

As part of this exercise chiller VFD and starter locations were reviewed for accessibility within existing footprint, first cost and efficiencies. Beyond the chillers within the existing plant footprint new chilled water and condenser water pumps were laid out for special requirements. The existing chiller plant roof was reviewed as well for new cooling towers to handle the enlarged chiller tonnages.

The existing 1400 ton electrical centrifugal chiller will remain in operation as there is still useful life on the machine and associated cooling towers and pumping systems.

The following options were evaluated as part of this study to increase the chilled water capacity for the campus:

Options:

1. (2) 2000-2400 ton steam turbine driven chiller operating off of purchased steam from L&S
2. (2) 2000-2400 ton steam turbine driven chiller operating off of steam generated by UWW
3. (2) 2000-2400 ton electrical water cooled chiller operating off of power purchased from WE Energies

Note: Existing chiller 4 associated cooling tower and pumps will remain in service.

OPTIONS	Total Equipment Costs (1)	Total Construction Costs	Annual Utility Costs	Annual Chiller Maintenance Costs (2)	Annual Personnel Operating Costs (3)
1	$3,000,000	$6,643,701	$449,286	$16,000	-
2	$3,350,000	$6,765,061	$826,493	$16,000	$100,000
3	$ 800,000	$8,018,327	$1,365,575	$13,000	-

1. Annual ancillary equipment first costs would be equivalent for each option.
2. Annual ancillary equipment maintenance costs would be equivalent for each option.
3. Additional 3rd shift required to operate Heating Plant boilers during the cooling system.
4. All costs are reflective of 2016 pricing. Costs shown will require inflation for each year construction is extended.

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PURPOSE

Based on existing chiller monitoring logs and utilizing campus load estimating, the campus peak chilling demand is currently exceeding the capacity available from the chillers on design days, forcing the campus chilled water loop to run at a low delta temperature and operate inefficiently.

Based on the information gathered during the campus Master Plan completed in 2014 the campus chilled water plant is operating at a deficiency of 79 tons of cooling on a design day. There are two major building projects slated for construction within the next 6 years (Residence Hall #1 and Residence Hall #2), where its estimated to require an additional 520 tons of plant cooling capacity.

The purpose of this study is to provide a comprehensive study to fully understand the life cycle cost and build out feasibility of various chiller options. The study will also review the continued use of purchased waste steam from L&S Cogeneration Power Plant with other possible chiller energy options.

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STUDY SCOPE

The scope of the study will encompass the following:

1. Sensitivity analysis of the following three options:

    a. Option 1 – New (2) steam turbine driven chillers (2000-2400 ton) operating off of purchased steam from L&S. Include recommendations for optimal building size, tower location and chiller/tower/pump sizes and type.

    b. Option 2 - New (2) steam turbine driven chillers (2000-2400 ton) operating off of steam generated by UWW. Include recommendations for optimal building size, tower location and chiller/tower/pump sizes and type.

    c. Option 3 - New (2) electric water-cooled chillers (2000-2400 ton) operating off of power purchased from WE Energies. Include recommendations for optimal building size, tower location and chiller/tower/pump sizes and type.

    Note: Existing chiller 4 associated cooling tower and pumps will remain in service.

2. Analysis includes review of existing plant space available for optimal building use and serviceability. Recommendation of plan layout, additional square footage requirements, piping and pump system upgrades.

3. Analysis of new/existing chiller plant equipment and chiller distribution system controls including cost and recommendations for integrating new controls with existing. Study to include recommendations for optimizing energy used by existing and new chilled water system equipment, e.g. full and part-load efficiency of new verses older equipment, equipment staging, pumping strategies, etc..

4. Electrical service review shall determine if the proposed chiller plant expansion can be supplied from either the 4.16 kV or 24.9 kV systems in the existing campus substation (near the heating plant) or if a new service from WE Energies is required. The review shall include recommendations and costs for the proposed options and for the modification to the existing substation or the cost of new electric service if required.

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Existing Chilled Water System Overview

The original chiller plant was built as an addition to the central heating plant in 1999 and is located on the east side of the heating plant and houses the original three (3) chillers. In 2006 a building addition was constructed on the south end of the chiller plant to house a fourth chiller.

Due to the proximity of underground utilities, adjacent heating plant structures, adjacent roadways, and capacity limitations of the chilled water distribution mains, there is limited space available for expansion of the existing chiller plant area to the south or east.

The original plant houses the following chillers:

Chiller	Make	Type	Nominal Tons	Installed
1	Trane	Absorption	800	1999
2	Trane	Absorption	800	1999
3	Trane	Absorption	800	1999
4	Carrier	Electrical	1400	2006

The current total nominal plant capacity is 3,800 tons. Actual performance is significantly less. Data for a design day the plant could only generate 3400 tons of chilled water at 46 F degree supply and 58 F degree return with 6689 gpm. The chillers are currently set to provide a supply water temperature of 41 F degrees with a 10 degree temperature difference. Based on this information it is anticipated that the absorption chillers are underperforming with Chiller–2 producing significantly less than its nameplate tonnage. Observations indicate that it is producing approximately 600 tons.

Currently the local power plant provides waste steam to the UW Heating Plant at 150-200 psi which then is reduced in pressure to 125 psi within the plant. The campus then reduces this steam again thru a separate reducing station to 80 psi for the campus distribution system. There is one additional reducing station which reduces the 125 psi steam to 12 psi steam to power the existing low pressure steam absorbers.

Chiller 4 is powered from a 4160 volt service and still has significant useful life remaining (10-20 years).

Each chiller has its own independent cooling tower and condenser water pump.

Cooling towers for Chiller-1, 2 and 3 are located on the original chiller plant roof. Cooling tower for Chiller-4 is located on the roof of the chiller plant addition.

Tower	Make	HP	Installed
1	Marley	2 @ 40 (ea)	1999
2	Marley	2 @ 40 (ea)	1999
3	Marley	2 @ 40 (ea)	1999
4	Marley	2 @ 50 (ea)	2006

The chilled water pumping is done with a primary-secondary pumping system with the following pumps:

Pump	Primary Pump	GPM	Head (ft)	HP (1)	Installed
1	Chiller Pump (CH-1)	1600	35	20	1999
2	Chiller Pump (CH-2)	1600	35	20	1999
3	Chiller Pump (CH-3)	1600	35	20	1999
4	Chiller Pump (CH-4)	2800	50	50	2006

1. Pump motors operate at constant speed.

Pump	Secondary Pump	GPM	Head (ft)	HP	Installed
1	Distribution	3200	180	200 (1)	1999
2	Distribution	3200	180	200 (1)	1999
3	Distribution	2800	180	250 (2)	2006

1. Pump motor operated by a steam turbine driven motor.

2. Pump motor operated with variable frequency drive.

Pump	Tower Pump	GPM	Head (ft)	HP (1)	Installed
1	Condenser Water (CH-1)	3600	75	100	1999
2	Condenser Water (CH-2)	3600	75	100	1999
3	Condenser Water (CH-3)	3600	75	125	1999
4	Condenser Water (CH-4)	4300	65	100	2006

1. Pump motors operate at constant speed.

Chilled water is distributed to the campus with one electrically driven secondary pump with a variable frequency drive and two steam driven secondary pumps with 13 psi backpressure steam. Low pressure steam from the backpressure turbine pump is used for the absorbers. A bypass/decoupler line is installed between the supply and return line upstream of the campus distribution pumps which creates a primary-secondary pumping arrangement.

The system distribution pumping differential pressure is approximately 9 psig on a design day.

Metering of chilled water is currently provided on Chillers 1, 2, and 3. A BTU meter is provided in the 20" chilled water supply line as it exits the plant to campus.

Controls are managed thru the campus Building Automation System (JCI).

A differential pressure control signal from Hyer Hall is used to control the distribution pumps. An informational differential pressure is obtained through the automation system at the plant and at Center for the Arts. Additional differential pressure sensors should be added.

The following buildings are equipped with chilled water flow meters:

- Power Plant
- Moraine
- Esker
- Drumlin
- University Center – 064B
- University Center – Bowling
- Starin
- Fischer
- Hyland – Penthouse
- Hyland – Building
- Arey/Fricker

The underground chilled water distribution system was constructed in 1999. Indications are that the original underground distribution piping is a combination of C900 PVC and ductile iron. There is indication that the pipe joints may have joint restraints. Piping ranges in size from 4” to 20”.

The system is protected by a 125 psig relief valve on the discharge side of the distribution pumps. The make-up water valve is set at 32 psig, currently the plant is filled off of the city water pressure which is controlled to 46 psig.

There are chilled water booster pumps located in Center for the Arts and Anderson Library.

These pumps are expected to be maintained in their current status.

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CAMPUS LOAD PROFILE

UW Systems prepared a preliminary Campus Chilled Water Load Projection table in May 2012. An updated version this table is attached in Appendix B-1 and was used as the starting point for this analysis. Loads were reviewed and several adjustments were made to the table as part of the 2014 Campus Master Plan Project.

Information gathered during the cooling season of 2013 was utilized to verify the Campus Chilled Water Load Projection (See Appendix B-2) this was used to verify the Campus Chilled Water Load Project table created with the Campus Master Plan.

The current plant cooling ton usage was established by compiling the measured chilled water flow at the existing (3) absorption chillers on an hourly basis of operation with known operating water temperatures. For the electrical chiller the charted power usage was broken down into on and off peak periods. From this information an "average" monthly peak cooling profile was derived for the existing campus. The derived average monthly profile indicates that the current chiller plant has insufficient cooling tonnage to operate on a design day.

The load projections indicate a need for a total of 5400 tons by the year 2021. The current plant has a capacity of 3400 tons. The project needed at this immediate time is for an additional 2,000 tons of capacity.

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REFRIGERANT OPTIONS

OVERVIEW

Manufacturers globally of centrifugal chillers currently either use R-123 or R-134a, both are HFC refrigerants.

R-123 has a safety classification B1 and is a low pressure refrigerant.

R-134a has a safety classification A1 and is a medium pressure refrigerant.

In 2016 the U.S. EPA (Environmental Protection Agency) announced SNAP (Significant New Alternatives Policy) ruling for use of HFC refrigerants in centrifugal equipment. De-listing of R-123 forces equipment manufactures to phase out the use of this refrigerant in any of their equipment starting in 2020. What this means is that R-123 will no longer be produced after 2030 but remaining supply can still be purchased for existing equipment still utilizing R-123.

The ruling in 2016 also simply identifies that after January 1, 2024 no new chillers (any style/design/compressor/capacity) in the United States shall be sold with HFC refrigerants (such as R-410A and R-134a). Chillers utilizing these two refrigerants following January 1, 2024 can continue to operate, and the refrigerant can continue to be produced until 2030.

Currently a few chiller manufactures are scheduled to replace the R-134a in new machines with R-513A in 2024, which is a HFO. This alternate refrigerant does not affect performance of the equipment but does currently carry a higher cost than current refrigerants.

Various manufacturers are currently producing equipment that allow “drop in” refrigerants to accommodate updated regulations. SNAP has currently approved several alternative HFO refrigerants, R-1233zd (low pressure), R-514A (medium pressure) and R-513A (low pressure). With the “drop in” refrigerant there is potential for decrease in capacity and performance. These refrigerants are also currently five times as expensive as the current HFC refrigerants. That cost is expected to decrease as production and use increases in time.

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Utility Rate Structure

The utility rate structure is a critical element to the economics of the system simulations.

The existing Heating/Chiller Plant is served by (2) dedicated 4160 volt feeders.

- (1) Service (27% loaded) with the following:
  - 300 kVA Transformer to the Heating Plant
  - 1000 kVA transformer with secondary voltage of 480 volts
- (1) Service (62% loaded) with the following:
  - 1000 kVA transformer with secondary voltage of 480 volts
  - (1) 4160 volt feeder to the existing 1400 ton chiller

Current electrical rates were based on the university's current rates through WE Energies Service which have been established at "General Primary Rates Cp1" at 29 kV service to campus.

Web access to Wisconsin Service and Rates WE Energies:

http://www.we-energies.com/business/wisconsin_service_rates/index.htm

Key components of the rate structure used in this study are presented in the following table:

Primary Service to Campus (Based on 2016 Rates)	
Electrical	
On-Peak	$0.07415/kWHr
Off-Peak	$0.05281/kWHr
Demand	
On-Peak	$13.519/kWHr
Distribution	$1.38/kW

WE Energies Account #7448-632-4230

On-peak energy charges are incurred from 9 am until 9 pm Monday through Friday, except holidays.

Off-peak energy charges are incurred from 9 pm to 9 am Monday through Friday and all day Saturday and Sunday.

UTILITY RATE STRUCTURES

The current campus steam distribution system and low pressure steam absorption chillers are utilizing purchased waste steam from the nearby combined cycle gas-fired LS Power cogeneration plant operated by NAES. The campus is currently paying a rate of $1.75/1000# of steam.

Natural gas rates are currently based on the university's contract through Wisconsin Electric Gas Operations which have been established at "Commercial and Industrial Firm Transportation Service" to receive firm delivery of natural gas at classification "Tf-2".

Key components of the rate structure used in this study are presented in the following table:

Primary Service to Plant (Based on 2016 Rates) (1)	
Facilities Charge	$2.85
Rate per Therm	$0.098
Annual Usage Limit	4,000 to 39,999 Therms

1. Note from Wisconsin Electric Gas Operation this is based on the current usage of the metered gas to the Heating Plant at this time.

If the Heating Plant is to bring on-line the existing steam boilers to produce steam for the campus distribution system in lieu of purchased steam from NAES the natural gas classification would be adjusted to Tf-4 or Tf-5 based on the annual gas consumption.

Primary Service to Plant (Based on 2016 Rates – Tf-4)	
Facilities Charge	$13.00
Rate per Therm	$0.0572
Annual Usage Limit	100,000 to 499,999Therms

Primary Service to Plant (Based on 2016 Rates – Tf-5)	
Facilities Charge	$37.00
Rate per Therm	$0.0538
Annual Usage Limit	500,000 to 999,999Therms

Electrical Service

The proposed chilled water equipment options have two significantly different power demands. For the steam absorption chillers, Options 1 or 2, the maximum power demand will be approximately 1600 kVA. For the electric chillers, Option 3, the maximum power demand will be approximately 5800 kVA.

The campus is supplied by single service from WE Energies. The service has a voltage of 24,900. The service equipment is in the electrical equipment yard near the existing Heating Plant. The power is supplied to (2) 7500 kVA transformers in the same yard. The intent of the transformers is to be redundant, should either transformer be out of service, the remaining transformer can carry the entire load. These transformers step the voltage from 24,900 to 4,160 volts. The transformers supply a lineup of 4,160 volt switchgear in a shelter aisle arrangement at the yard also. From the 4,160 volt switchgear power is distributed to the campus.

The current demand on the 24,900 volt service is 6823 kVA. Thus there is only limited spare capacity on the 7500 kVA transformers and still maintain the redundancy. Therefore the new chilled water equipment cannot be supplied from the existing 4,160 volt system and maintain the desired redundancy.

After discussion with WE Energies, the existing 24,900 volt line serving the campus has capacity to handle the proposed maximum demand increase of either option. There will be some minor Utility costs to provide this additional capacity. At the time of this report, WE Energies has to replace about 1,900 feet of cable in the existing feeder to the campus. Since the new electric chillers will be an increase in the load, the typical imbedded credits for the new service capacity should cover the vast majority of this cost, thus the impact to the project should be minor to zero. New 24,900 volt substations will be provided to supply the new chilled water equipment. These substations will be sized to supply the major of the existing load in the heating/chiller plant to reduce the load on the 7500 kVA transformers. This load is currently estimated at 273 amps at 4,160 volts or 1967 kVA. The major load is the existing 4,160 volt 1400 ton chiller rated at 130 amps or 937 kVA. Current demand metering is not available for all the existing distribution points in the existing Heating/Chiller plant. Recommend these be metered next year to confirm load assumptions.

It should be noted that the proposed residence hall will have an electrical demand of approximately 1200 kVA.

For any of the options, new 24,900 volt switch/fuse feeder bays will be required at the existing service switchgear. The existing electrical yard and the old electrical yard have space for the new equipment if the existing capacitor directly in front of the switch/fuse bays is relocated to the southeast of its current location.

New 24,900 volt feeders will be extended from the new switch/fuse bays via underground duct bank to the new chiller plant addition which will house the new substation(s). Refer to Appendix E-1 for the site plan and the routing of the new duct bank.

For Options 1 and 2 there is no difference in the electrical equipment for the chilled water system. Therefore the new substations shall consist of two 1500/2000 kVA transformers and 480 volt distribution connected in a main-tie-main arrangement for redundancy. These substations will also supply the existing 480 volt and 208 volt distribution systems in the heating plant.

For Option 3, there are two electrical power options. Option 3A is to supply the chillers at 4,160 volts and Option 3B would be to supply the chillers at 480 volts. One significant advantage of Option 3A is the existing 4,160 volt chiller can be supplied from the new substation thus reducing the load on the 7500 kVA transformers. Refer to Appendix E-2 for the one line diagram and Appendix E-3 for the layout of the equipment in the new addition.

Option 3A

The 24,900 volt feeders as described above will extend to a new 4,160 volt substation in the plant addition. The new substation shall be rated at 6000 kVA. This substation shall consist of main circuit breaker and switch/fuse bays to supply the chillers along with switch/fuse bays to supply the new 480 volt substation. The 480 volt substation shall be the same as the steam absorption options since the loads are equivalent. Refer to Appendix E-4 for the one line diagram and Appendix E-5 for the equipment layout in the new addition.

Option 3B

Standard equipment ratings impact the sizing of the 480 volt equipment, 3750 kVA transformer and 5000 amp bus in the distribution equipment. Therefore this option will have four 24900 volt substations to create the 480 volt system. This will require (4) 24,900 volt switch/fuse feeder bays in lieu of 2 in the previous options. One substation will function primarily as a spare to the other 3 substations but will supply some minor loads to keep the system operational instead of being de-energized until needed. The substations shall be 3750 kVA with 5000 amp distribution. Refer to Appendix E-6 for the one line diagram and Appendix E-7 for the equipment layout in the new addition.

While Option 3A is the most expensive electrically, this option allows the transfer of significant existing load to the new substations. This shifting of load delays any modifications to the existing distribution system supplying the rest of the campus due to the increase load of the new residence hall.

Chiller Starter/Voltage Options

The following is a comparison of 480 volt vs 4160 volt chillers with solid state or variable speed drive starters. The first cost difference of $200,000 between a 4160 volt variable speed drive compared to the solid state starter is significantly greater than the first cost difference of $45,000 between a 480 volt variable speed drive compared to a solid state starter.

First Cost Comparisons (1)

Unit Capacity (Tons)	480 Volt Solid State Starter	480 Volt VFD	4160 Volt Solid State Starter	4160 Volt VFD
2000	$415,000	$460,000	$600,000	$800,000
2200	$475,000	$520,000	$600,000	$815,000
2400	$500,000	$550,000	$600,000	$815,000

1. Based on 2016 equipment pricing.

There is a premium cost of $387,000 for both a 480 volt transformer and 4160 volt transformer that would be required if 4160 volt power is used for the chillers. The campus is suited to provide maintenance for either 480 volt systems or 4160 volt systems.

Based on the tonnage for the proposed plant upgrade, the electrical power provided to the chiller will determine whether a unit mounted or remote mounted VFD/Starter can be provided. Chillers provided with 480 volt power have the option for either unit mounted or remote mounted VFD/Starters. However, chiller powered by 4160 volts only have the option of a remote mounted VFD at these tonnages.

A basic energy analysis indicates that there is a simple payback of about 20 years for the 480 Volt variable speed drive compared to a solid state starter. The comparison also review 480 Volt chiller with a variable speed drive to a 4160 Volt chiller with variable speed drive the analysis indicates over 800 year payback. The additional costs for switchgear and transformers to provide the higher voltage to the chillers increases the payback. The comparison indicates that a 480 volt chiller with a variable speed drive is recommended for this project.

Chiller Comparison

Unit Capacity (Tons)	Voltage	Starter	kW/Ton Max	kW/Ton IPLV
2400	480	Solid State	0.534	0.434
2400	480	VFD	0.523	0.322
2400	4160	Solid State	0.565	0.412
2400	4160	VFD	0.535	0.328

CHILLER STARTER/VOLTAGE OPTIONS

Starter Comparison					
Unit Capacity (Tons)	**Voltage**	**Starter**	**kW/Ton Max**	**kW/Ton IPLV**	**Chiller Costs**
2400	480	Solid State	0.534	0.434	$ 500,000
2400	480	VFD	0.523	0.322	$ 550,000
			(0.011)	(0.112)	$ 50,000
				2400 Tons	
				(268.8) kW	
				1000 Hours/yr	
				(268,800) kW/yr	
				0.00858 $/kW	Note 1
				$ 2300 $/yr	
				Pay Back For VFD	21 years

Voltage Comparison					
Unit Capacity (Tons)	**Voltage**	**Starter**	**kW/Ton Max**	**kW/Ton IPLV**	**Chiller Cots**
2400	480	VFD	0.523	0.322	$ 550,000
2400	4160	VFD	0.535	0.328	$ 650,000
			0.012	0.006	$ 100,000
				2400 Tons	
				14.4 kW	
				1000 Hours/yr	
				14,400 kW/yr	
				0.00858 $/kW	Note 1
				$ 125 $/yr	
				Pay Back For 4160V	800 years

Notes:

1. Energy rate is a blended rate which included demand. Rate taken from existing campus billings. See Appendix A-1.

Chilled Water System Options

Steam Absorption Chillers

The existing chiller plant is currently comprised of (3) existing low pressure steam absorption chillers; this study evaluated the installation of new low pressure steam absorption chillers. Currently there are two manufactures that produce this style of chiller. The largest size low pressure steam absorption chiller currently manufactured is 1380 tons. However do to the large foot print of these chillers and height there is not sufficient clearance to install and maintain such a machine within the existing plant space and the available space for a plant addition.

Steam Turbine Driven Chillers

The current market for steam turbine driven chillers operate in the 90-125 psi steam pressure range which allows for them to produce larger tonnage machines. As was with the steam absorption chillers this is not widely used option, so available manufactures and sizes are limited so first cost is a premium. With the proposed additional plant square footage there is sufficient space to install (2) new 2400 ton machines to maximize the operating tonnage of the plant. With these machines operating from a steam service the L&S contract would need to be continued or if that option is not available the existing heating plant steam boilers will require upgrades to accommodate the summer steam load as well as the steam load to the chillers. Operation of steam chillers from the heating plant steam boilers would require the facility to operate an additional shift of man power to handle operation of the entire facility.

Electric Centrifugal Water Cooled Chillers

With the presence of an electrical chiller already in the plant, the option to transition the plant to a complete electrically driven chiller facility becomes a viable option. There are multiple chiller manufacturers available to provide chiller options for this facility leading to a competitive bidding environment at a considerably reduced price than a steam driven machine. The electrical chillers offer a more energy efficient and less maintenance option over the steam driven chillers. The overall foot print at comparable tonnages is significantly less than that of steam driven chillers. This scenario provides the facility to operate these as un-maned plants as other UW System campus are currently running at this time.

Cooling Towers

The original chiller plant is equipped with crossflow cooling towers. However, there is insufficient clearance space around towers to allow adequate air flow. The minimal clearance allows a safe working environment all around the towers and properly cleaning of the air intake louvers. The existing tower basins have required extensive repairs over the years based on inferior material construction. The new cooling towers will be constructed with stainless steel basins. Cooling tower size is based on a 10 degree F lift in condenser water.

Chiller Plant Chemical Treatment

The current condenser water systems are treated with a sulfuric acid compound which has provided excessive corrosion to the existing tower basins. It is also a chemical that requires extensive safety procedures for handling and cleanup. The chilled water system is currently provided with a bypass type feeder at the pumps. Currently there is no pre-treatment of the make-up water to the cooling towers or the chilled water loop. Cooling tower water is currently treated only as chemical packs call for treatment and the chilled water loop is treated after a manual test of water provides direction. It's recommended that the make-up water chemical treatment move away from the current process to a system salt softener system. The system provides a more cost effective and safer system to actively treat make-up water required within the plant.

Pumping Arrangement

Standard System

Based on previous experience with campus chilled water systems around the state, the standard system configuration seen are plants with electrical centrifugal variable speed water cooled chillers with cross flow cooling towers. The pumping systems include constant flow primary pumping through the chillers and variable speed secondary pumping to the campus distribution system. The use of building tertiary pumps varies throughout the campuses.

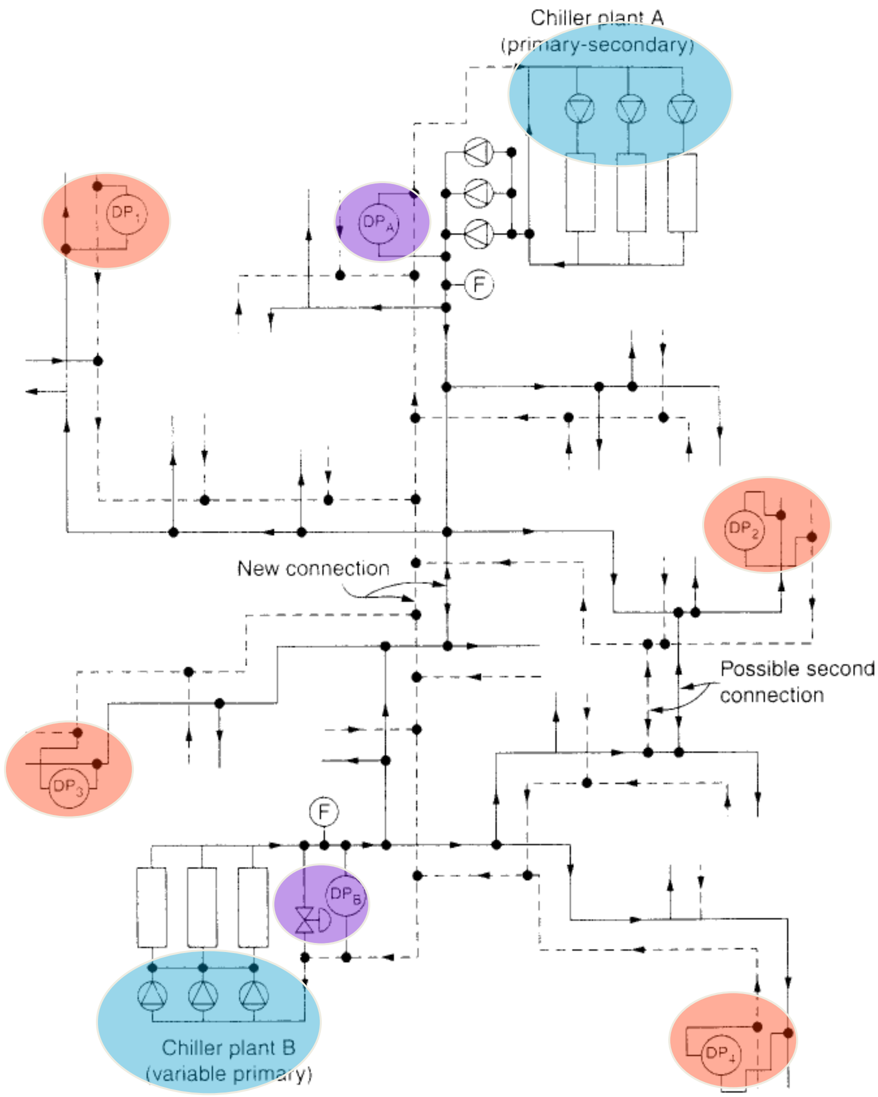
Vari-Prime System

Recent chiller plant designs with central chilled water plants located at UW-Stevens Point and UW-La Crosse, the vari-primed pumping arrangement was implemented where pumping thru the chillers and out to the distribution system was configured.

Since the existing chiller #4 and associated pumps still have sufficient useable life remaining they should remain in use with the new chiller plant set up. The existing system is piped up around as a standard system. The new chiller plant would be designed around a vari-prime pumping system. Essentially the facility would operate like to (2) separate plants.

Multi-Plant Operation

Control of the distribution pumping for the two plants would be set up as indicated in the following diagram.



With two plants tied together one plant would be designated as a “Trim Plant (varying flow/varying load)” and the other plant would be designated as the “Base” plant (constant flow/constant load)”. The “Trim” plant would vary to meet campus demands while the “Base” plant would push out a fixed flow and demand. Both the existing and new plants would be set up so they could operate as either a “Trim” plant or a “Base” plant as conditions would dictate. The trim plant is chiller plant B in the diagram. The base plant is chiller plant A in the diagram.

It is anticipated that the new plant would operate as the “Trim Plant” to take benefit of the efficiency of the variable speed chillers and the variable primary pumping. The existing plant would normally operate as the “Base Plant”. The “Base” plant would not operate until the “Trim” plant reached its capacity. This dispatch of the chillers is the basis of the plant integration table as indicated in Appendix B-3. The existing plant is arranged in a constant flow primary-variable flow secondary configuration.

The new plant would be set up with a variable primary flow configuration. Primary pumps would pump through the chillers as well as serving as system distribution pumps. Flow would vary through the chillers. Minimum flow would be maintained through the chillers via a minimum flow bypass control valve. The variable primary pumping arrangement reduces the number of pumps and related maintenance, as well as saving energy by varying the flow through the chiller when compared to the primary–secondary arrangement of the existing plant.

A flow meter in the main piping exiting the “Trim” plant would modulate its respective distribution pumps to maintain the system differential set point in the outlying buildings. The flow meter in the main piping exiting the “Base” plant would modulate its respective distribution pumps to maintain a fixed flow from the plant that corresponds to the flow of the respective number of chillers operating. If the plants are switched from “Trim” plant to “Base” plant, the pump control would also switch.

Differential pressure would be monitored at multiple key points by the Johnson Control Facility Management System in the system due to the varying dynamics of the system. Sensors that were not satisfied would reset the differential pressure set point across the distribution pump(s) in the “Trim” plant.

In the existing plant metering would be added to each chiller and controls would be upgraded to operate as either a “Trim” or “Base” plant.

The following buildings currently served with chilled water are not equipped with flow meters and would have flow meters installed:

- Laurentide Hall
- Center for the Arts
- Upham Hall
- Winther Hall
- Heide Hall
- Hyer Hall
- Young Auditorium
- Williams Center
- McGraw Hall
- Anderson Library
- Roseman Building

Plant Layout Options

The scope of the study required evaluation of the existing chiller plant facility for implementation of the new chillers and pumps, as well as review of the existing roof area for new cooling towers. The existing plant was also evaluated for available service and maintenance clearances as it would pertain to laying out new equipment within the space.

Currently there is insufficient space to adequately and properly maintain chillers and system pumps as shown in Appendix D-1. On the roof of the plant there is insufficient air inlet clearance and protective access to properly maintain tower performance and cleaning operations as shown in Appendix D-4.

When evaluating the existing plant space for the proposed options of the study, it was determined that the overall size of the new chillers does not provide adequate room to properly operate and maintain the equipment. Thus the overall size of the plant will require enlargement as shown in Appendix D-2 to provide appropriate clearances around each piece of equipment. The east wall of the original plant would need to be extended out to the east a minimum of 10 feet for the entire length of the structure adding an additional 900 square feet of space. This will provide the chillers with adequate space to be properly maintained. However, overhead doors are required to be installed at the new wall for each chiller to provide the required room to clean and pull any tubes within the chiller.

As a result of pushing the east wall of the plant out to the east, the new cooling towers can be adjusted on the roof from the current location to allow for the appropriate clearances for air flow into the cells as shown in Appendix D-5. This will allow the cooling towers to operate at design performance as well as allow for appropriate clearance to maintain the equipment. Each of the new cooling towers are approximately 12,000 lbs heavier than the existing cooling towers, in total an additional 24,000 lbs of additional load would need to be supported. The original building structural frame will require enhancement to handle this additional weighted load.

Currently the chiller plant can see temperatures over 110 degrees F during the summer months. Excessive heat over time can lead to reduced life and efficiencies of chiller components, motors, variable speed drives and electrical equipment. Whether steam driven chillers or electric water cooled machines are selected, space temperature control shall be implemented to handle rejected heat to space from chillers with the use of outside air and exhaust fans. Heat pumps can be utilized to maintain space temperature during the winter months as well as provide plant heating when connected to the underground distribution loop as a heat source.

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Project Costs for Proposed Upgrades

The following project costs for each of the (3) options are summarized in Appendix F.

All costs are based on 2016 pricing.

Proposed Construction Phasing Outline

Implementation of the proposed chiller upgrades are going to be challenging in all aspects. The current plant is the only source cooling for the entire campus. This project involves not only new equipment installation but intense building upgrades. The following are some key schedule items that should be taken into account.

1. Pre-bid major long lead time items – Chillers, cooling towers, electrical equipment.
2. Chiller Plant and electrical building additions shall be completed while the existing chiller plant is in operation as is. This time frame would include installation of new equipment within the electrical plant addition along with any miscellaneous equipment that can be installed in the chiller plant addition.
3. Coordinate with campus personal on campus cooling shut down date to provide as much time as possible over the non-cooling season to upgrade facility.
4. Demolition of all equipment shall be within the plant and on roof shall be completed at same time so existing building structural upgrades can be completed in a timely manner.
5. Intention of the pre-bid equipment is to have new equipment installation starting no later than mid-October. This shall provide contractors with five (5) months to complete work within plant.
6. Commissioning of upgraded facility shall be a process that starts on the first day of construction and continues through out to ensure plant is prepared to operate for cooling season.

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Appendix A-1
University of Wisconsin - Whitewater
Metered Data FY 2015-16 (Entire Campus)

ELECTRIC

Month	July	August	September	October	November	December	January	February	March	April	May	June	TOTAL
On Peak	1,267,403	1,312,166	1,319,348	1,249,106	1,002,065	875,953	1,009,947	1,063,480	1,105,428	1,164,930	1,046,330	1,250,390	**13,666,546**
Off Peak	2,004,466	1,937,944	1,688,427	1,691,224	1,436,801	1,539,534	1,425,099	1,455,677	1,444,853	1,654,151	1,555,510	2,077,159	**19,910,845**
KWH	3,271,869	3,250,110	3,007,775	2,940,330	2,438,866	2,415,487	2,435,046	2,519,157	2,550,281	2,819,081	2,601,840	3,327,549	**33,577,391**
Annual Dmd (3/97)	5,475	6,215	6,319	6,030	4,726	4,131	4,318	4,438	5,271	5,650	5,137	5,322	5253
Mnth Dmd	6,535	6,605	6,605	6,605	6,605	6,605	6,605	6,605	6,605	6,605	6,605	6605	**6,599**
Pwr Fctr %	96	97	97	98	99	99	99	99	95	98	100	97	**98**
Total Cost $	**$265,985.84**	**$280,423.99**	**$264,960.26**	**$256,444.80**	**$209,872.67**	**$203,021.17**	**$209,614.99**	**$216,557.08**	**$226,188.65**	**$245,465.52**	**$229,700.49**	**$272,161.92**	**$2,880,397.38**
Cents/KWH	8.129	8.628	8.809	8.722	8.605	8.405	8.608	8.596	8.869	8.707	8.828	8.179	**8.58**
%On Peak	39	40	44	42	41	36	41	42	43	41	40	38	**41**

WeEnergies POWER, MILW 800-714-7777 Rate Schedule Cp 1
Acct # 7448-632-430 (July 98), meter # PFXZT1344, constant=2,400 & meter # PFXZT1379, constant=2,400 (Jan 99)

GAS

Month	July	August	September	October	November	December	January	February	March	April	May	June	TOTAL
10^6 Btu (DTH)	78.4	52.5	71.1	41.4	42.0	65.9	87.3	67.0	44.1	42.0	215.6	65.0	**872**
Gas Supplier $	$ 252.89	$ 176.14	$ 222.96	$ 200.57	$ 122.25	$ 141.94	$ 249.48	$180.09	$ 109.78	$ 90.25	$ 263.64	$ 51.68	**$ 2,061.67**
Gas Local $	$ 154.91	$ 137.25	$ 143.27	$ 122.01	$ 134.89	$ 195.61	$ 157.75	$ 166.51	$124.19	$ 119.64	$ 523.51	$ 231.17	**$ 2,210.71**
Total Cost $	**$ 407.80**	**$ 313.39**	**$ 366.23**	**$ 322.58**	**$ 257.14**	**$ 337.55**	**$ 407.23**	**$346.60**	**$ 233.97**	**$ 209.89**	**$ 787.15**	**$ 282.85**	**$ 4,272.38**
$/10^6 BTU	5.20	5.97	5.15	7.79	6.12	5.12	4.66	5.17	5.31	5.00	3.65	4.35	**4.90**

WeEnergies, MILW 800-714-7777 Rate : IT4, Interruptible Trans
Acct # 2491-0801-01, meter # 153624-3 Note: On 1-1-96 Wis Natural Gas merged with Wis Electric

ENERGY

Month	July	August	September	October	November	December	January	February	March	April	May	June	TOTAL
ELECT 10^6BTU	11,166.9	11,092.6	10,265.5	10,035.3	8,323.8	8,244.1	8,310.8	8,597.9	8,704.1	9,621.5	8,880.1	11,356.9	**114,600**
GAS 10^6 BTU	78	53	71	41	42	66	87	67	44	42	216	65	**872**
Stm purchased (M-lbs)	22,620	21,407	23,309	21,501	21,180	22,526	30,195	26,301	22,150	20,401	12,182	18,789	262,561
Btu content	0.983	0.983	0.983	0.983	0.983	0.983	0.983	0.983	0.983	0.983	0.983	0.983	
STEAM 10^6 BTU	22,235	21,043	22,913	21,135	20,820	22,143	29,682	25,854	21,773	20,054	11,975	18,470	**258,097**
Purchased Stm Cost	$ 45,598.98	$ 43,149.31	$ 45,827.55	$ 40,331.54	$ 39,733.28	$ 42,260.14	$ 56,766.60	$ 49,362.48	$ 41,551.68	$ 38,259.00	$ 22,849.00	$ 35,233.85	**$ 500,923.41**
Oil Gallons								0				0	0
Heat value	138,000	138,000	138,000	138,000	138,000	138,000	138,000	138,000	138,000	138,000	138,000	138,000	
OIL 10^6 BTU	0	0	0	0	0	0		0	0	0	0	0	**0**
HEAT 10^6 BTU	22,313.9	21,095.6	22,983.8	21,176.9	20,861.9	22,209.0	29,769.0	25,920.9	21,817.6	20,096.2	12,190.5	18,534.6	**258,970**
TOTAL 10^6 BTU	**33,480.7**	**32,188.2**	**33,249.4**	**31,212.2**	**29,185.8**	**30,453.0**	**38,079.8**	**34,518.8**	**30,521.7**	**29,717.7**	**21,070.6**	**29,891.5**	**373,569**

Appendix B-1
University of Wisconsin - Whitewater
Chilled Water Load Projections (Based on (2) 2000 Ton Chillers Installed)

13-Mar-14

Building Name	Building Characteristics: Occupancy (Existing/Future)	Area (GSF)	GSF per Ton	Building Load (Tons)	Plant Tonnage: Running Total (Tons)	Diversity Factor	Plant Load (Tons)	Cumm. Adj Total Load (Tons)	Plant Cap (Tons)	Surplus (Deficit)	Building Flow (GPM) Deg. Delta T 12	Building Flow (GPM) Deg. Delta T 14	Cummulative Plant Flow (GPM) Deg. Delta T 12	Cummulative Plant Flow (GPM) Deg. Delta T 14	Date Online	Connected Load (Tons)	GPR Connected Load	PR Connected Load	GPR Area (GSF)	PR Area (GSF)
Three 800 Ton Chillers (1A)	System Gain (1B)	N/A	N/A	161	161	1.00	161	161	2,000	1,839					2000					
Esker Dining Hall	Planned Demo	74,076	325	228	389	0.70	160	321	2,000	1,679	456	391	641	550	2000	228		228		74,076
Laurentide Hall (27)	Existing (4)	100,960	459	220	609	0.60	132	453	2,000	1,547	440	377	905	776	2000	220	220		100,960	
Center of the Arts	Existing (5)	153,310	268	572	1,181	0.60	343	796	2,000	1,204	1,144	981	1,592	1,364	2000	572	572		153,310	
Upham Hall	Existing (6)	112,352	250	450	1,631	0.60	270	1,066	2,000	934	900	771	2,132	1,827	2000	450	450		112,352	
Winther Hall (25)	Existing (7)	89,010	318	280	1,911	0.60	168	1,234	2,000	766	560	480	2,468	2,115	2000	280	280		89,010	
Heide Hall (26)	Existing (8)	64,752	272	238	2,149	0.60	143	1,377	2,000	623	476	408	2,753	2,360	2000	238	238		64,752	
Connor Center with '64 & '88 Addt'ns	Existing (9)	139,540	300	465	2,614	0.70	326	1,702	2,000	298	930	797	3,404	2,918	2000	465		465		139,540
Hyer Hall	Existing (10)	65,893	392	168	2,782	0.60	101	1,803	2,000	197	336	288	3,606	3,091	2000	168	168		65,893	
Moraine Bookstore	Existing	28,176	350	81	2,863	0.65	52	1,855	2,000	145	161	138	3,711	3,181	2000	81		81		28,176
Young Auditorium	Existing (11)	63,179	226	280	3,143	0.70	196	2,051	2,000	(51)	560	480	4,103	3,517	2000	280	280		63,179	
Williams Center	Existing (12)	134,232	355	120	3,263	0.65	78	2,129	2,000	(129)	240	206	4,259	3,650	2001	120	120		134,232	
Drumlin Dining Hall	Existing	33,407	325	103	3,365	0.70	72	2,201	2,000	(201)	206	176	4,403	3,774	2001	103		103		33,407
Upham Hall Renovation & Addition	New (13)	29,572	230	129	3,494	0.70	90	2,291	2,000	(291)	257	220	4,583	3,928	2003	129	129		29,572	
Connor Center Renovation & Addt'n	Exist/New (14)	8,080	N/A	(18)	3,476	0.70	-13	2,279	2,000	(279)	(36)	(31)	4,557	3,906	2005	(18)		(18)		8,080
McGraw Hall	Existing (15)	44,393	313	142	3,618	0.60	85	2,364	2,000	(364)	284	243	4,728	4,052	2005	142	142		44,393	
Andersen Library	Existing (15)	198,813	427	465	4,083	0.65	302	2,666	2,000	(666)	930	797	5,332	4,570	2005	465	465		198,813	
Roseman Building	Existing (16)	51,333	375	147	4,230	0.65	96	2,762	2,000	(762)	294	252	5,523	4,734	2005	147	147		51,333	
1400 ton electric Chiller	System Gain (2)	N/A	N/A	0	4,230	1.00	0	2,762	3,400	0	0	0	0	0	2006					
Hyland Hall (C.O.B.E.)	Existing (17)	185,225	350	529	4,759	0.60	318	3,079	3,400	321	1,058	907	6,158	5,279	2008	529	529		185,225	
Starin Hall	Existing (18)	197,200	350	563	5,323	0.60	338	3,417	3,400	(17)	1,127	966	6,834	5,858	2009	563		563		197,200
Fischer Hall	Existing (19)	6,000	350	17	5,340	0.60	10	3,428	3,400	(28)	34	29	6,855	5,876	2011	17		17		6,000
Fricker Hall	Existing (21)	15,000	350	43	5,383	0.60	26	3,453	3,400	(53)	86	73	6,906	5,920	2015	43		43		15,000
Arey Hall	Existing (21)	15,000	350	43	5,425	0.60	26	3,479	3,400	(79)	86	73	6,958	5,964	2016	43		43		15,000
Install (1) 2000 ton Steam Chiller, Remove Absorber -1 & 2	System Gain (2)	N/A	N/A	42	5,467	1.00	42	3,521	4,100	579	84	72	7,042	6,036	2017					
Res Hall #1	New (22)	130,000	350	371	5,839	0.70	260	3,781	4,100	319	743	637	7,562	6,482	2017	371		371		130,000
Res Hall #2	New (22)	130,000	350	371	6,210	0.70	260	4,041	4,100	59	743	637	8,082	6,927	2019	371		371		130,000
Install (1) 2000 ton Steam Chiller Remove Absorber -3	System Gain (2)	N/A	N/A	0	6,210	1.00	0	4,041	5,400	1,359	0	0	0	0	2021					
Benson Hall	Exist/Future	47,733	350	136	6,347	0.85	116	4,157	5,400	1,243	273	234	8,314	7,126	2021	136		136		47,733
Clem Hall	Exist/Future	47,788	350	137	6,483	0.85	116	4,273	5,400	1,127	273	234	8,546	7,325	2022	137		137		47,788
Bigelow Hall	Exist/Future	47,788	350	137	6,620	0.85	116	4,389	5,400	1,011	273	234	8,778	7,524	2024	137		137		47,788
Lee Hall	Exist/Future	47,739	350	136	6,756	0.85	116	4,505	5,400	895	273	234	9,010	7,723	2025	136		136		47,739
New Dining Hall	New (24)														2027					
Res Hall #3	Future	130,000	350	371	7,128	0.70	260	4,765	5,400	635	743	637	9,530	8,168	2027	371		371		130,000
Academic #1 (Upham)	Future	75,000	230	326	7,454	0.70	228	4,993	6,000	1,007	652	559	9,986	8,560	2027	326	326		75,000	
Knilans Hall	Exist/Future	53,122	350	152	7,605	0.85	129	5,122	5,400	278	304	260	10,244	8,781	2029	152		152		53,122
Tutt Hall	Exist/Future	53,122	350	152	7,757	0.85	129	5,251	5,400	149	304	260	10,502	9,002	2030	152		152		53,122
Install (1) 2000 ton Electric Chiller Remove 1400 ton Elec	System Gain (2)	N/A	N/A	0	7,757	1.00	0	5,251	6,000	749	0	0	0	0	2032					
Athletic Facility	Exist/Future	80,000	355	225	7,983	0.65	146	5,398	6,000	602	451	386	10,795	9,253	2030	225		225		80,000
Res Hall #4	Future	130,000	350	371	8,354	0.70	260	5,658	6,000	342	743	637	11,315	9,699	2032	371		371		130,000
Academic #2 (Carter Mall)	Future	170,000	350	486	8,840	0.70	340	5,998	5,400	(598)	971	833	11,995	10,282	2032	486	486		170,000	
Res Hall #5	New (22)	130,000	350	371	9,211	0.70	260	6,258	6,000	(258)	743	637	12,515	10,727		371		371		130,000
Academic #3 (Hyer)	Future	68,000	350	194	9,405	0.70	136	6,394	6,000	(394)	389	333	12,787	10,961		194	194		68,000	
Ambrose Health Center	Existing/Future (23)	24,841	469	53	9,458	0.65	34	6,428	6,000	(428)	106	91	12,856	11,020		53	53		24,841	
Alumni Center Addition/ Remodel	Exist/Future	8,000	375	21	9,480	0.70	15	6,443	6,000	(443)	43	37	12,886	11,045		21	21		8,000	
McCutchan Hall	Planned Demo	38,958	0	0	9,480	0.85	0	6,443	6,000	(443)	0	0	12,886	11,045		0		0		38,958
White Hall	Planned Demo	40,538	0	0	9,480	0.85	0	6,443	6,000	(443)	0	0	12,886	11,045		0		0		40,538
Wells Hall	Planned Demo	237,870	0	0	9,480	0.85	0	6,443	6,000	(443)	0	0	12,886	11,045		0		0		237,870

	Connected Load (Tons)	GPR Connected Load	PR Connected Load	GPR Area (GSF)	PR Area (GSF)	
Existing Buildings	5,384	3,860	1,525	1,427,256	516,479	1,943,735
% Split		72%	28%	73%	27%	
Planned Future Buildings	3,147	812	2,335	245,000	897,292	1,142,292
Total Existing & New	8,531	4,672	3,860	1,672,256	1,413,771	3,086,027
% Split		55%	45%	54%	46%	
Buildings outside timeline of master plan	640	269	371	100,841	130,000	230,841
Total Existing & New & Unplanned	9,171	4,940	4,231	1,773,097	1,543,771	3,316,868
% Split		54%	46%	53%	47%	
Buildings scheduled for Demo	228	0	228	0	391,442	391,442
Total Existing & New & Unplanned	8,944	4,940	4,003	1,773,097	1,152,329	2,925,426
% Split		55%	45%	61%	39%	

Approximate limit of 20" distribution pipe at 10 Ft/Sec

Unconfirmed

Notes:

1A. Absorption Chiller #2 is performing noticably below nameplate capacity based on plant feedback. Data on a warmer than design day would indicate the other obsorbers are also underperforming. Since metered data is not available Absorber-1 & 3 is estimated to provide 700 tons each and Absorber #2 is estimated to provide 600 tons.

1B. Distribution pump gain estimated at (2) 200 HP = 85 Tons. Piping system gain estimated at 2% of 3800 Tons = 76 Tons.

2. Distribution pump gain estimated at (1) 200 HP = 42 Tons. No additional system piping gains added.

4. Laurentide (formerly Carlson Hall) load based on the size of the retrofit to the original Chrysler chiller, Project 8412-02. Plus 40 tons.

5. Center of the Arts load based on average GSF per ton for four (4) similar facilities at other campuses.

6. Upham Science Hall load based on original chiller selection.

7. Winther Hall load based on original chiller selection plus 30 tons for addition

8. Heide Hall load based on capacities of unit ventilators and cooling coils scheduled on original building plans plus 5 tons for an addition.

9. Original Connor University Center load based on average GSF per ton for three (3) similar facilities at other campuses.

10. Hyer Hall load from cooling coils scheduled on Sheet HV-10 of Hyer Hall capital renewal Project 95A33 (2017 MBH/12 = 168 tons).

11. Young Auditorium load from cooling coils scheduled on Sheet HV12 of the Multi-Purpose Auditorium Project 8810-15 (3369 MBH/12 = 280 tons).

12. Williams Center load from AHU schedule on Sheet H0.2 of Field House Addition Project 98186 (1445 MBH/12 = 120 tons). 42,650 GSF of facility cooled based on design drawings.

13. Upham Science Hall Addition load based on average of two (2) recently updated science facilities.

14. Renovated Conner Center net GSF is based on a 49,991 GSF addition with demolition of the original 41,911 GSF 1959 building. Cooling load is based on consultants design, 155 tons for 6" service to 1963 addition and 292 tons for 8" service to 1988 & 2007 additions.

15. Andersen Library & McGraw Hall loads CHW piping schematic on Sheet H4 of Andersen Library Computer Center Addt'n Project 8507-36 (GPM/2.4).

16. Roseman CW Load based on 2005 DSF Project 05L2U when 2-1/2" lines run to roof. 3-inch line to existing services were already functional.

17. Hyland Hall (College of Business & Economics) GSF based on Design Report information.

18. Starin Residence Hall GSF based on Feb 2008 Design Report.

19. GSF for cooling estimate is based on just the common spaces that are cooled within Res Hall.

20. GSF in blue font from 05/2005 General Building Report

21. GSF for cooling estimate is based on just the Res Hall common areas that will be cooled including one-half of the GSF associated to the new "link" building between Arey and Fricker. (Mead and Hunt Study - Jan 2013). GSF for campus split include one-half of link bldg GSF.

22. Res Hall GSF based on preliminary campus planning conversations (400 bed semi suite style)

23. Ambrose Health Center load based on cooling coil capacites shown on Sheet HV-3 of Student Health Center Project 6807-16 (640 MBH/12 = 53 tons).

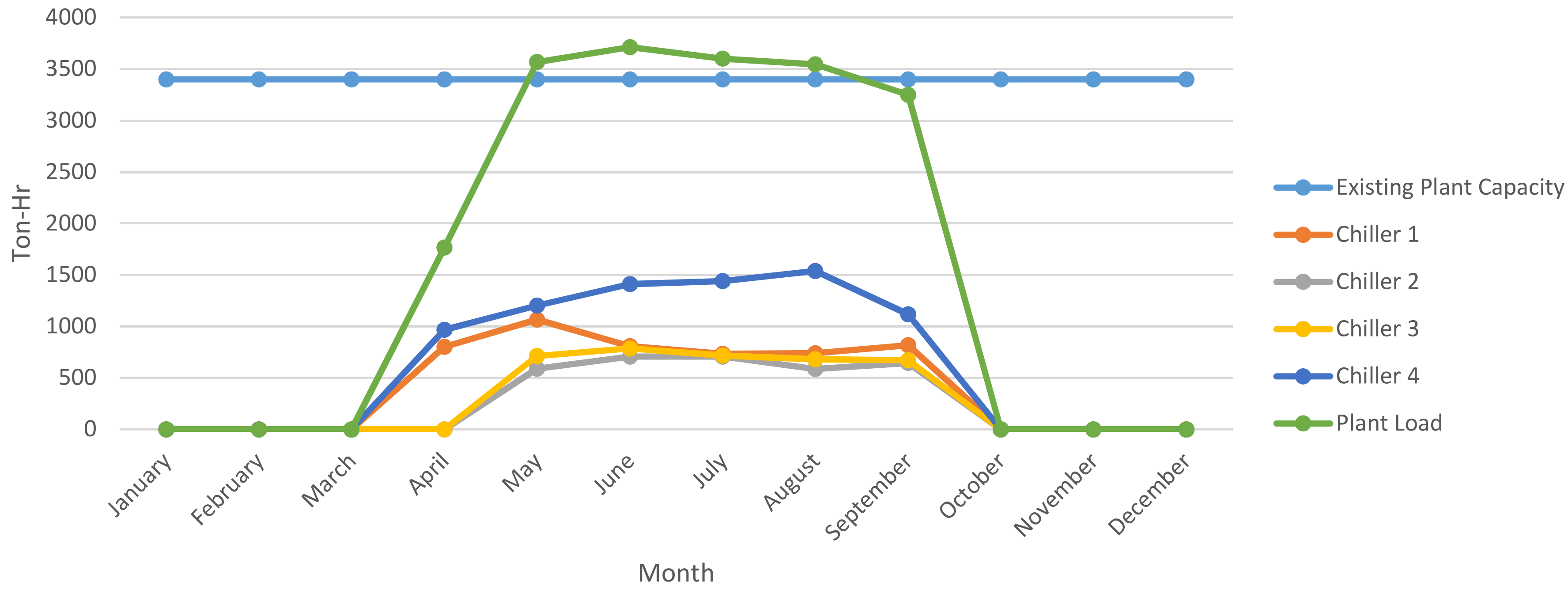
24. Replacement facility for Esker. Sqaure footage and loads offset by Esker Demo.

25. Includes 12,000 GSF for future proposed addition

26. Includes 2,200 GSF for future proposed addition

27. Includes 18,390 GSF for future proposed addition

Appendix B-2
Average Monthly Peak Load Profile - 2013
University of Wisconsin - Whitewater



Appendix B-3
UW-Whitewater Chiller Plant Study Report
DFD Project Number 15K2E

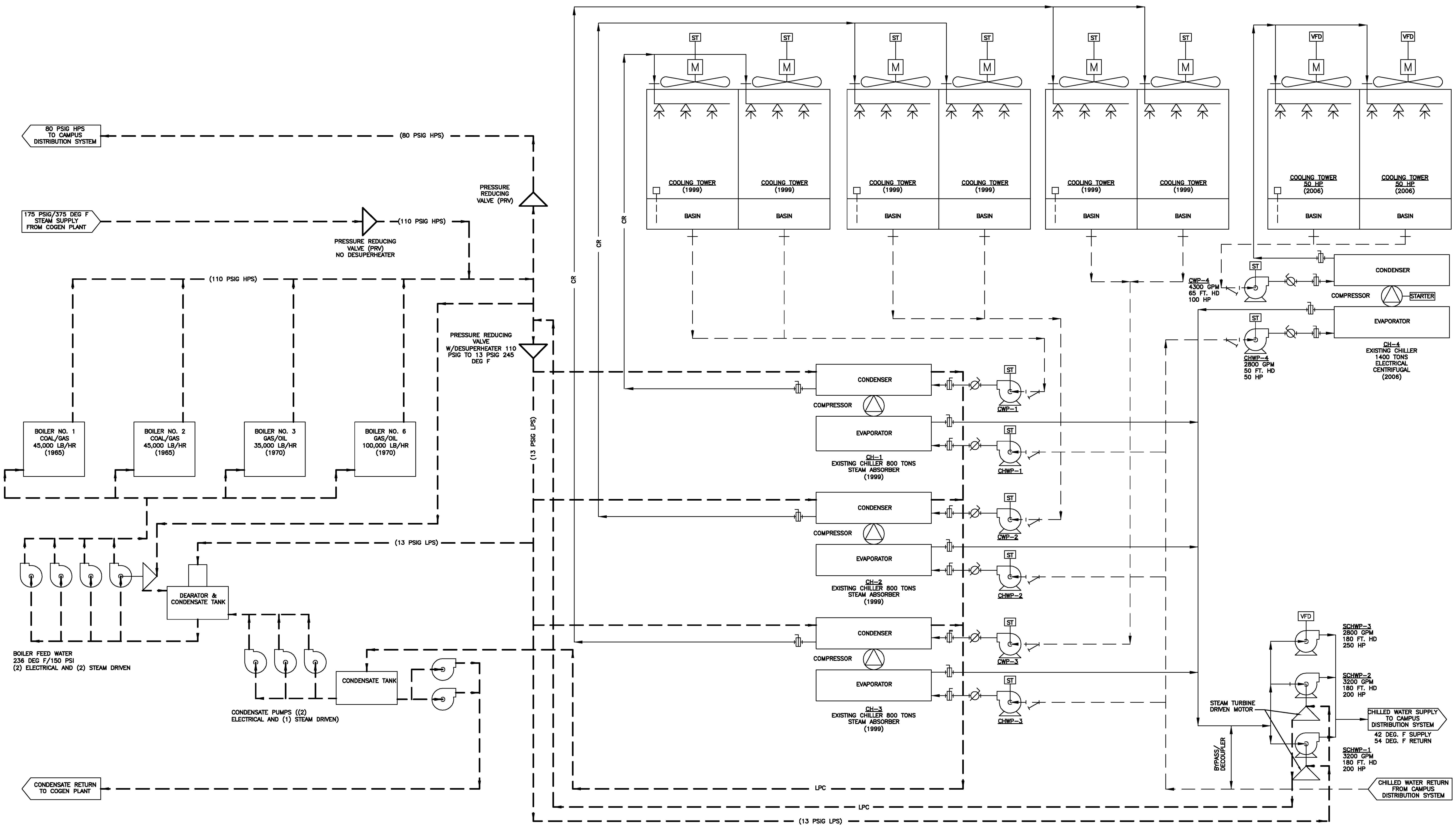
PLANT INTEGRATION

DESCRIPTION	MAX. TONS	MIN. TONS	DELTA F.	PLANT LOCATION	PUMP ARRANG.	CHILLED WATER DISTRIBUTION GPM	CHILLER VFD	TOWER FAN VFD	CHILLER MAX. KW/TON	CHILLER NPLV KW/TON
CHILLER NO. 1	2400			ORIGINAL	VPF	4100	YES	YES	0.561	0.366
CHILLER NO. 2	2400			ORIGINAL	VPF	4100	YES	YES	0.561	0.366
CHILLER NO. 3	1400			EXISTING	P/S	2800	NO	YES	0.573	0.510
TOTAL	6200		14			11000				

VPF VARIABLE PRIMARY FLOW
P/S PRIMARY - SECONDARY FLOW

% LOAD	TONS	CAMPUS CH.W. GPM	CHILLER NO. 1 STATUS	CHILLER NO. 1 TONS	CHILLER NO. 1 CH.W. GPM	CHILLER NO. 1 TOTAL KW	CHILLER NO. 2 STATUS	CHILLER NO. 2 TONS	CHILLER NO. 2 CH.W. GPM	CHILLER NO. 2 TOTAL KW	CHILLER NO. 3 STATUS	CHILLER NO. 3 TONS	CHILLER NO. 3 CH.W. GPM	CHILLER NO. 3 TOTAL KW	TOTAL KW/ TON
0%	0	0	OFF	0	0	0	OFF	0	0	0	OFF	0	0	0	0
5%	300	514	ON	300	514	270	OFF	0	0	0	OFF	0	0	0	0.898
10%	610	1046	ON	610	1046	453	OFF	0	0	0	OFF	0	0	0	0.743
15%	920	1577	ON	920	1577	463	OFF	0	0	0	OFF	0	0	0	0.503
20%	1230	2109	ON	1230	2109	463	OFF	0	0	0	OFF	0	0	0	0.376
25%	1540	2640	ON	1540	2640	472	OFF	0	0	0	OFF	0	0	0	0.307
30%	1850	3171	ON	1850	3171	472	OFF	0	0	0	OFF	0	0	0	0.255
35%	2160	3703	ON	2160	3703	537	OFF	0/660	0	0	OFF	0	0	0	0.249
40%	2470	4234	ON	1235	2117	537	ON	1235	2117	537	OFF	0	0	0	0.435
45%	2780	4766	ON	1390	2383	625	ON	1390	2383	625	OFF	0	0	0	0.450
50%	3090	5297	ON	1545	2649	625	ON	1545	2649	789	OFF	0	0	0	0.458
55%	3400	5829	ON	1700	2914	789	ON	1700	2914	789	OFF	0	0	0	0.464
60%	3710	6360	ON	1855	3180	789	ON	1855	3180	789	OFF	0	0	0	0.426
65%	4020	6891	ON	2010	3446	978	ON	2010	3446	978	OFF	0	0	0	0.487
70%	4330	7423	ON	2165	3711	978	ON	2165	3711	978	OFF	0/1400	0	0	0.452
75%	4640	7937	ON	1615	2769	1182	ON	1615	2769	1182	ON	1400	2400	929	0.710
80%	4950	8486	ON	1775	3043	1182	ON	1775	3043	1182	ON	1400	2400	929	0.665
85%	5260	9017	ON	1930	3309	1407	ON	1930	3309	1407	ON	1400	2400	929	0.712
90%	5570	9549	ON	2085	3574	1407	ON	2085	3574	1407	ON	1400	2400	929	0.672
95%	5880	10080	ON	2240	3840	1670	ON	2240	3840	1670	ON	1400	2400	929	0.726
100%	6200	10629	ON	2400	4114	1670	ON	2400	4114	1670	ON	1400	2400	929	0.689

CHILLER IS OFF.
CHILLER IS ON.
BYPASS CONTROL VALVE MODULATES TO MAINTAIN MINIMUM FLOW OF 1486 GPM.
CHILLER IS BASED LOADED BY FIXING THE DISTRIBUTION PUMP FLOW TO GPM INDICATED.



1 EXISTING STEAM & CHILLED WATER SYSTEM DIAGRAM
NO SCALE

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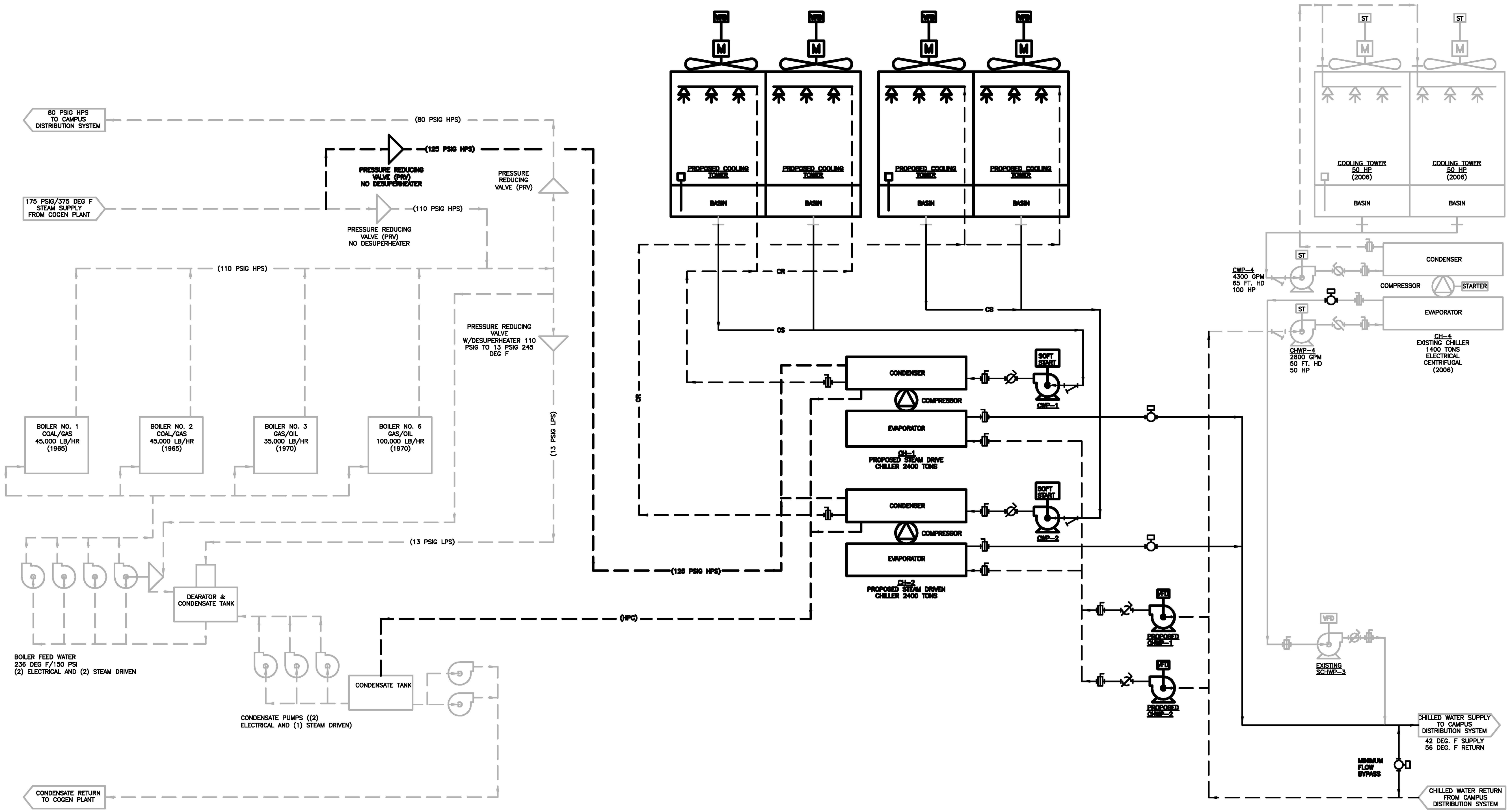
Sheet Title:
EXISTING STEAM & CHILLED WATER SYSTEM DIAGRAM

Revisions:

No.	Date:	Description:

Graphic Scale	NO SCALE
DFD Number	15K2E
Set Type	FR
Date Issued	12/16/2016
Sheet Number	C-1



1 PROPOSED STEAM & CHILLED WATER SYSTEM DIAGRAM – OPTION 1 & 2
NO SCALE

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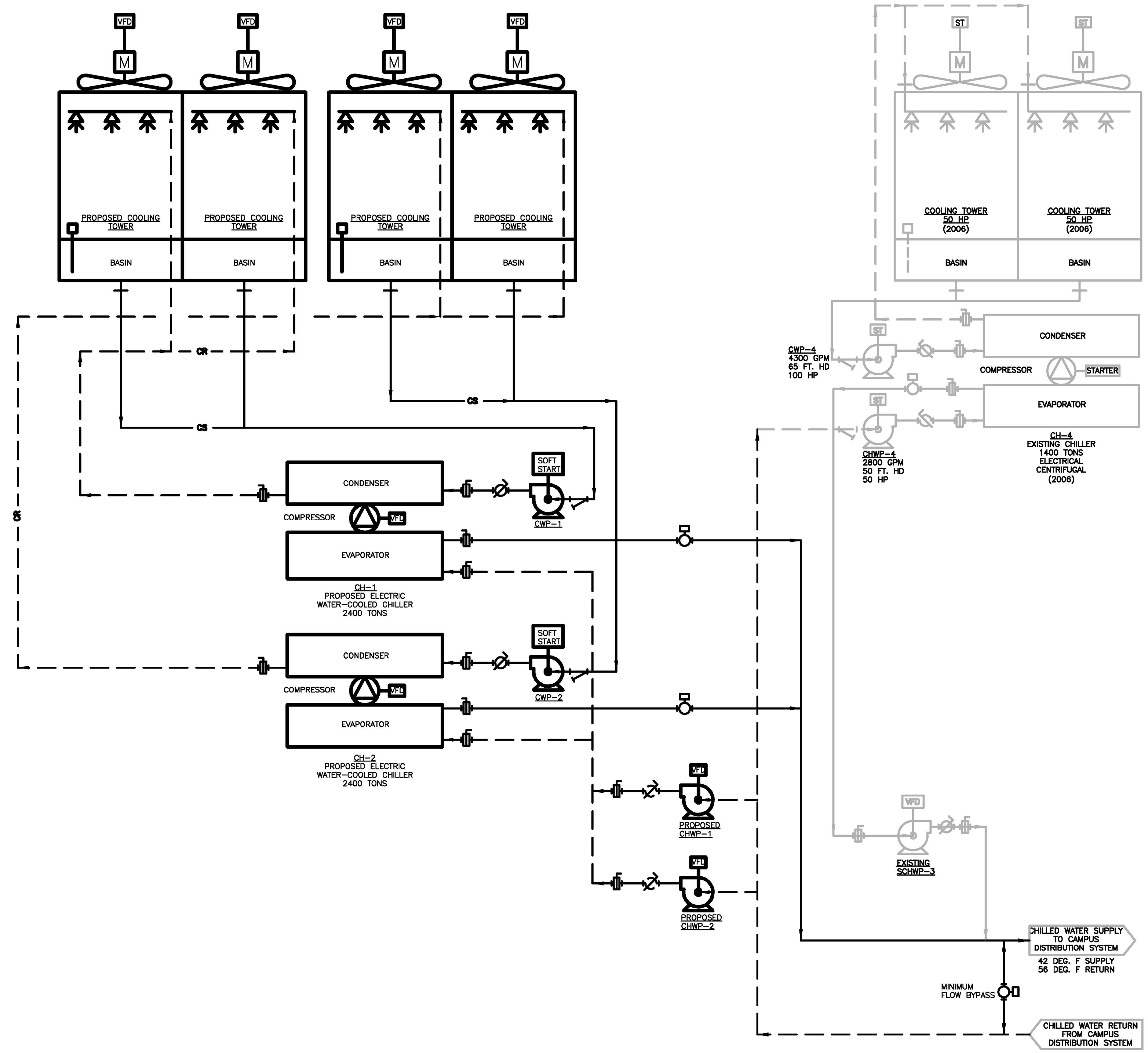
Sheet Title:
PROPOSED STEAM & CHILLED WATER SYSTEM DIAGRAM – OPTION 1 & 2

Revisions:

No.	Date:	Description:

Graphic Scale	NO SCALE
DFD Number	15K2E
Set Type	FR
Date Issued	12/16/2016
Sheet Number	C-2



1 PROPOSED CHILLED WATER SYSTEM DIAGRAM – OPTION 3
NO SCALE

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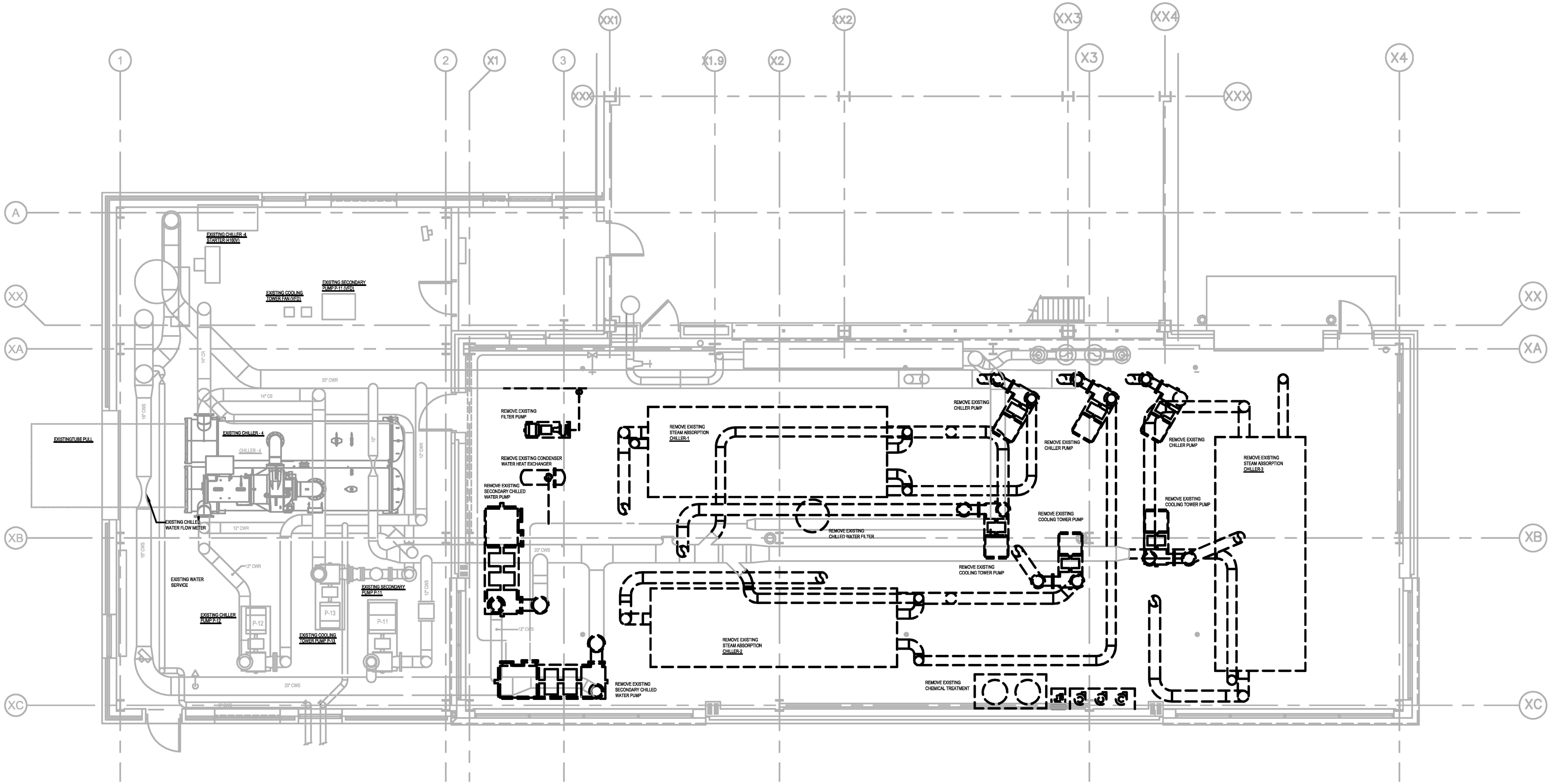
Sheet Title:
PROPOSED CHILLED WATER SYSTEM DIAGRAM – OPTION 3

Revisions:

No.	Date:	Description:

Graphic Scale	NO SCALE
DFD Number	15K2E
Set Type	FR
Date Issued	12/16/2016
Sheet Number	C-3



1 GROUND FLOOR PLAN - DEMOLITION

SCALE: 1"=10'

NORTH

RING & DUCHATEAU
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Sheet Title:
GROUND FLOOR PLAN – DEMOLITION

Revisions:

No.	Date:	Description:

Graphic Scale: 0' 5' 10' 15' 20'

DFD Number	15K2E
Set Type	FR
Date Issued	12/16/2016
Sheet Number	D-1

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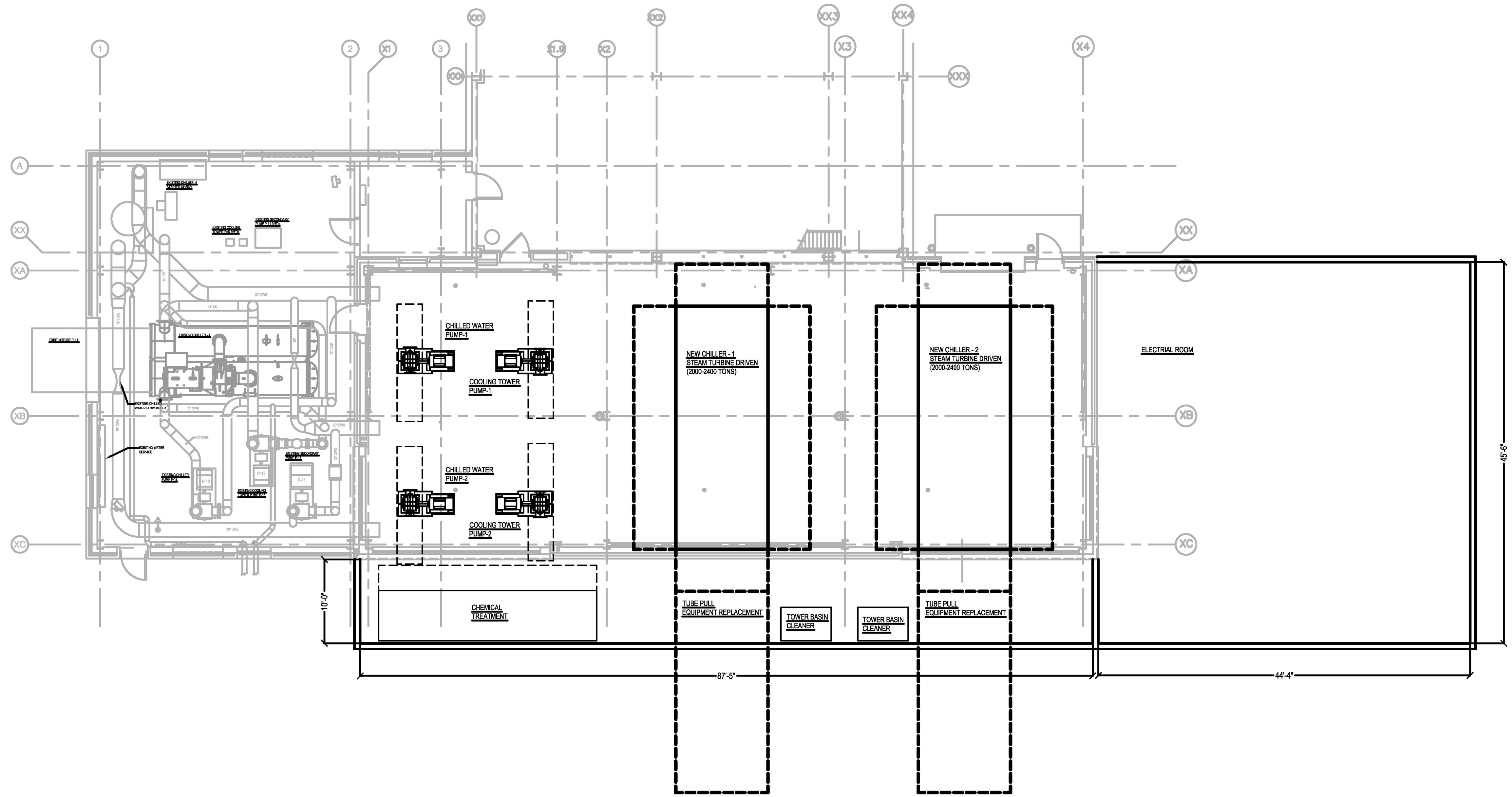
Sheet Title:
GROUND FLOOR PLAN – OPTION 1 & 2 NEW CONSTRUCTION



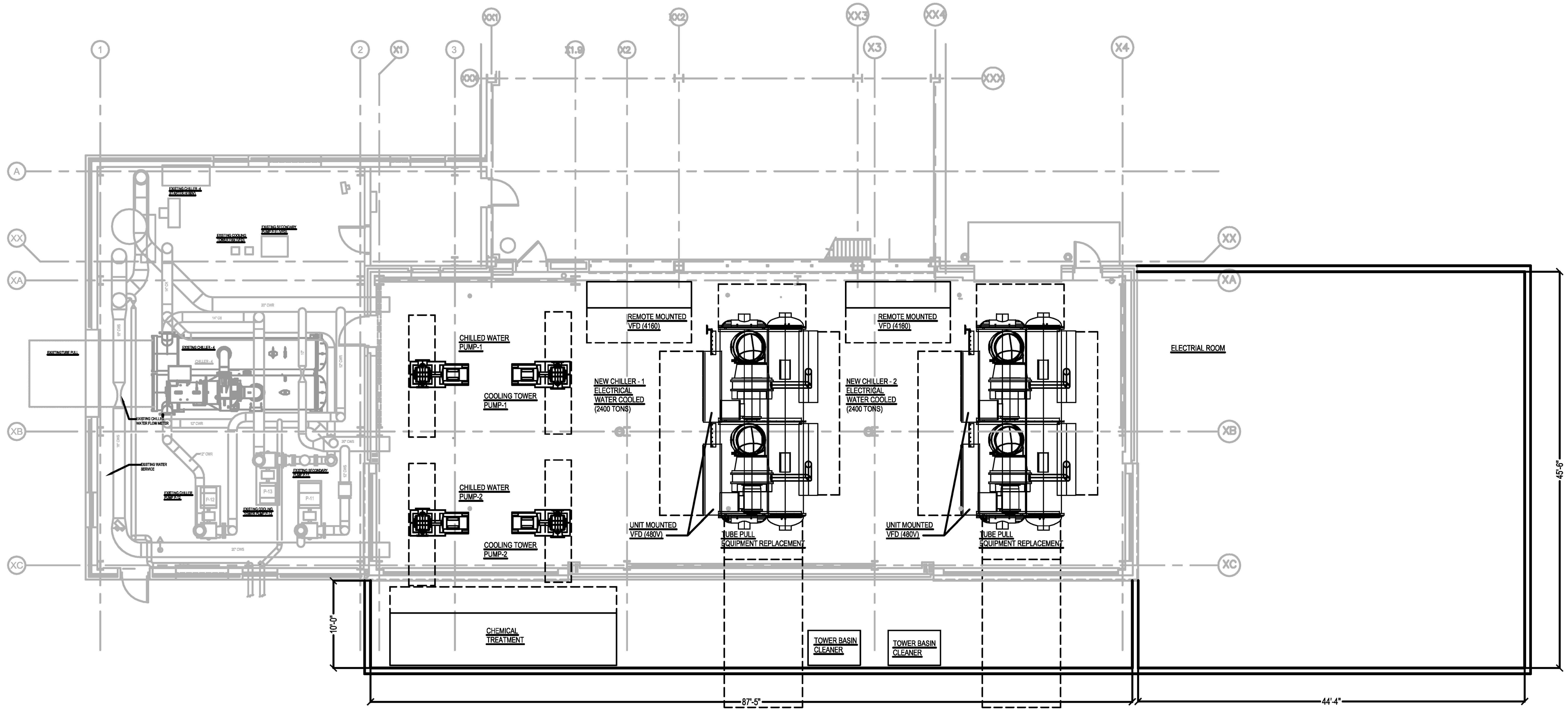
1 GROUND FLOOR PLAN - OPTION 1 & 2 NEW CONSTRUCTION
STEAM TURBINE DRIVEN (2000-2400 TONS)
SCALE: 1"=15'-0"

NORTH

Revisions:

No.	Date:	Description:

Graphic Scale	0' 1' 2' 4' 6'
DFD Number	15K2E
Set Type	FR
Date Issued	12/16/2016
Sheet Number	D-2



GROUND FLOOR PLAN - OPTION 3 NEW CONSTRUCTION
ELECTRIC WATER-COOLED CHILLER (2000-2400 TONS)

1

SCALE: 1"=15'-0"

NORTH

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Sheet Title:
GROUND FLOOR PLAN - OPTION 3 NEW CONSTRUCTION

Revisions:

No.	Date:	Description:

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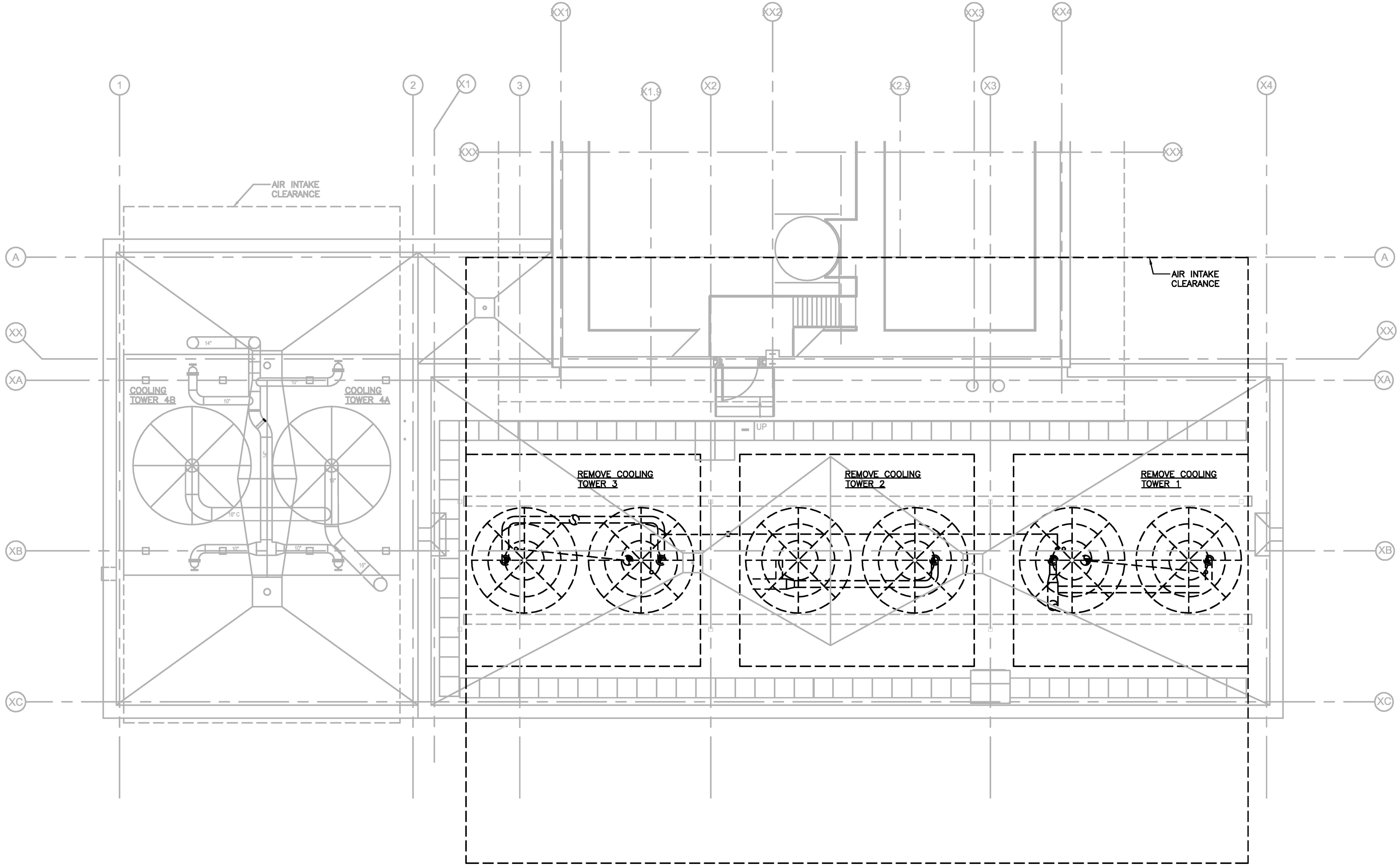
DFD Number	15K2E
Set Type	FR
Date Issued	12/16/2016
Sheet Number	D-3



1 ROOF PLAN - DEMOLITION
SCALE: 1"=10'

NORTH

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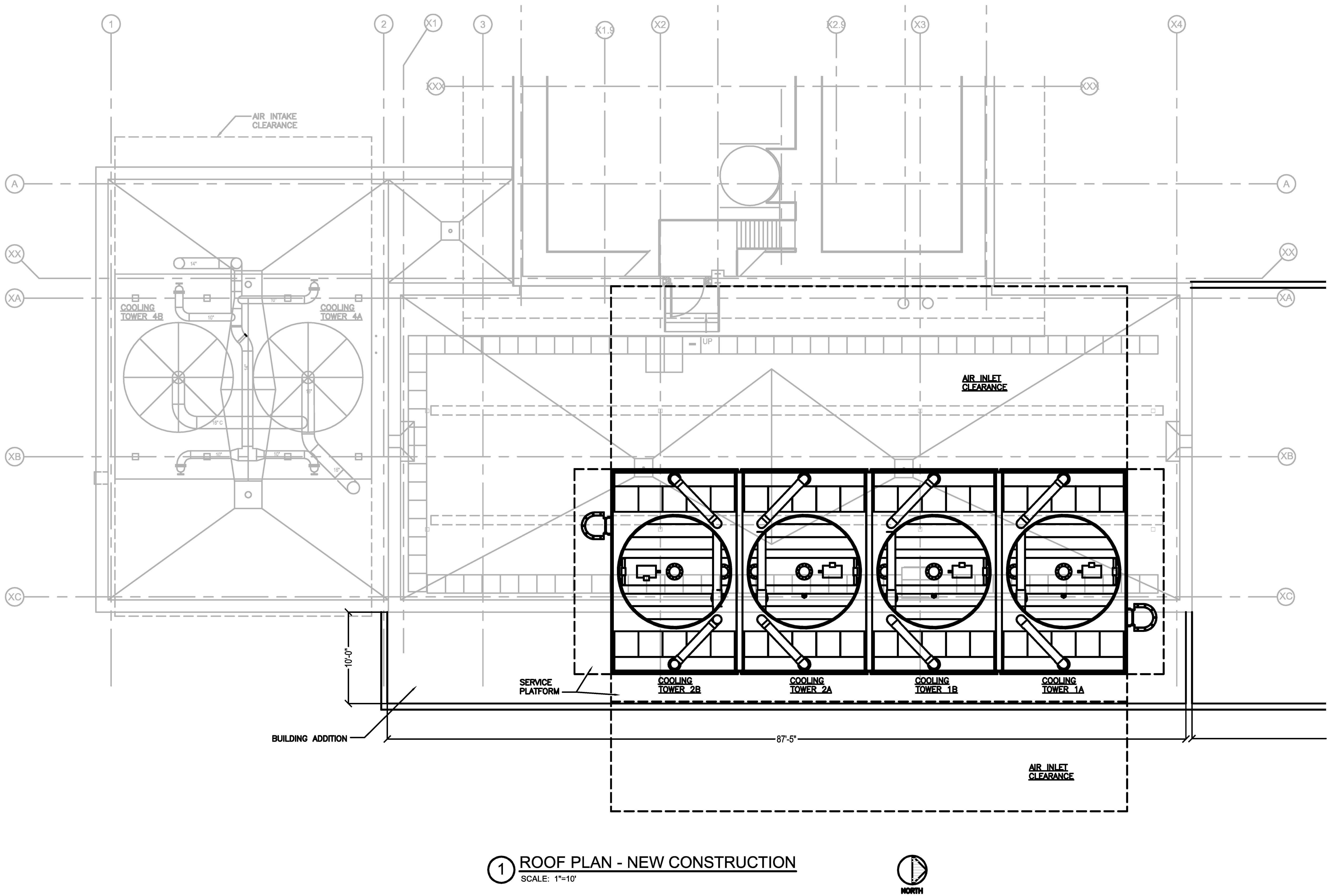
Sheet Title:
ROOF PLAN – DEMOLITION

Revisions:

No.	Date:	Description:

Graphic Scale	0' 2.5' 5' 10' 15'
DFD Number	15K2E
Set Type	FR
Date Issued	12/16/2016
Sheet Number	D-4



1 ROOF PLAN - NEW CONSTRUCTION

SCALE: 1"=10'

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Sheet Title: ROOF PLAN – NEW CONSTRUCTION

Revisions:		
No.	Date:	Description:

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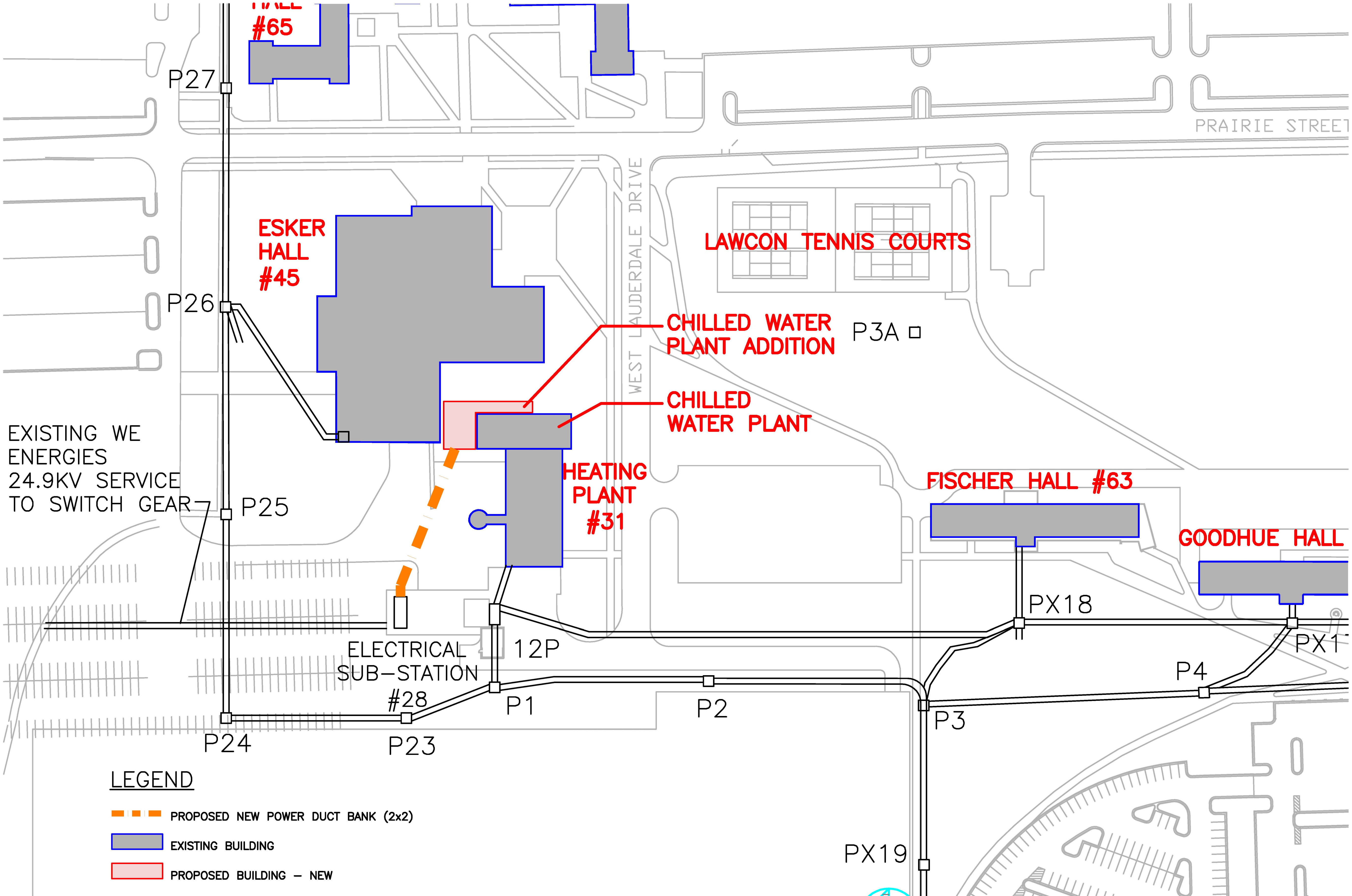
DFD Number	15K2E
Set Type	FR
Date Issued	12/16/2016
Sheet Number	D-5



POWER DISTRIBUTION PLAN – NEW

1" = 100'

0' 50' 100' 150'

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Sheet Title: ELECTRICAL SITE PLAN

Revisions:		
No.	Date:	Description:

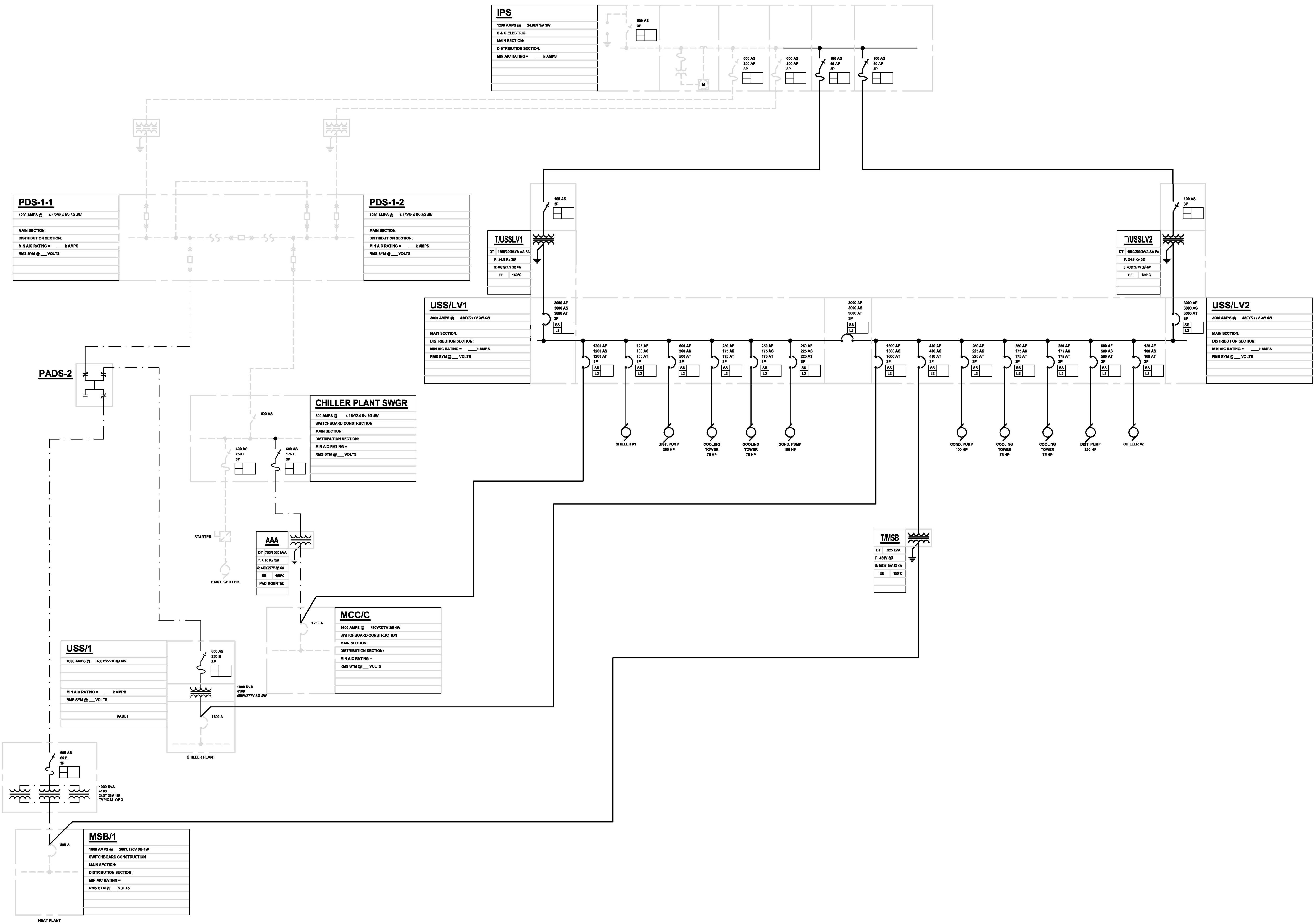
Graphic Scale

DFD Number: 15K2E

Set Type: FR

Date Issued: 12/16/2016

Sheet Number: E-1



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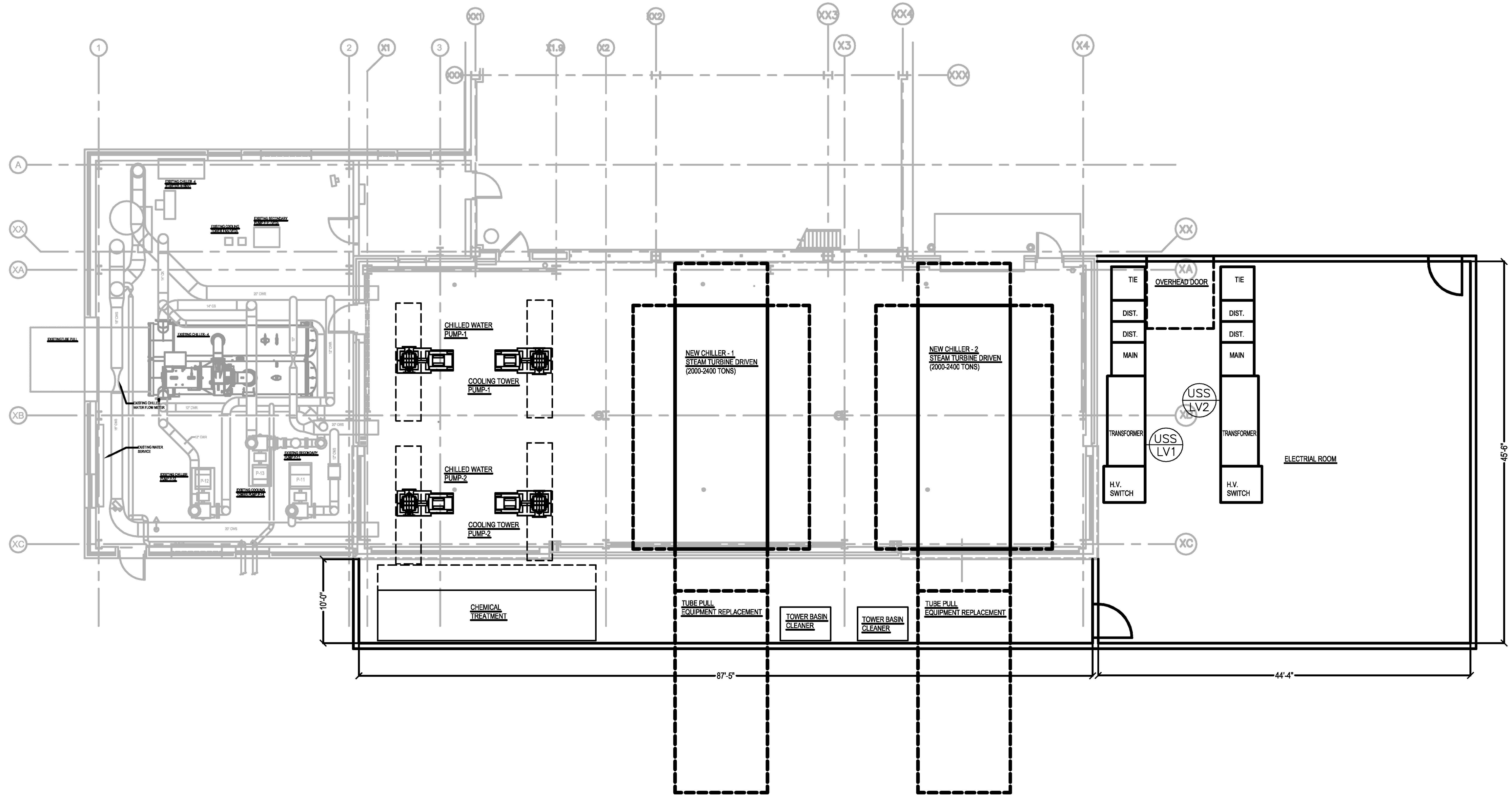
Sheet Title:
PROPOSED STEAM & CHILLED WATER SYSTEM ONELINE DIAGRAM - OPTION 1 & 2

Revisions:

No.	Date:	Description:

Graphic Scale	
DFD Number	15K2E
Set Type	FR
Date Issued	12/16/2016
Sheet Number	E-2



GROUND FLOOR PLAN - OPTION 1 & 2 NEW CONSTRUCTION STEAM TURBINE DRIVEN

1

SCALE: 1"=15'-0"

NORTH

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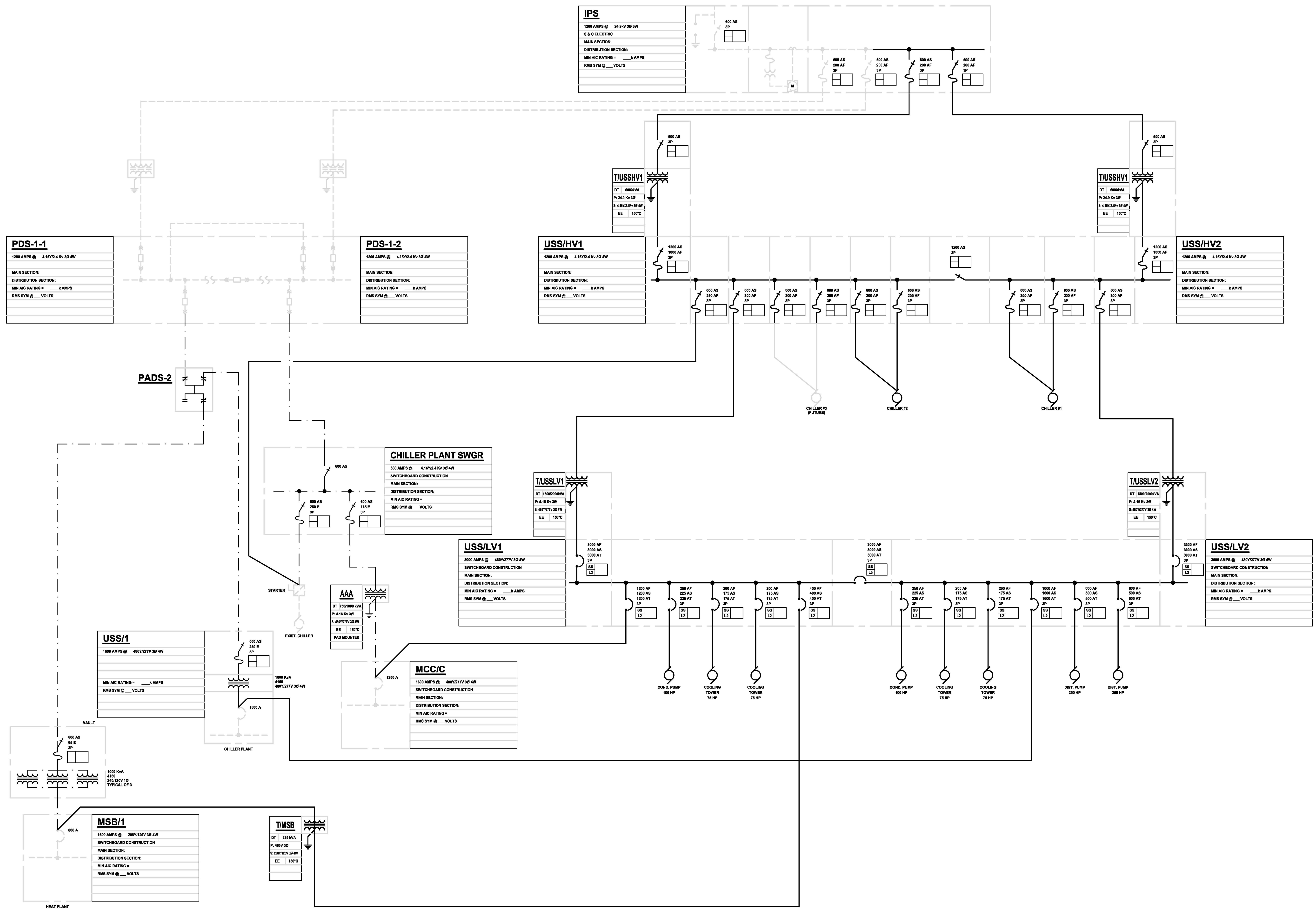
Sheet Title:
GROUND FLOOR PLAN – OPTION 1 & 2 NEW CONSTRUCTION

Revisions:

No.	Date:	Description:

Graphic Scale	0' 1' 2' 4' 6'
DFD Number	15K2E
Set Type	FR
Date Issued	12/16/2016
Sheet Number	E-3



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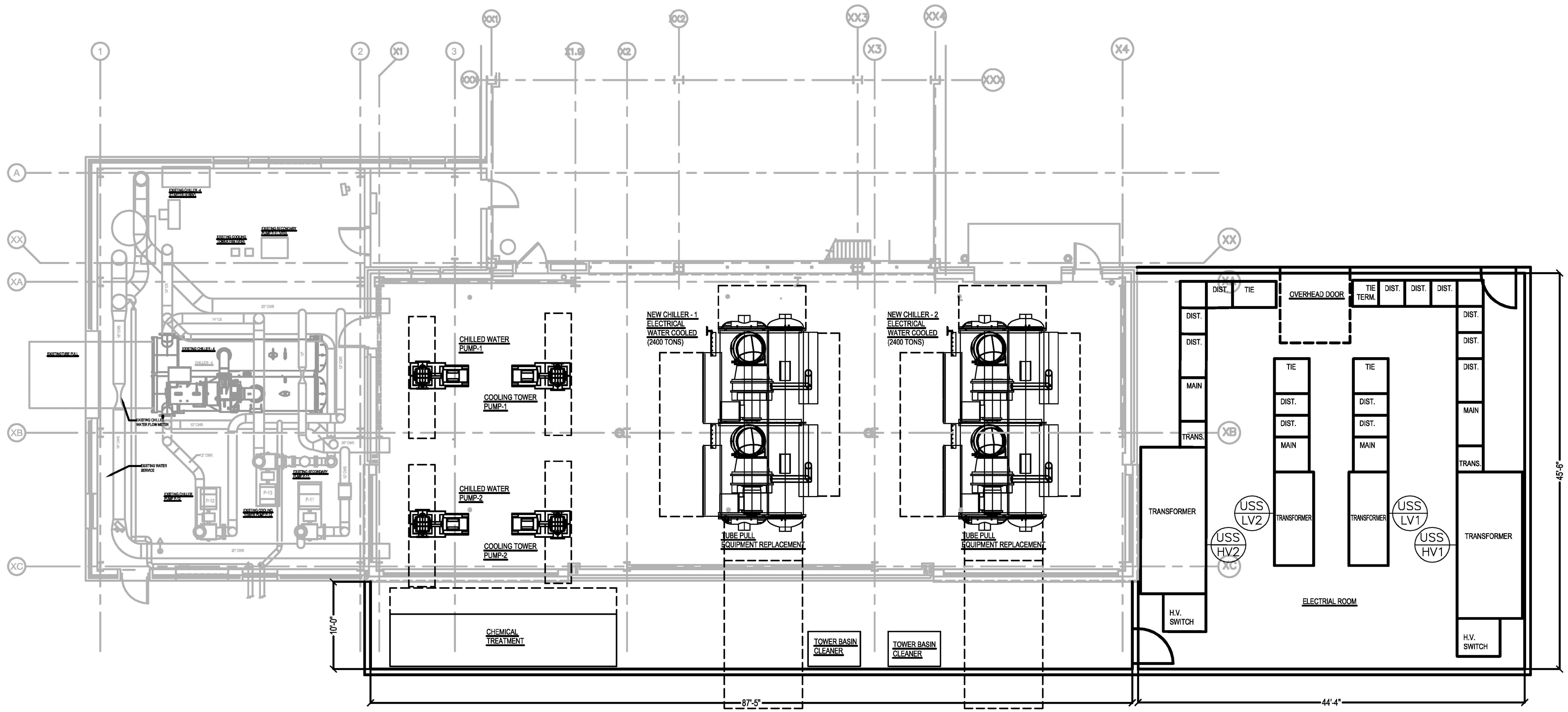
Sheet Title:
PROPOSED STEAM & CHILLED WATER SYSTEM ONELINE DIAGRAM - OPTION 3A

Revisions:

No.	Date:	Description:

Graphic Scale	
DFD Number	15K2E
Set Type	FR
Date Issued	12/16/2016
Sheet Number	E-4



GROUND FLOOR PLAN - OPTION 3A NEW CONSTRUCTION ELECTRIC WATER-COOLED CHILLER (4160V)

1

SCALE: 1"=15'-0"

NORTH

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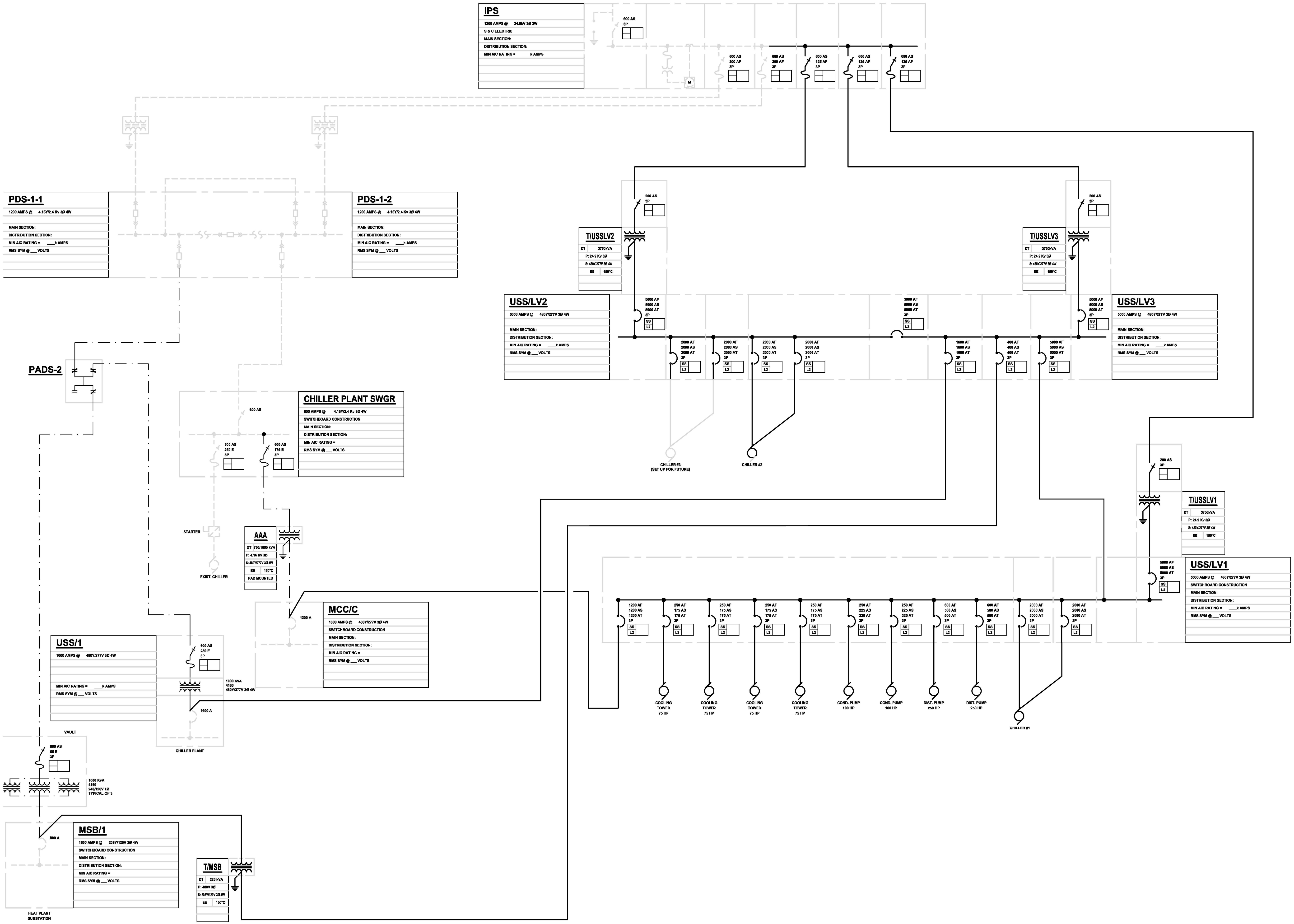
Sheet Title:
GROUND FLOOR PLAN - OPTION 3A NEW CONSTRUCTION

Revisions:

No.	Date:	Description:

Graphic Scale 0' 1' 2' 4' 6'

DFD Number	15K2E
Set Type	FR
Date Issued	12/16/2016
Sheet Number	E-5



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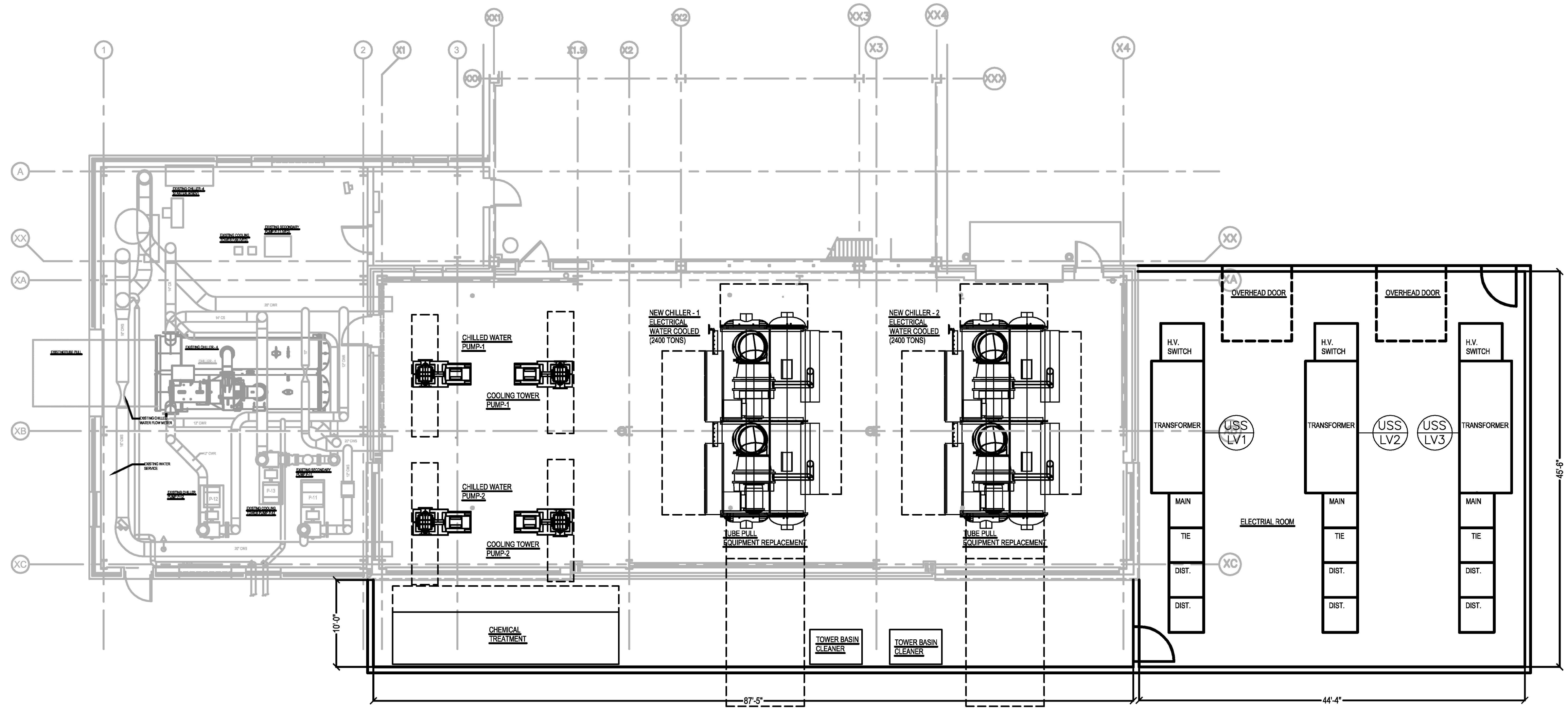
Sheet Title:
PROPOSED STEAM & CHILLED WATER SYSTEM ONELINE DIAGRAM - OPTION 3B

Revisions:

No.	Date:	Description:

Graphic Scale	
DFD Number	15K2E
Set Type	FR
Date Issued	12/16/2016
Sheet Number	E-6



1 GROUND FLOOR PLAN - OPTION 3B NEW CONSTRUCTION
ELECTRIC WATER-COOLED CHILLER (480V)

SCALE: 1"=15'-0"

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Sheet Title:
GROUND FLOOR PLAN – OPTION 3B NEW CONSTRUCTION

Revisions:

No.	Date:	Description:

Graphic Scale	0' 1' 2' 4' 6'
DFD Number	15K2E
Set Type	FR
Date Issued	12/16/2016
Sheet Number	E-7

Appendix F-1
UW-Whitewater Chiller Study Report

Project Estimate Per-Study

Construction	Option 1 - L&S Steam (2) 2400 Ton Steam Chillers	Option 2 - (2) 2400 Ton Steam Chillers	Option 3 - (2) 2400 Electrical Chillers
General	$ 723,000	$ 723,000	$ 1,125,150
Plumbing	$ 65,000	$ 65,000	$ 67,500
Mechanical	$ 3,683,655	$ 3,783,655	$ 3,583,655
Electrical	$ 978,000	$ 978,000	$ 1,793,674
Total Base Construction Cost	$ 5,449,655	$ 5,549,655	$ 6,569,979
A/E Design Fee	$ 435,972	$ 443,972	$ 525,598
Other Fees			
EIA	$ 15,000	$ 15,000	$ 15,000
Reimbursables			
Plan Approv	$ 5,000	$ 5,000	$ 5,000
Su	$ 5,000	$ 5,000	$ 15,000
Soil Bor	$ 5,000	$ 5,000	$ 10,000
DFD Management 4%	$ 237,605	$ 241,965	$ 286,451
Contingency 9%	$ 490,469	$ 499,469	$ 591,298
Total	$ 6,643,701	$ 6,765,061	$ 8,018,327

1. All costs are reflective of 2016 pricing. Costs shown will require inflation for each year construction of project is extended.

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Appendix F-2
UW-Whitewater Chiller Study Report

Construction Estimate

Budget Item	Option 1 - L&S Steam (2) 2400 Ton Steam Chillers	Option 2 - (2) 2400 Ton Steam Chillers	Option 3 - (2) 2400 Electrical Chillers

Site Work-Plant

Erosion Control	$ 2,000	$ 2,000	$ 2,000
Fencing	$ 1,500	$ 1,500	$ 1,500
Demo Landscape	$ 1,000	$ 1,000	$ 1,000
Total Site Work-Plant	$ 4,500	$ 4,500	$ 4,500

Plant

Excavation/Backfill	$ 15,000	$ 15,000	$ 40,000
Soil Retention	$ 150,000	$ 150,000	$ 150,000
Concrete	$ 63,500	$ 63,500	$ 81,000
Masonry	$ 85,000	$ 85,000	$ 198,400
Structural Steel	$ 65,000	$ 65,000	$ 150,000
Cooling Tower Roof Support Steel	$ 110,000	$ 110,000	$ 110,000
Roofing	$ 17,000	$ 17,000	$ 47,000
Windows	$ 30,000	$ 30,000	$ 57,000
Overhead Door/Doors	$ 19,000	$ 19,000	$ 31,000
Interior Finishes	$ 25,000	$ 25,000	$ 50,000
Equipment Hoist (2 Total)	$ 125,000	$ 125,000	$ 125,000
Total Plant	$ 704,500	$ 704,500	$ 1,039,400

Plant Utilities

Storm Sewer	$ 2,500	$ 2,500	$ 6,500
Water	$ 5,000	$ 5,000	$ -
Sanitary Sewer	$ 2,500	$ 2,500	$ 2,500
Total Plant Utiliites	$ 10,000	$ 10,000	$ 9,000

Landscape-Plant

Asphalt Pavements	$ 2,000	$ 2,000	$ 2,000
Sod	$ 2,000	$ 2,000	$ 2,000
Total Landscape-Plant	$ 4,000	$ 4,000	$ 4,000

Site Work-Duct Bank Distribution

Erosion Control	$ -	$ -	$ 500
Fencing	$ -	$ -	$ 500
Demo Hardscape	$ -	$ -	$ 2,500
Total Site Work-Distribution	$ -	$ -	$ 3,500

Duct Bank Distribution

Power Ductbank (175 feet)	$ -	$ -	$ 52,500
Total Duct Bank Distribution	$ -	$ -	$ 52,500

Landscape-Duct Bank Distribution

Asphalt Pavements	$ -	$ -	$ 12,250
Total Landscape-Distribution	$ -	$ -	$ 12,250

Total General	$ 723,000	$ 723,000	$ 1,125,150

Plumbing

Plumbing	$ 5,000	$ 5,000	$ 7,500
Water Treatment	$ 60,000	$ 60,000	$ 60,000
Total Plumbing	$ 65,000	$ 65,000	$ 67,500

Mechanical

Demolition Existing Chillers, Towers, Pumps	$ 500,000	$ 500,000	$ 500,000
Upgrade Steam Piping System	$ 100,000	$ 100,000	$ -
Upgrade Existing Heating Plant Boilers	$ -	$ 100,000	$ -
Pre-Bid (2) New Chiller (4160v) w/VFD	$ 640,000	$ 640,000	$ 640,000
Pre-Bid (2) New Cooling Tower (480v)	$ 330,000	$ 330,000	$ 330,000
New Pumps (480v Motors)	$ 290,000	$ 290,000	$ 290,000
Pump and Cooling Tower (480v)VFD's/Starters	$ 118,000	$ 118,000	$ 118,000
New Piping/Equipment Upgrade	$ 1,560,655	$ 1,560,655	$ 1,560,655
New Ventilation System Existing Plant	$ 15,000	$ 15,000	$ 15,000
New Ventilation System Elec. Building	$ 10,000	$ 10,000	$ 10,000
Plant Controls Upgrade	$ 120,000	$ 120,000	$ 120,000
Total Mechanical	$ 3,683,655	$ 3,783,655	$ 3,583,655

Electrical

Substation Rework	$ 219,494	$ 219,494	$ 268,000
Cabling Substation to Building Addition	$ 11,400	$ 11,400	$ 30,000
Building Addition Equipment	$ 503,100	$ 503,100	$ 991,000
Plant Equipment	$ 211,506	$ 211,506	$ 472,174
Building Addition Conduits, Cabling, Wiring	$ 32,500	$ 32,500	$ 32,500
Total Electrical	$ 978,000	$ 978,000	$ 1,793,674

Total Base Construction Cost	**$ 5,449,655**	**$ 5,549,655**	**$ 6,569,979**
Upgrade existing chiller plant to Vari-Prime	$ 100,000	$ 100,000	$ 100,000.00
Provide 4160v power to Chillers	$ -	$ -	$ 387,000

Total Option Construction Cost	**$ 5,549,655**	**$ 5,649,655**	**$ 7,056,979**

Note: The above cost estimates are based on costs as of the date of this report.