UNIVERSITY OF WYOMING

West Campus Satellite Energy Plant

Heating and Cooling Analysis

February 28, 2017

GLHN
Architects & Engineers Inc.
In Association with
Henneman Engineering Inc
COFFEY ENGINEERING & SURVEYING
Proj No.: 16051.00 | 2939 E. Broadway Blvd. Tucson, Az. 85716

University of Wyoming

Table of Contents

Acknowledgements

We would like to express our appreciation to all who helped to provide input and insight to make this report possible.

Bill Mai Vice President for Administration

Larry Blake Deputy Director, Facilities Architecture

Matt Newman Assoc. University Architect

John Davis Executive Director, Operations

Forrest Selmer Deputy Director, Operations/ Utilities

Frank Barrows Mechanical/ Electrical

Steve Fletcher Mechanical/ Electrical

Matt Peterson Mechanical/ Electrical

Michael McConahay Mechanical/ Electrical

Erik McCartor Mechanical/ Electrical

Ainsley Thrailkill Mechanical

Matt Kibbon Construction Manager

Executive Summary

The University of Wyoming's Long Range Development plan and Utility Master Plan project a campus growth rate of 1-3% per year. Much of this growth is concentrated in the area known as West Campus. Chilled water and Steam produced at the University's Central Energy Plant (CEP), located on the north-east corner of campus is distributed throughout campus through a series of direct buried and walking tunnel piping. A significant percentage of these tunnels and some of the piping date back to the 1920s and have reached the end of their useful and dependable life. Substantial energy losses are occurring within the steam distribution system. These losses are calculated to be approximately 12% of peak capacity and 27% of annual fuel consumptions in waste energy per year.

Paralleling ageing infrastructure, ongoing issues at the CEP require constant attention and efforts from Facilities Management. Although in remarkably good condition for 36 years of continuous duty, the coal stoker boilers, originally installed in the early 1980s when the plant was constructed, were tailored around a plentiful, high quality and low cost regional coal supply and sized for future growth. The future growth has arrived and the heating plant is now operating at near design capacity; the cooling plant is working well beyond its design capacity. In recent years, the availability of a quality coal source has pushed the University into purchasing increasing quantities of natural gas to burn in these boilers originally designed for coal.

A juncture in time has been reached to either spend capital funds to repair and replace these deteriorating liabilities and undersized equipment or explore other avenues of production and distribution. The analysis outlined within this report explores several plausible options and strategies to accommodate the growing campus with heating and cooling utilities in the most efficient and cost effective manner for the next 30 years. The highlights of these recommendations to provide a source of reliability in capacity and distribution are as follows:

- Installation of a West Campus hot water direct buried distribution system that can be extended in the future as campus grows.
- Connect approximately (30) buildings to this system for heating and domestic hot water needs.
- Construction of a West Campus Satellite Utility Plant housing high efficiency, modular type hot water boilers, pumps, and appurtenances.
- Integration of construction of a chilled water Thermal Energy Storage (TES) tank into the West Campus Satellite Plant design and Construction which eliminates the need for a new water chiller and allows the majority of the University's existing system assets to be utilized and provide the necessary cooling to satisfy the growing demand

Results of the 30 year Life Cycle Cost Evaluation modelling (Section 5) demonstrate that the transition to a modular heating hot water concept on West Campus has practical economic value even under a conservative set of campus growth and fuel cost escalation assumptions. The HHW approach addresses the three impending campus utility system challenges of load growth and remaining heating/cooling capacity, costs of renewing aging steam infrastructure, and high cost of service due to poor thermal and labor efficiencies.

Over the past 10 years, universities across the United States have been under increasing pressure from students, staff and administrators to improve system reliability and building facility control, manage efficiency and operating cost, and reduce campus environmental impact, particularly the campus CO_2 emission footprint. Although difficult to consider quantitatively, all of these factors are likely to be involved in a decision on investing in renewal of campus utility infrastructure.

Transition to heating hot water on the West Campus provides future flexibility in heating fuel sources and technologies. The new thermal distribution system, sized to operate at substantially lower temperature, pressure, and exergy than the current 125 psi steam system and with substantially less energy loss, can be served in future by a range of production alternatives. These could scale from electric heat pumps driven by a renewable energy grid, to biofuel or syngas driven Combined Heat and Power engine generators, to some future form of campus scale clean coal, carbon sequestration, or waste-to-energy technology. The high efficiency modular condensing boilers themselves are a relatively small element of the cost of renewal. More substantial is the heating hot water distribution system that eliminates a major source of thermal inefficiency on campus and can be expanded and/or adapted to accommodate future improvements or regulated change in heat production technology over the next decades.

The estimated capital cost to make the recommended West Campus improvements is **$38,500,000**. This cost includes the previously mentioned bulleted points. Although the most appealing life cycle cost is the full conversion of West Campus to a hot water based system, the project can be achieved in Phases if required by budget allocations.

Section 1
Section 2
Section 3
Section 4
Section 5

03 Introduction

Introduction

The University of Wyoming contracted with GLHN Architects and Engineers and their Sub Consultants Coffey Engineering and Surveying, Henneman Engineering, and Rider Levett Bucknall in July of 2016, to investigate the utility options for future campus growth over the next thirty years. As the projected growth is dominant around the north western portion of campus, the focus of the study is to provide recommendations on how West Campus growth will be accommodated from a building heating and cooling standpoint. The Long Range Development Plan identifies campus growth projections are expected to occur at a rate of 1-3% per year. This Plan along with other University provided documentation including the Design and Construction Standards, the Historic Preservation Master Plan, and the 2009 Utility Master Plan were all utilized as a basis and incorporated into this West Campus Evaluation Report. The major GLHN scope items include:

- Analysis of the existing utility production capacity and condition assessment of the Central Energy Plant (CEP)
- Analysis of the existing steam and chilled water distribution systems
- Analysis of available fuel sources
- The generation of a feasibility study to maintain the CEP for the next 30 years
- Identification of potential options to accommodate future growth on West Campus including the construction of a Satellite Plant
- Analysis of the approved owner preferred site
- Development of a conceptual plan for the recommended solution including preliminary design, project budget, schedules, and life cycle cost analysis. In early August, 2016 the GLHN/UW team met onsite in Laramie WY for a three day investigation and informational partnering kickoff session.

These series of meetings acted as a medium to understand the goals of the project, the future utility needs, the operation and condition of the CEP, and narrow down potential satellite plant locations. From these series of meetings and investigations, the following overall concepts were determined:

- The CEP is in good working condition. This is due to the consistent and high quality upkeep that has taken place throughout its lifespan. There are reliability issues with the provision of a boiler coal source that is compliant with the original combustion specification requirements.
- Recent campus growth has brought the heating system generation capacity to approximately 85% of its reliable capacity. The chilled water system generation capacity is already beyond its N+1capacity in that if the largest piece of equipment is offline for any reason, the system will not be able to provide the necessary cooling capacity over the course of a design day.
- From a combustion efficiency standpoint, the CEP runs approximately 75% efficient. System wide, the current combustion and distribution system efficiency is approximately 53% efficient, with an estimated 12,000 lb/hr of steam loss occurring during a “no load” condition.
- Potential CEP improvement options investigated include:
  - ◊ The addition of a 1,200 ton chiller with a cross campus interconnect
  - ◊ The installation of a chilled water thermal energy storage tank
  - ◊ Installation of additional boiler capacity
- Potential West Campus solution option locations investigated include:
  - ◊ The area north of the Agriculture Building
  - ◊ The area around Bureau of Mines
  - ◊ The area in the vicinity of 13th Street and Bradley
  - ◊ The basement of the Biosciences Building

03 Introduction

A preliminary analysis was provided by GLHN in a draft report format issued for review on August 18th of 2016. This Draft report compared the various sites and strategies, and its information is included in Section IV of this report.

The various options explored include:

- Boiler addition at the CEP (Option CEP-H1)
- Boiler removal and addition at the CEP (Option CEP-H2)
- Chiller addition at the CEP (Option CEP-C1)
- Chilled water thermal storage tank at the CEP (Option CEP-C2)
- Satellite Plant (heating and cooling) at the area north of Agriculture (Option SAT-1)
- Satellite Plant (heating and cooling) at the Bureau of Mines (Option SAT-2)
- Boiler installation at Bureau of Mines (Option WCE-H1)
- Boiler Installation at Bio Sciences (Option WCE-H2)
- Steam to hot water converters at Agriculture (Option WCE-H3)
- Chilled water thermal storage tank at Agriculture (Option WCE-C1)
- Chilled water thermal storage tank at Bureau of Mines (Option WCE C2)

Onsite review meetings with the GLHN and UW teams occurred August 24th through the 26th, 2016. A presentation by GLHN was provided with various combinations of the aforementioned options. Based on anticipated life cycle costs and University preferences, it was decided that the path forward would be the changeover from a steam to a hot water production and distribution system on west campus. A new boiler plant housing natural gas boilers, pumps, and equipment dedicated to a new chilled water thermal energy storage (TES) system, would be located on the open lot north of the Agriculture Building. New hot water direct buried piping would require installation to each building served. New chilled water piping from the TES pumps to the existing distribution system would have to be provided. Portions of the deteriorating West Campus underground tunnel system would have to be addressed.

This option analysis was presented by GLHN and members of the UW team to the Board of Trustees at the monthly meeting on November 18th, 2016 in Laramie. It was at this point that the decision to move forward with the proposed concept was confirmed and the beginnings of this final report assembled.

The financial analysis comparing options was performed utilizing an Excel based model generated by GLHN. This model has a variety of variable inputs including associated capital expenses, energy costs, escalation/inflation rates of energy, taxes, and labor/operational costs. Through this model, life cycle projections were calculated and compared. Assumptions were input bases on US Energy Information Administration (EIA) projections, discussions with peer University decision makers, and observations of energy industry trends. The results of these comparisons are provided in Sections IV and V of this report.

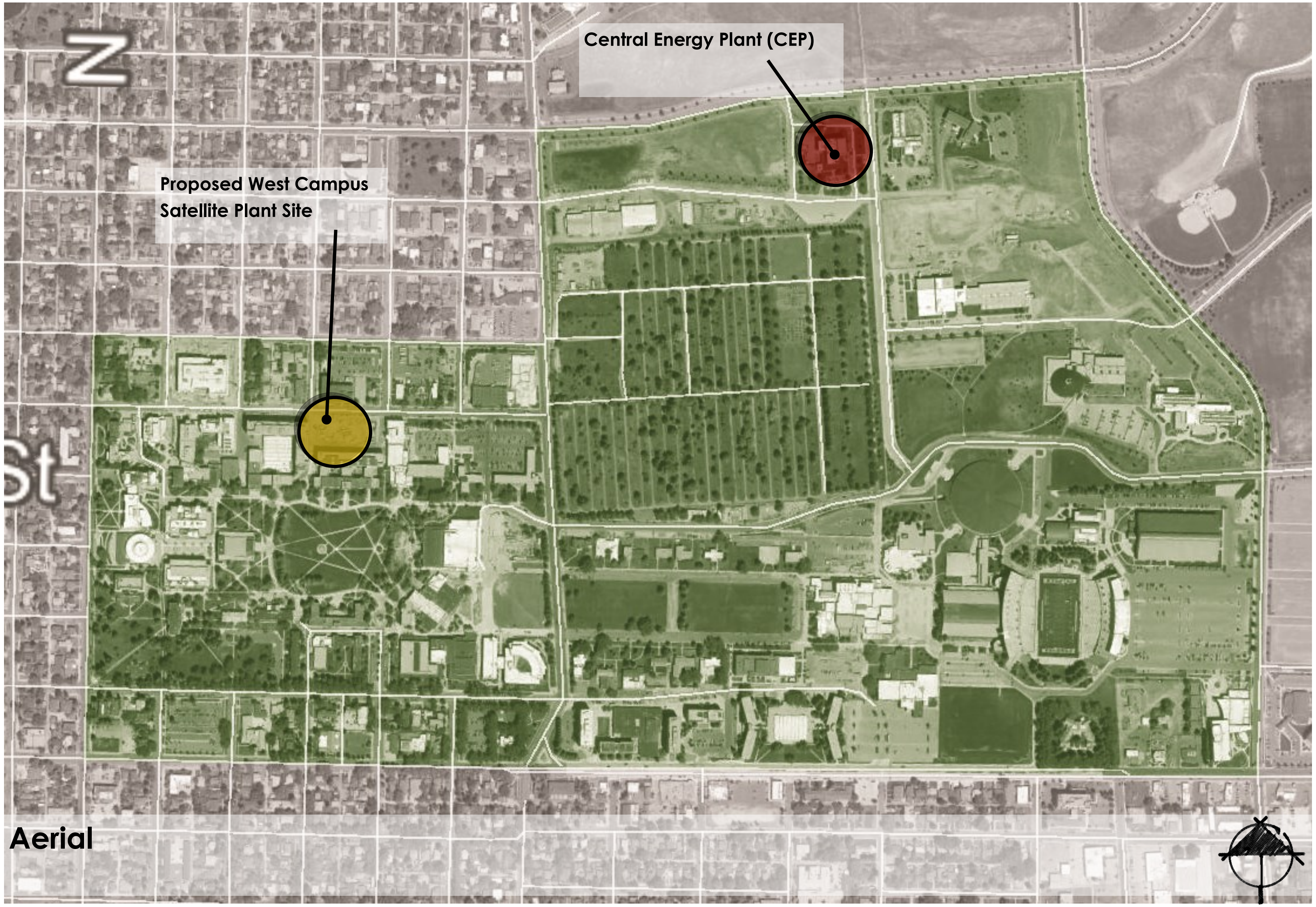
Simulations of existing and future Chilled Water (CHW), Hot Water (HW), and steam utility expansions on the University of Wyoming (U.W.) campus were performed. The flow simulation software, PipeFLO, was used to create a flow model to provide a better understanding of the system's hydraulic performance as well as its constraints in response to the projected UW campus cooling and heating load growth. The results of this modeling are provided in Section III of this report.

This West Campus Evaluation Report was generated by GLHN with the help and support of various departments within the University of Wyoming. It is divided into five distinct sections and includes Supporting Documentation appendices for additional references. Section I of the report consists of the Introduction, Project Overview, and Executive Summary. Section II provides the information regarding the CEP analysis. Section III identifies the campus load and distribution constraints and findings. Section IV details the analysis and investigative options. Section V pertains to the West Campus recommended solution with budget information, schedules, and preliminary design.

03 Introduction

Location

The University Wyoming campus is located in the city of Laramie located on the Laramie River in southeastern Wyoming. Laramie is located on a high plain region at an elevation of about 7,200 feet above sea level between the Snowy and the Laramie mountain ranges. Because of the high elevation, it is a semi-arid climate with long, cold dry winters, and shorter, somewhat wetter and warm summers.



03 Introduction
West and Central Campus Aerial

04 Scope of Work

Central Energy Plant

- **Heating Option 1** (CEP-H1) Plant addition plus new boiler .
- **Heating Option 2** (CEP-H2) Existing boiler removal and addition.
- **Cooling Option 1** (CEP-C1) Plant addition plus new chiller.
- **Cooling Option 2** (CEP-C2) Add thermal energy storage (TES) tank.

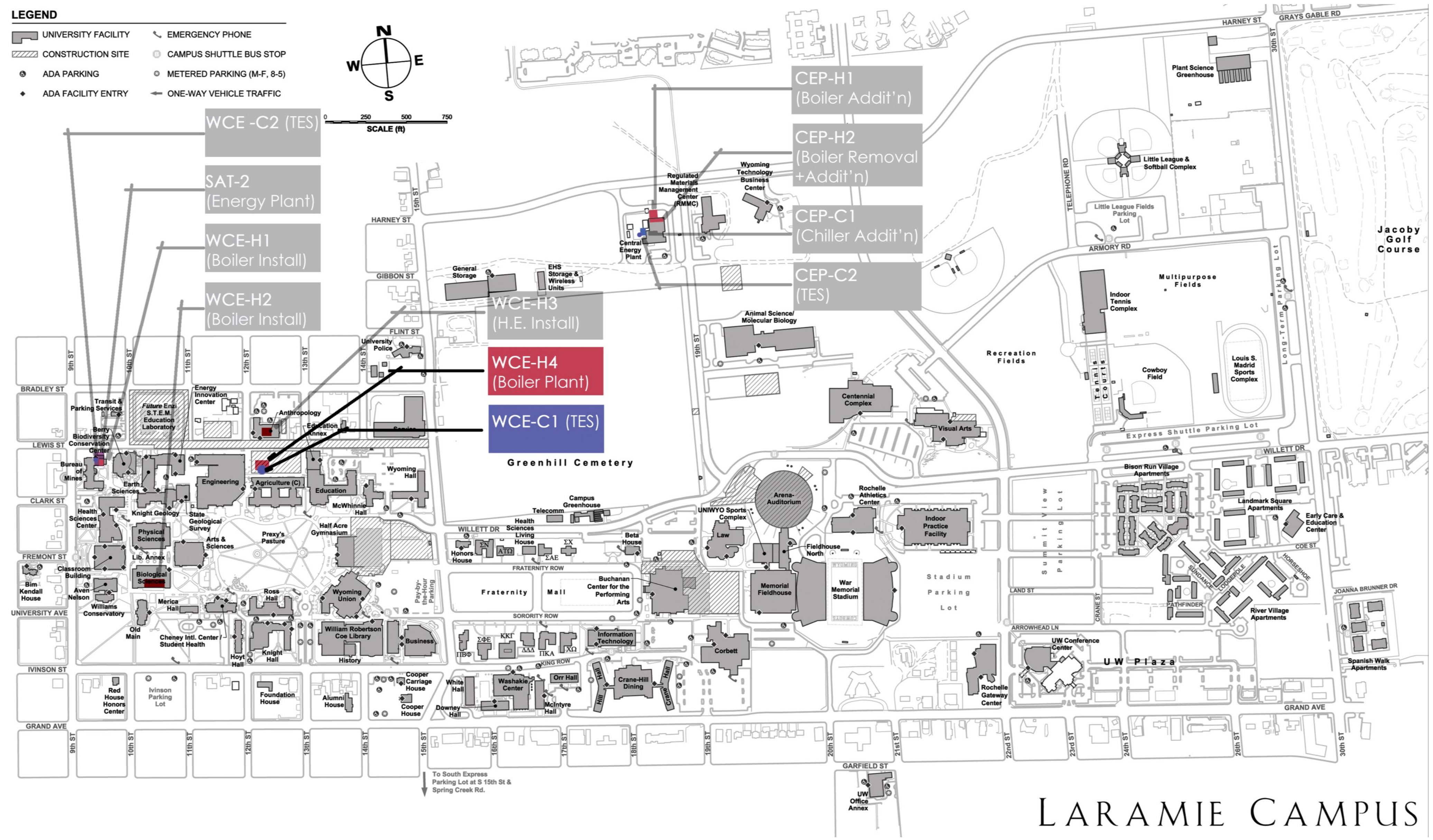
Satellite Plant

- **Heating/Cooling Option 1** (SAT-1) New satellite plant with modular hydronic boilers plus chillers.
- **Heating/Cooling Option 2** (SAT-2) New satellite plant with modular hydronic boilers plus chillers.

West Campus Energy

- **Cooling Option 1** (WCE-C1) Add thermal energy storage (TES) tank.
- **Cooling Option 2** (WCE-C2) Add thermal energy storage (TES) tank.
- **Heating Option 1** (WCE-H1) Add modular hydronic boilers to existing space at Bureau of Mines storage area.
- **Heating Option 2** (WCE-H2) Add modular hydronic boilers to existing space at basement of Biological Sciences.
- **Heating Option 3** (WCE-H3) Add modular Steam to Water Heat Exchangers to existing space in Anthropology. Location to be determined.

Campus Map



Moving Forward

As the body of this report will reveal, the heating and cooling generation capacities of the CEP are nearing their current reliable and installed maximums respectively. The steam production and distribution efficiencies are wasting University funds in the form of energy lost to through the boiler stacks and into the ground. The securement of a reliable quality coal source is a continued effort by University Utilities Management. It is for these reasons that GLHN recommends the transition of the majority of West Campus building heat source from a steam based system to a much higher efficient hot water system as well as the installation of a chilled water thermal energy storage system. Short term new building interconnection to the University's district heating and cooling system including the New Engineering Building, the New Science Initiative, and High Bay Research Facility have occurred or are expected to occur within the next four years. These additional loads will drive the need to expand the current systems. The necessary steps to achieve a system startup in the year 2020 in descending order of importance include:

- Securing funding for design and construction of the project
- Design and Engineering of a West Campus design
- Improve boiler coal introduction system at the CEP
- Securing a long term natural gas supply source
- Continuing recommissioning of existing buildings to increase temperature control, system temperature differential, and decrease energy waste
- Construction and commissioning of new system

End of Section 1

Section 2: Central Energy Plant Analysis

01 Overview

Overview

The University of Wyoming's existing Central Energy Plant is located on the north-east corner of campus. It produces and distributes steam and chilled water to the entire campus for heating and cooling needs. Steam is produced at 125psig saturated pressure and reduced at various points within the distribution system. The majority of buildings on campus have local hot water systems. Shell and tube heat exchangers provide the steam to hot water exchange for heating and domestic water requirements. Some of the older buildings on campus utilize direct steam throughout the building. Chilled water is produced and distributed via a direct primary, variable flow chilled water system with the pumps located at the CEP.

Steam System

The steam system consists of one 30,000 PPH gas boiler and three 60,000 PPH coal-fired stoker boilers. Boiler No. 1 (30,000 PPH) is a D -style, watertube boiler manufactured by E. Keeler Co. that fires natural gas with a single burner manufactured by Faber and utilizes single-point positioning. Boiler Nos. 2 through 4 (60,000 PPH each) are balanced draft, watertube, spreader stoker boilers capable of firing natural gas with two side-mounted burners at a rate of 60,000 PPH on oil or gas. Boiler Nos. 2 through 4 were manufactured by International Boiler Works Co., and the burners were manufactured by Coen Co. All three are equipped with air pre-heaters. None of the existing boilers have economizers used for pre-heating boiler feedwater, and all four boilers were installed in 1980. Information relating to the heating system equipment follows.

Boiler Tag Data

Boiler No. 1:

- Burner: Faber Air Register burner unit. Size VP-20, Contract No. 16720, E.Keeler Co, Williamsport, PA.
- Boiler: E.Keeler Co. Manufacturers Serial Number 16719, Std. number NB5418, built in 1980. Model SWP-200. Boiler Heating Surface: 2220; W.W.H.S.: 375; 30,000 pounds of steam per hour.

Boiler No. 2:

- Burner: Coen Gas burner, Coen File D7829-1. Gas only, fuel oil was removed. Detroit Stoker, Job No. RG967, Stoker No. 2195.
- Boiler: International Boiler Works, East Stroudsburg, PA. National Board No. 11728. 250 psi maximum working pressure, 460 square feet radiant heating surface, 6540 square feet boiler heating surface. Serial No. 14803, built in 1980. 406°F design temperature, 60,000 pounds per hour rated capacity.

Boiler No. 3:

- Burner: Coen file D7829-3. Detroit Stoker, Monroe, MI; Job number RG967, Stoker no. 2196.
- Boiler: International Boiler Works, East Stroudsburg, PA. National Board No. 11729. 250 psi maximum working pressure, 460 square feet radiant heating surface, 6540 square feet boiler heating surface. Serial No. 14004, built in 1980. 406°F design temperature, 60,000 pounds per hour rated capacity.

Boiler No. 4:

- Burner: Coen file D7829-2. Detroit Stoker, Monroe, MI; Job number RG967, Stoker no. 2197.
- Boiler: International Boiler Works, East Stroudsburg, PA. National Board No. 11730. 250 psi maximum working pressure, 460 square feet radiant heating surface, 6540 square feet boiler heating surface. Serial No. 14805, built in 1980. 406°F design temperature, 60,000 pounds per hour rated capacity.

Feedwater pumps, 2 electric and 2 steam.

- Electric Pumps 1 and 2: Pentair, Aurora, No. 13-2356648-1 and No. 13-2356648-2. Size 2x4x9, type 431B BF. 144 gpm, 346 feet of head, 3500 rpm, 25 hp, 208-230/460V.
- Steam Turbine Drive Pumps 1 and 2: Pentair, Aurora, No. 13-2356651 and No. 12-2241753, size 2x4x9, type 431B BF. 144 gpm, 346 feet of head, 3500 rpm.
- Steam Turbine: Coppus, Serial No. 07-4237, Model no. RL-20L, Tre-Job No. 07-4237. 30 hp, 3550 rated rpm, 125/15 psi inlet/discharge pressure, 352.9°F inlet temperature. Single stage. Trip RPM: 4509.

Air Compressor for all steam control valves in steam tunnels, and two more compressors in the basement of Eng that only serve the tunnels. These two compressors control boiler pneumatic positions and all in-plant boilers and chillers. One is 100% standby. Total hours: 14254 No. 1, 14290 No. 2.

Air Compressor for steam control valves: Model SSR-EP75. 332 CFM capacity, 125 psig rated operating pressure, 75 hp nominal drive horsepower. Serial No. CK176OU99333.

Air compressors in power plant main floor: Ingersoll Rand, Model SSR-EP100, 446 CFM capacity, 125 psig rated operating pressure, 100 HP nominal drive horsepower. Serial Numbers CK2335U99212 and CK233U99212.

Two air compressors in basement: Ingersoll Rand, Model SSR-EPE50, 208 CFM capacity, 128 psig rated operating pressure, 50 HP nominal drive horsepower. Serial Numbers F4923U92 and F4999U92.

Gas burner in IBW boilers did not fire well until they installed new controls. Contact John Zink Hanworthy, Fyr-Logix BMS.

Gas service: Comes from Source Gas. 6" out of ground, 25-30 psig operating pressure. Burners require 9 psig.

DA No.1 and No.2: Chicago Heater Co. SN 3884 and SN 3885. Allied Steel Products, Cordova, Alabama. National Board No. 9246 and 9247. Serial No. C80-119 and C80-120. 50 psi maximum working pressure, 650°F maximum water temperature. Installed in 1980.

ID Fan: 150 HP, 1192 RPM, VFD present.
South ID fan: VFD does work. Harmonic Guard Power conditioning is suspect.

Center ID fan: Clarage Fan, manufactured by Air Systems, Kalamazoo, MI. Serial No. 2696CM-5. Size 132, type XLR, series 1250. 1200 Max safe RPM at 430°F.

North ID fan: Clarage Fan, manufactured by Air Systems, Kalamazoo, MI. Serial No. 2696CM-4. Size 132, type XLR, series 1250. 1200 Max safe RPM at 430°F.

No. 2 FD fan: Clarage Fan, Serial No. 2696CM-1, Series 5350A. Size 66, type AFM. 1800 Max safe RPM at 200°F.

Section 1
Section 2
Section 3
Section 4
Section 5

No. 3 FD fan: Clarage Fan, Serial No. 2696CM-2, Series 5350A. Size 66, type AFM. 1800 Max safe RPM at 200°F.

No. 4 FD fan: Clarage Fan, Serial No. 2696CM-3, series 5350A. Size 66, type AFM. 1800 Max safe RPM at 200°F.

No. 2 Overfire Air Fan: Buffalo, Shop order number N2345. 26" wheel diameter, Size 7x26, Type E, 50 HP.

No. 3 Overfire Air Fan: Buffalo, Shop order number N2345. 26" wheel diameter, Size 7x26, Type E, 50 HP.

No. 4 Overfire Air Fan: Buffalo, Shop order number N2345. 26" wheel diameter, Size 7x26, Type E, 50 HP.
Have O2 analyze on each of 3 coal machines. Rosemount, model no. IFT 3000.

Feedwater storage tanks: Built by American Steel and Iron Works, Denver, CO. Working pressure 50 psig, built in 1980. Two tanks present.

Macawber: From truck dump, goes to Denseveyor Pot in basement. This can blow to the silos or dry storage. Silos are along outside wall, 3 present. Dry storage is boiler specific. East pot is from truck dump.

Roots vacuum for bottom ash: Easyair X2, model 250-600 RAMX, Serial No. 0903985001, Part No. RH-EAPK600350. Ash vacuum: 5-7000 pounds per hour, lasts for 2 hours per 8 hour shift. 2 operators, 3 maintenance staff. Ash silo holds 70 tons of ash and is constructed of steel. Each semi load carries 15-20 tons. Rotary feeder is available. No ash conditioner is available; it had been removed as it produced a slurry. Have 7 cells of baghouse (5 original); have replaced bags in all 7 cells, at 165 bags per cell.

Gas boiler has no economizers. Feedwater: 6" stubbed out, 4" natural gas, 2" fuel oil return, 1-1/2" fuel oil supply. Gas service has capacity to produce 110,000 pounds per hour.

02 Existing CEP Equipment
Heating Equipment
Cooling Equipment

Section 1
Section 2
Section 3
Section 4
Section 5

Chilled Water System

The University's chilled water production is accomplished via two centrifugal water cooled chillers, 800 and 1,200 tons in capacity. The 800 ton chiller was installed in 2000 and the 1,200 ton in 2009. These chillers produce 42F-44F degree chilled water and (3) variable speed chilled water pumps distribute the water through the distribution system. Two plate and frame economizers provide up to 1,000 tons of cooling utilizing two 1,200 ton cooling towers. Condenser water flow is variable as are the fans on the cooling towers. See the existing cooling equipment schedules for additional information.

EXISTING CEP CHILLED WATER MECHANICAL EQUIPMENT SCHEDULES

Chillers

						Condenser			Evaporator			Electrical		
Mark	Manufacturer	Nominal Size	Installed	Refrigerant		EWT/LWT	Flow	WPD	EWT/LWT	Flow	WPD	kW	kW/Ton	Voltage
		(Tons)	Year		(Lbs)	(F)	(GPM)	(ft)	(F)	(GPM)	(ft)			
CH-1	McQuay	800	2000	134A	-	70/78	2,400	26.8	60/40	960	13.7	360	0.45	460
CH-2	York	1200	2009	134A	3,194	75/88	2,400	14.6	54/42	2,400	14.6	585	0.49	460

Cooling Towers

								Electrical				Refurbished	Remarks
Mark	# Cells	Size	Installed	Type	EWT/LWT	Flow	EWB	Fan	Fans total	Speed	KW/ton	Year	
		(Tons)	Year		(F)	(GPM)	(F)	(HP)	(kW)	Control			
CT-1	3	1200		Crossflow				60	45	VFD	0.0373	2009	BAC
CT-2	2	1200		Counterflow				60	45	VFD	0.0373	2009	Field Erected

Condenser Water Pumps

Mark	Installed	Type	Head	Flow	Motor	Motor	Speed	KW/ton	Remarks
	Year		(ft)	(GPM)	(hp)	(kW)	Control		
CWP-1	2008	Vertical Turbine	80	2,400	75	56	VFD	0.046625	Dedicated CT-1
CWP-2	2008	Inline	80	2,400	75	56	VFD	0.046625	Dedicated CT-2
CWP-3	2008	Inline	80	2,400	75	56	VFD	0.046625	Dedicated CT-2, Redundant

Chilled Water Distribution Pumps

Mark	Installed	Type	Head	Flow	Motor	Motor	Speed	Size	KW/ton	Remarks
	Year		(ft)	(GPM)	(hp)	(kW)	Control	(Tons)		
CHWP-1	2009	Inline	160	1,500	100	75	VFD	625	0.11936	
CHWP-2	2009	Inline	160	1,500	100	75	VFD	625	0.11936	
CHWP-3	2009	Inline	160	1,500	100	75	VFD	625	0.11936	

Plate and Frame Heat Exchangers

Mark	Installed	EWT/LWT	Flow	DP	EWT/LWT	Flow	DP	Capacity	Remarks
	Year	(F)	(GPM)	psi	(F)	(GPM)	psi	(Tons)	
HX-1	1995	40/48	1,500	6	54/42	1,000	3	500	
HX-2	2009	42/50	1,500	10	56/44	1,000	5	500	

Centrifugal Separator Pumps

Mark	Installed	Type	Head	Flow	Motor	Motor	Speed	KW/ton	Remarks
	Year		(ft)	(GPM)	(hp)	(kW)	Control		
CS-1					5	4	On/Off	0.003	
CS-2					5	4	On/Off	0.003	

03 Power Plant Upgrades

Scope:

The condition assessment has identified several significant capital expenditures that must be considered over the next 20 years. We have developed a description of the improvements, estimate of probable construction cost, and estimated timeline for the work.

Summary:

Our inspections of the boilers and associated equipment along with discussions of equipment condition with boiler plant leadership led to the recommendations of the following improvements.

Summary of Capital Improvements:

1. **Repair or Replace Induced Draft Fans on Coal Boilers**:

   Fan is $158,695; Installation is $100,000. The induced draft fans on the coal boilers are subject to the abrasive fly ash and operate at temperatures of 425⁰F which can cause bearing failure and erosion of the fan housing. The existing ID fans are Clarage Series 1250 Model 132XLR rated at 44,387 CFM at 375⁰F. A quotation on a complete new fan assembly including the 150 horsepower motor is $158,695 (See Supporting Documentation SD-II-1 and SD-II-2). Installed in 1980, the ID fans are now 36 years old, and should not require complete replacement. At this age, the parts that may require replacement are the fan wheel, shaft and cartridge bearings. On a similar ID fan we have also encountered erosion of the outside radius of the fan housing. In this case, we developed a plan to repair the housing by re-lining it with a layer of Hastelloy -C alloy steel welded to the outside of the fan housing. For capital planning purposes, we have projected an overhaul of the three ID fans before year 2020, and complete replacement in year 2030. The mechanical overhaul estimate consists of new fan shaft, wheel, cartridge bearings, and limited fan housing repair with Hastelloy-C at a budgetary cost of $100,000 per fan. Complete replacement of the ID fan and motor assembly in year 2030 is estimated at $250,000 per ID fan.

2. **Replace Elbow Sweeps on Macawber Coal Conveying System**:

   Coal from the outdoor truck dump pit gravity flows to a Macawber Denseveyor pneumatic transfer system that can blow the coal to either the coal silos or the day storage. Coal from the silos can be transferred to any of the day storage bunkers, but once in a day bunker it is destined for a particular boiler. Discussions with powerplant engineers have indicated that two areas are expected to require upgrades in the next five years. The ten dump valve boxes located and the individual silos and day storage bunkers will require replacement. Cost for each of ten dump valve boxes is estimated at approximately $1,000,000. Replacement of the pneumatic 8" coal conveying line pipe and radiused elbows is considered on-going maintenance, with elbows requiring replacement approximately every 2 years. The cost of elbow replacement is approximately $10,000 each.

3. **Boiler Condition Assessment:**

   Boiler tubes would be expected to last at least 50 years as long as water chemistry and blowdown are managed and the tubes are not subjected to flame impingement. Wyoming's three IBW and one Keeler boilers were all installed together in 1980, and are now 36 years old. Some selective tube repair and replacement has occurred over the past years, but there is no reason to believe that a complete tube replacement on any of the boilers is imminent.

   We recommend performing tube evaluation, both non-destructive and destructive testing, to obtain an assessment of tube condition and determine what sections of the boiler may require retubing. A definitive assessment of tube condition will also allow us to identify specific tube sections that may require replacement as well as an estimate of when this expense would occur.

   Babcock & Wilcox Power (B&W) can provide both the nondestructive evaluation (NDE) and the destructive tube testing to determine the condition of the boiler. Their NDE evaluation consists of an ultrasonic testing of all tubes to determine wall thickness. A linear regression analysis is performed on the data to develop an analysis that predicts remaining tube life. B&W predicts that a two man crew could do the ultrasonic testing on one of the IBW boilers in approximately one day. Assuming two days of travel to/from Worcester, MA to Laramie, and one day on each of three boilers, we could expect a total travel and inspection time of ten man days. Preparation of the report is expected to take an additional eight hours per boiler. Total cost is estimated at $15,000 - $20,000 for this evaluation on all three IBW boilers.

With the boilers now 36 years old, B&W recommends that we do a tube sample analysis in which we remove a small section of a representative tube and send for metallurgical analysis. The tube section is analyzed for deposits on the inside and outside diameter. A composition analysis determines if the deposits are corrosive and if the metallurgy of the tube has been changed. Our local boiler contractor would be responsible for removing and replacing the tube. They recommend only doing this analysis on one representative tube; cost is $2720 per tube. See Supporting Documentation SD-II-3 and SD-II-4.

4. Boiler Retube and Refractory Repair:

Should retubing be required, we anticipate a cost of approximately $400,000 to retube each of the IBW boilers. This estimate is based upon actual project costs for a full retube and rebuild of both the front and rear wall refractory on a 70,000 lb/hour Springfield dual fuel (natural gas and No. 2 fuel oil) fired boiler in Chicago, Illinois that had been in near continuous operation since 1964. Wyoming's IBW boiler does have a more complex tube geometry, as many tubes originate in the burner side of the boiler, and offset over ten feet with six bends to their entry into the steam drum. See IBW's General Assembly drawing No. 20-79E-671-0 showing tube arrangement in this boiler.

03 Power Plant Upgrades

	Age (Years)	Recommended Time	Option	Materials Cost Per Boiler	Labor Cost Per Boiler	Total Cost All Boilers
Induced Draft Fans on Coal Boilers	36	2020	Repair	$50,000	$50,000	$300,000
		2030	Replacement	$160,000	$100,000	$780,000
Elbow Sweeps on Macawber System		Replacement Every 2 years	Replacement	$5,000	$15,000	$200,000
Dump Valve Replacement (10)		2021	Replacement	$20,000	$2,880	$251,680
Boiler Tube Evaluation	36	2017	Non Destructive Testing	-	$20,000	$20,000
		2017	Destructive Tube Testing	$10,000	$10,000	$20,000
Boiler Retubeand Refractory Repair		Dependent on Tube Testing	Total boiler Retube	$400,000		$400,000
Coal Stoker Replacement			Replace Stokers	$959,000		$959,000
Feedwater Economizer Installation				$55,000	$100,000	$465,000
Low Nox Burners on Coal Boilers		Required only if Regulations are generated		$500,000		$500,000
Dual Burner Low Nox Replacement (Removes coal capability)		Not Recommended		$1,620,000		$1,620,000

04 Energy Saving Opportunities

Scope:
Identify and provide preliminary evaluation of energy saving opportunities within the power plant.

Summary:
Installation of feedwater economizers on both the Keeler natural gas fired boiler and the IBW coal/natural gas fired boilers are recommended process improvements to reduce energy costs. The energy savings will support the estimated cost savings with an acceptable payback. We recommend additional analysis that is based upon the expected future steam load profile and operating hours, assuming that an off-site boiler plant is constructed on campus.

Background:
Approximately 89% -95% of the steam generated in the heating plant is reported to be returned from the campus load as condensate. With a large campus and steam distribution network, having this high level of condensate return is indicative of a tight, well maintained and monitored system. While some improvements can likely be made to steam trap performance and condensate pump operation, greater gains in efficiency can be achieved with boiler improvements.

The three IBW dual fuel coal and natural gas boilers were designed with limited process devices to improve boiler efficiency. An air/air preheater is fitted to the back of the boiler to extract exhaust gas heat from the last pass and transfer it to preheat outdoor combustion air. The boilers are currently operated to control fluegas gas temperature to 425°F. At this exhaust gas temperature to the baghouse, we are 72°F above the steam temperature of 353°F (125 psig saturated steam). An opportunity may exist to install feedwater economizer on the gas-fired Keeler boiler and three IBW coal-gas fired boilers.

Add Boiler Feedwater Economizers:
Use of a feedwater economizer will create an increase in boiler efficiency of approximately 1% for every 40°F reduction in flue gas exhaust temperature. The lower limit of flue gas temperature depends upon the fuel being fired and the possibility for flue gas condensation and corrosion in the baghouse or boiler stack. We would expect approximate lower limits of 300°F -350°F on coal-fired flue gas and 250°F -300°F for natural gas combustion to prevent condensation. Assuming that condensation would not occur at a 350°F fluegas temperature, the economizer heat exchanger would lower the fluegas temperature by 75°F, thereby yielding a 2% gain in boiler efficiency. See Supporting Documentation SD-II-5 for general information pertaining to Economizers.

To determine if the addition of the economizers would have an acceptable financial payback, a preliminary analysis was done to determine the potential energy and cost savings. To measure the maximum potential savings, the boilers were evaluated operating on natural gas, which historically has given greater fuel costs. Natural gas may also provide greater payback, as we can reduce the boiler's exhaust gas temperature below the 425°F temperature that is currently the operating minimum when firing coal. The attached analysis produced by Cain Economizers, show the greatest potential savings under "Load 1". In this scenario, we are operating a gas boiler at full load (60,000 lb/hour) for one-third of the total hours each year. Adding an economizer results in annual natural gas savings of approximately $66,000 per year from each boiler operating at this load profile. This savings, however, is based upon a gas cost of $0.50/therm and Wyoming's price at the burner tip is likely less, which would reduce the potential savings. Further operating analysis is also required to validate the gas boiler's exhaust leaving temperature and the allowable temperature drop through the economizer. Supporting Documentation SD-II-6 presents the material quote and economic analysis of the economizer on a 60,000 lb/hour gas boiler.

The economizer has been priced at $55,000 from Cain Economizers; this price is for the material only and does not include any installation or controls. Installation costs will be significant, as the economizer will be installed in the boiler breeching and will require significant rigging and rework of the breeching. If the economizer were to be designed for coal-firing, steam sootblowers are commonly installed to keep ash deposits from reducing the economizer's heat transfer capability. Assuming an installation and controls cost of an additional $100,000 the total cost for installation on a gas-fired boiler would be approximately $150,000 per boiler, not including the sootblowers.

Based upon this preliminary cost and energy savings potential, installation of feedwater economizers does appear to have merit and a reasonable payback of less than five years. We recommend further analysis of installing economizers on the Keeler gas-fired and IBW coal/gas fired boilers.

05 Coal Stoker Upgrades

Improvements to Coal Stokers:

The three IBW coal-fired boilers have Detroit Stoker Rotograte overthrow style spreader stokers which feature a top discharge rotor to distribute the coal evenly over the chain type travelling grate which were designed for Wyoming's Powder River Basin coal. Although the coal specifications call for a coal size distribution of one-third at ¾" or less, one-third at ¾" – 1-1/4", and one third at 1-1/4" -2", the plant regularly receives coal with significantly greater quantity of fines. Oftentimes the coal is sized at 60% at less than ¾", which creates significant combustion problems.

With the existing Rotograte stoker, coal with a high concentration of fines will be unevenly distributed from the front of the boiler to the back, resulting in high concentration of fines at the front of the boiler and ash bridging. Temperature of the travelling chain grate can also become elevated due to inadequate insulating ash cover at the rear of the chain grate.

Having an EPA permit limit of 36,000 tons of coal per year, the plant is not a large enough coal consumer to have significant market influence with the larger mines. As a small plant, the likelihood is that irregular coal size will continue to be an operational issue for the future. Several of the plant's previous coal suppliers have closed mines, succumbed to bankruptcy, or are not interested in supplying the relatively small amounts of properly graded stoker coal. While the recommendations on alternate mines should be explored, addressing the excessive coal fines through machinery modifications is a viable alternative.

The three coal boilers currently have Detroit Stoker overshot coal stokers that distribute the coal from the top of the rotary feeder. This overshot design worked very well on stokers when a consistent supply of properly sized coal was available. With significantly greater variability in coal size, the overshot coal feeders did not distribute the coal fines to the back of the boiler. Seeing this operational complaint from many coal-fired plants about twenty years ago, Detroit Stoker developed the Underthrow Coal Distributor that contacts the coal at the bottom of the rotor and flings it into the boiler. The new underthrow distributor also has an air assist that helps blow the fines to the rear of the boiler. Specifically designed for the size gradation and coal characteristics of Wyoming's Powder River Basin coal, the underthrow stoker provides a viable solution to efficient combustion of local Wyoming coal for many years. See Supporting Document SD-II-9 for additional information.

Since their introduction, Detroit Stoker has installed the Underthrow Coal Distributor in over one hundred powerplants and report excellent results. A peer institution, the University of Iowa, has installed the Detroit Underthrow distributors on their coal boilers and do not have the problems with ash bridging at the front of the boilers, or too many fines combusting in the upper sections of the boiler. Several other universities with similar size boilers have the underthrow distributors and would be available for tour. The list includes, the University of Kentucky, Duke University, Clemson, University of Cincinnati, and many others. A customer testimonial is included from Manitowoc Public Utilities on their installation of the underthrow feeders to improve combustion on variable sized coal (Supporting Document SD-II-7). Locally, the Solvay soda ash plant located in Green River, WY and Brigham Young University in Provo have installed the Detroit Stoker Underthrow Coal Distributors. Several other plants having underthrow feeders along with contact information for the boiler plant engineers are listed on the next page.

Scope of Improvements:
Installation of the underthrow feeders is relatively easy, as they are made to bolt into the place of the existing feeders. The coal delivery chute may have to be modified, but no other significant changes are required to the stoker. Each boiler will be fitted with three underthrow distributors, six separate drives for the conveyor and rotor drums, and one distribution air fan. Electrical installation consists of wiring and control of these motors.
Detroit Stoker has been to the plant and inspected their stokers, as they performed a complete rebuild of the three stokers in 2015. The stokers are thus in excellent condition and additional overhaul work is not anticipated prior to installation of the new feeders. Detroit has provided a quotation of $509,000 for the equipment, and estimates an additional $300,000 for mechanical installation and $150,000 for electrical installation (Supporting Document SD-II-8). Total installed cost is thus $959,000 for all three boilers. Planning the installation of the new feeders will depend upon the amount of heating load that may be shifted to a new off-site hot water boiler plant. As the peak steam load decreases from the current peak of 110,000 lb/hour, conversion of all three boilers may not be necessary.

05 Coal Stoker Upgrades

References for Installation of Detroit Stoker Underthrow Distributors:

Solvay Chemical: Green River, Wyoming
Joe Gutieriez, ph. (307) 872-6617
Installed underthrow distributors in 2005 on two process calciners.

Brigham Young University: Provo, Utah
Dave Stringfellow, ph. (801) 422-3540
Email: davestring@gmail.com

Completed a project in 2002 to convert overthrow spreaders to underthrow distributors on a steam boiler for campus heating. This boiler may be coming off-line as BYU evaluates their steam production.

American Crystal Sugar: Moorhead, Minnesota
Brian Smith, ph. (218) 291-5528
Installed underthrow stokers on process boilers in 2012.

Michelin Tire: Louisville, KY
Rick Vinson, ph. (502) 449-8400
Installed underthrow stokers on process boilers in 2011.

New Low NOx Burners in IBW Boilers:
The three existing IBW boilers were built in 1980 to have the capacity to fire three fuels: coal, natural gas, and No. 2 fuel oil. Firing of No. 2 fuel oil has been eliminated and the boilers now can combust only coal and natural gas. The current NOx emissions permit limits on the boilers are 0.7 lb/MMBtu of heat input and a maximum of 210.2 tons per year. These emission rates were developed based upon firing coal, and if the coal option were to be eliminated the EPA would likely significantly reduce this NOx emission allowance. USEPA Region 8 air quality engineers advised that the Wyoming boilers may be evaluated in the next round of Regional Haze Planning, but that does not begin until 2021. USEPA Region 8 could not predict whether the State would require any SO2 or NOx controls on these small institutional boilers. This is important because the future NOx emissions requirements will drive the options on how the three existing coal boilers could be upgraded for continued operation on natural gas and/or coal.

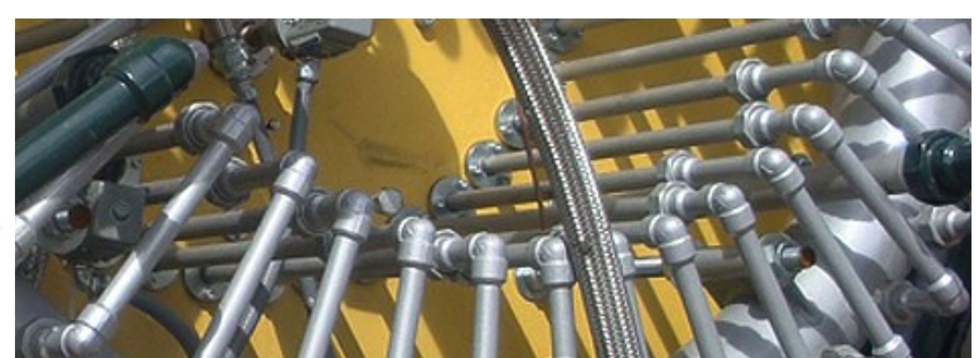
Two boiler upgrade strategies were evaluated to extend the life of the gas burners while meeting future NOx emission requirements.

Option No. 1 attempts to minimize the cost of the burner upgrade while installing two new burners in each boiler. This would essentially be a burner replacement, but would still drastically reduce NOx emissions from the boilers. In this option, two new replacement burners would be installed in the existing two burner throat openings on the side of the boiler. The boiler would keep its ability to fire coal. Having just the new burners, we could expect the NOx emissions to decrease from the current permit's allowance of 0.7 lb/MMbtu to approximately 0.14 lb/MMbtu (150 ppm). The CO emissions would be approximately 400 ppm. Since we do not have future NOx emissions requirements for these boilers from EPA and likely won't until 2021, it is difficult to predict whether this will be an acceptable improvement. It does, however, establish the lowest project cost at approximately $500,000 total conversion cost for all three boilers.

Option 2 involves significant modifications to the boiler furnace and installation of two new Low NOx burners. For a low NOx burner to work effectively the flame length must be significantly longer than the IBW boiler's 10 foot width; installing the two new burners in the current location in the boiler sidewall is thus not an option. The length of the boiler furnace is only 11'-7", and that is not acceptable either. To achieve proper burner performance, the burner must be installed beneath the boiler, and fire up through a new burner throat opening installed in a sealed boiler floor. The chain grate stoker would be removed and the boiler would never fire coal again. Coen Combustion has modelled this installation, and predicts the following emissions when fired from 25% to 100% capacity:

NOx: 30 ppm
CO: 100 ppm
Particulate Matter: 0.007 lb/MMbtu

These emission rates would certainly be acceptable to EPA, but the installation is complex and very expensive. To achieve the 30 ppm NOx and 100 ppm CO, the furnace would have to be sealed to eliminate tramp air. The existing chain grate stoker would be removed and replaced with a steel plate floor covered in refractory. Achieving the flame length to minimize NOx emissions requires installing the burner in the basement to take advantage of the boiler's 18'-8" high furnace. While this does achieve emissions that would be acceptable for the foreseeable future, the project cost and loss of capability to fire coal are not favorable.
Coen's quote carries the six burners (two for each boiler) and associated equipment for three fully operational boiler at $550,000. Installation of all mechanical and electrical work adds $925,000. The total project cost, with 10% contingency is estimated at $1.62 million. See Supporting Document SD-II-10 for additional information.



07 Emissions Regulations

Future Federal EPA Air Emission Regulations:

Summary:
The Clean Power Plan (CPP) was enacted to reduce emissions of CO_2 and greenhouse gasses such as SO_2 and NOx in order to mitigate global climate change. To achieve the 32% target reduction in CO_2 emissions, the CPP focuses on large fossil-fuel fired emitters of greenhouse gasses throughout the nation. In Wyoming, an estimated 141 of Wyoming's larger generating stations will be subject to reductions in greenhouse gas emissions. As a small coal-fired heating plant that does not generate electrical power, the University of Wyoming's Heating Plant is not subject to the 2022 -2030 regulations for reductions of CO_2, SO_2, and NOx emissions required by the Clean Power Plan.

US EPA Clean Power Plan
Carbon dioxide has been identified as contributing 82% of the nation's greenhouse gas emissions and the leading contributor to global climate change. In August 2015 the President and US EPA enacted the Clean Power Plan intended to reduce greenhouse gas emissions from fossil fuel combusting power plants. Once fully implemented in 2030, Clean Power Plan will have reduced CO_2 emissions by approximately 32%, SO_2 by 90%, and NOx by 72% as compared to 2005 levels. In February 2016, the Supreme Court stayed implementation of the Clean Power Plan pending review; EPA, however, fully expects the regulations to be upheld with emissions limitations beginning in 2022.

Once fully enacted, the Clean Power Plan creates a partnership between the federal EPA and each state, which allows individual states to determine on how to meet their emission requirements. US EPA has established an enforceable limit for each state's emission of CO_2 based upon their 2012 emissions. Wyoming's 2012 baseline emissions are 2,331 lbs of CO_2 per Megawatt Hour of electric generation. EPA has established Wyoming's Year 2030 CO_2 emission rate as 1,299 lbs of CO_2 per Megawatt Hour of electric generation, a 44.3% reduction.

Effects Upon the University of Wyoming:
In its current state, the Clean Power Plan applies only to fossil fuel-fired steam boiler plants having electric generation, with one-third of that power generation supplied to the nation's power grid. The Clean Power Plan also applies to natural gas-fired combined cycle electric generation units. Since our UW Powerplant only generates steam at 125 psig for heating of campus buildings and no electric generation, the Clean Power Plan does not apply.
Wyoming does have 141 generating units that are operated by electric utilities or industrial combined heat and power plants that are subject to CPP; a full list of these generating units is given in Supporting Document SD-II-11. The three coal-fired boilers at the University of Wyoming-Laramie are not included on this list.

Our review with USEPA's Region 8 air quality engineers revealed that the University's boilers ***may*** be evaluated by the State of Wyoming in the next round of Regional Haze Planning, which would not begin until 2021. USEPA Region 8 could not predict whether the State would require any SO2 or NOx controls. They also advised that they are not aware of any other upcoming regulations that would impact small institutional boilers such as the four in the Wyoming heating plant.

Effect Upon the State of Wyoming:
Having an abundance of low sulfur coal and being a major exporter of coal to eastern powerplants, the CPP will have a significant effect upon Wyoming's mining industry. To meet the carbon reductions planned for Wyoming's top ten coal consuming state's, the total reduction in Wyoming coal for these ten states is approximately 100 million tons per year. Valued at $13 per ton, Wyoming's coal revenue will be reduced by $1.3 billion per year.

USEPA anticipates that achieving the carbon emissions requirements will result in the retirement of 27-38 gigawatts of electric coal-fired power generation nationally from plants that are not economically feasible for emissions controls upgrades. Natural gas combined cycle power plants are planned to serve as a bridge to match power demands from retired coal-fired generating plants.

Wyoming Department of Environmental Quality
Following is a review of the current Wyoming Department of Environmental Quality permit and recommendations.

Wyoming's Department of Environmental quality has issued the Operating Permit No. 3-3-156 for the University of Wyoming's Central Energy Plant. This operating permit expires on August 27, 2017, and must be renewed by submitting an operating permit renewal application at least nine months, but not earlier than eighteen months before August 27, 2017. The operating permit renewal must thus be submitted between February 27, 2016 and November 27, 2016.

Existing Requirements of Wyoming DEQ Permits:
Six existing source emission points are identified in the permit:

A. The Keeler 30,000 lb/hr oil and gas-fired boiler
B. The three IBW VSG-60 coal/oil/gas boilers at 73.17 MMBtu/hour. The permit should be modified with the correction that these three boilers were modified, and no longer have the capability of combust oil.
C. Ash handling system.
D. Cummins KTA-3067 – CS emergency generator.

Potential Permit Issues:
The permit should be modified with the correction that these three IBW VSG-60 boilers were modified, and no longer have the capability of combust oil.
Review permit requirements to ensure that the two new Cummins emergency generators have been added to the permit, if required.

Conditions of Existing Permit:

1. **Only three** of the four existing boilers may operate simultaneously. During the operation of any combination of the Keeler or the three IBW boilers, the emission rates shall not exceed the maximum allowable rates shown in **Table I.**

Pollutant	**Emission Limit**	**Testing Requirement**	**Recording Require-ment**	**Reporting Requirement**
Particulate	20% Opacity 0.05 lb/MMBtu 11.0 lb/hour 18.9 tons/year	Once every five years	1. CAM: Monitor visible emissions daily 2. Record baghouse maintenance	1. Report test results every 45 days 2. Report excessive emissions and permit deviations
	1. Coal consumption limited to 36,000 tons/year 2. Sulfur content of coal cannot exceed 0.7% 3. Fuel oil usage limited to 50,000 gallons/year Fuel oil sulfur content cannot exceed 0.45%	Once every five years	1. Monitor and record coal and fuel oil use and sulfur content	1. Report test results every 45 days 2. Report coal and fuel oil usage, sulfur content, and SO2 every 6 months 3. Report excess emissions and permit durations.
NOx	1. 0.7 lb/MMBtu 2. 153.7 lb/hour 3. 210.2 tons/year	Once every five years	Record test results	1. Report test results every 45 days 2. Report excess emissions and permit duration.
CO	1. 65.8 lb/hour 2. 90.0 tons/year	Once every five years	Record test results	1. Report test results every 45 days 2. Report excess emissions and permit duration.

Table 1: Summary of Source Emission Limits and Requirements

07 Emissions Regulations

2. **Visible Emissions:**
   Visible emissions from each boiler stack shall not exceed 20% opacity, except that 40% shall be allowed for not more than 2 minutes in any hour.

3. **Coal and Fuel Oil Requirements:**
   a. Coal consumption for the IBW boilers shall not exceed 36,000 tons/year. The coal sulfur content shall not exceed 0.7%.
   b. Combined fuel oil consumption for all four boilers and the emergency generator shall not exceed 50,000 gallons per year. This section of the permit (F3) should be edited to remove the three IBW boilers, as they no longer have the capability of combusting fuel oil.

4. **Boiler Emissions Testing:**
   The three coal-fired IBW boilers must have emissions testing performed every five years for the following pollutants: Particulate Matter, SO_2, NOx, and CO. Testing methods are specified by the DEQ, and additional testing may be required.

5. **Emissions Monitoring:**
   a. The permit requires monthly monitoring of coal and fuel oil consumption. Sulfur content of the coal must be analyzed two times each week, and all fuel oil must be delivered with a sulfur content analysis.
   b. The permit's Compliance Assurance Monitoring Plan (CAM) requires that visible emissions from the baghouse exhaust will be monitored daily by EPA Method 22, Visual Opacity Measurement.
   c. The three coal-fired IBW boilers must have emissions testing performed every five years for the following pollutants: Particulate Matter, SO_2, NOx, and CO. Testing methods are specified by the DEQ, and additional testing may be required.
   d. All coal and fuel oil consumption shall be monitored for sulfur content to ensure compliance with the sulfur limit.

6. **Recordkeeping Requirements:**
   a. Records must be maintained for ten years on the calculations used to prove compliance with SO_2 emissions.
   b. Records for all activities of the Compliance Assurance Monitoring Plan must be maintained.

7. **Reporting Requirements:**
   a. Annual SO_2 emissions must be reported annually.
   b. The results of the Particulate Matter, SO_2, NOx, and CO testing must be reported every five years.
   c. Coal and fuel oil consumption must be reported annually. Sulfur content monitoring for coal and fuel oil shall also be reported.
   d. The results of CAM for the baghouse on the coal boilers shall be reported. Quality Improvement Plans enacted shall be reported.
   e. Greenhouse Gas Reports required by USEPA shall also be submitted to Wyoming DEQ.
   f. Emissions in excess of permit limits and deviations from permit

Future Workforce Recruitment and Development:

Scope:
Operation of a complex steam heating plant with coal-fired boilers, the associated emissions controls equipment, along with gas-fired boilers requires a well-trained and experienced workforce to ensure the safe, efficient and reliable operation of the Wyoming heating plant. Facilities leadership wants to ensure that the University has a continual source of capable employees to lead the operation of the powerplant. We have evaluated employment, training and development techniques from a peer university for ensuring this workforce is available.

Summary:
Efficient, safe operation of a complex coal and gas-fired boiler plant requires highly skilled and conscientious workforce; the University wants to be proactive in developing a source for these skilled employees and to develop a training program specific to this plant. With federal EPA's emission regulations affecting operation in smaller coal-fired generating plants nationwide, many coal-fired plants are closing now, and the reductions will continue. This group of displaced workers are well-trained, highly experienced and are available for recruitment to the Wyoming power plant.
A peer university's employee training and evaluation program was evaluated and is recommended for implementation for the Wyoming power plant.

Background:
We interviewed the chief utility plant operating engineer at a large academic research university who is responsible for the operation of a power plant that supplies steam for heating of campus buildings and also generates electrical power. Although having more equipment and capacity than the Wyoming plant, the employment and training processes presented may be beneficial to the University. Recommendations on staffing levels necessary to operate and maintain the Wyoming plant have been requested, and we believe that the staffing is scalable between plants.
The comparable plant (University A) has three coal-fired boilers, three gas-fired boilers, two gas-fired electric generating turbines, two heat recovery steam generators coupled to the gas-fired turbines, and twelve steam turbine generators. Emissions controls consist of a pulse –jet baghouse and scrubber. Peak wintertime steam generation is 660,000 lbs./hour. Peak electrical generation is 80 megawatt.

Recruitment and Identification of Prospective Employees:
Chief engineers at both coal-fired power plants we interviewed advised that their best source for candidates for boiler operators and supervisors was to recruit from similar power plants. Although this has been difficult in the past because investor owned power plants had the capability to provide significant salary and benefit packages, the public sector plants are now seeing more applicants. Previous EPA emissions regulations for SO_2 and PM have already resulted in the closure of many smaller coal-fired generating stations for public utilities and industrial power plants. From 2002 to 2014, the nation's total electrical power generated from coal dropped from over 50% coal to approximately 38% coal. When fully implemented between 2022 -2030, it is anticipated that the Clean Power Plan will likely result in the retirement of 27-38 gigawatts of coal fired generation. Regardless of the metric, it is clear that hundreds of coal-fired utility generators and industrial coal-fired steam plants have already closed and many more will close in the next 20 years.
These displaced workers are an excellent source of candidates for the UW powerplant; most will be trained through formal classroom and apprenticeship programs and will have significant experience in coal and gas fired power plants. Identifying these employees can be accomplished by obtaining a list of coal and gas-fired plants to be closed in the western states and contacting the utility for guidance. The utility will often provide career placement for their displaced workers and UW may be able to participate in recruiting these employees. The university we interviewed has hired three new employees using this approach. With Laramie being a desirable location to live, we anticipate that employees in eastern powerplants facing loss of their job may welcome the opportunity provided at UW and have the desire to relocate to the West.

08 Operator Labor and Training

Employee Training and Development:

All power plant employees at University A undergo continuous training with testing and job performance observations to improve their skillset and prepare for advancement and greater reward. The University utilizes an outside vendor, GP Strategies of Columbia MD, (http://fossilfuelcourses.gpstrategies.com/crs.aspx) who have developed a series of coursework applicable to coal-fired and natural gas boilers. See Supporting Document SD-II-12 that describes the coursework available. With courses selected to match each employee's job description and responsibilities, the employee is expected to complete the prescribed coursework within a defined time period and must score at least 80% on all examinations for successful completion.

In addition to the on-line training and examinations, each employee must pass a job-specific proctored comprehensive exam prepared by the University. Employees must score a minimum of 85% on this exam to move forward. This exam is to demonstrate competency on the basic skills on-line training and the University training specific to the operation and understanding of the equipment in the University's powerplant for which the employee is responsible.

The third step in training and evaluation of skill is a job performance walkdown. In this evaluation, the employee is trained and evaluated on situational events, and how they would diagnose the problem and solve it. For example, an employee would observe an operating boiler and be told that the opacity was exceeding the 20% EPA limit; they would be expected to explain the possible causes and solutions for each cause. The job performance walkdowns are done on every system in the power plant that can affect performance, safety, emissions, and operational efficiency.

The fourth and final step in each tier of the training process is a personal interview and evaluation by the plant's chief operating engineer. This interview is to evaluate the employees "soft skills" such as working collaboratively with others, conscientious efforts, and working to support team goals.

Once an employee has completed all four steps of the training and development plan for their particular job, they are recommended for promotion to an advanced job within the powerplant with an increase in pay. Attachment SD-II-13 shows a sample letter documenting an employee's progression and successful completion of one tier of training and recommendation for advancement.

Staffing:

The Wyoming power plant has requested a benchmark comparison of their staffing level to other peer institutions. As we discussed, the University A power plant has a total staff of 35 employees comprised of 6 supervisors, 22 boiler operators, 7 mechanics, and 6 electricians/ instrument technicians. One additional employee is fully assigned to developing or teaching the training.

When operating on coal, up to the peak coal-fired steam output of 660,000 lbs./hour, the plant requires four boiler operators. If fully operating on the gas boilers with no coal, the plant requires three operators. Prior to the implementation of the training program about five years ago, the power plant was typically staffed with six operators for coal operations. The boiler operators are expected to maintain operations on the boilers, deaerators, coal handling systems, water treatment systems, and the baghouse and scrubbers.

Powerplant Operating Documentation:

Written operating procedures are recommended for every major piece of equipment in the power plant. Suporting Document SD-II-14 is an example of an operating procedure developed for a Babcock & Wilcox coal-fired boiler, specific to this plant. Each boiler operator is trained to this Standard Operating Procedure (SOP) and expected to operate the equipment according to these directions.

Operators are expected to continually make observations and take corrective action. Each piece of significant equipment has been studied and key operating indicators and setpoints have been established. Supporting Document SD-II-15 presents a "Boiler Operator Box" that shows the key operating parameters for a particular coal boiler. Operators are trained and expected to make their own judgments and take corrective actions as they see fit to maintain the boiler operating parameters within these limits. If any operating parameter falls outside of these limits, or does not respond to corrective action, the operator is required to contact and get the advice and direction from the chief engineer. By establishing this "operator box" in which the operator has the latitude to run the plant, we have significantly decreased calls for help to the engineering staff.

Coal Supply

The CEP plant operations staff have been working through a range of problems with quality and reliability of coal supply in recent years. Although quality and availability of coal mined in the Powder River Basin (PRB) in north east Wyoming remains robust and supplying fuel to electric power utilities throughout the Midwest and Texas, the relatively low annual volume required to heat University of Wyoming, combined with long trucking distance from mine mouth the CEP make it a relatively expensive source. Coal supply to UW has historically been provided by mines of substantially smaller scale, and with shorter haul distance to Laramie. Many of these have closed in years, and quality of loads from the remaining alternatives has created problems. General demand for coal in Colorado and Wyoming has dropped in recent years along with declining price of natural gas and increasing regulatory pressures. Similarly, the number of alternative ash disposal sites is diminishing. Longer haul distances for coal and ash increase the sensitivity of coal price at UW to the cost of transportation fuel, a more volatile commodity than coal. Coal quality can create operational issues when the heat content, moisture level, and % of fines diverge from the plant equipment design specification. At the CEP this has manifested in early bag house bag replacement, incomplete combustion, high stoker maintenance and problems with the conveying systems. Installation of underthrow coal distribution is intended to mitigate some of the issues with fines. The option to truck (or rail) PRB coal does exist, and could be employed if all else fails, but is currently estimated to be on the order of a 25% premium.

End of Section 2

Section 3: Campus Load Analysis

01 Building Heating and Cooling Loads

Existing/Projected

Steam

All steam produced on campus is generated at the CEP at approximately 125 psig. Through a network of tunnel routed and direct buried piping, steam is distributed throughout campus. Condensate is pumped back to the CEP for reuse via steam powered and electric pumps located at various collection points. The 125 psig steam is transported through this piping to pressure reducing stations around campus and at the building entrances. These stations reduce the CEP generated pressure to 70 psig or 12 psig, depending on the point of use need.

Due to the distance of the CEP from the mathematical locus of building heating demand and portions of poorly insulated piping, there are significant thermal distribution losses through the systems 38,000 LF of steam and 37,000 linear feet of condensate. A thermal loss calculation suggests steam piping losses on the order of 5,500 lbs/hr. Additional losses in building mechanical rooms, pressure regulating equipment, building heating water converter stations, and motive steam to power condensate return pumps is estimated at an additional 6,500 lb/hr. Plant metering data corroborates university utility engineers estimates that residual steam necessary maintain the system with no building load is on the order of 12,000 lb/hr. Annualizing this number (and considering a 760 hr summer steam shutdown) yields an estimate of 96,000 MMBTU/year or 28% of annual steam production. Losses on the condensate return system are estimated by adding the heat necessary to bring the 90% condensate returned, from a temperature of 180F to 210F (feedwater temperature leaving the deaerator) to the heat necessary to bring the 10% cold make up water to the 210F feedwater temperature. Annualized, this amounts to a loss of roughly 4.2% of total plant thermal output. Combining these inefficiencies (fuel-boiler steam, plant (deaerator) losses, and distribution losses results in a net conversion efficiency of approximately 53%.

Chilled Water

Many of the buildings on the University of Wyoming campus are not cooled. For the buildings that are cooled, several methods are in place. These methods include evaporative cooled buildings (locally), local direct expansion mini split units (approximately 100 units around campus) and CEP provided chilled water cooled. Several critical buildings such as High Bay Research and the Information Technology Building contain local redundant chillers to utilize in the event that the CEP is unable to produce chilled water. CEP chilled water conditions roughly 30% of the net square footage of occupied space on campus, and peaks at approximately 1,800 tons. This is the area of cooling to which we analyzed in this report.

Chilled water is generated at the CEP between 42F and 44F and supplied to campus via a direct primary, variable speed pumping system. Chilled water leaves the plant through 14" diameter chilled water piping and makes its way to the West Campus partial loop. The majority of chilled water supply and return piping is direct buried with a variety of materials including ductile iron, transite, schedule 20 steel, high density polyethylene (HDPE), and C900 Polyvinyl chloride.

As outlined in this report, several concepts were preliminarily evaluated to satisfy the cooling load for the next 30 years. Overall concepts include:

- Expansion to the existing CEP
- Thermal Energy storage at West Campus
- A Satellite Plant at West Campus

All of these options and associated impacts were investigated. Costs associated with initial construction, energy and water, maintenance, and labor were compared over the course of 30 years. Various escalation rates in all of these categories were assigned along with a discount rate to determine the present value the future cash flow. The results of the comparison are included in the Cooling Options table below.

Cooling Options

Option	CEP Cooling Expansion-Chiller Addition CEP-C1	CEP Cooling Expansion-Thermal Energy Storage CEP-C2	West Campus Expansion-Thermal Energy Storage WCE-C1 (North of Agriculture) or WCE-C2 (Bureau of Mines)	West Campus Expansion-Satellite Plant SAT-1 (North of Agriculture) or SAT-2 (Bureau of Mines)
	-	-	-	*$20,260,000*
Projected Project Cost	$9,150,000	$13,130,000	$1,790,000	$15,195,000
Projected 30 Year Life Cycle Cost	$16,050,000	$25,420,000	$9,660,000	$25,050,000

An expansion to the existing CEP plant or to east campus in general, will require a new interconnect to west campus. West campus is projected to carry the majority of the chilled water load over the next 30 years. The capacity issue not only lies in the production equipment (chillers, pumps, towers, etc.), but is also in the distribution piping. The CEP and underground piping is not sufficient in size to carry these projected loads without sustaining substantial pressure losses and associated energy cost required to overcome this pressure. It was determined with the use of flow modeling software that either the existing piping would have to be upsized or another set of supply and return lines would need to be installed. All of the identified east campus options identified in this analysis, take into account the installation of a new 14" direct buried campus interconnect which was proposed to run north and west of Greenhill Cemetery to provide support to the heart of the west campus growth. It was determined by the University that the installation of interconnect lines would not be a worthwhile investment as initial costs and coordination efforts with City owned right of ways appeared to outweigh the benefits.

Thermal energy storage is another option investigated. This option would take advantage of the current off-peak electric rates which are almost half the average cost of the on-peak rate. Average rates are approximately:

-$0.076/kwh on-peak (7:00am to 11:00pm)

-$0.044/kwh off-peak (all other hours and weekends)

See the Electrical Power Rate portion of this section for additional information pertaining to the current rate structures.

Included in this analysis was the use of hydronic economizers in the form of plate and frame heat exchangers. This equipment in conjunction with the cooling towers, would handle the campus chilled water load when ambient wet bulb temperatures were below 40F. Also compared in this analysis is the sole operation of chillers without economizer or TES. Current plant operation utilizes a combination of chiller and heat exchanger to facilitate cooling demand load. The installation of TES would allow the plant to generate chilled water during off-peak evenings and nighttime conducive conditions to pull warmer water from the tank and recharge with cooler water that would be used the following day. This would generate a reduction of chiller operation during the more costly hours of the day. Average kw/ton for each scenario were assumed to be:

-0.694 kw/ton for conventional plant operation

-0.206 kw/ton for hydronic economizer operation

-0.119 kw/ton for TES discharge

A comparison of these options for existing and 5 year projected load is shown below.

OPERATIONAL STRATEGY COMPARISION-CHILLER-HX-TES					
EXISTING CHILLED WATER LOAD					
	Chiller Only	**Chiller/HX Combination**	**Chiller/HX/TES Combination**	**Monthly HX Ton-Hrs**	**Monthly Chiller Ton-Hrs**
January	$5,946	$1,765	$1,981	131,028	0
February	$5,271	$1,565	$1,759	115,206	0
March	$6,339	$1,882	$2,116	138,487	0
April	$6,706	$1,991	$2,232	148,438	0
May	$14,466	$8,745	$4,866	304,857	0
June	$31,227	$31,227	$27,662	0	648,701
July	$28,675	$28,675	$25,020	0	594,134
August	$21,548	$21,548	$17,847	0	458,599
September	$25,915	$22,495	$12,839	414,476	121,096
October	$16,360	$4,856	$5,496	346,798	0
November	$8,749	$2,597	$2,913	193,199	0
December	$8,475	$2,516	$2,832	184,170	0
ANNUAL TOTAL	***$179,678***	***$129,862***	***$107,564***	***1,976,658***	***1,822,531***

5 YEAR PROJECTED LOAD					
	Chiller Only	**Chiller/HX Combination**	**Chiller/HX/TES Combination**	**Monthly HX Ton-Hrs**	**Monthly Chiller Ton-Hrs**
January	$7,432	$2,206	$2,476	163,785	0
February	$6,589	$1,956	$2,199	144,008	0
March	$7,924	$2,352	$2,645	173,108	0
April	$8,382	$2,488	$2,790	185,548	0
May	$18,083	$10,932	$6,052	381,072	0
June	$39,034	$39,034	$35,951	0	810,876
July	$35,844	$35,844	$32,518	0	742,668
August	$26,935	$26,935	$23,583	0	573,249
September	$32,393	$28,119	$19,296	423,894	245,570
October	$20,450	$6,070	$6,758	433,498	0
November	$10,936	$3,246	$3,642	241,498	0
December	$10,594	$3,145	$3,540	230,212	0
ANNUAL TOTAL	***$224,597***	***$162,327***	***$141,450***	***2,376,623***	***2,372,364***

Section 1
Section 2
Section 3
Section 4
Section 5

02 Heating and Cooling Loads by Building

Existing and Projected Heating and Cooling Loads by Building:

Northwest Campus
North and North-East Campus
West and South-West Campus

Accompanying charts identify all buildings on campus categorized by location with areas, heating, and cooling requirements. Five year and thirty year projected loads were calculated based on UMP data.

UNIVERSITY OF WYOMING BUILDINGS ON CEP STEAM & CHILLED WATER		CEP HEATING				CEP COOLING				
UW BUILDING NAME	UW BUILDING #	Area Conditioned by Steam (sq-ft)	Peak Steam Load (lb/hr)	Diversified Steam Load (lb/hr)	Diversified Heating BTU/sqft	Area Conditioned by CHW (sq-ft)	Peak CHW Load (Tons)	Diversified CHW Load (Tons)	Diversified CHW Flow (gpm)	Diversified Cooling Sqft/Ton
NORTH-WEST CAMPUS										
Existing										
Engineering and Applied Science 1927/59/83	1	309,365	15,446	9,697	34					
Agriculture C	2	107,053	3,854	2,221	22	3,400	6.8	3.3	8	1,030
Agriculture C Addition	2	114,726	5,354	3,361	32					
Education Annex (Vocational)	6	27,840	1,002	577	22	27,840	22.6	18.1	43	1,538
Education (LRC)	14	123,674	4,452	2,565	22	6,000	62.6	50.1	120	120
McWhinnie Hall	19	26,625	959	552	22					
Half Acre Gymnasium w/o 2014 addition	22	119,306	7,249	4,873	44	6,000	7.6	6.1	15	984
Service Bldg Orig w/1956 & 60 additions	36	81,268	2,117	1,219	16					
Wyoming Hall	38	69,579	2,505	1,443	22					
Earth Sciences	81	65,000	3,033	1,904	32	65,000	62.6	50.1	120	1,297
Berry Center (39081sf)	92	39,081	1,230	824	23					
Bureau of Mines	93	77,916	3,247	2,370	33					
Anthropology (AARF)	133	52,499	1,890	1,089	22	52,499	44.6	35.7	86	1,471
Half Acre Gym Addition (HAG)		75,034	2,223	1,490	21	75,034	95.5	76.4	183	982
Enzi STEM	130	99,000	4,125	3,011	33			EVAPORATIVELY COOLED		
Energy Innovation Center (ERC, EIC)	87	57,000	2,375	1,734	33			EVAPORATIVELY COOLED		
Existing Subtotals		***1,444,966***	***61,061***	***38,930***	***29***	***235,773***	***302.3***	***239.8***	***576***	***983***
Projected 5 Year Growth North of Lewis										
(Future) Engineering Building (North of Lewis) (2018)		*107,000*	*4,458*	*3,255*	33	*96,388*	*143*	*107*	257	900
(Future) UW Science Initiative (North of Lewis) (2019)		*125,842*	*5,243*	*3,828*	33	*125,842*	*186*	*140*	336	900
5 Year Projected Totals		***1,677,808***	***70,763***	***46,012***	***30***	***458,003***	***632***	***487***	***1,168***	***941***
Projected 30 Year Totals										
Block Growth (Estimated 2% per year after initial 5 years) North of Lewis		*66,355*	*2,765*	*2,018*	33	*66,355*	*133*	*119*	287	556
Projected 30 Year Totals		***1,618,321***	***68,284***	***44,203***	***29***	***398,516***	***578***	***466***	***1,119***	***855***
NORTH AND NORTH-EAST CAMPUS										
Animal Sci/Molecular Biology	80	93,631	4,369	2,743	32					
Central Energy Plant	90	57,803	1,505	867	16					
Central Energy Plant Ash Silo	101	585	5,000	1,250	2307					
Regulated Materials Mgmt Ctr	111	19,000	684	394	22					
Centennial Complex	125	126,200	4,543	2,481	21	126,200	121.5	97.2	233	1,298
WY Technology Business Center	150	31,793	1,979	1,336	45	31,793	46.2	37	89	859
Visual Arts Facility (VAF)		74,833	2,425	1,625	23					
Existing Subtotals		***403,845***	***20,505***	***10,696***	***2,468***	***157,993***	***168***	***134***	***322***	***1,177***
Projected 5 Year Growth										
High Bay Research Facility (2017)		*79,701*	*2,952*	*2,214*	30	*79,701*	*118*	*106*	255	*750*
5 Year Projected Totals		***483,546***	***23,457***	***12,910***	***2,498***	***237,694***	***286***	***240***	***577***	***988***
Projected 30 Year Totals										
Block Growth (Based on UMP Projections)		*582,000*	*18,861*	*13,769*	26	*582,000*	*1,164*	*1,048*	2514	556
Projected 30 Year Totals		***1,065,546***	***42,318***	***26,678***	***27***	***819,694***	***1,450***	***1,288***	***3,091***	***636***
WEST AND SOUTH-WEST CAMPUS										
Arts & Sciences	7	66,186	2,317	1,335	22					
Biological Sciences (includes Science Library Annex)	9	205,350	9,583	6,016	32	81,200	78.2	62.6	150	1,297
Health Sciences Complex (Bio-Chem; Pharmacy; HS in 07)	11	124,348	5,181	3,782	33	124,348	119.7	95.8	230	1,298
Classroom Bldg w/2007 addn	12	96,061	2,852	1,992	22	96,061	78	62.4	150	1,539
College of Business w/o auditorium (demo 2008)	13	61,081	2,232	1,286	23	61,081	109.8	87.8	211	696
College of Business Addition	13	102,821	3,332	2,233	23					
Geology w/ 56 addn	18	57,771	2,080	1,144	21	12,220	11.4	9.1	22	1,343
Cheney International Center/Student Health	23	32,013	1,152	664	22	32,013	51.9	41.5	100	771
Hoyt Hall	24	29,939	1,078	621	22					
Coe 1977 addition	26	85,676	3,084	1,777	22	85,676	101.3	81	194	1,058
Coe 58 orig and History	26	119,390	4,298	2,477	22	100,000	118.2	94.5	227	1,058
Coe Library ILLC Addition	26	92,876	3,010	2,017	23	92,876	*169*	*110*	263	846
Merica Hall	27	17,651	635	366	22					
Aven Nelson	30	32,832	1,182	681	22					
Old Main	31	34,089	1,227	707	22					
Physical Sciences	33	179,777	9,798	6,292	38	65,157	77.2	61.8	148	1,054
Wyoming Union 2002 addition	39	25,000	1,050	605	26				0	
Wyoming Union w 79 additions	39	137,418	5,772	3,326	26	68,480	38	30.4	73	2,253
Knight Hall 41 orig/46 addn/50 food ser	44	81,671	2,940	1,694	22	14,056	12.3	9.8	24	1,434
Ross Hall	50	90,665	3,536	2,037	24					
Aven Nelson - Williams Conservatory	82	15,443	472	330	23					
WY State Geological Survey	920	23,171	834	481	22	23,171	20.3	16.2	39	1,430
Existing Subtotals		***1,711,229***	***67,645***	***41,863***	***26***	***856,339***	***985***	***763***	***1,830***	***1,123***
Projected 30 Year Totals										
Block Growth (Based on UMP Projections)		*200,000*	*6,481*	*4,343*	23	200,000	*250*	*200*	480	*1,000*
Projected 30 Year Totals		**1,911,229**	**74,127**	**46,205**	**26**	**1,056,339**	**1,235**	**963**	**2,310**	**1,097**

UNIVERSITY OF WYOMING BUILDINGS ON CEP STEAM & CHILLED WATER		CEP HEATING				CEP COOLING				
UW BUILDING NAME	UW BUILDING #	Area Conditioned by Steam (sq-ft)	Peak Steam Load (lb/hr)	Diversified Steam Load (lb/hr)	Diversified Heating BTU/sqft	Area Conditioned by CHW (sq-ft)	Peak CHW Load (Tons)	Diversified CHW Load (Tons)	Diversified CHW Flow (gpm)	Diversified Cooling Sqft/Ton
			EAST CAMPUS							
Campus Greenhouse Main	21	5,737	175	123	23					
Information Technology Center	64	86,664	5,377	3,630	45	86,664	150	150	360	578
Law School w 93 addn/09 Moot addn	77	69,805	2,357	1,358	21	69,805	61.1	48.9	117	1,428
Fine Arts w/ 1999 Studio Addn/ w/o 2014 PAI	78	180,958	6,406	3,711	22	180,958	140.4	112.3	270	1,611
Corbett	79	83,646	4,113	2,573	33					
East Campus Distribution Center	91	276	12	8	33					
Campus Greenhouse Equip Shop	118	1,216	37	26	23					
Performing Arts Center (Addn to Fine Arts		52,073	1,543	1,034	21					
Existing Subtotals		***480,375***	***20,020***	***12,463***	***28***	***337,427***	***352***	***311***	***747***	***1,084***
Projected 30 Year Totals										
Block Growth (Based on UMP Projections)		*180,000*	*5,833*	*3,908*	*23*	*180,000*	*225*	*180*	*432*	*1,000*
Projected 30 Year Totals		***660,375***	***25,853***	***16,371***	***27***	***517,427***	***577***	***491***	***1,179***	***1,053***
			SOUTH CAMPUS							
Memorial Fieldhouse	16	195,855	6,463	3,724	21					
Fieldhouse North Addition	17	71,694	2,581	1,487	22					
Orr Hall	34	85,361	2,390	1,377	17					
Crane Hall	40	88,935	2,490	1,435	17					
Crane Hill Cafeteria	41	49,622	2,084	1,201	26					
Downey Hall	42	85,361	2,390	1,435	18					
Hill Hall	43	85,361	2,490	1,435	18					
McIntyre Hall	46	134,518	3,702	2,133	17					
Washakie Center	51	81,516	3,423	1,973	26					
White Hall	52	132,054	3,698	2,131	17					
Honors House (Kappa sigma w/addn)	55	12,345	309	207	18					
Sigma Phi Epsilon House (old Kappa Delta)	56	16,634	466	268	17					
Health Sciences Living House (ΦΔθ, ΔΓ, HSL,PM)	57	5,247	147	85	17					
Beta House	61	12,567	452	261	22					
Rochelle Athletics Center	73	47,450	1,637	943	21					
Indoor Practice Facility	74	88,759	2,764	1,593	19					
Arena Auditorium	89	260,990	8,613	4,963	21					
Alpha Tau Omega Fraternity	902	9,154	256	148	17					
Sigma Alpha Epsilon Fraternity	905	10,557	296	170	17					
Sigma Chi Fraternity	906	10,881	305	176	17					
Sigma Nu Fraternity	907	10,226	286	165	17					
Pi Kappa Alpha Fraternity (old Alpha Chi Omega)	908	16,750	379	219	14					
Delta Delta Delta Sorority	909	6,007	150	101	18					
Kappa Kappa Gamma Sorority	911	20,082	562	324	17					
Pi Beta Phi Sorority w/ 1994 addn)	912	15,758	441	254	17					
Existing Subtotals		***1,553,684***	***48,774***	***28,207***	***20***	***0***	***0***	***0***	***0***	***-***
Projected 5 Year Growth										
(Future) New Natatorium (2020)		55,000	1,630	1,092	21	55,000	*183*	*165*	396	333
(Future) Arena II (2017)		14,680	435	291	21	14,680	*27*	*7*	16	2,200
(Future) Rochell II (Addition to RAC I) (2018)		55,000	1,630	1,092	21	*55,000*	*100*	*25*	*60*	*2,200*
5 Year Projected Totals		***1,678,364***	***52,468***	***30,683***	***20***	***124,680***	***310***	***197***	***472***	***634***
Projected 30 Year Totals										
Per UW, no growth is projected in this portion of campus at this time		-	0	0	-	-	0	0	0	-
Projected 30 Year Totals		***1,678,364***	***52,468***	***30,683***	***20***	***124,680***	***310***	***197***	***472***	***634***

02 Heating and Cooling Loads by Building

Existing and Projected Heating and Cooling Loads by Building:

East Campus
South Campus

Accompanying charts identify all buildings on campus categorized by location with areas, heating, and cooling requirements. Five year and thirty year projected loads were calculated based on UMP data.

Section 1

Section 2

Section 3

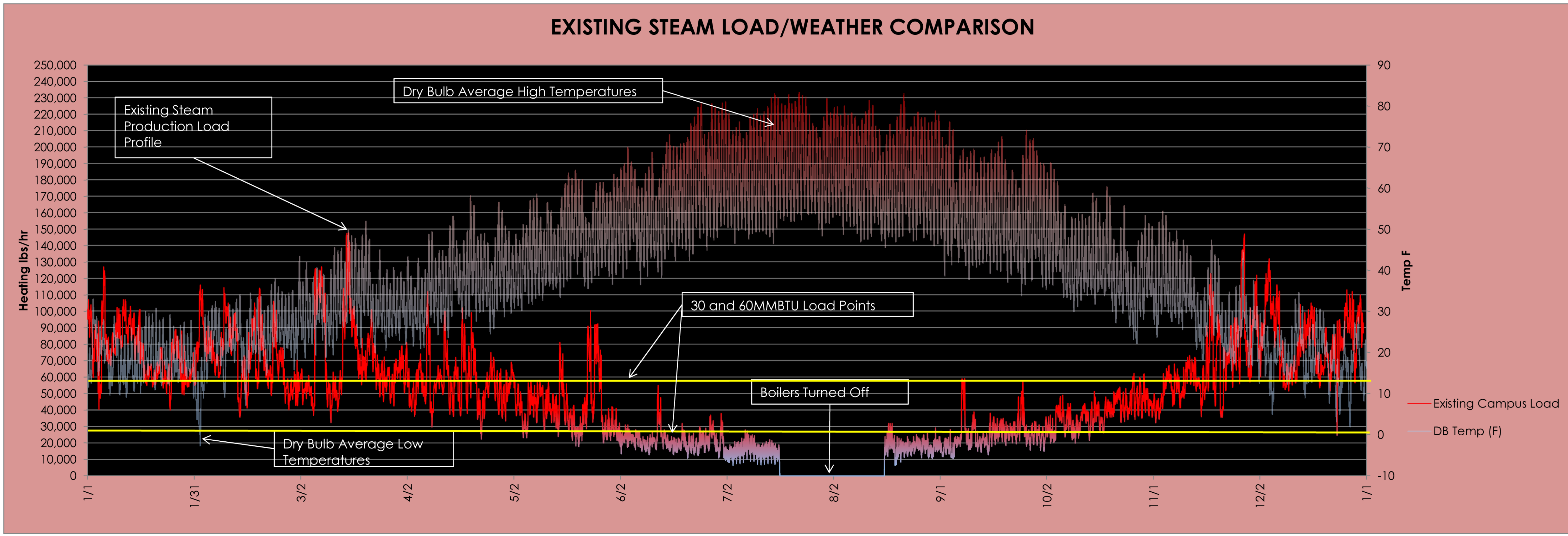
Section 4

Section 5

02 Existing Heating Load Profile

Existing Steam Load/Weather Comparison

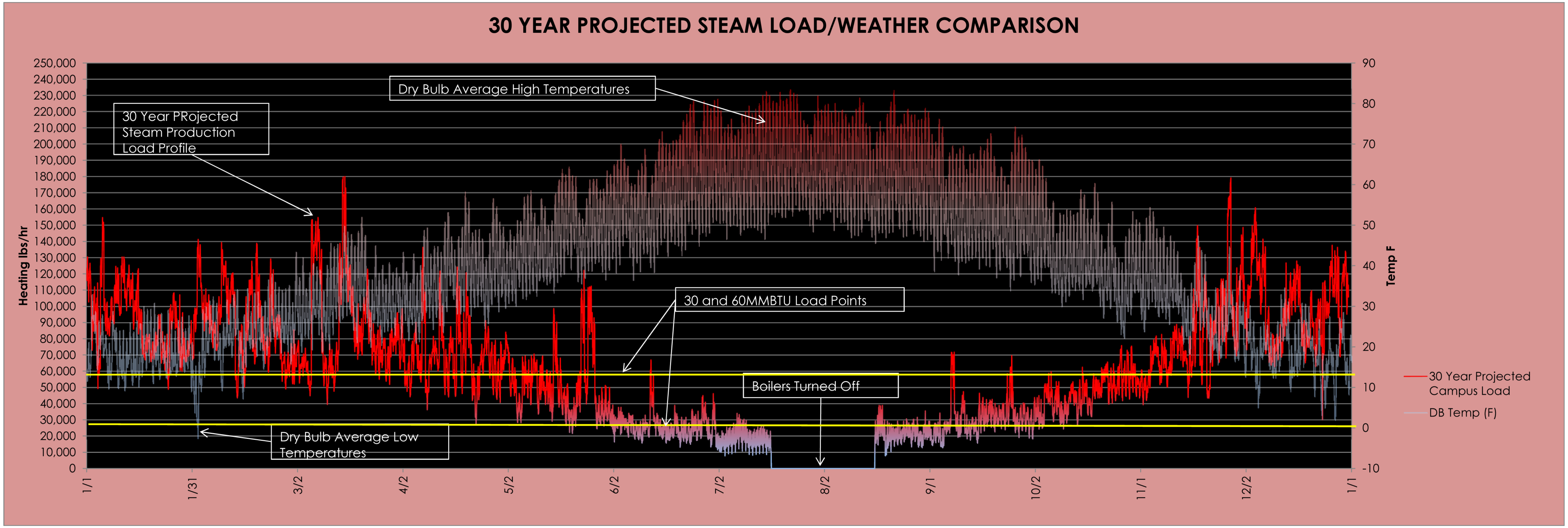
This plot identifies the existing calculated existing campus steam load profile in pounds per hour over the course of a year (left vertical axis) and the corresponding dry bulb temperatures (right vertical axis).



This plot identifies the 30 year projected existing campus steam load profile in pounds per hour over the course of a year (left vertical axis) and the corresponding dry bulb temperatures (right vertical axis).

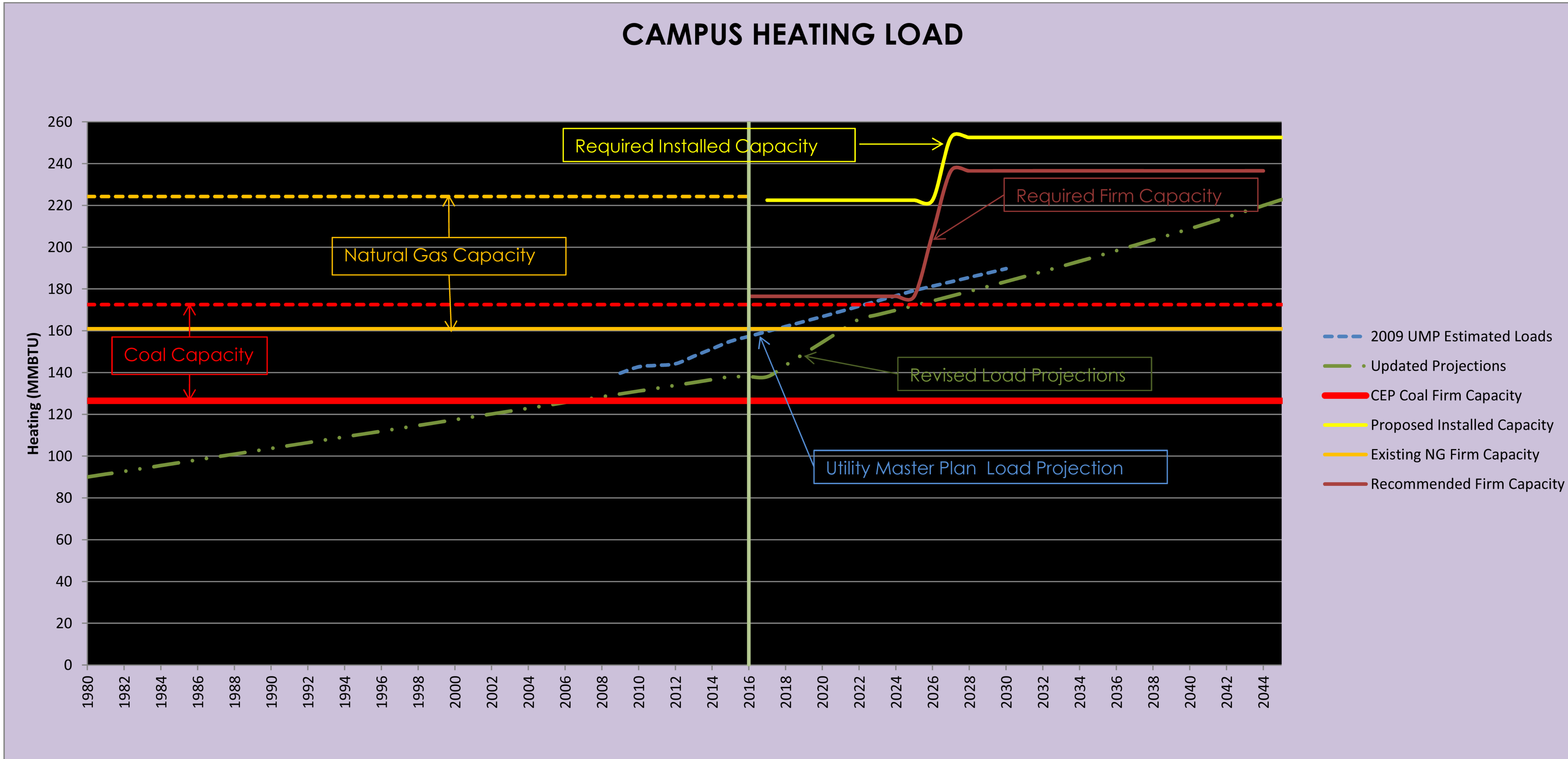
03 Projected Heating Load Profile

30 Year Projected Steam Load/Weather Comparison



04 Campus Heating Projections

This plot portrays the past and projected campus heating loads with corresponding CEP coal and natural gas installed and N+1 production capacities. Increased production capacity is achieved when burning natural gas in the dual fired boilers over burning coal.



05 Cooling Load Profiles

The following pages depict graphically the cooling requirements.

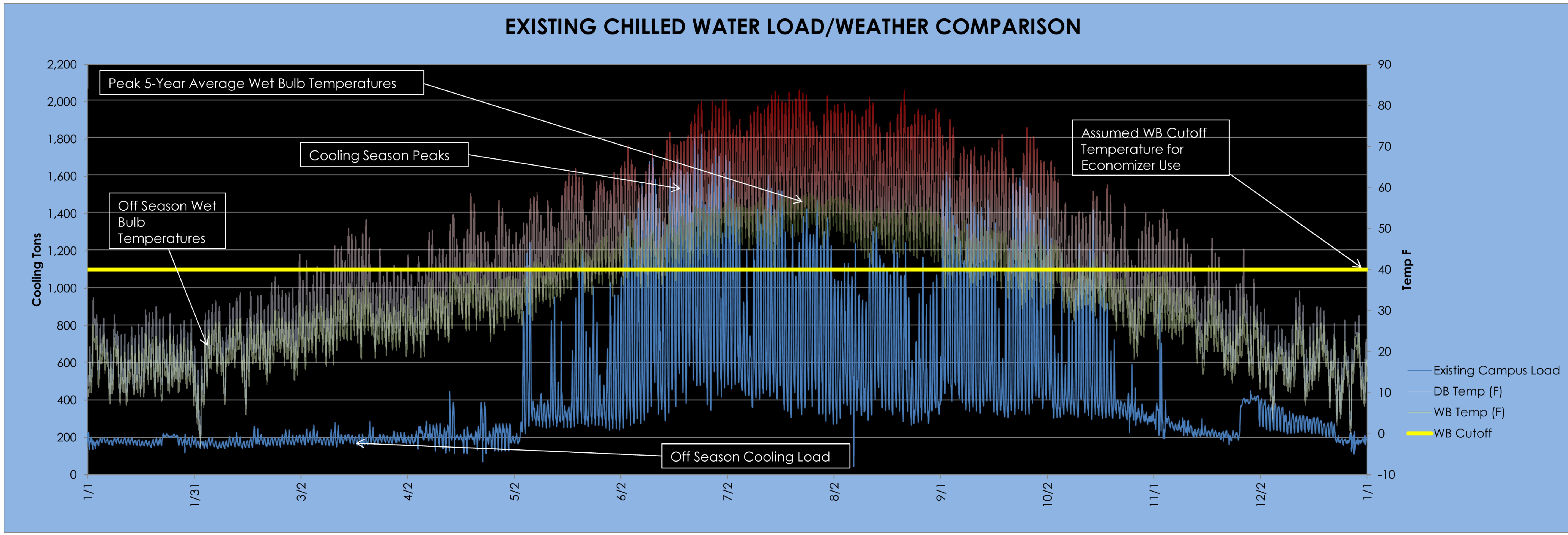
Campus Chilled Water Annual Load Profile
Campus Chilled Water Load Profile by Month

Existing and Projected January Profile
Existing and Projected February Profile
Existing and Projected March Profile
Existing and Projected April Profile
Existing and Projected May Profile
Existing and Projected June Profile
Existing and Projected July Profile
Existing and Projected August Profile
Existing and Projected September Profile
Existing and Projected October Profile
Existing and Projected November Profile
Existing and Projected December Profile
Campus Cooling Projections

05 Cooling Load Profiles

Campus Chilled Annual Load Profile

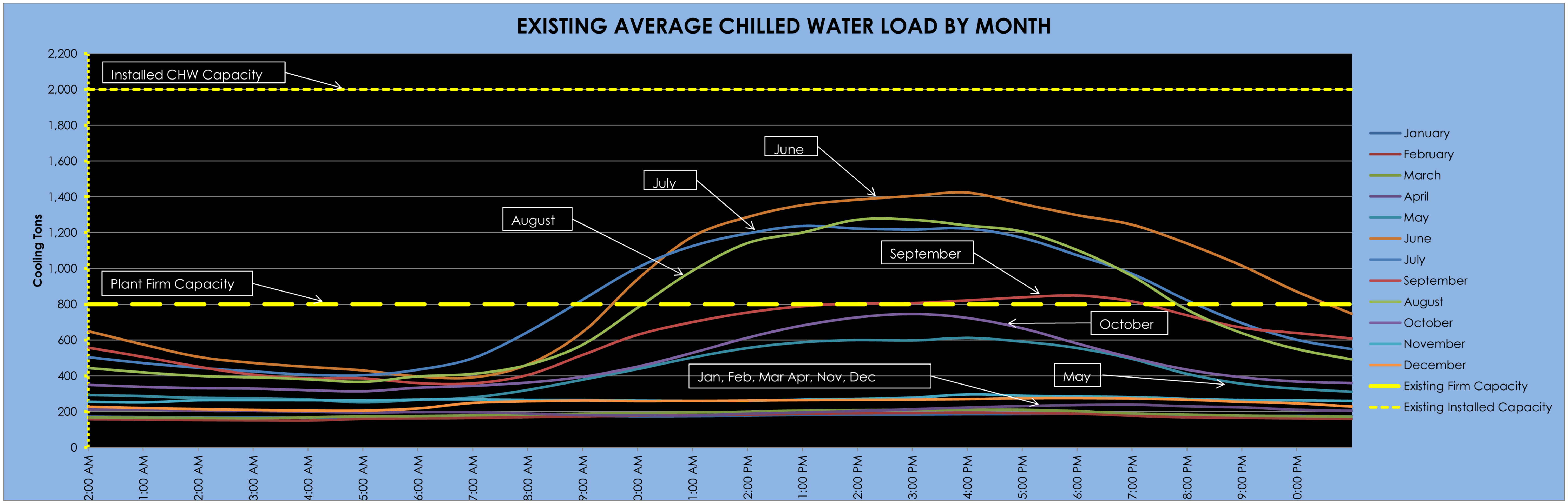
This plot identifies the existing campus chilled water load profile in tons over the course of a year (left vertical axis) and the corresponding dry and wet bulb temperatures (right vertical axis). The solid yellow line represents the estimated wet bulb cutoff to which hydronic economizer would not be able to satisfy load conditions. When the wetbulb temperature is above this cutoff, cooling would have to be achieved via the use of much power intensive chillers. When ambient wetbulb is below this cutoff line, the chilled water load can be satisfied utilizing hydronic plate and frame economizers.



This plot is a combination of existing average daily chilled water load profiles for each month of a year. Plant firm and installed capacities are identified via the yellow lines. Note that these plots are average daily temperature, not peak loads as peak loads can spike significantly above an average. The following pages provide more detailed hourly profiles for each month with five and 30 year projections included.

05 Cooling Load Profiles

Campus Chilled Water Profile by Month

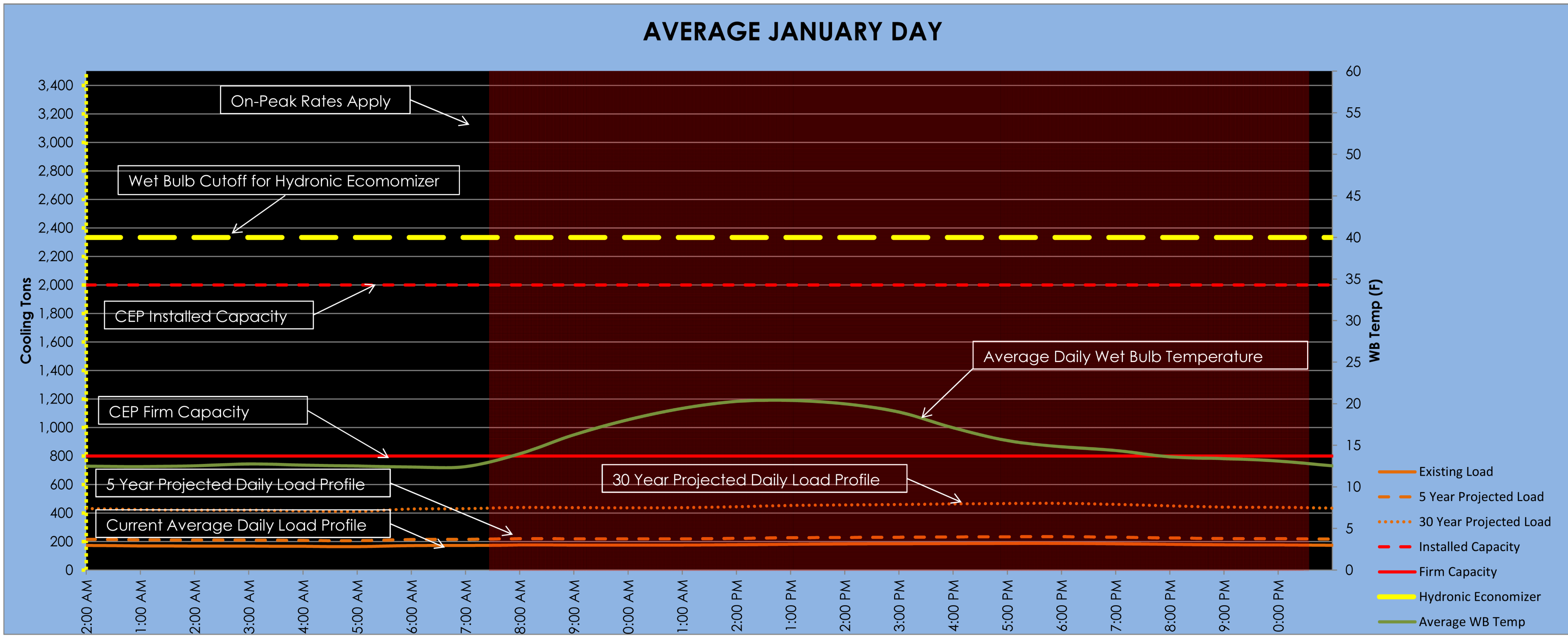


Section 1
Section 2
Section 3
Section 4
Section 5

Section 1
Section 2
Section 3
Section 4
Section 5

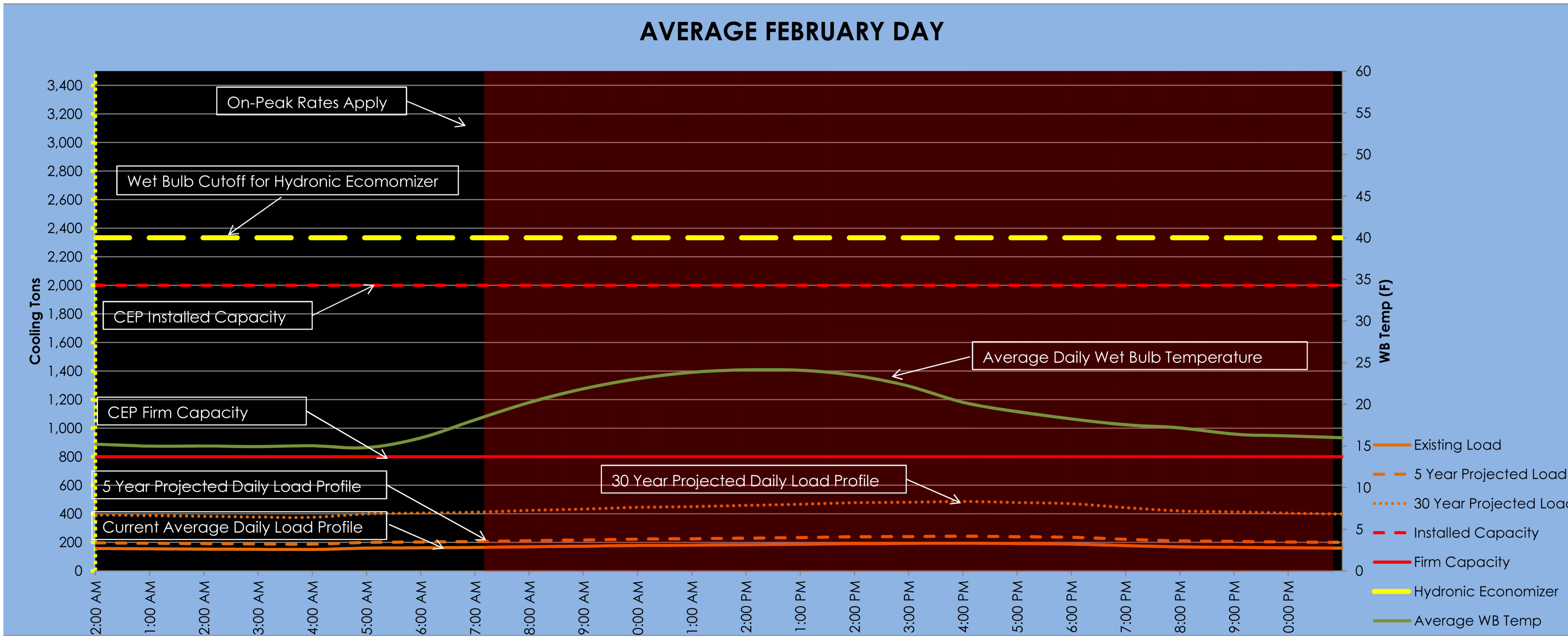
05 Cooling Load Profiles

Existing and Projected January Profile



05 Cooling Load Profiles

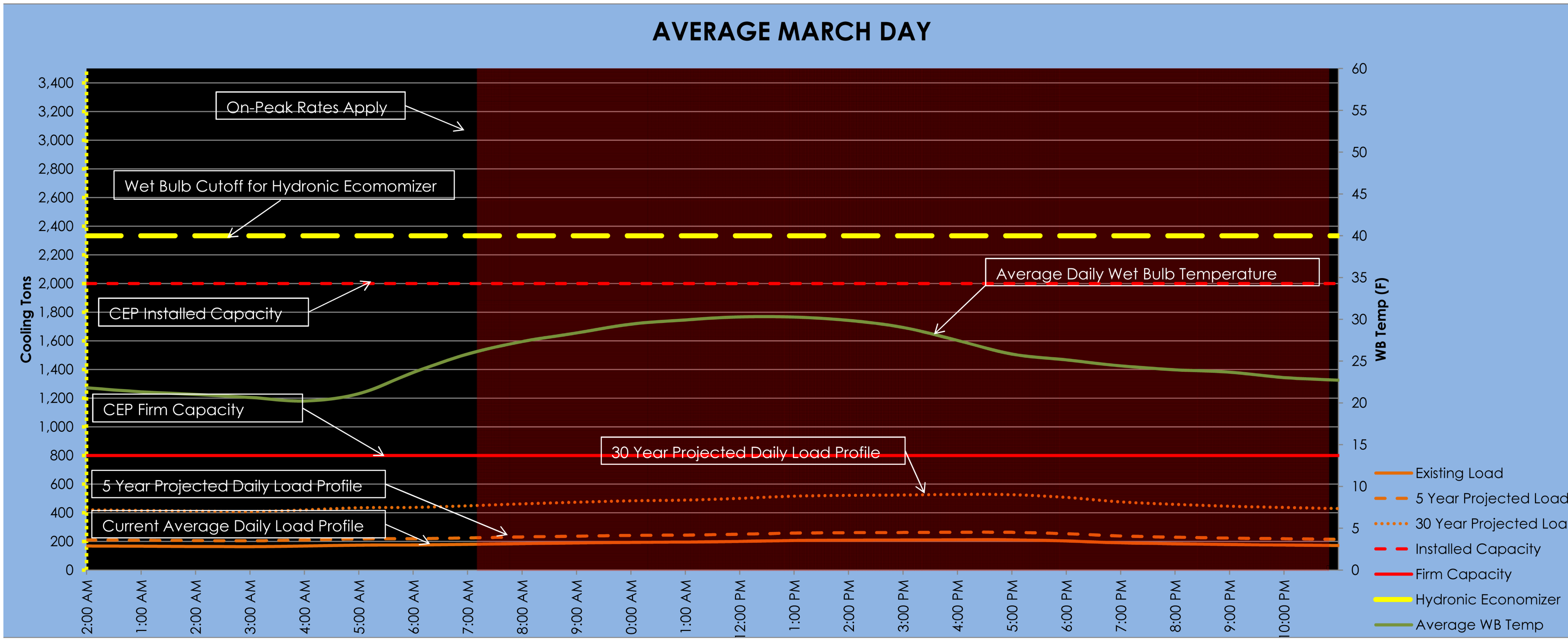
Existing and Projected February Profile



Section 1
Section 2
Section 3
Section 4
Section 5

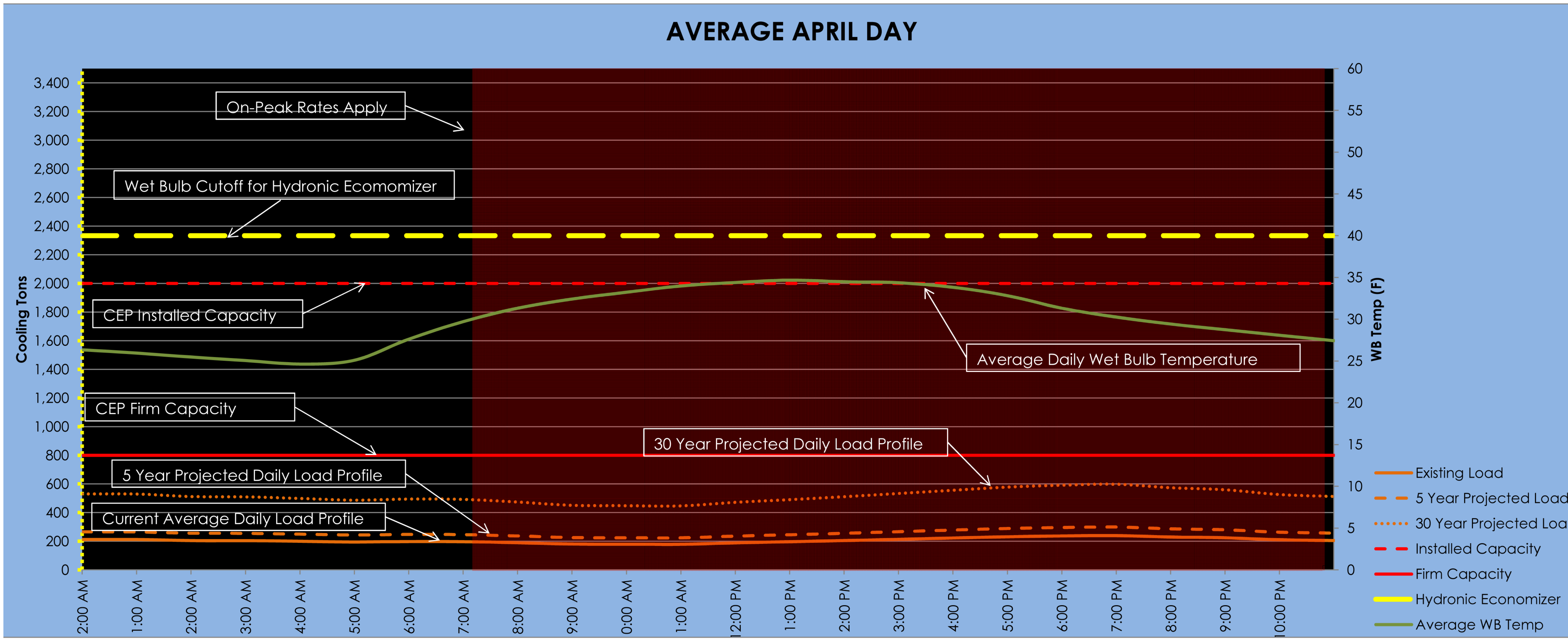
05 Cooling Load Profiles

Existing and Projected March Profile



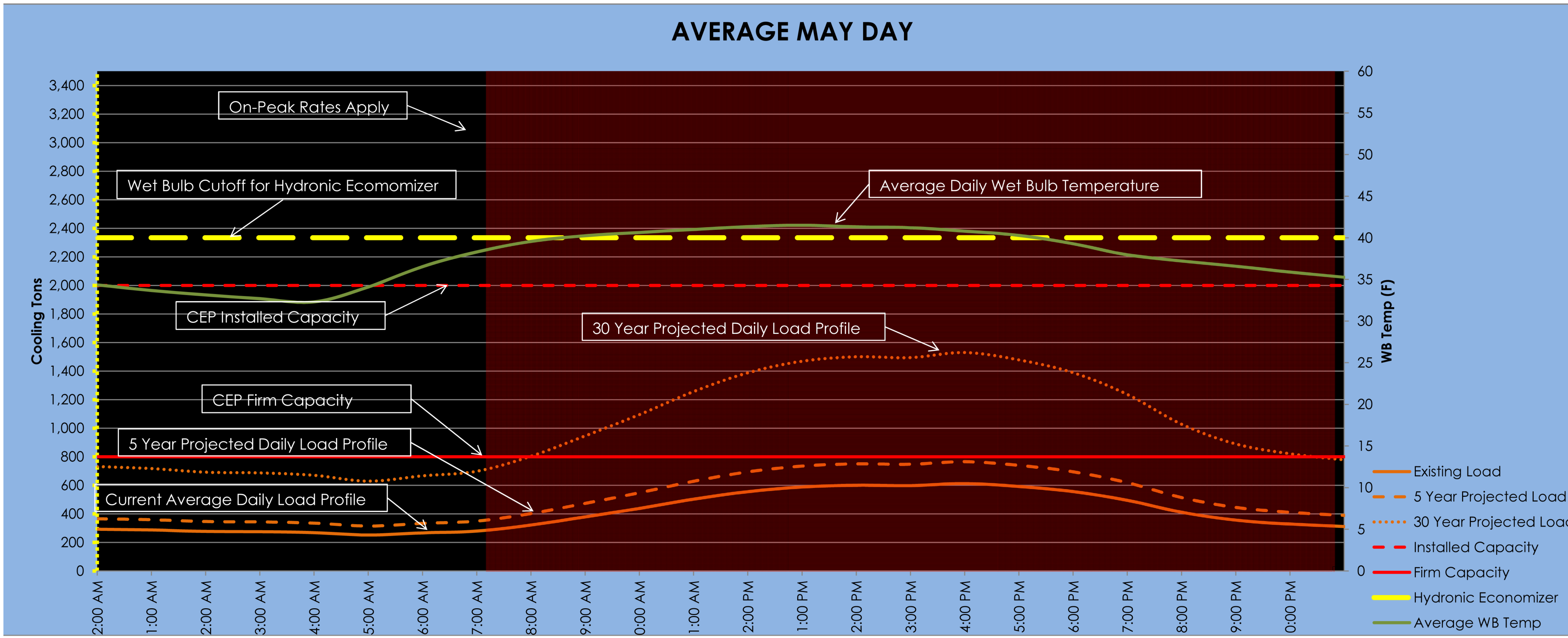
05 Cooling Load Profiles

Existing and Projected April Profile



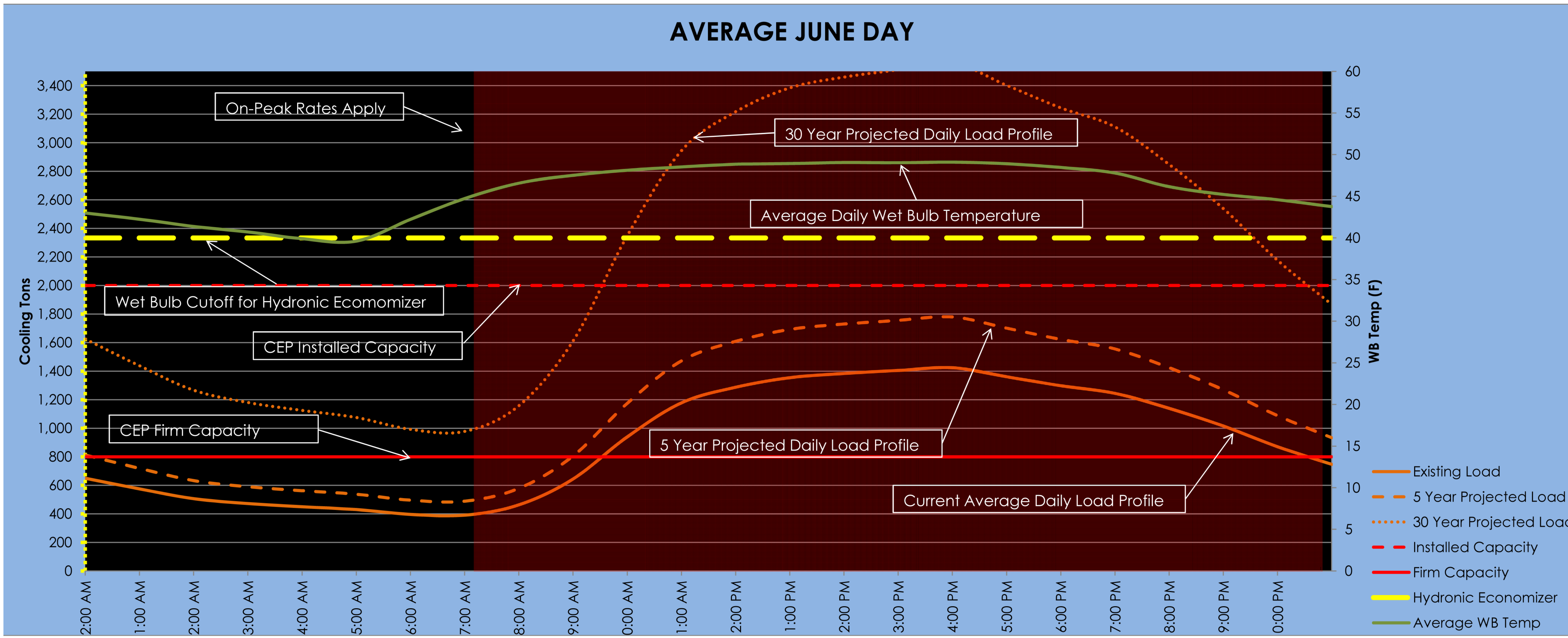
05 Cooling Load Profiles

Existing and Projected May Profile



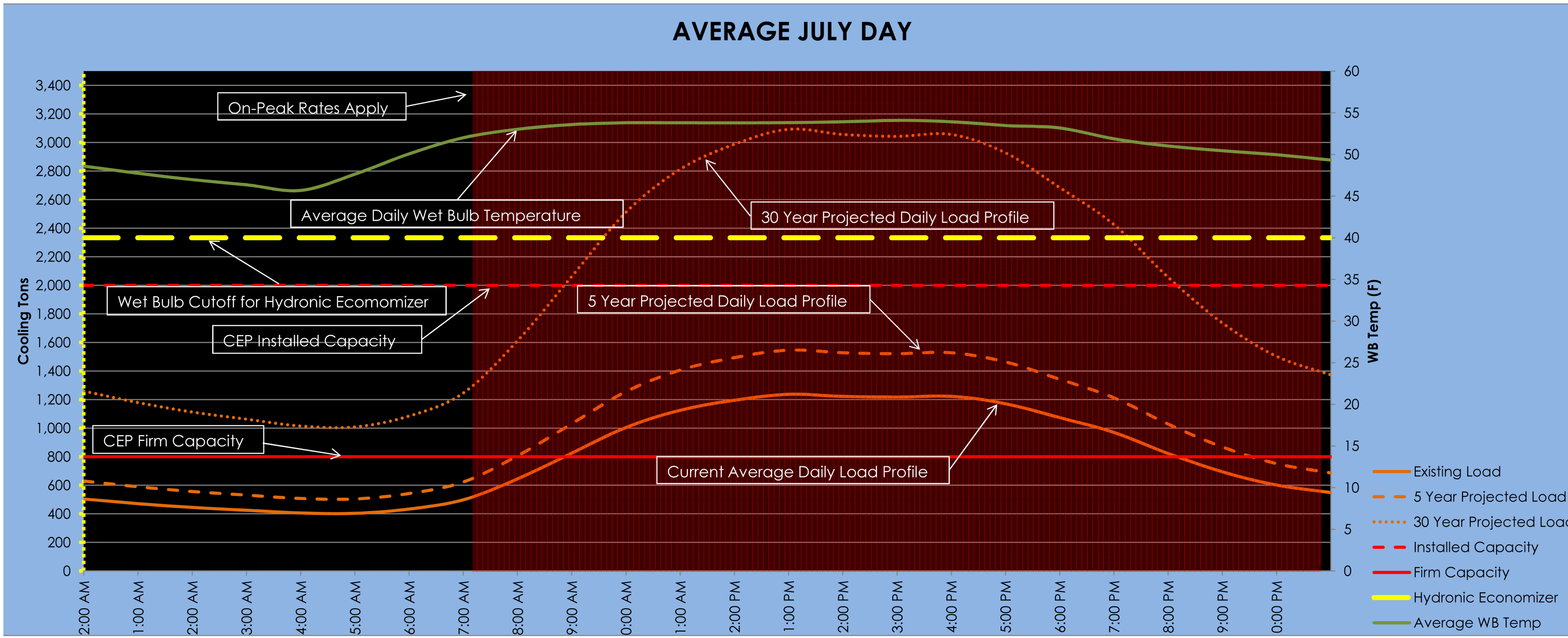
05 Cooling Load Profiles

Existing and Projected June Profile



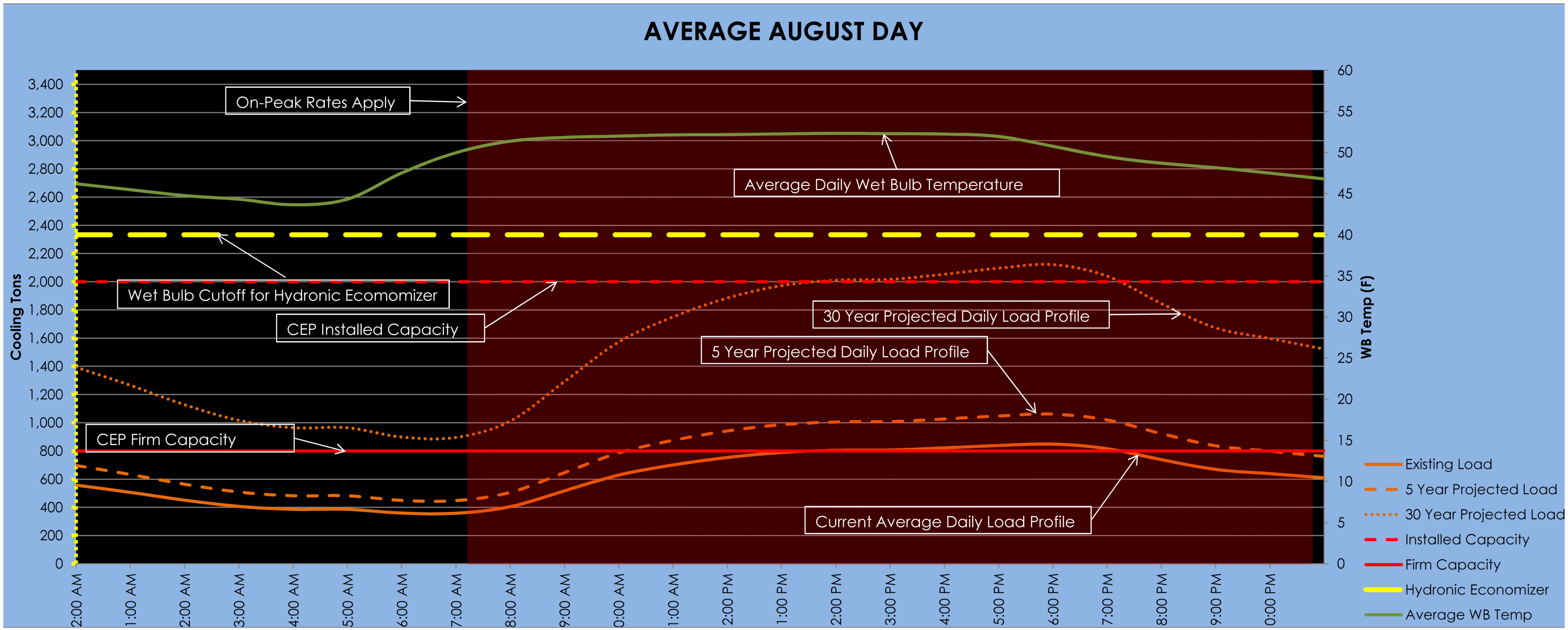
05 Cooling Load Profiles

Existing and Projected July Profile



05 Cooling Load Profiles

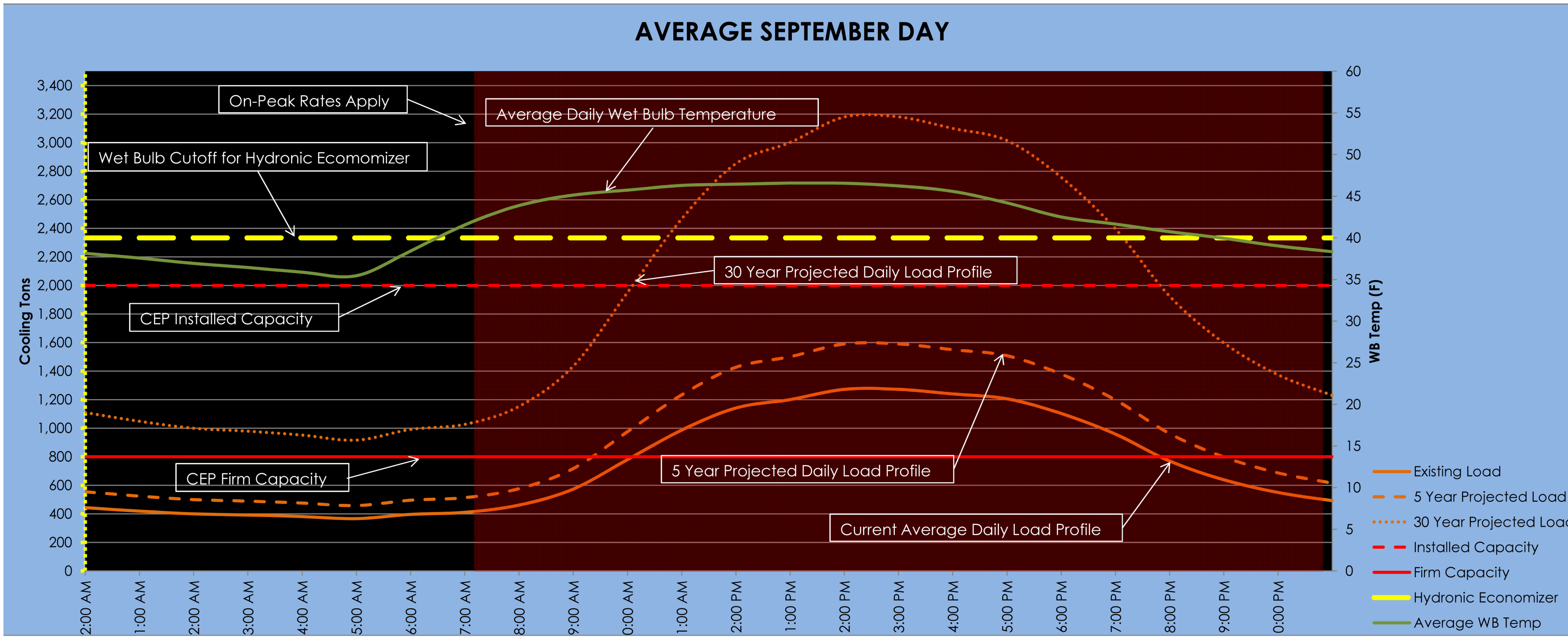
Existing and Projected August Profile



Section 1
Section 2
Section 3
Section 4
Section 5

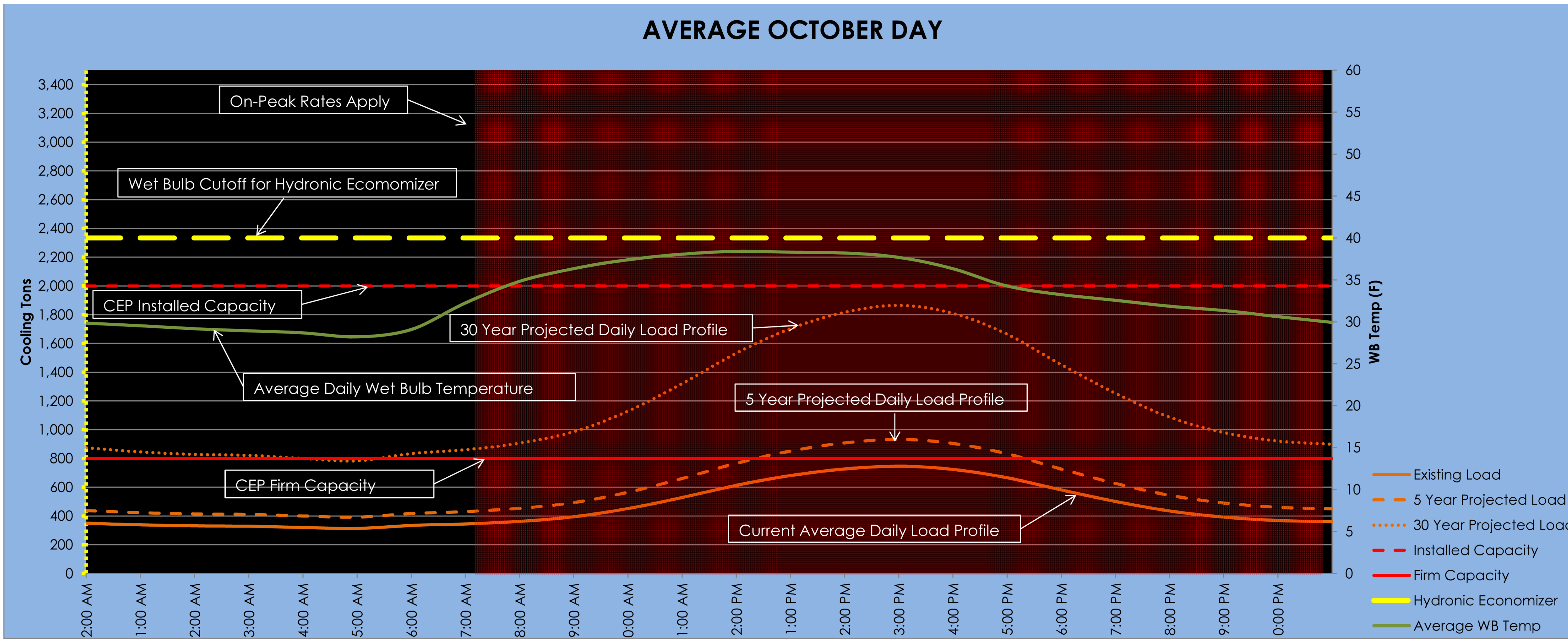
05 Cooling Load Profiles

Existing and Projected September Profile



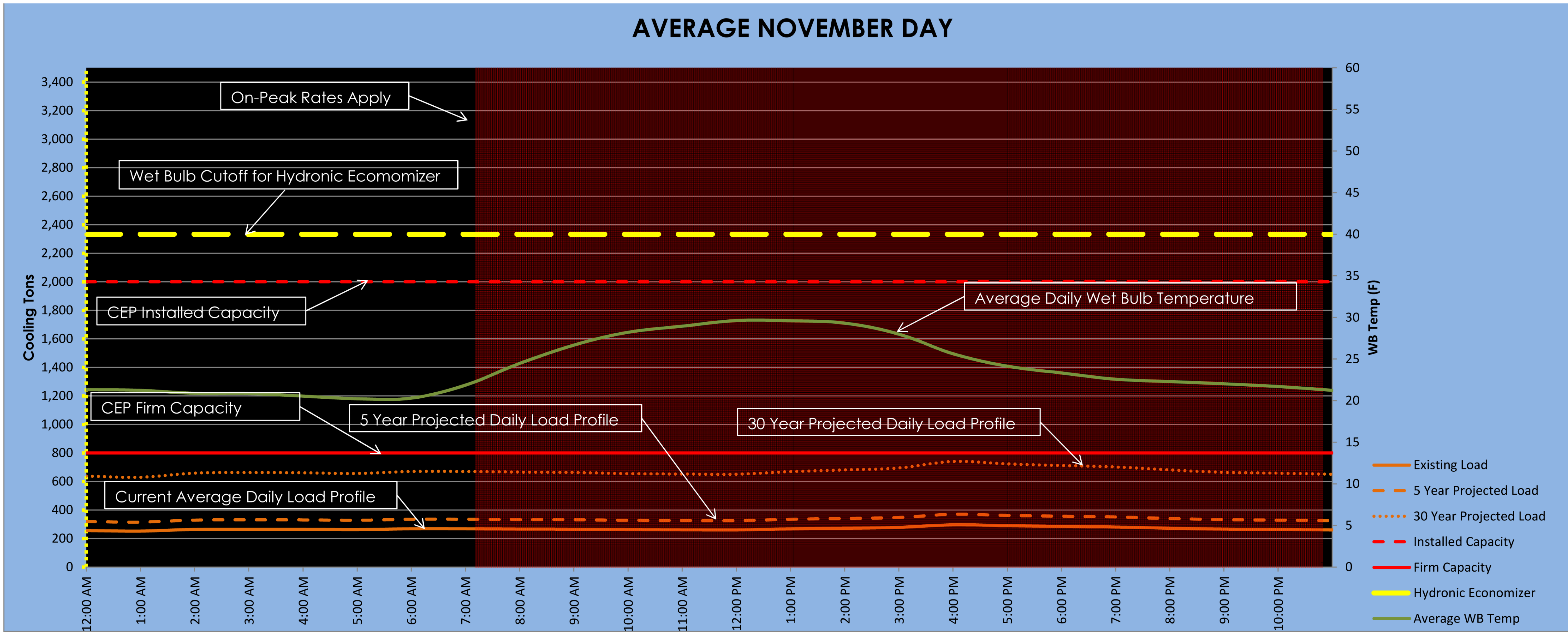
05 Cooling Load Profiles

Existing and Projected October Profile



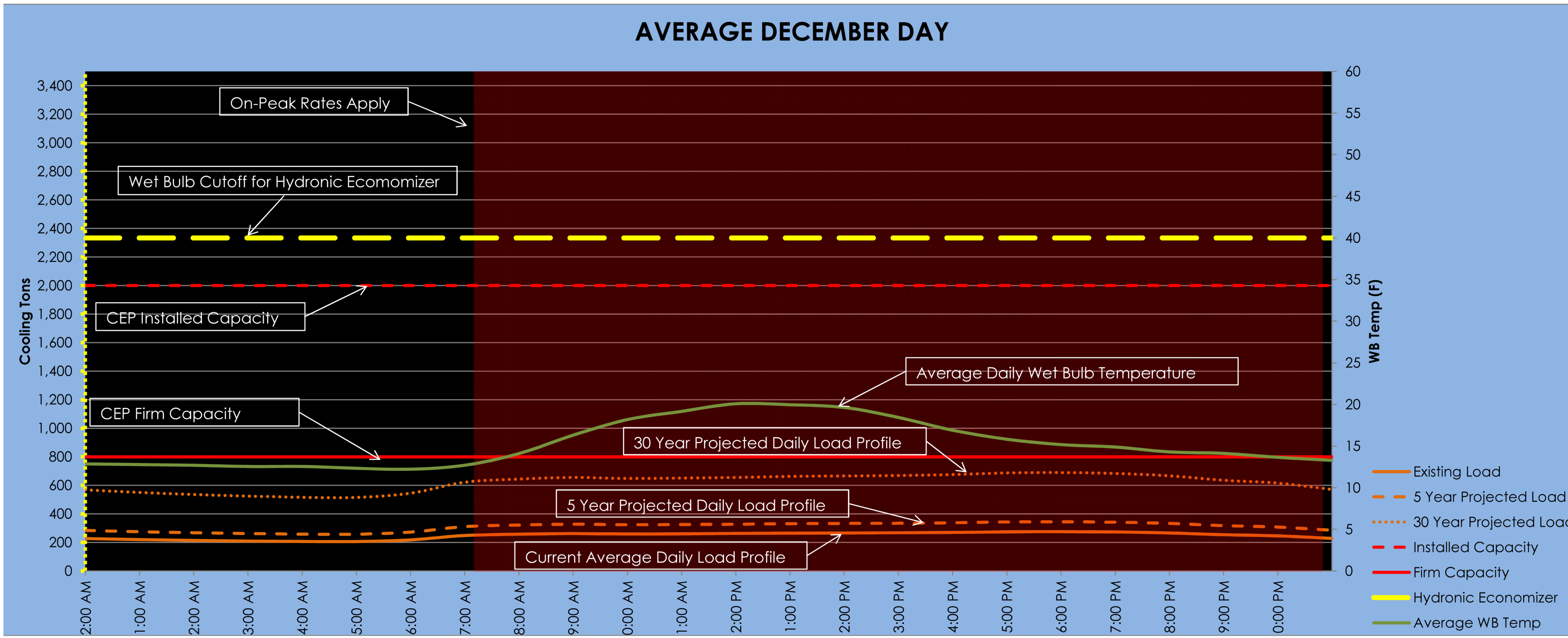
05 Cooling Load Profiles

Existing and Projected November Profile



05 Cooling Load Profiles

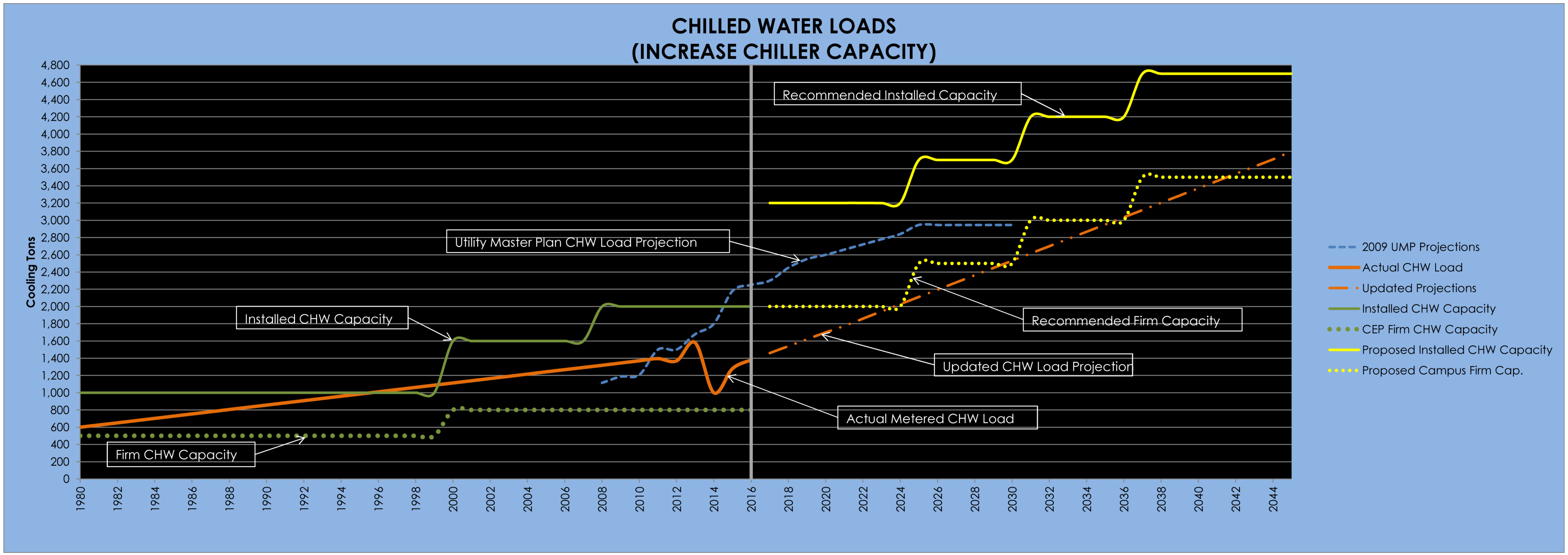
Existing and Projected December Profile



05 Cooling Load Profiles

Campus Cooling Projections

This plot portrays the past and projected campus cooling loads with corresponding installed and N+1 production capacities. As shown, the chilled water system is beyond the firm capacity and will be approaching the installed capacity in the near future.



Medium Voltage Campus Distribution-Existing

The campus is fed with a 13.2 kV loop system from the West and East Campus Substations. The former is fed by the Cowboy Feeder and distributes six lines, one of which backs up the CEP on the east campus. The latter is fed by the Alta Vista Feeder and distributes five lines, one of which directly feeds the CEP. For the most part, the campus can be fed by either substation in the event of a sustained power outage at one of the two, and all of the new work will be connected to the loop system. The existing East and West Campus loops are included for reference.

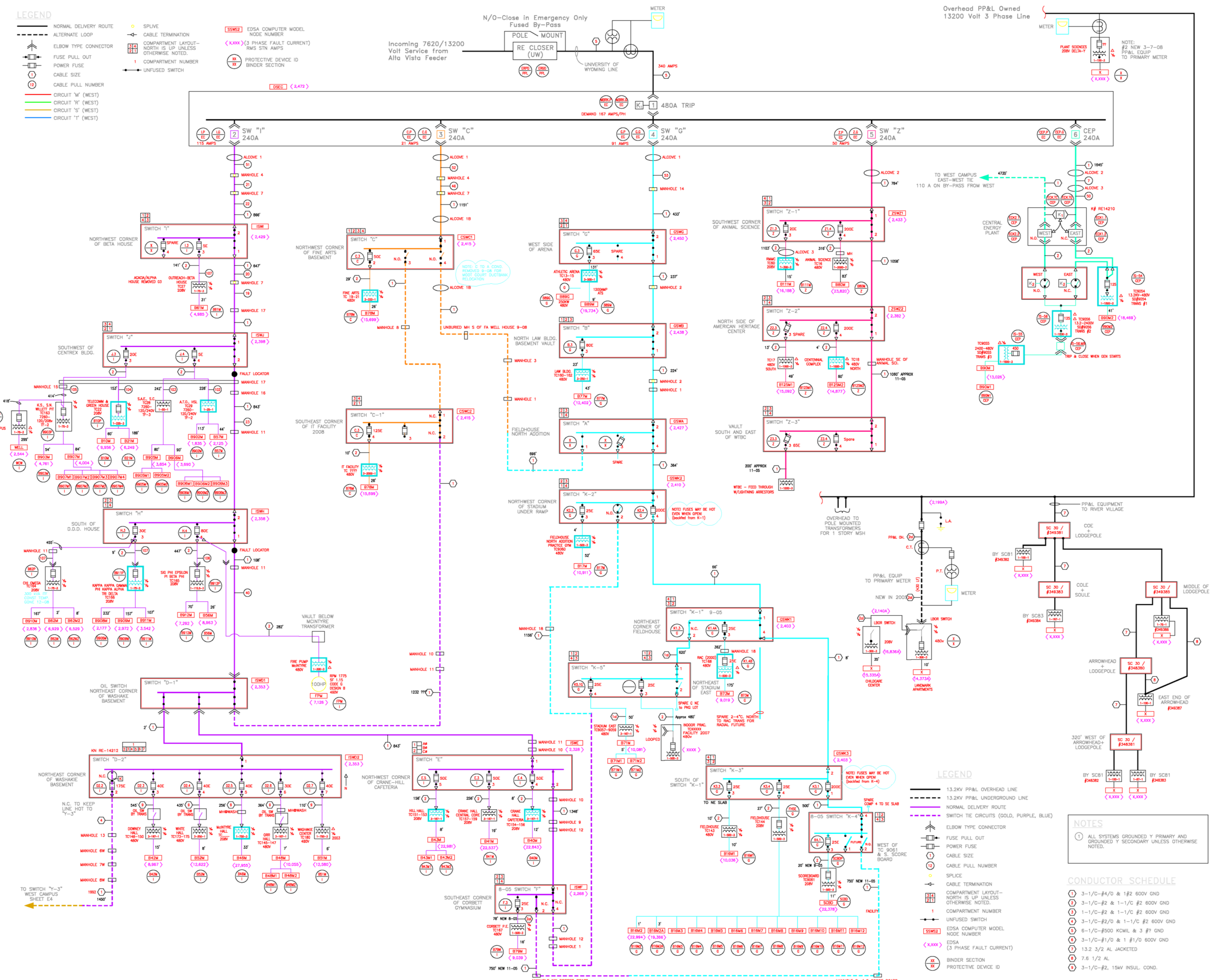
Where critical and emergency loads require, standby generators provide power in the event of power loss to the low voltage loads. None of the standby generators provide backup power through the medium voltage loop system. This theoretically could be accomplished, but we do not recommend this due to the lengthy coordination that would be required with the public utility. Any emergency loads can be more easily and safely supported by local generators.

Electric Utility Rate Structure

The University's power is supplied by Rocky Mountain Power under a large General Service, Time of Use rate structure (Schedule 46). This structure contains Base, Demand, Consumption, and Reactive Power charges. During on-peak periods, demand is identified to be the greatest use over a 15 minute period during the billing month rounded to the nearest whole KW. The on peak demand period is Monday through Friday, 7:00am through 11:00pm. See Supporting Documentation SD-III-1 for details pertaining to the University's electric rate structure.

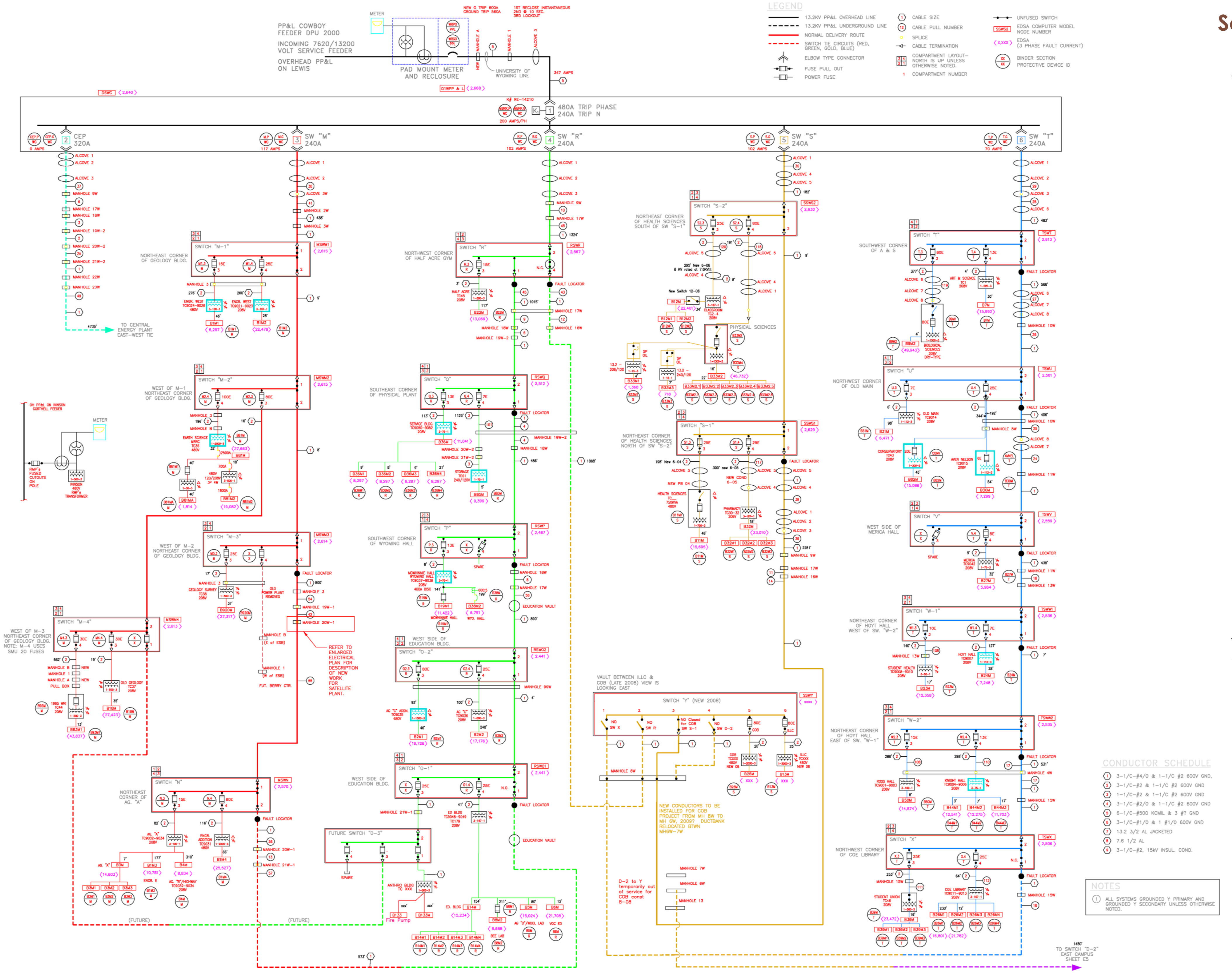
07 Electrical East Campus One-Line Diagram

This electrical single line diagram provides information pertaining to major equipment and distribution of East Campus



ONE-LINE DIAGRAM EAST CAMPUS

07 Electrical West Campus One-Line Diagram



ONE– LINE DIAGRAM WEST CAMPUS

This electrical single line diagram provides information pertaining to major equipment and distribution of West Campus

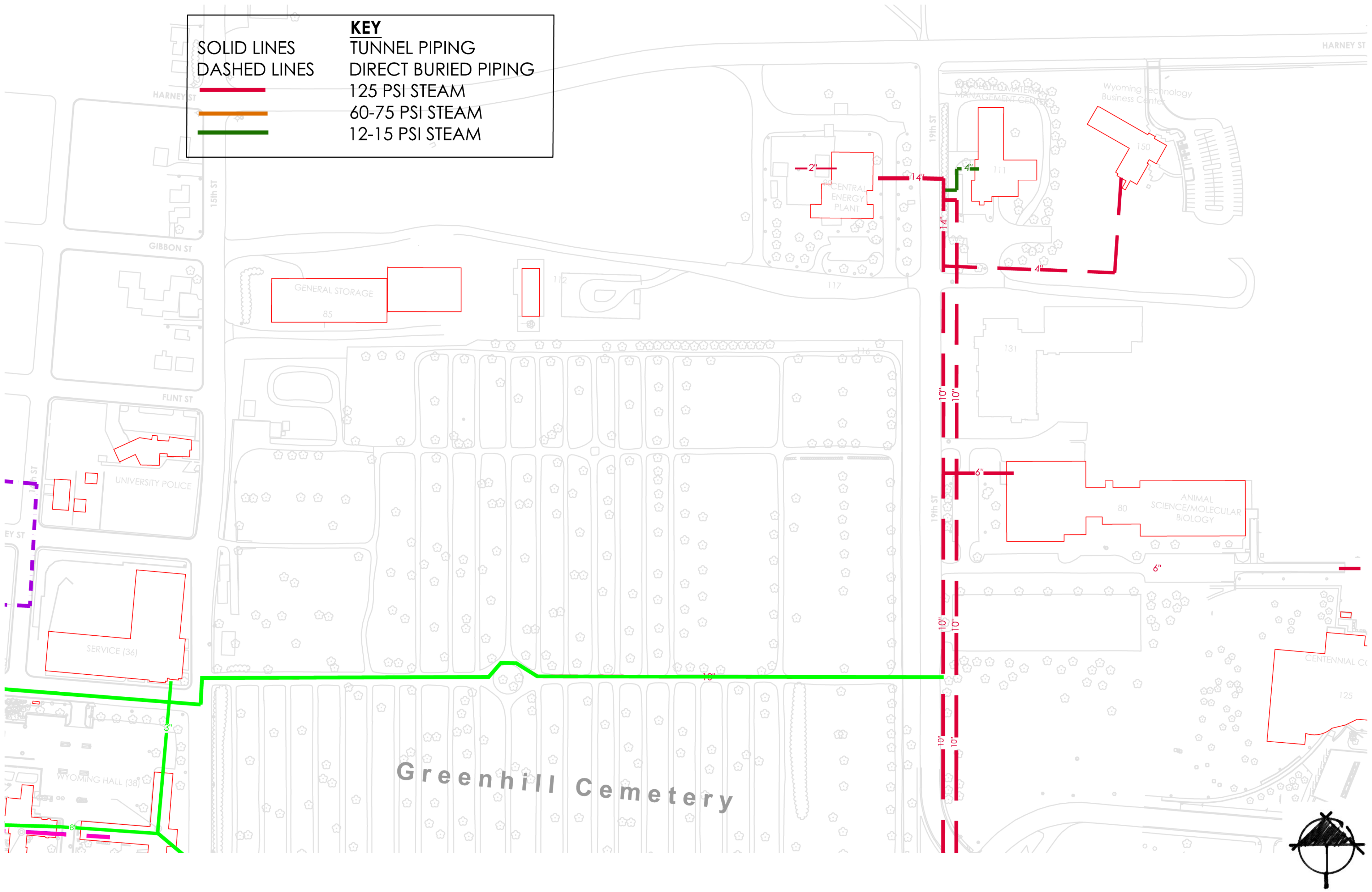
08 Existing Steam Distribution

Campus Map-Steam
Area 1-Steam
Area 2-Steam
Area 3-Steam

This overall existing campus steam distribution piping plan shows approximate routings of steam mains throughout campus. Pressures are identified by color. Dashed piping identifies direct buried piping. Solid lines are distribution mains located in the Utility Tunnel System. See accompanying drawings for enlarged area plans.

OVERALL STEAM SITE PLAN EXISTING

08 Existing Steam Distribution

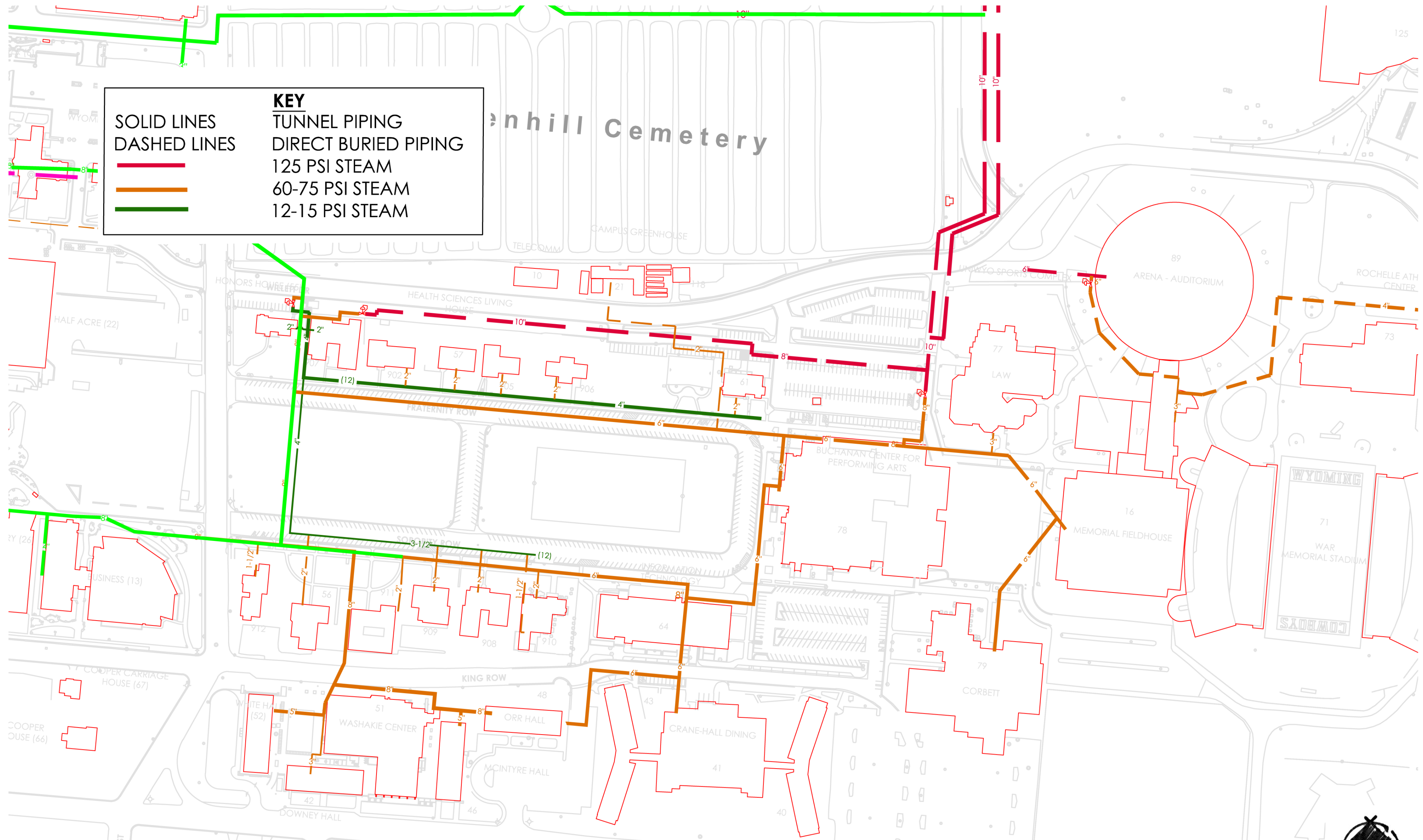


ENLARGED STEAM SITE PLAN – AREA 1 EXISTING

Section 3: Campus Load Analysis

08 Existing Steam Distribution

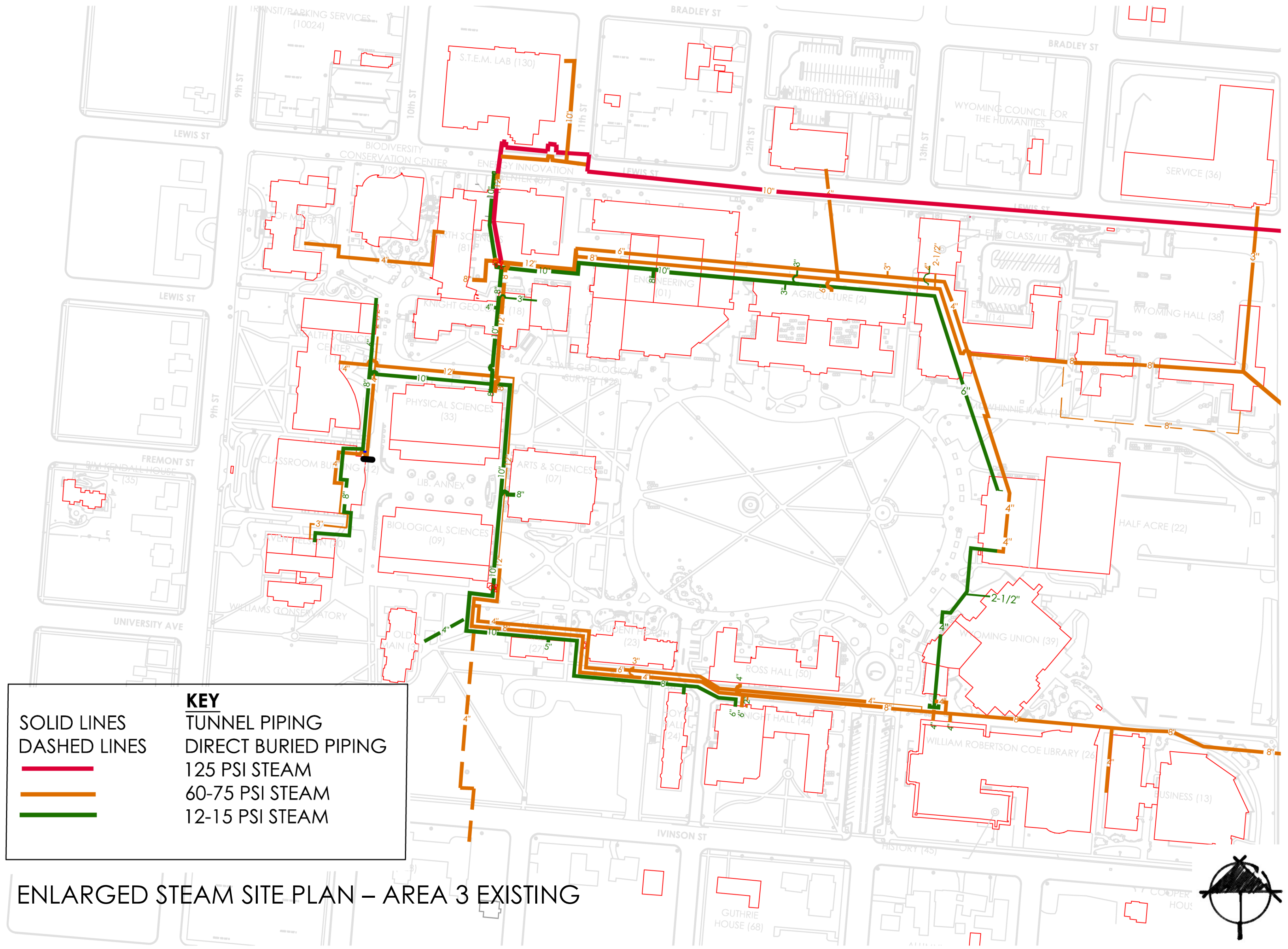
Campus Map-Steam
Area 1-Steam
Area 2-Steam
Area 3-Steam



ENLARGED STEAM SITE PLAN – AREA 2 EXISTING

08 Existing Steam Distribution

Campus Map-Steam
Area 1-Steam
Area 2-Steam
Area 3-Steam



ENLARGED STEAM SITE PLAN – AREA 3 EXISTING

Area 3 includes West Campus, the main focus of this Report.

09 West Campus Heating Type

This West Campus Map identifies how the individual buildings are locally heated. The red buildings contain local steam to hot water heat exchangers which convert energy from the steam to a local building hot water loop. The orange buildings contain steam distribution within the building itself. These orange colored buildings can be converted to a local water heating source if renovated in the future, but for now must remain on steam.

ENLARGED STEAM SITE PLAN – AREA 3 EXISTING HEATING

10 West Campus Heating Intensity

ENLARGED STEAM SITE PLAN – AREA 3 HEATING INTENSITY

This plan shows the relative intensity of the West Campus heating loads. The diameter of the circle is proportional to the intensity of the heating load. The Red circles represent water heated buildings where as the orange circles represent the direct steam heated buildings. The Purple areas show the relative intensity of future heating loads.

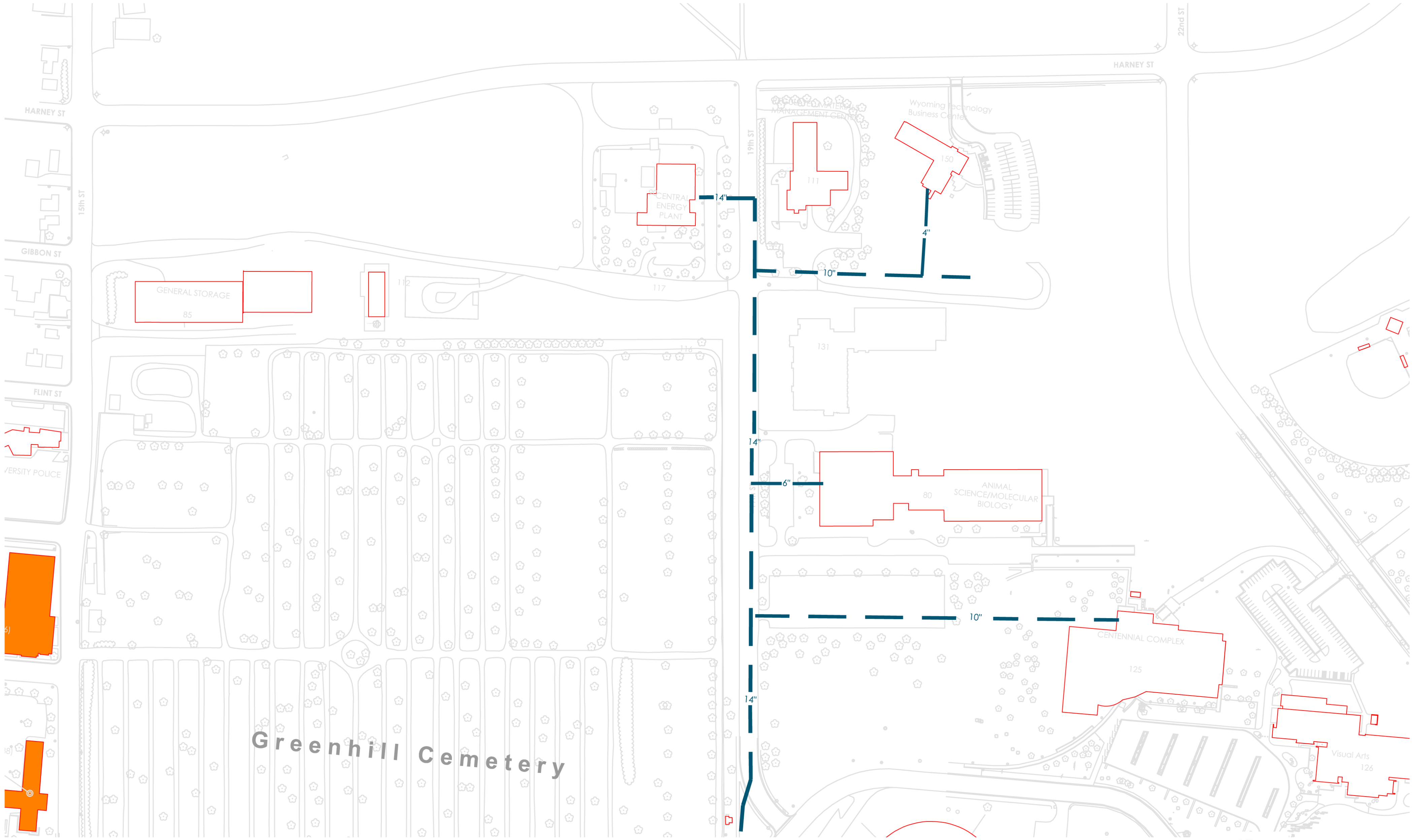
11 Existing Site Chilled Water Distribution

Campus Map-CHW
Area 1-Chilled Water
Area 2-Chilled Water
Area 3-Chilled Water
West Campus Building Cooling Type

This overall existing campus chilled water distribution piping plan shows approximate routings of mains throughout campus. Most chilled water piping is direct buried. See accompanying drawings for enlarged area plans.

OVERALL CHILLED WATER SITE PLAN EXISTING

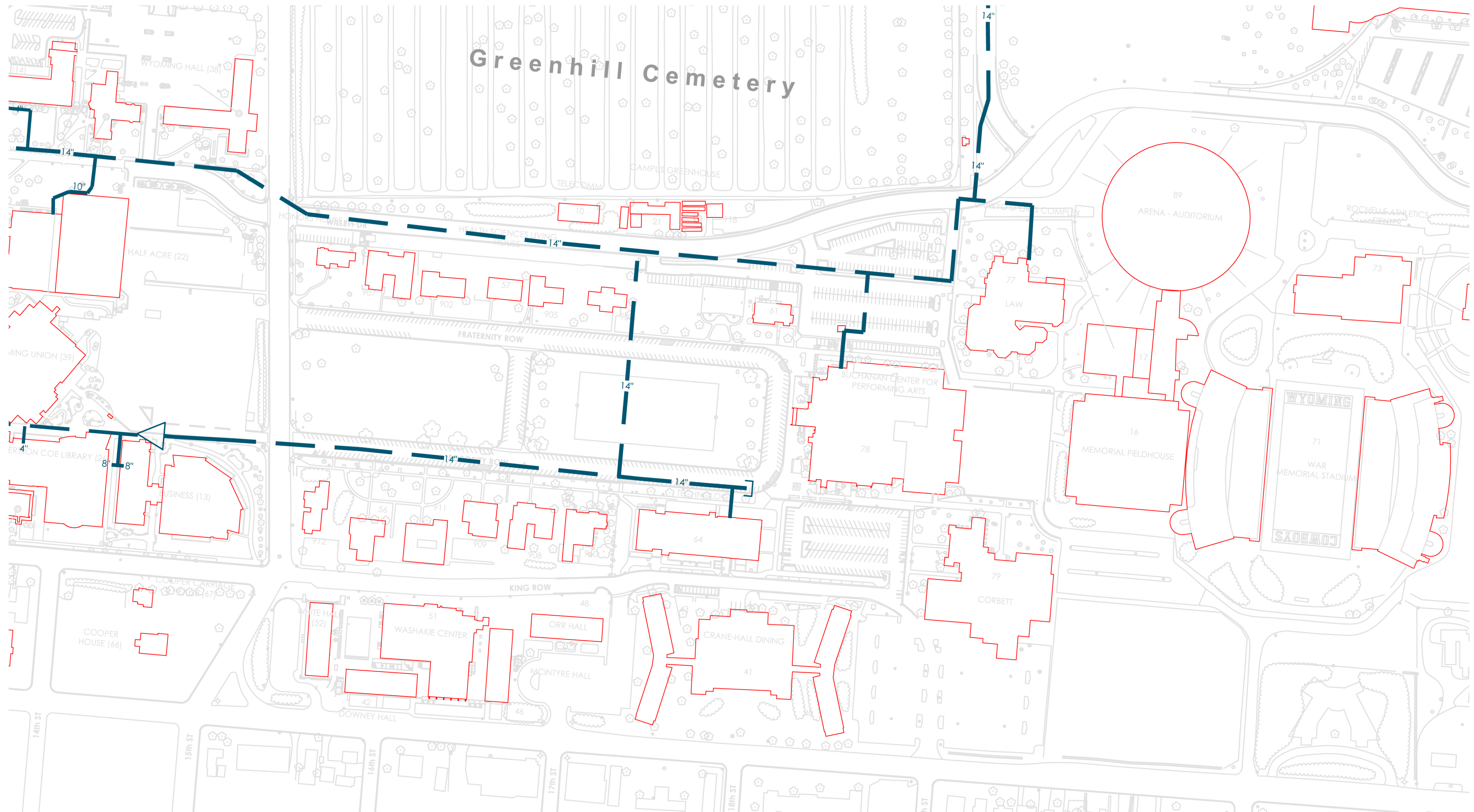
11 Existing Site Chilled Water Distribution



ENLARGED CHILLED WATER SITE PLAN AREA – 1 EXISTING

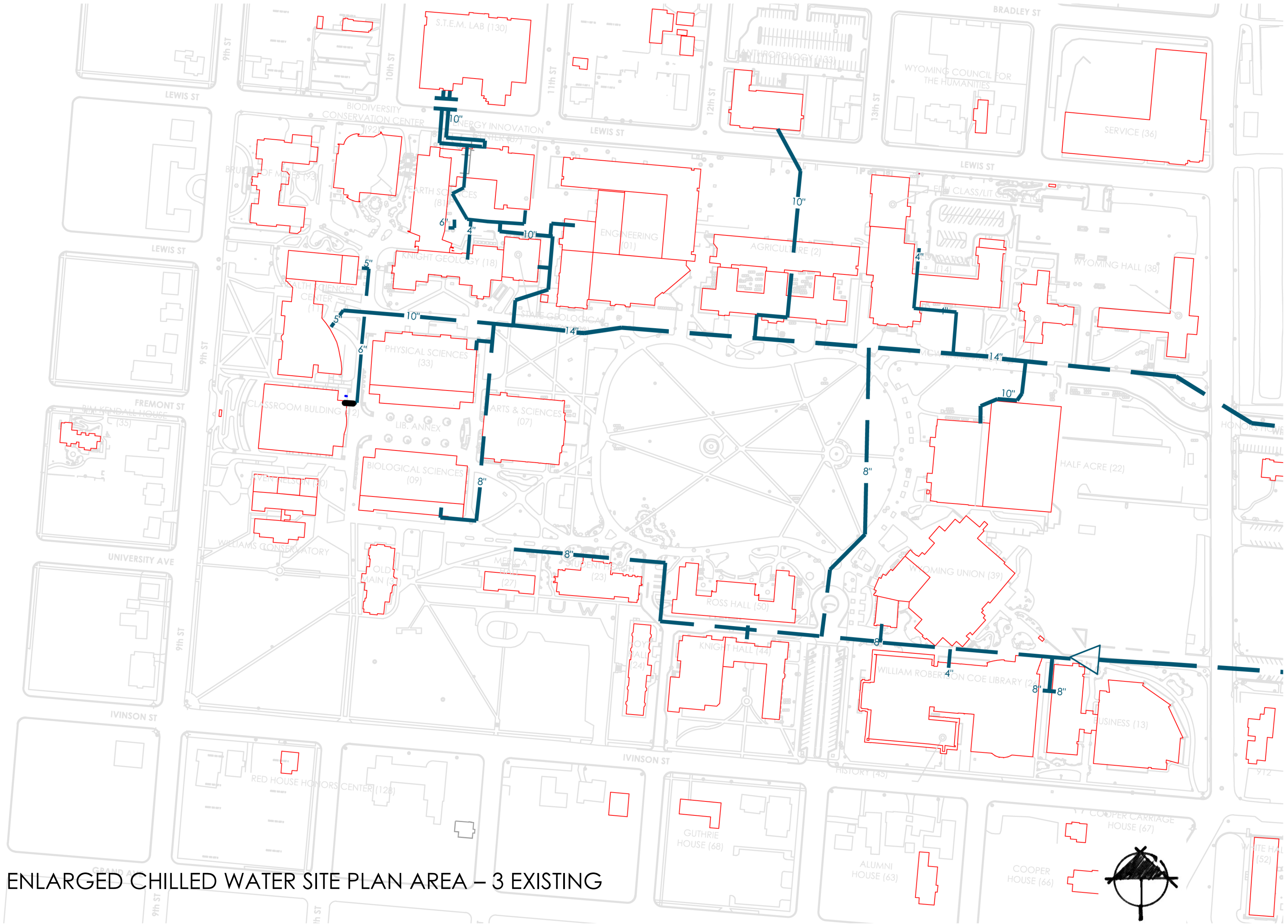
11 Existing Site Chilled Water Distribution

Campus Map-CHW
Area 1-Chilled Water
Area 2-Chilled Water
Area 3-Chilled Water
West Campus Building Cooling Type



ENLARGED CHILLED WATER SITE PLAN AREA – 2 EXISTING

11 Existing Site Chilled Water Distribution

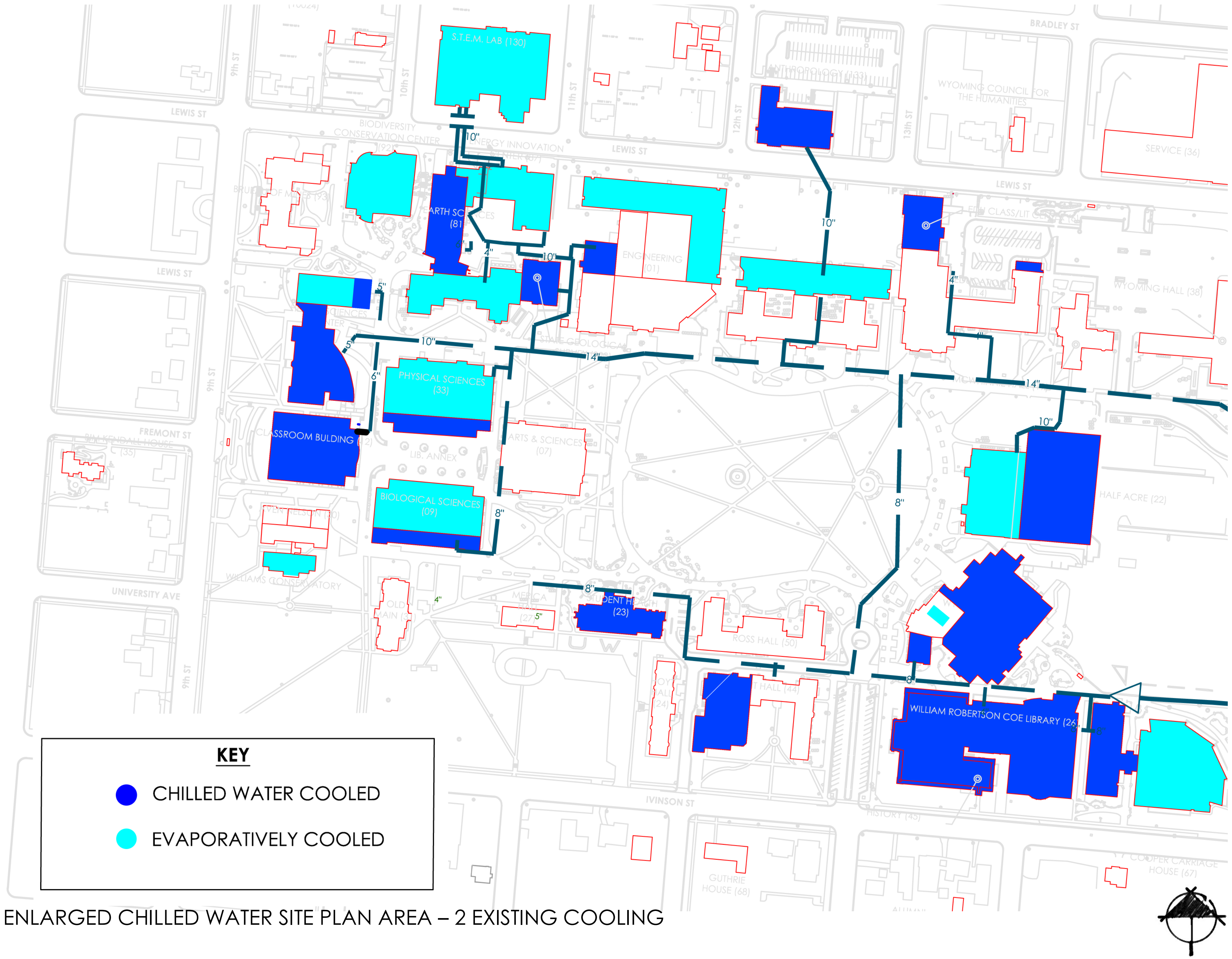


ENLARGED CHILLED WATER SITE PLAN AREA – 3 EXISTING

11 Existing Site Chilled Water Distribution

Campus Map-CHW
Area 1-Chilled Water
Area 2-Chilled Water
Area 3-Chilled Water
West Campus Building Cooling Type

This West Campus Map identifies how the individual buildings are locally cooled. The dark blue buildings contain CEP chilled water coils. The Light blue buildings represent local evaporatively cooled buildings.



ENLARGED CHILLED WATER SITE PLAN AREA – 2 EXISTING COOLING

End of Section 3

This Page Left Intentionally Blank

Section 4: Analysis and Investigative Options

Section 4 Summary

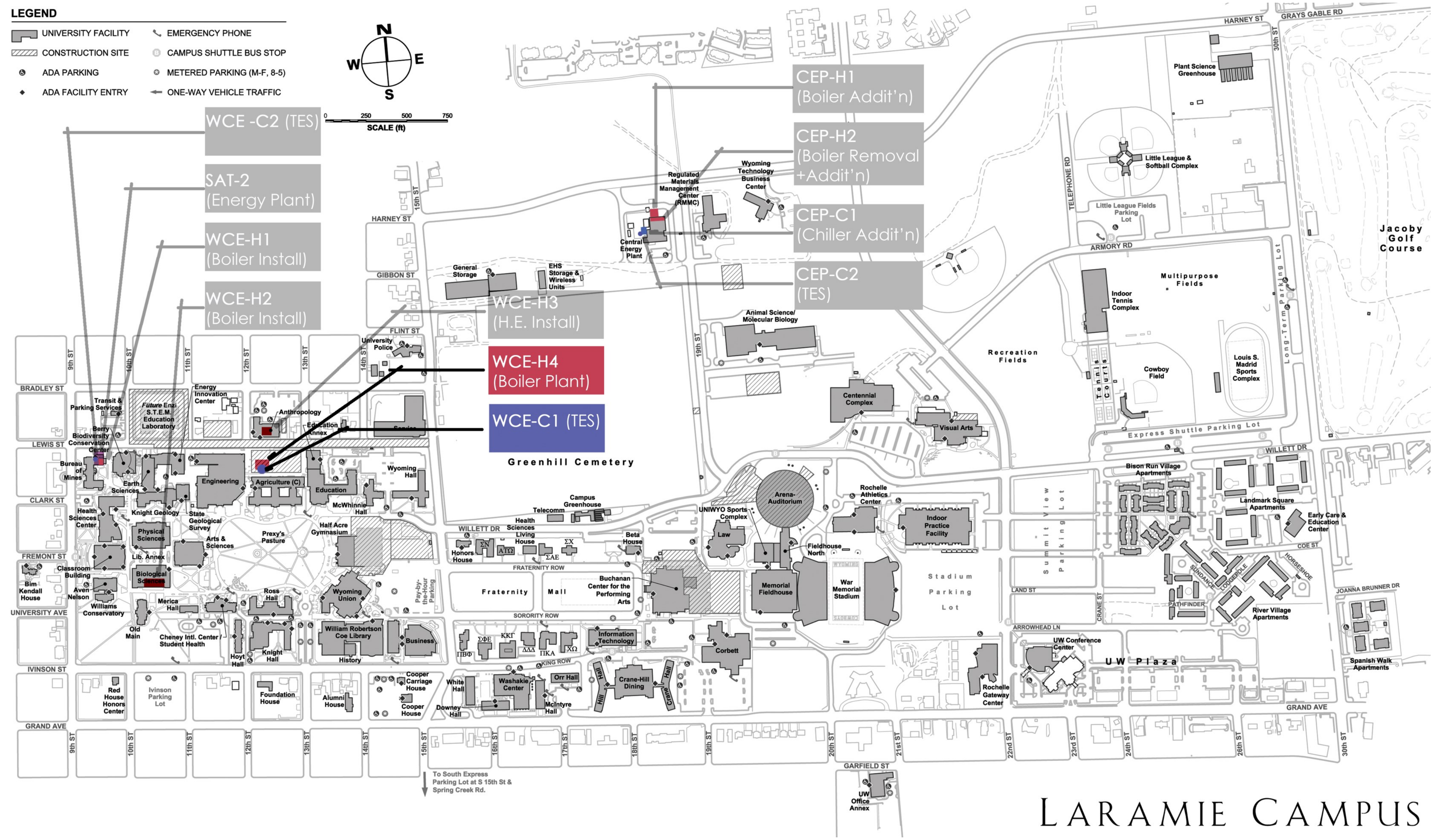
This section provides information regarding the initial study phase of the analysis. Various heating, cooling, and architectural solutions were explored. See Section 5 of this report for information regarding the proposed recommended solution.

01 Option Summary Map

Central Energy Plant (CEP)

- **Heating Option 1** (CEP-H1) Plant addition plus new boiler .
- **Heating Option 2** (CEP-H2) Existing boiler removal and addition.
- **Cooling Option 1** (CEP-C1) Plant addition plus new chiller.
- **Cooling Option 2** (CEP-C2) Add thermal energy storage (TES) tank.

Campus Map



Satellite Plant (SAT)

- **Heating/Cooling Option 1** (SAT-1) New satellite plant with modular hydronic boilers plus chillers.
- **Heating/Cooling Option 2** (SAT-2) New satellite plant with modular hydronic boilers plus chillers.

West Campus Energy (WCE)

- **Cooling Option 1** (WCE-C1) Add thermal energy storage (TES) tank.
- **Cooling Option 2** (WCE-C2) Add thermal energy storage (TES) tank.
- **Heating Option 1** (WCE-H1) Add modular hydronic boilers to existing space at Bureau of Mines storage area.
- **Heating Option 2** (WCE-H2) Add modular hydronic boilers to existing space at basement of Biological Sciences.
- **Heating Option 3** (WCE-H3) Add modular Steam to Water Heat Exchangers to existing space in Anthropology. Location to be determined.

Central Energy Plant Expansion Options CEP-C1, CEP-C2, CEP-H1, and CEP-H2 Technical Summary

Both CEP cooling options CEP-C1 and CEP-C2 include chilled water expansion equipment at the CEP and would require upgrades to the chilled water production and distribution systems. The current CHW load exceeds the plant firm capacity. If an expansion to the existing CEP is the path forward, it is recommended that a chiller capacity increase be installed. This will provide proper N+1 redundancy in equipment. From a flow design standpoint, the existing plant chilled water header piping (14") is sufficient in size to handle up to 5,000 gpm or 2,100 tons at a 10F DT before velocities and corresponding pressure drops become problematic. New or additional chilled water air separators would be required to manage the inherently high pressure drop across this equipment. An additional 1,000 tons of heat exchanger capacity would also be necessary to take full advantage of hydronic economizer throughout the dry, off peak seasons. A 14" CEP west chilled water feed would be required to supply chilled water to west campus. This would be necessary to reduce total peak pumping horsepower by approximately 575. This extra HP would be required to overcome the pressure losses associated with undersized distribution piping. For the 30 year buildout scenario and number of hours operating at higher flows, an estimated $50,000 per year of extra pumping energy would be witnessed if the west campus feed is not installed.

CEP Options CEP-H1 and CEP-H2 include modification to the steam system at the CEP. Option H1 would construct an addition to the CEP plant and provide accommodations for additional steam boiler capacity. Option H2 would involve the removal of an existing boiler and installation of a new natural gas steam boiler. Both of these options were removed from the analysis as additional steam boiler capacity would only perpetuate the distribution issues identified in previous section of this analysis.

The new 4000A 480/277V Eaton switchgear in the central Energy Plant (CEP) has plenty of spare capacity for proposed load increases, including space for a new 1600A bucket and (2) 800A spares. The maximum recorded demand on the new gear is 826 kW or 1033 kVA at 0.8 power factor. The 2500 kVA/3125 kVA 12.4 kV-480/277V transformers serving the board and fed from West Campus and East Campus Substations are capable of providing normal power redundancy, and we anticipate that each 1250 kW Cummins generator will continue to provide redundant standby power after the completion of any of these proposed expansions.

For CEP-C1 (CEP Chiller Addition) and CEP-C2 (CEP Thermal Storage Tank), utilize one of the spare 800A buckets in the new switchgear to serve a new distribution board for the new chiller and/or auxiliary pumps. For CEP-H1 (CEP Boiler Addition) and CEP-H2 (CEP Boiler Replacement), reuse of existing motor control centers may be acceptable for nominal electrical load increases. The motor control centers are approaching the end of useful life, so it may be worth considering replacing the affected MCC.

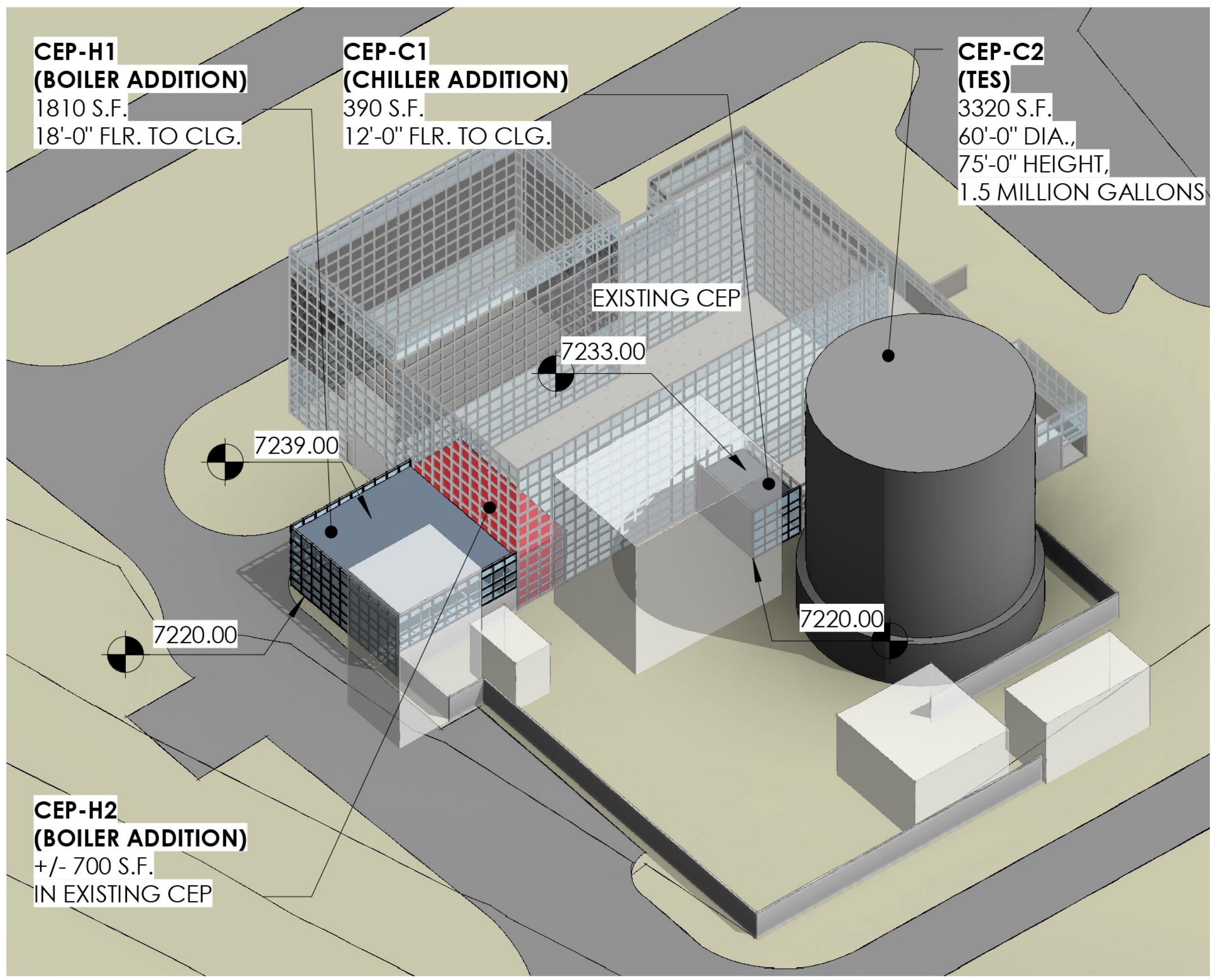
02 Central Energy Plant Expansion Options

CEP-H1 Boiler Addition

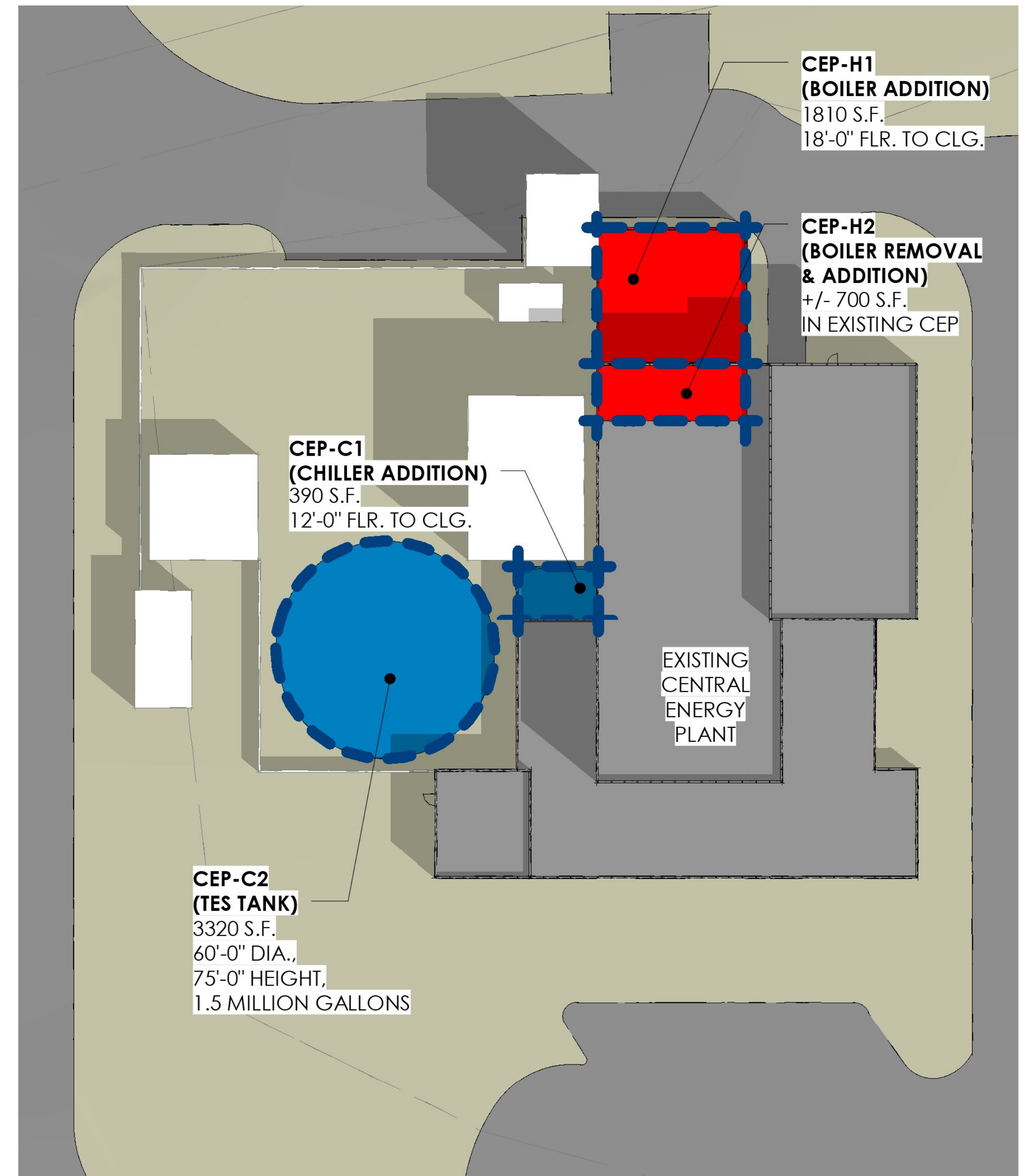
CEP-H2 Boiler Removal and Addition

CEP-C1 Chiller Addition

CEP-C2 Thermal Energy Storage at CEP



2 CEP-ALL OPTIONS_ ISOMETRIC VIEW



1 CEP SITE PLAN_ALL OPTIONS
1" = 50'-0"

CEP-C1-CENTRAL ENERGY PLANT-CHILLER ADDITION

This Central Energy Plant Expansion Option includes an increase in chilled water production capacity to provide N+1 redundancy until projected year 2025. After this point in time when the campus chilled water load is above 2,400 tons, additional chillers would be required to be installed at this location or another. Major components of the CEP-C1 option include:

- (1) 1,200 ton chiller
- (1) 1,200 ton cooling tower with remote sump and pump vaults
- (2) 500 ton plate and frame heat exchangers
- Approximately 5,000 linear feet of 14" direct buried CHWS/R piping
- Plant chilled and condenser water piping
- CEP chiller bay addition

CEP-C2-CENTRAL ENERGY PLANT-THERMAL ENERGY STORAGE

This Central Energy Plant Expansion option includes all of the upgrades identified in Option CEP-C1 along with the means to store energy in the form of a chilled water storage tank. This would allow the plant to generate and store chilled water during off peak hours when the electric rate is low and the nighttime conditions more conducive to cooling tower performance. During projected peak conditions of the 5 Year Buildout Scenario, the proposed 1.5 million gallon TES tank would require a peak instantaneous chiller load of 1,800 tons. This would provide the capacity to satisfy evening instantaneous cooling load as well as charge the storage tank for the next day's use. Even with the University's funded project to replace the existing 800T McQuay chiller with a new 1,200 ton machine, this instantaneous load is above firm capacity. For redundancy purposes, it is recommended that an additional chiller be included in this project for this expansion option. Major new items for the CEP-C2 option would include:

(1) 1.5 million gallon steel storage tank and associated CHW pumps
(1) 1,200 ton chiller
(1) 1,200 ton cooling tower with remote sump and pump vaults
(2) 500 ton plate and frame heat exchangers
Approximately 5,000 linear feet of 14" direct buried CHWS/R piping
Plant chilled and condenser water piping
CEP chiller bay addition

02 Central Energy Plant Expansion Options

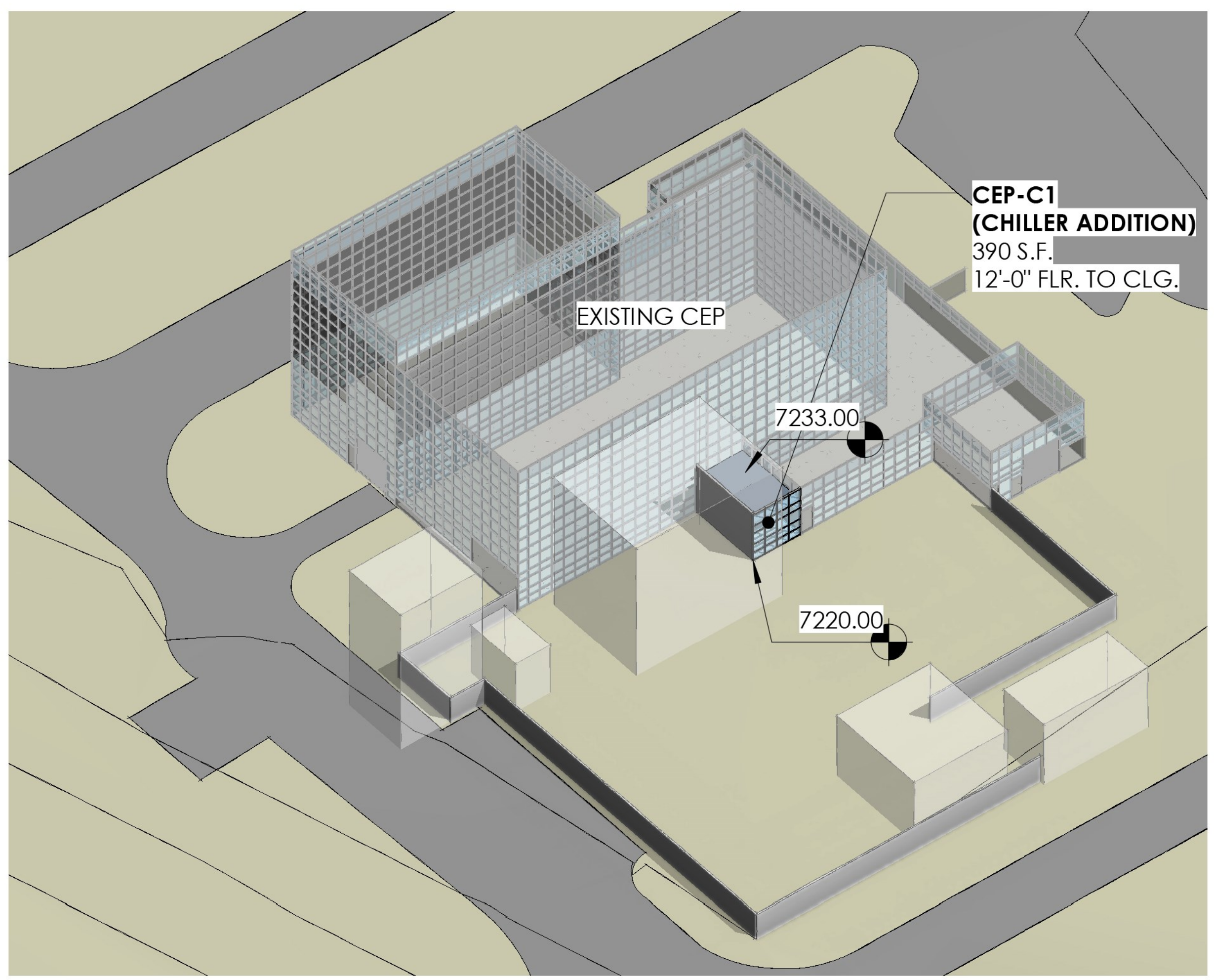
CEP-H1-Boiler Addition

CEP-H2-Boiler Removal and Addition

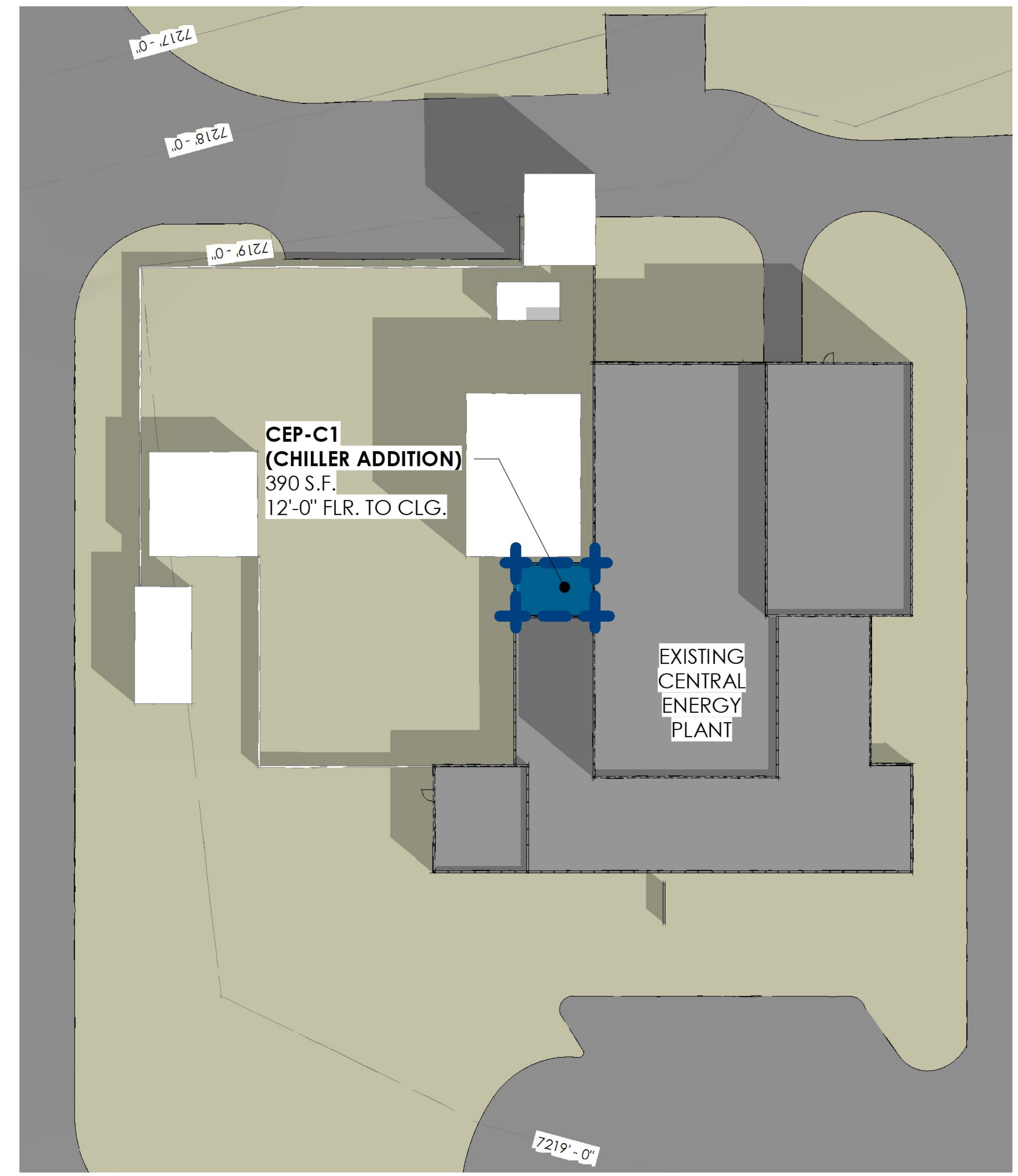
CEP-C1-Chiller Addition

CEP-C2-Thermal Energy Storage at CEP

02 Central Energy Plant Expansion Options



2 CEP-C1_ ISOMETRIC VIEW

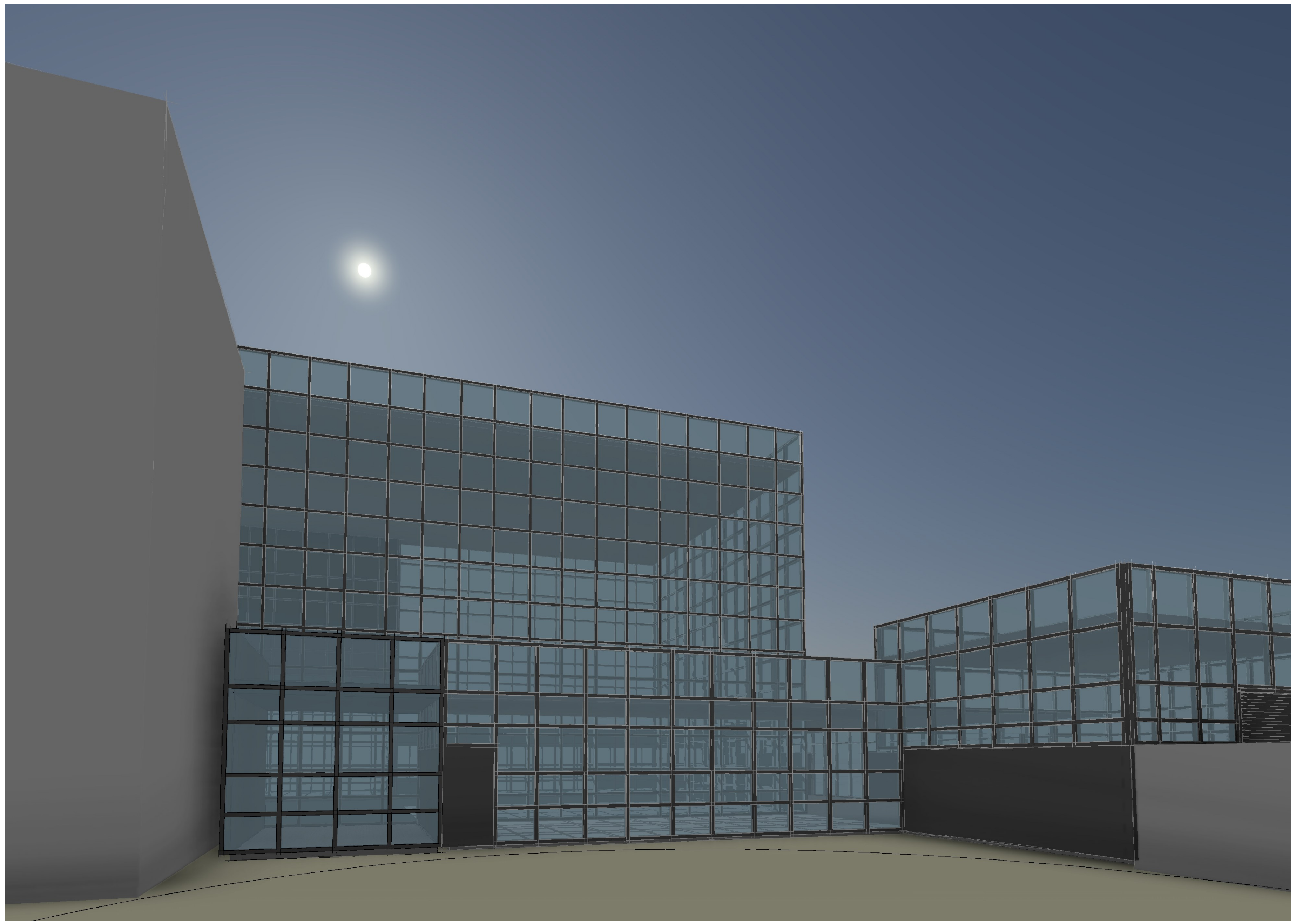


1 CEP SITE PLAN_CEP C1
1" = 50'-0"

02 Central Energy Plant Expansion Options

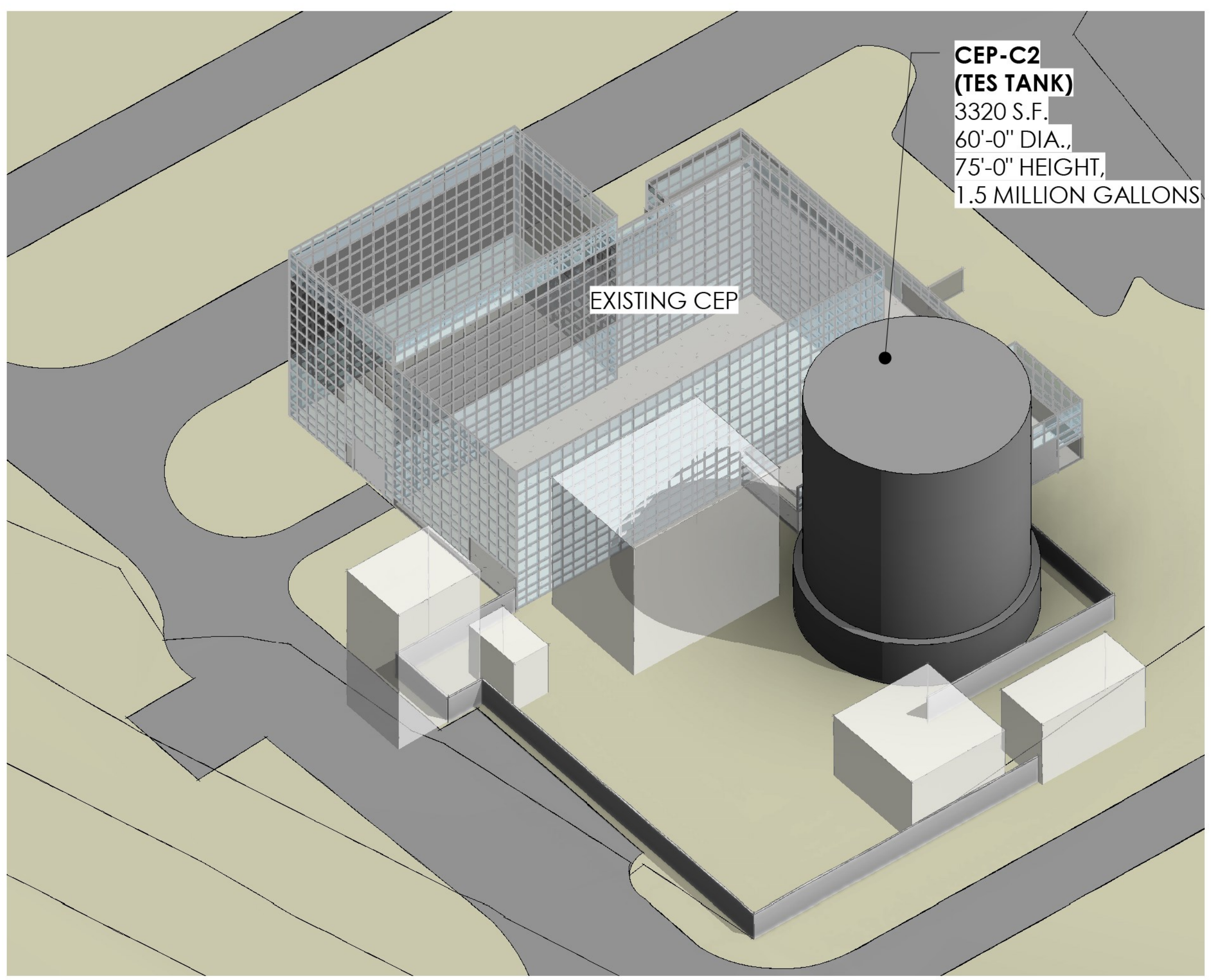
CEP-C1, CHILLER ADDITION

Chiller Bay Expansion at CEP (another 1,200 ton of cooling) within a 390 S.F., single story 12'-0" floor to clg. height addition, located at west side of existing CEP.

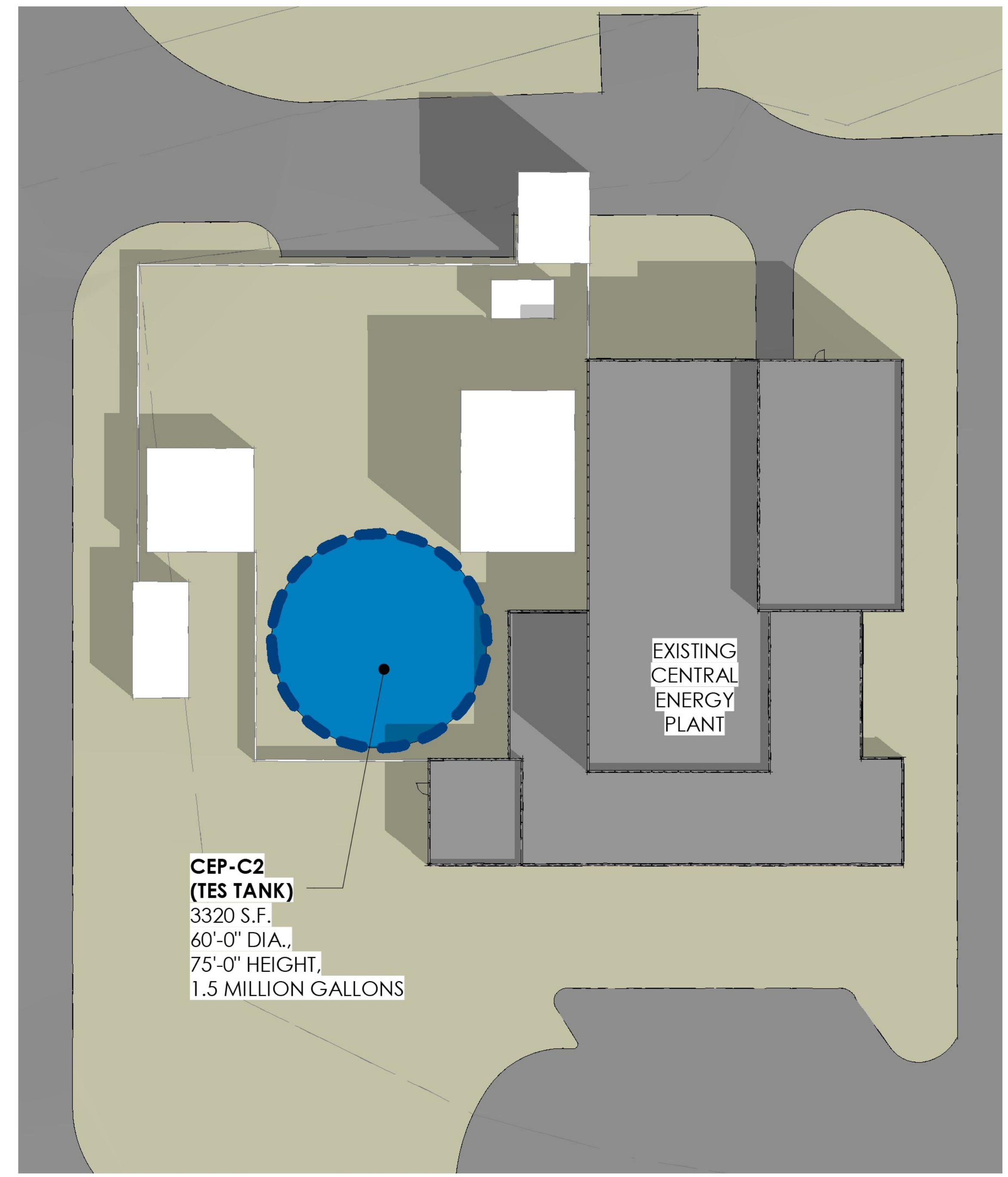


CEP-C1, CHILLER ADDITION PERSPECTIVE VIEW LOOKING EAST FROM WITHIN CENTRAL ENERGY PLANT COURTYARD.

02 Central Energy Plant Expansion Options



2 CEP-C2_ ISOMETRIC VIEW

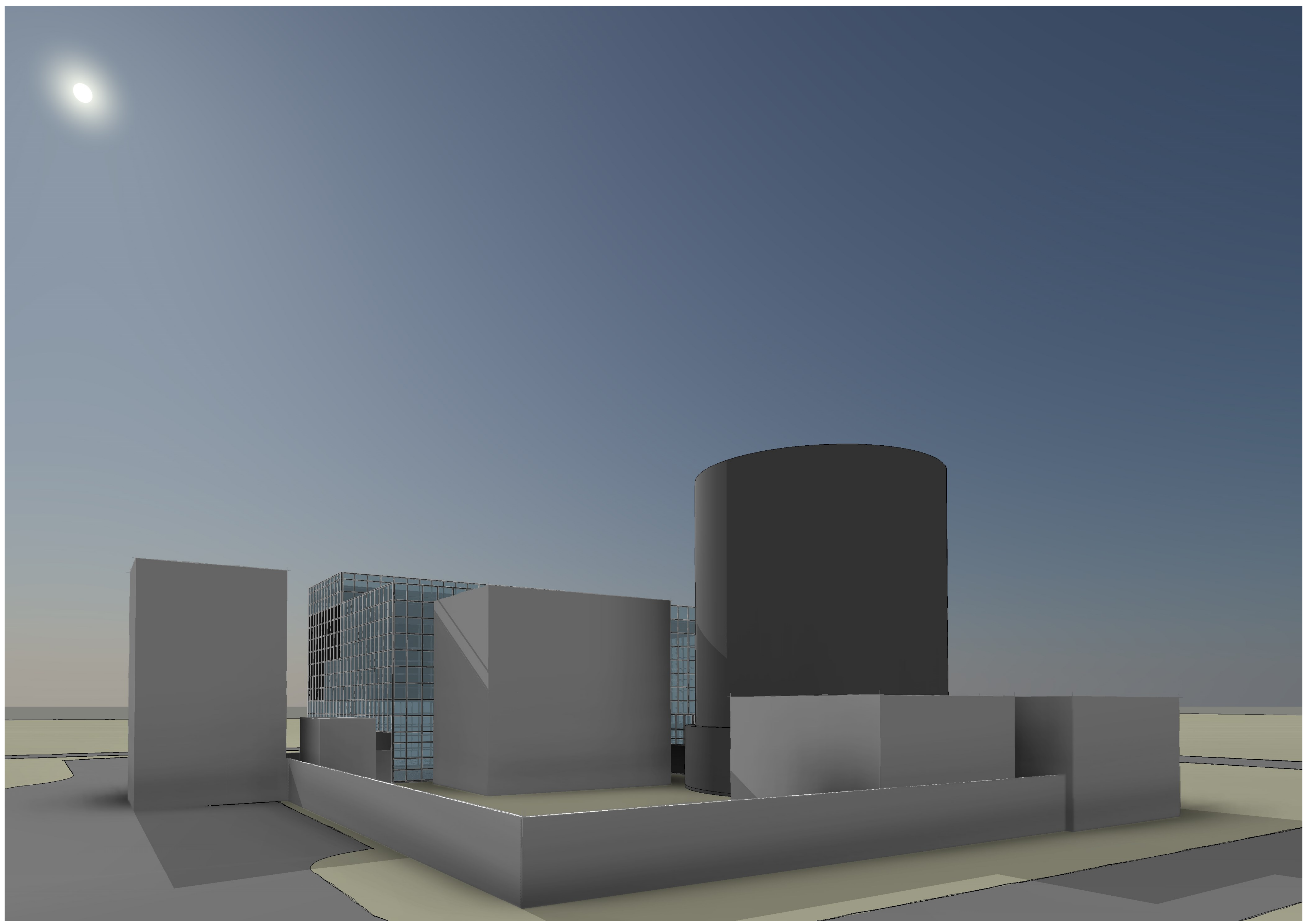


1 CEP SITE PLAN_CEP C2
1" = 50'-0"

02 Central Energy Plant Expansion Options

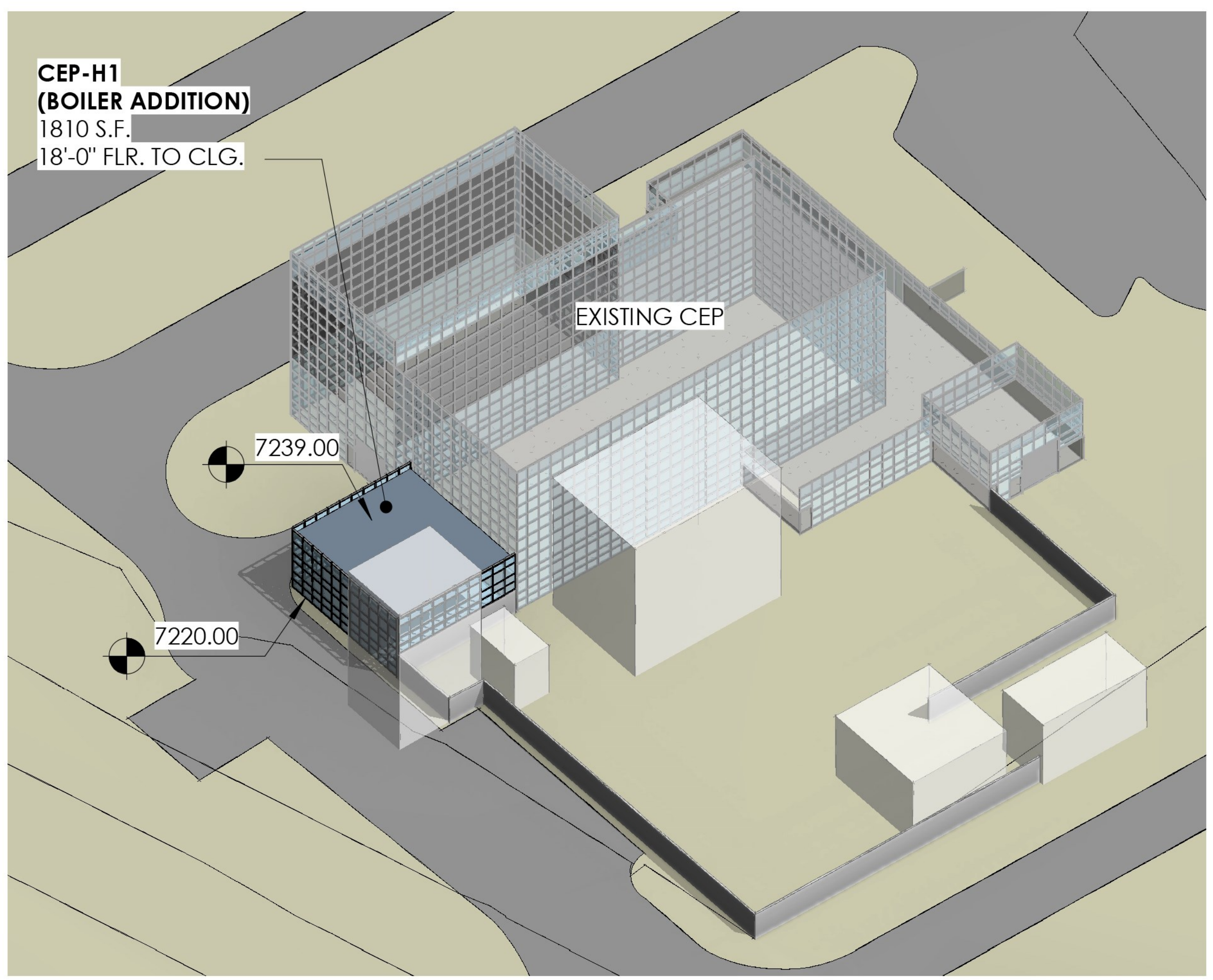
CEP-C2, TES TANK

3320 S.F., 60'-0" diameter tank, 75'-0" tall, 1.5 million gallons storage capacity, located west of CEP. Some reconfiguration of existing site walls may be required to fit within enclosed courtyard in order to provide clearance between existing buildings.

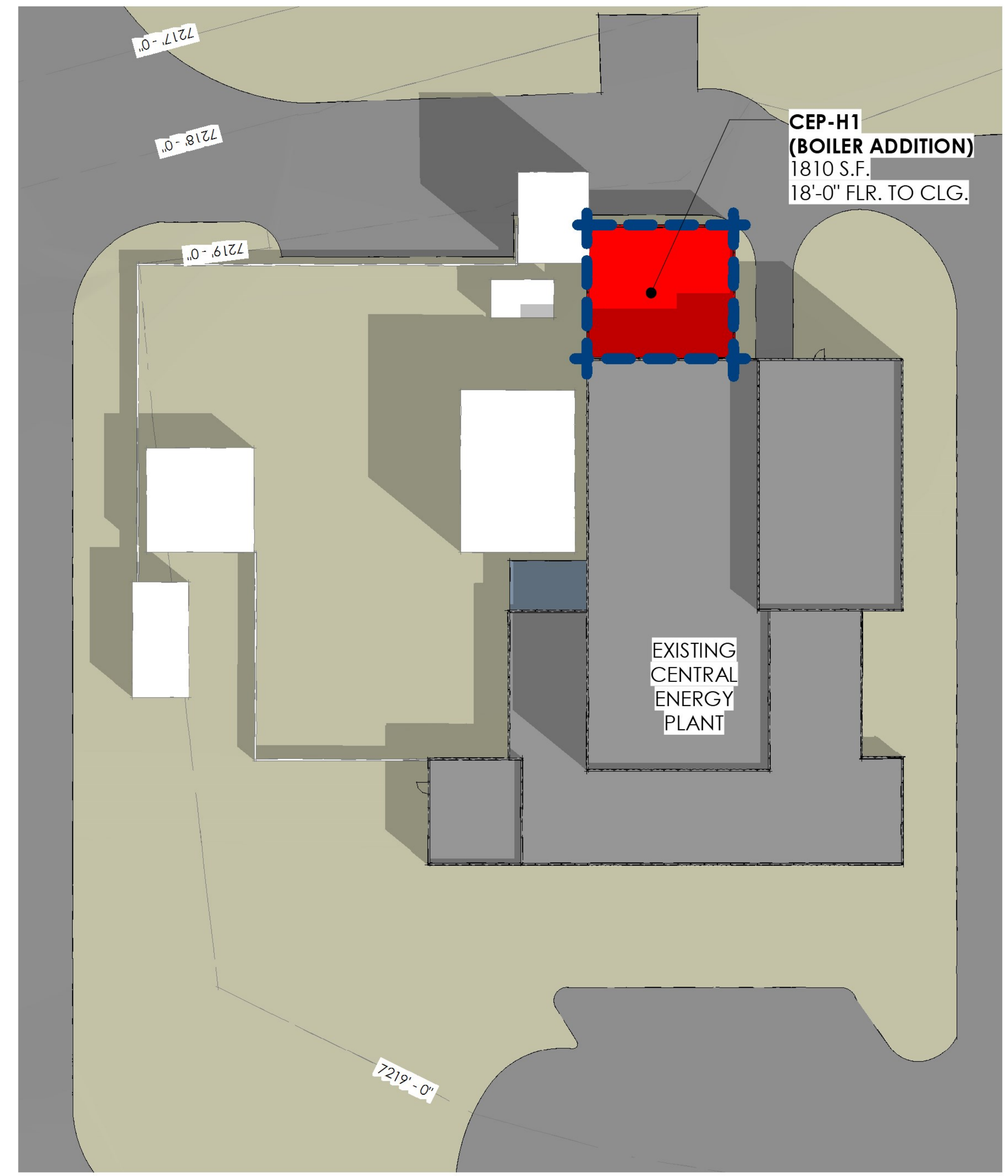


CEP-C2, TES TANK PERSPECTIVE VIEW LOOKING SOUTHEAST FROM NORTHWEST OF CENTRAL ENERGY PLANT COURTYARD.

02 Central Energy Plant Expansion Options



2 CEP-H1_ ISOMETRIC VIEW

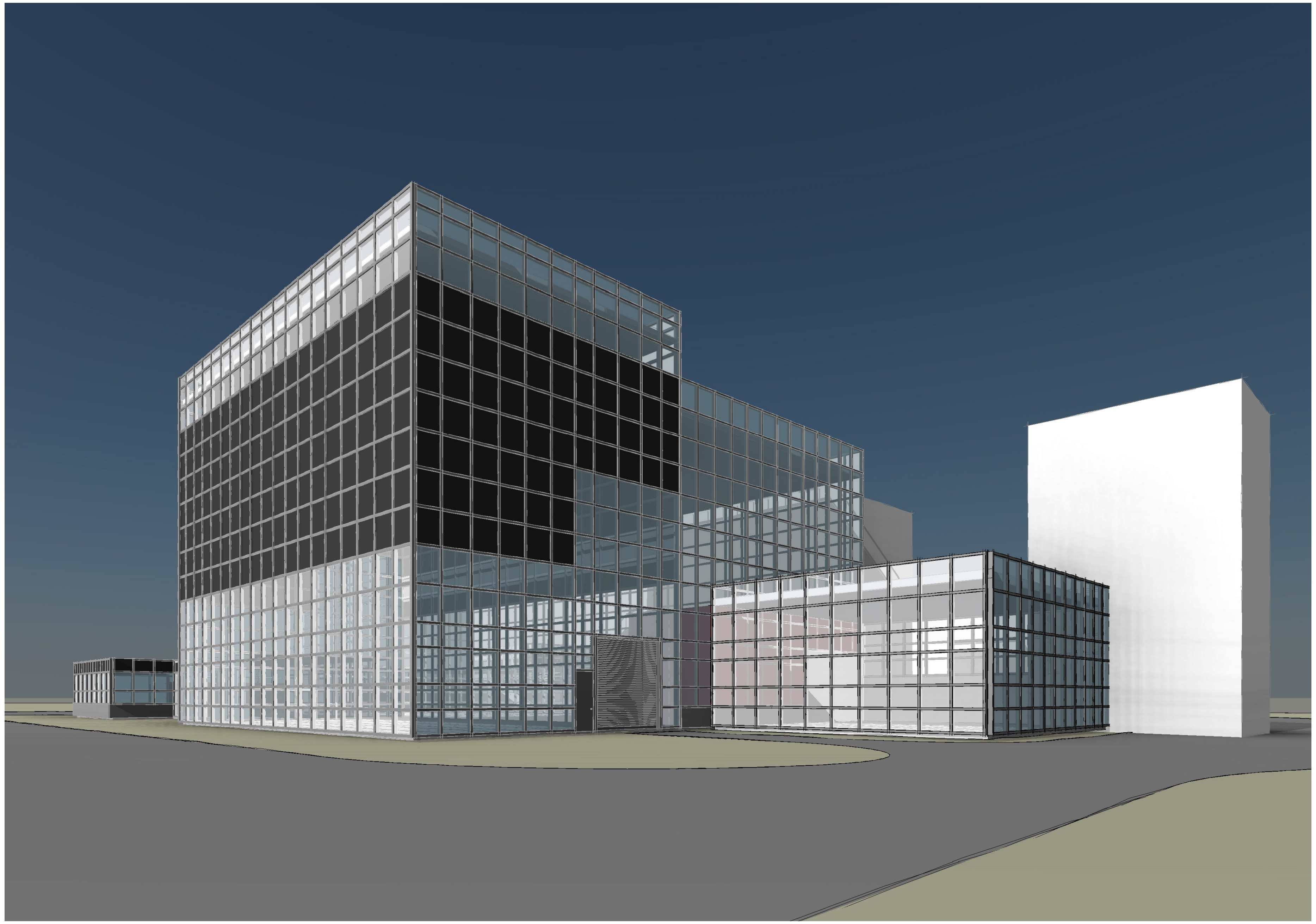


1 CEP SITE PLAN_CEP H1
1" = 50'-0"

02 Central Energy Plant Expansion Options

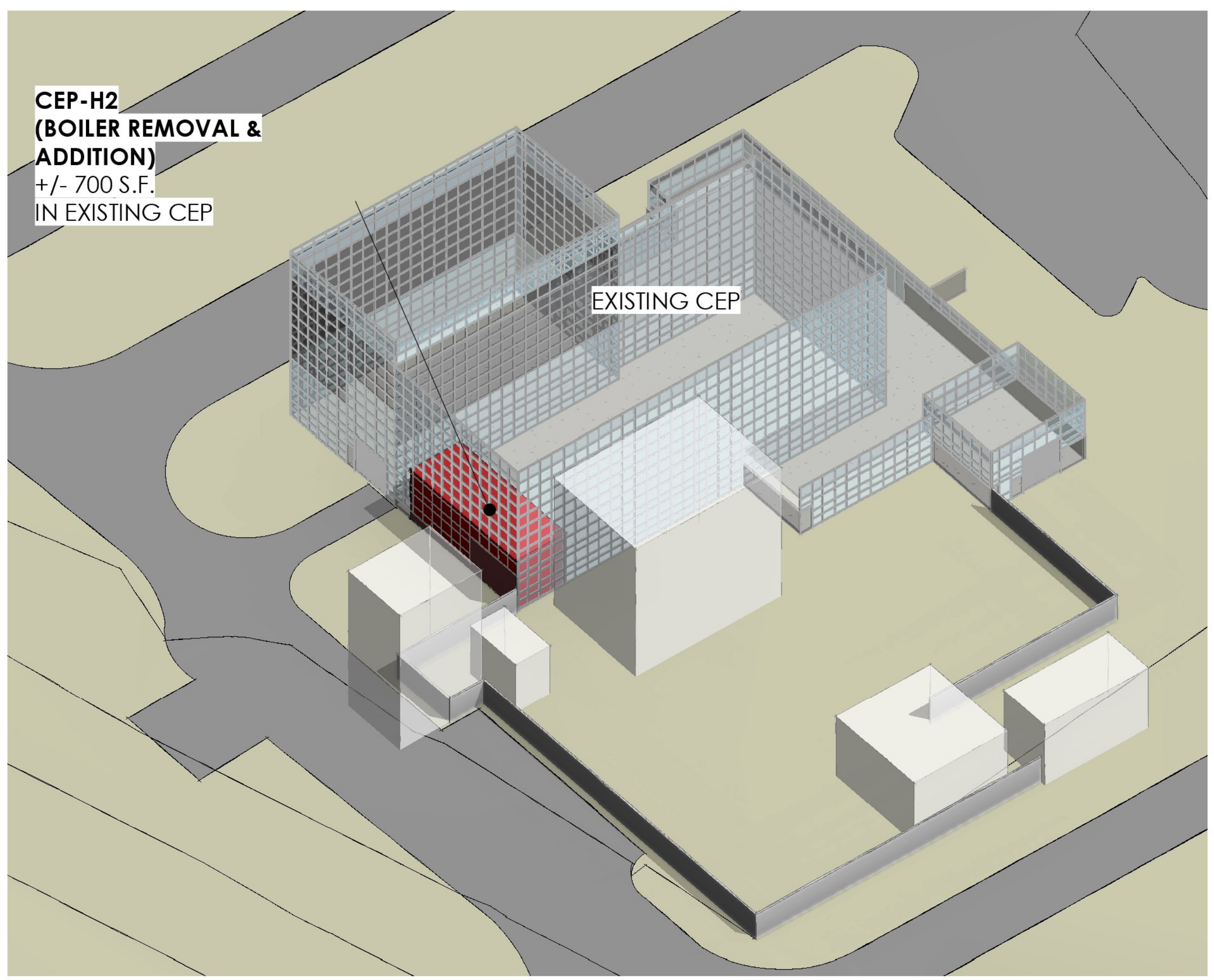
CEP-H1, BOILER ADDITION

Boiler Bay expansion at the CEP (65,000 lb./hr. natural gas boiler). 1810 S.F., single story 18'-0" Floor to clg. Height, located north of the existing CEP.

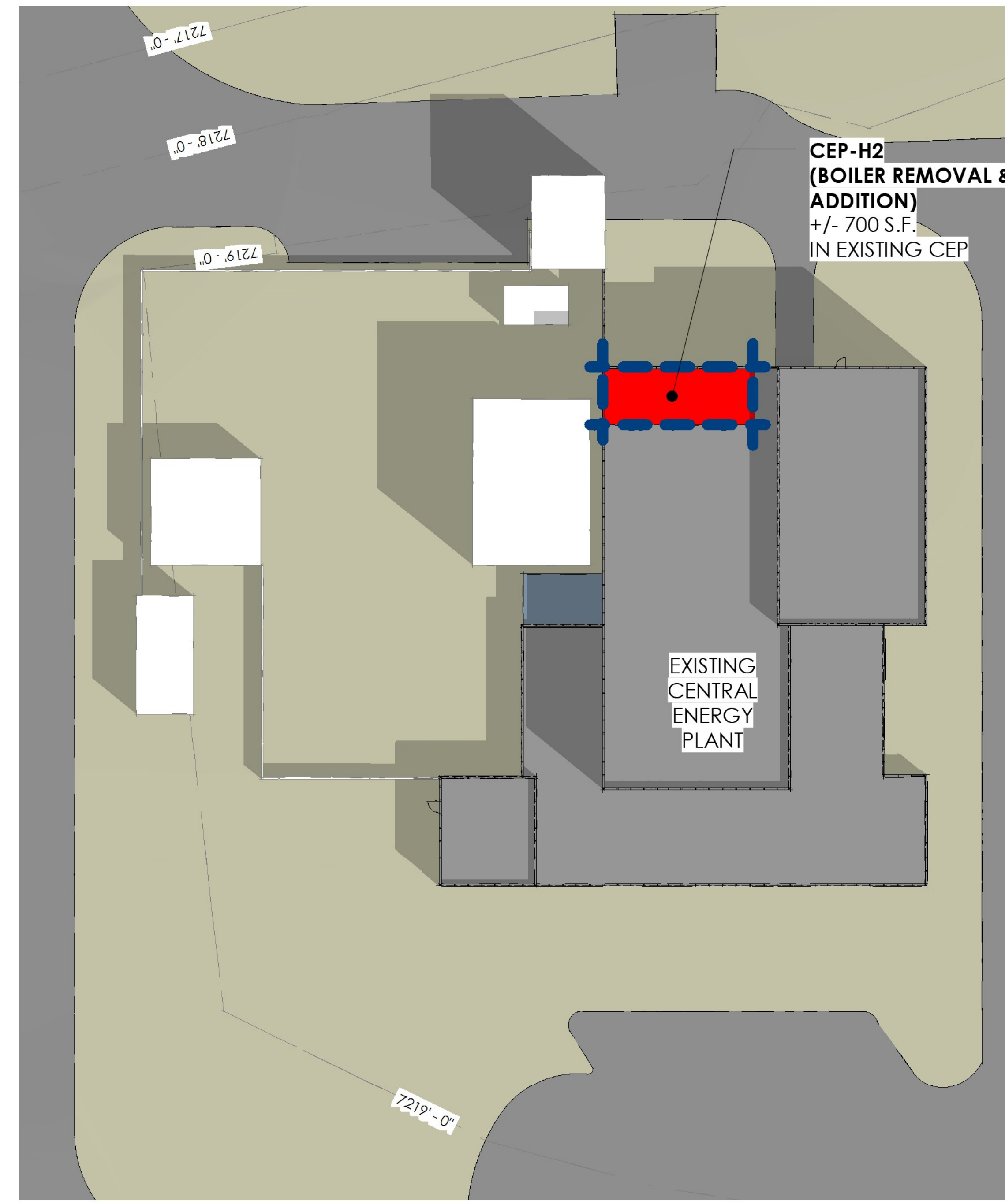


CEP-H1, BOILER ADDITION PERSPECTIVE VIEW LOOKING SOUTHWEST FROM NORTHEAST OF THE CENTRAL ENERGY PLANT.

02 Central Energy Plant Expansion Options



2 CEP-H2_ ISOMETRIC VIEW

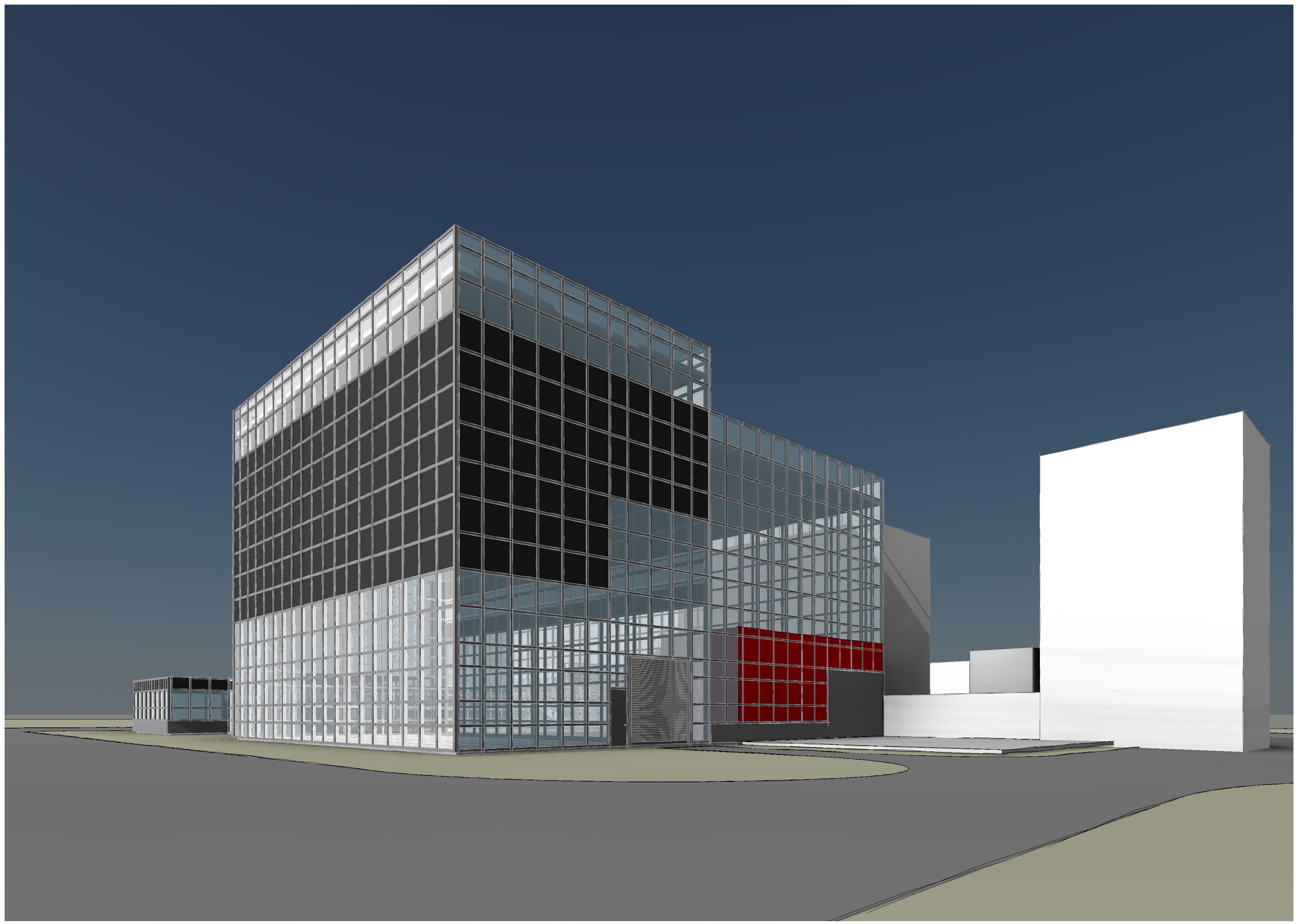


1 CEP SITE PLAN_CEP H2
1" = 50'-0"

02 Central Energy Plant Expansion Options

CEP-H2, BOILER REMOVAL & ADDITION

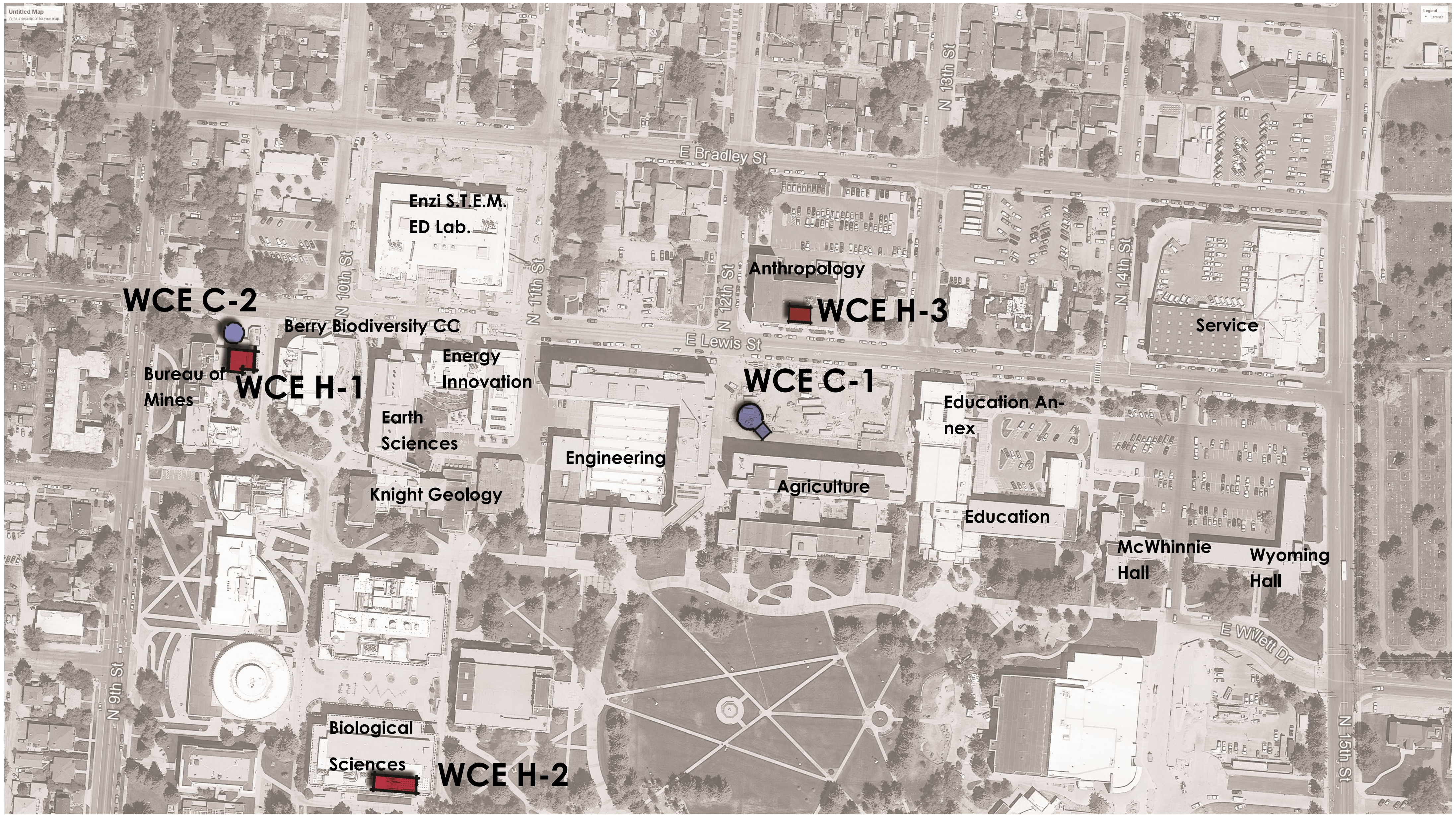
+/- 700 s.f. removal of existing coal boiler and replacement with new natural gas boiler(s) within existing north west corner of CEP.



CEP-H2, BOILER REMOVAL & ADDITION PERSPECTIVE VIEW LOOKING SOUTHWEST FROM NORTHEAST OF THE CENTRAL ENERGY PLANT. RED AREA WITHIN EXISTING REPRESENTS LOCATION OF NEW BOILER.

03 West Campus Expansion Options

This Page Intentionally Left Blank



03 West Campus Expansion Options

WCE C-1 North of Agriculture

Thermal Energy Storage Tank (TES) be located north of Agriculture.

WCE C-2 Bureau of Mines

Thermal Energy Storage Tank (TES) be located north of the Bureau of Mines.

WCE H-1 Bureau of Mines

Repurposing existing storage space for Hydronic Boilers

WCE H-2 Biological Sciences

Utilizing existing mechanical space for Hydronic Boilers in the basement of the Biological Sciences.

WCE H-3 Anthropology

Utilizing existing mechanical space for Steam to Water Heat Exchangers in Anthropology.

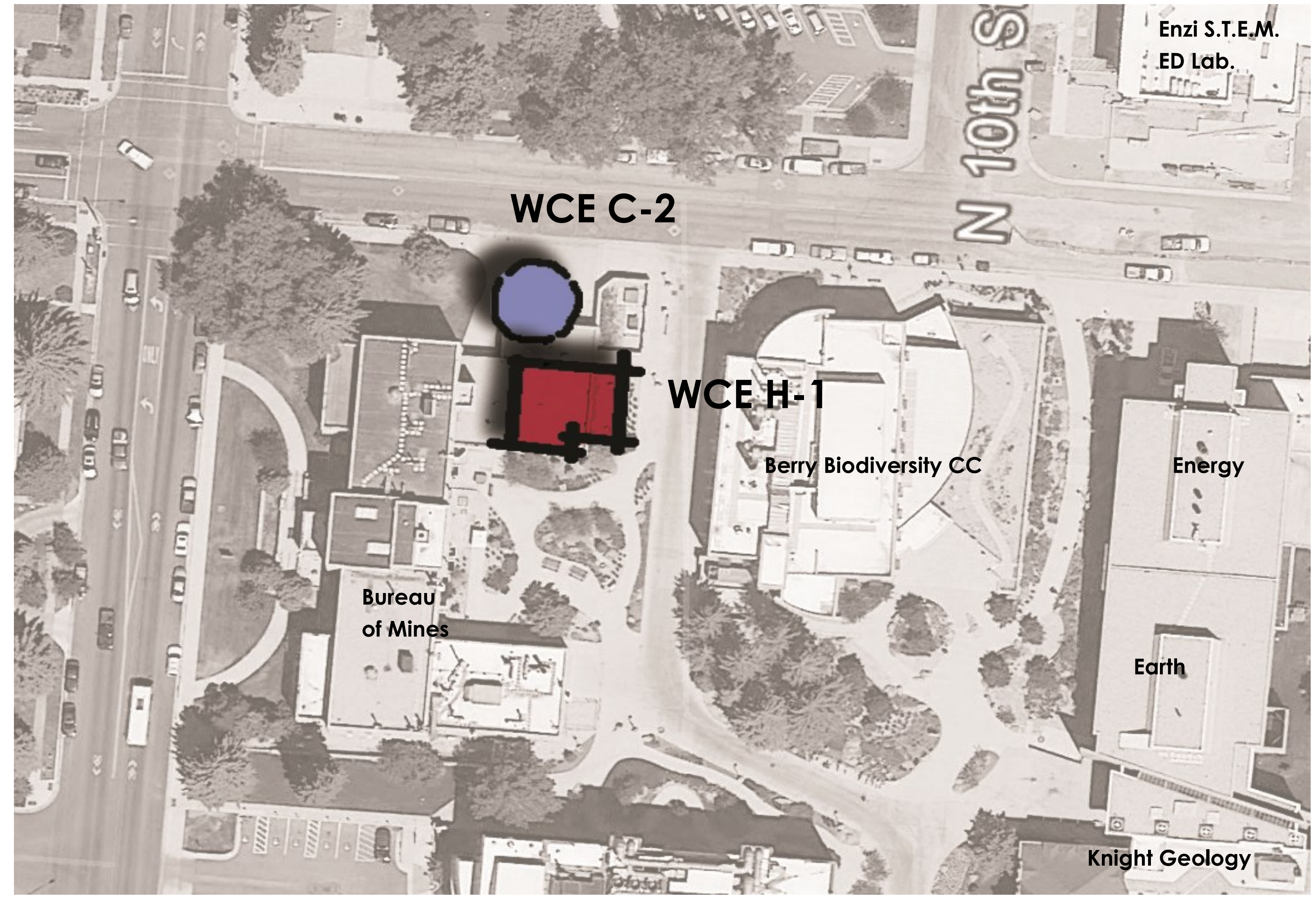
03 West Campus Expansion Options

WCE H-1 Bureau of Mines

This option proposes repurposing existing storage space for Hydronic Boilers in a single story portion of the Bureau of Mines. This location is central to the existing and future loads on this area of campus.

WCE C-2 Bureau of Mines

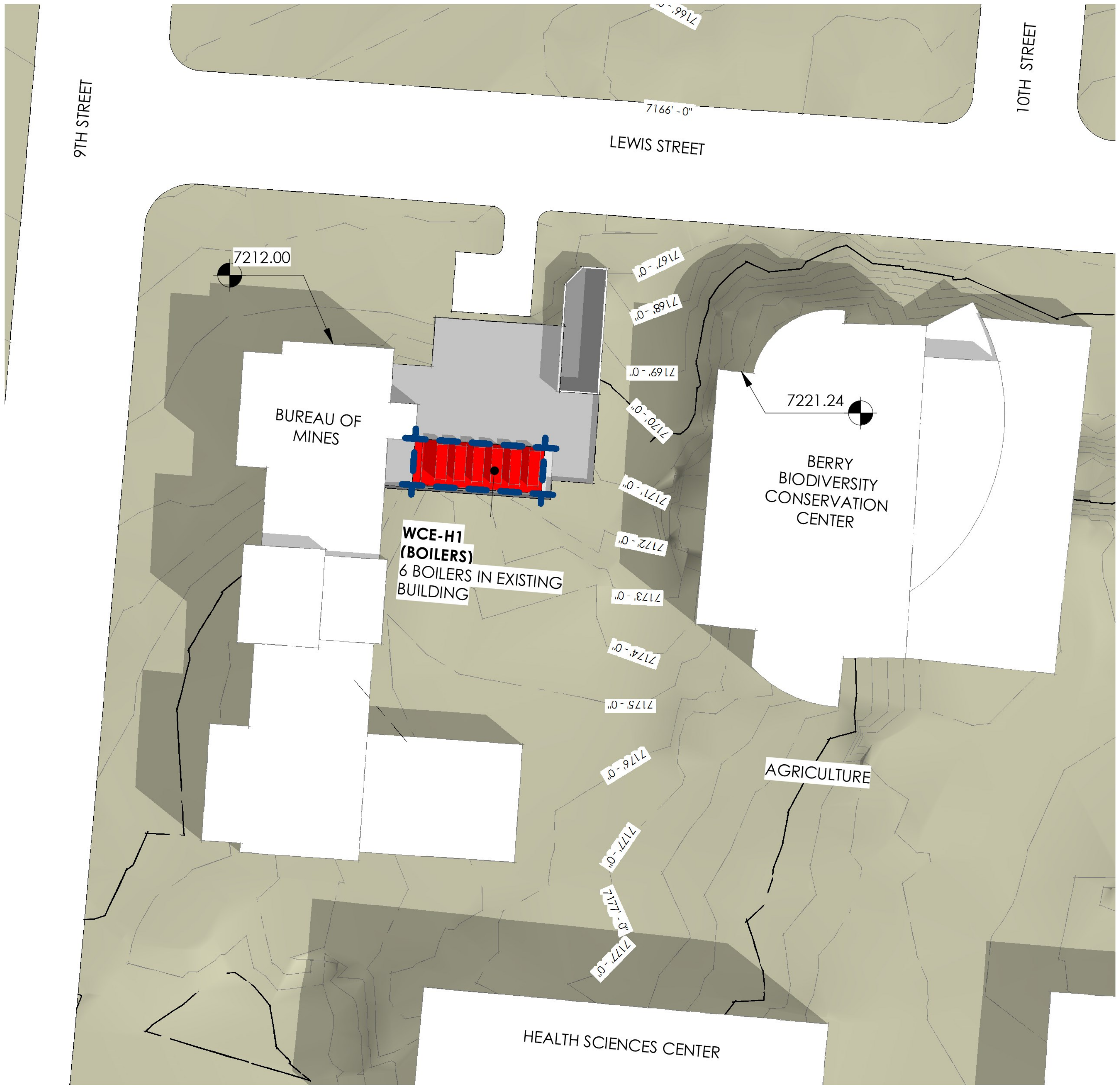
This option proposes a Thermal Energy Storage Tank (TES) be located east of the Bureau of Mines to provide off-peak production storage of chilled water for use during peak loading needs during the day. This location is at the western edge of the existing and future loads requiring added costs to serve these areas. A portion of the existing building would be demolished to accommodate the TES.



03 West Campus Expansion Options

WCE H-1 Bureau of Mines

This option proposes utilizing existing 1 story building to locate new natural gas boilers.

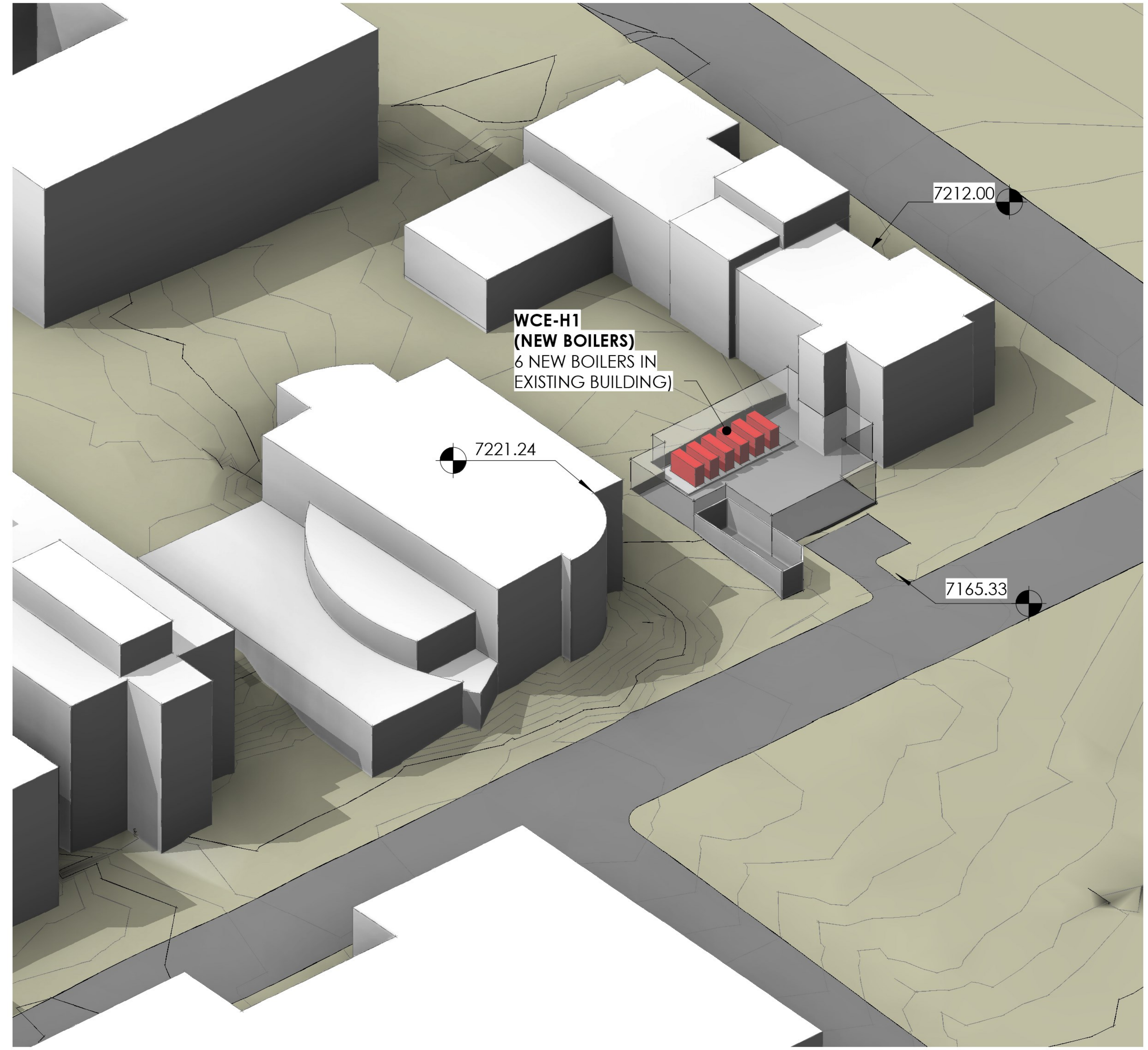


1 WCE-H1 SITE PLAN
1" = 50'-0"

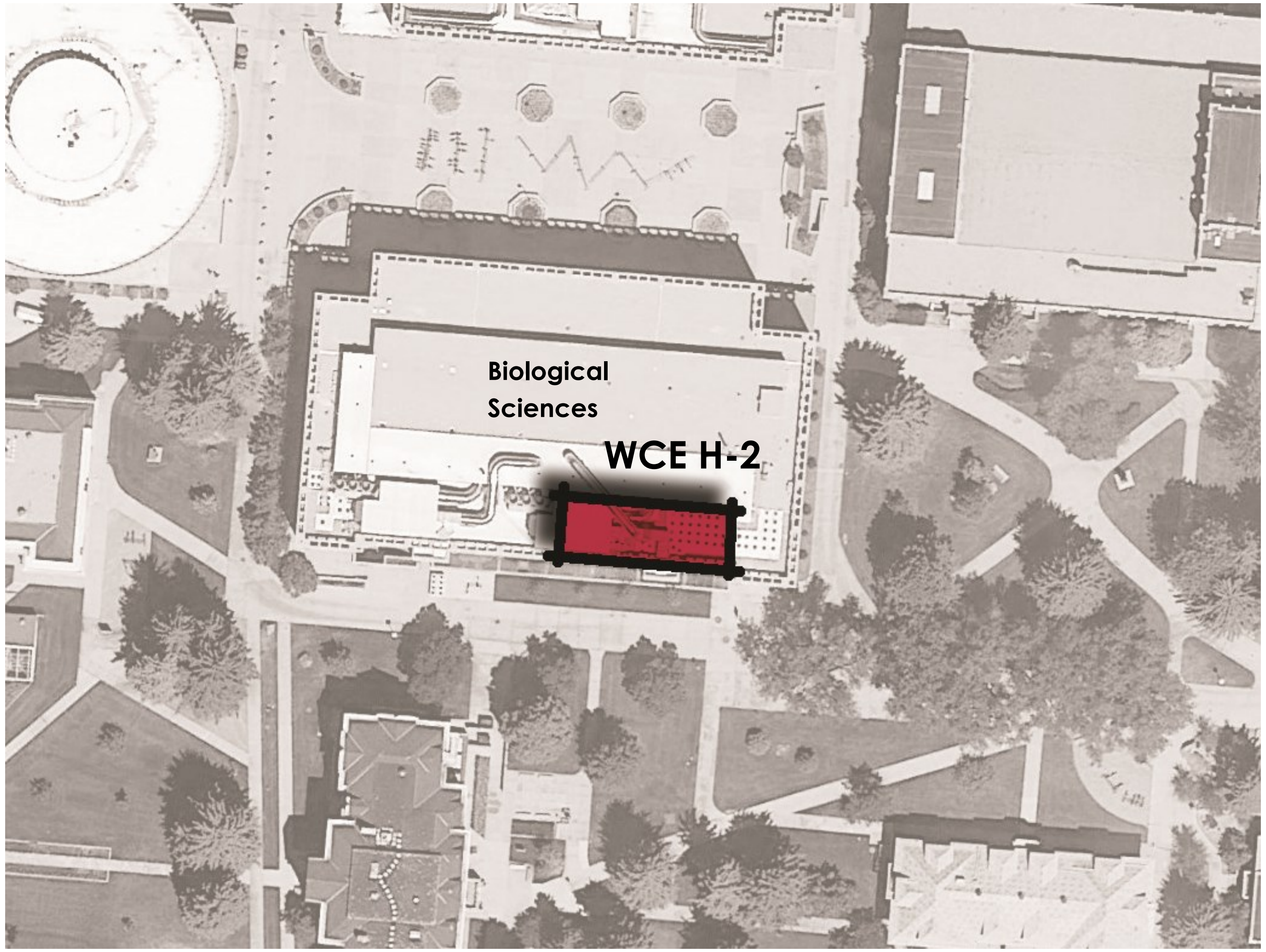
03 West Campus Expansion Options

WCE H-1 Bureau of Mines

Isometric showing existing 1 story building with new natural gas boilers.



1 WCE-H1 ISOMETRIC VIEW



03 West Campus Expansion Options

WCE H-2 Bio Sciences

This option proposes utilizing existing mechanical space for Steam to Water Heat Exchangers in Bio Sciences basement.

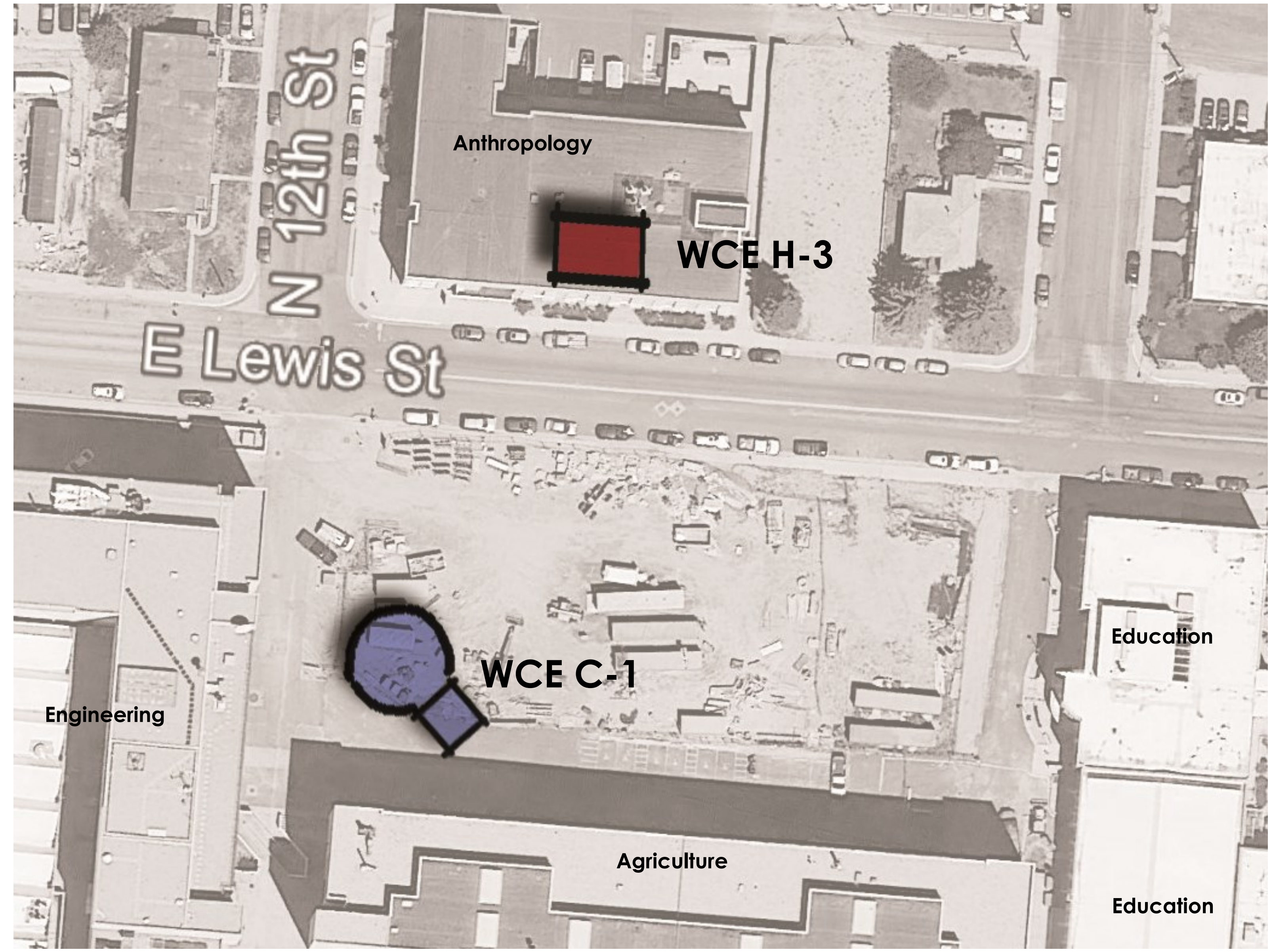
03 West Campus Expansion Options

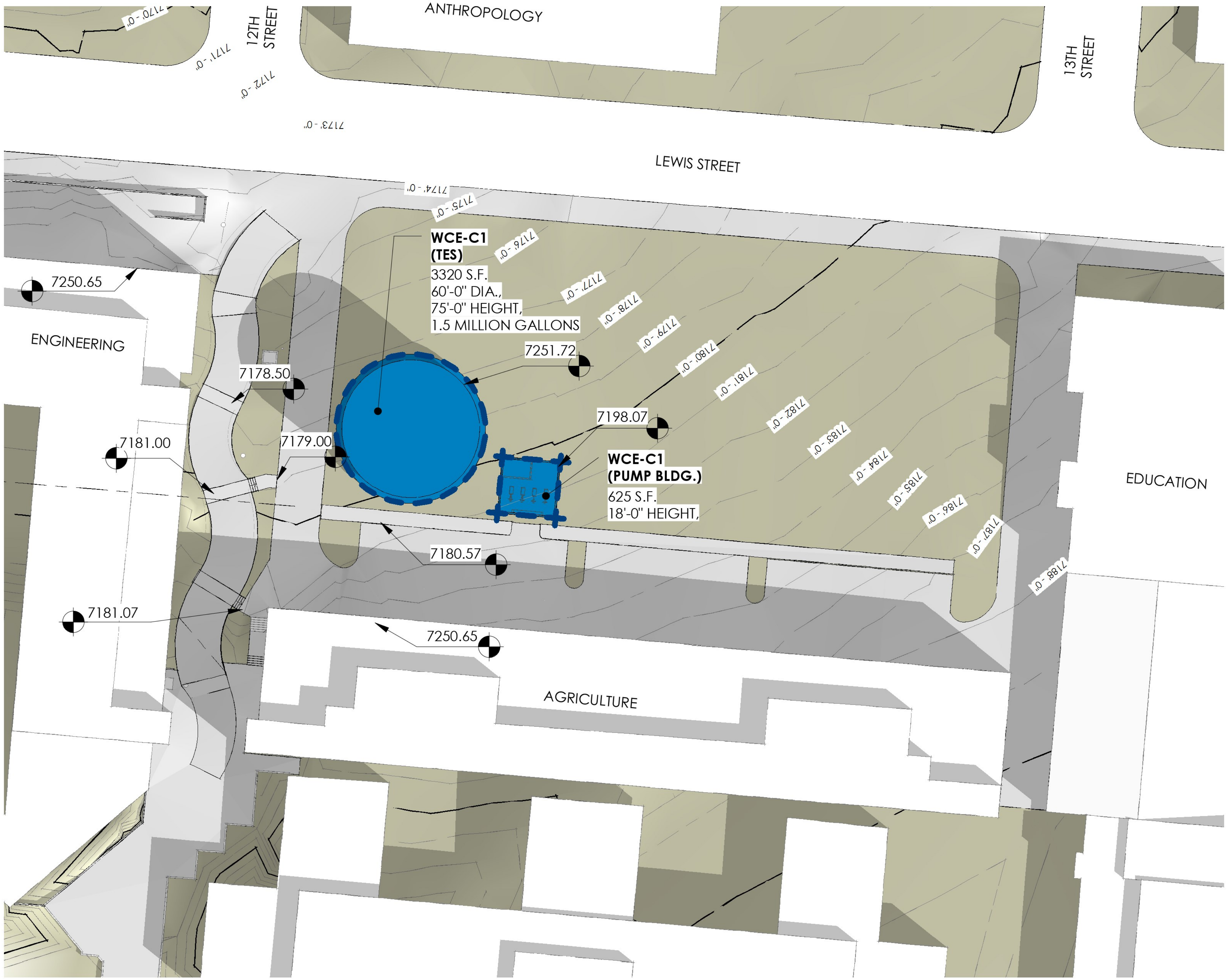
WCE C-1 North of Agriculture

This option proposes a Thermal Energy Storage Tank (TES) be located north of Agriculture to provide off-peak production storage of chilled water for use during peak loading needs during the day. This location is central to the existing and future loads on this area of campus.

WCE H-3 Anthropology

This option proposes utilizing existing mechanical space for Steam to Water Heat Exchangers in Anthropology.





1 WCE-C1 SITE PLAN
1" = 50'-0"

03 West Campus Expansion Options

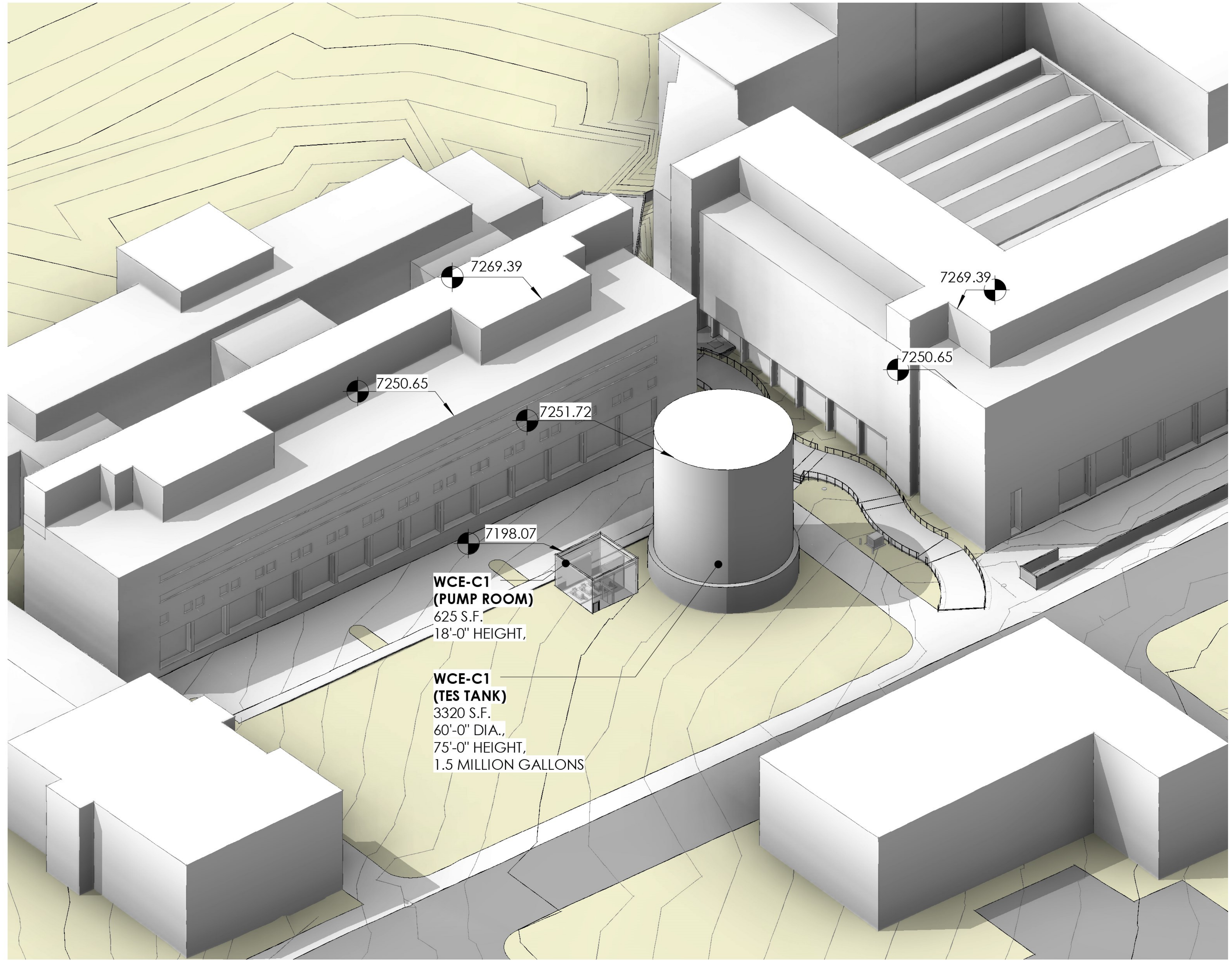
WCE C-1

Proposed TES tank to be 3,320 s.f. footprint at 60'-0" diameter and 75'-0" tall with 1.5 million gallons storage capacity. Adjacent to the TES tank is a 625 s.f. pump building that includes a pump room and electrical room.

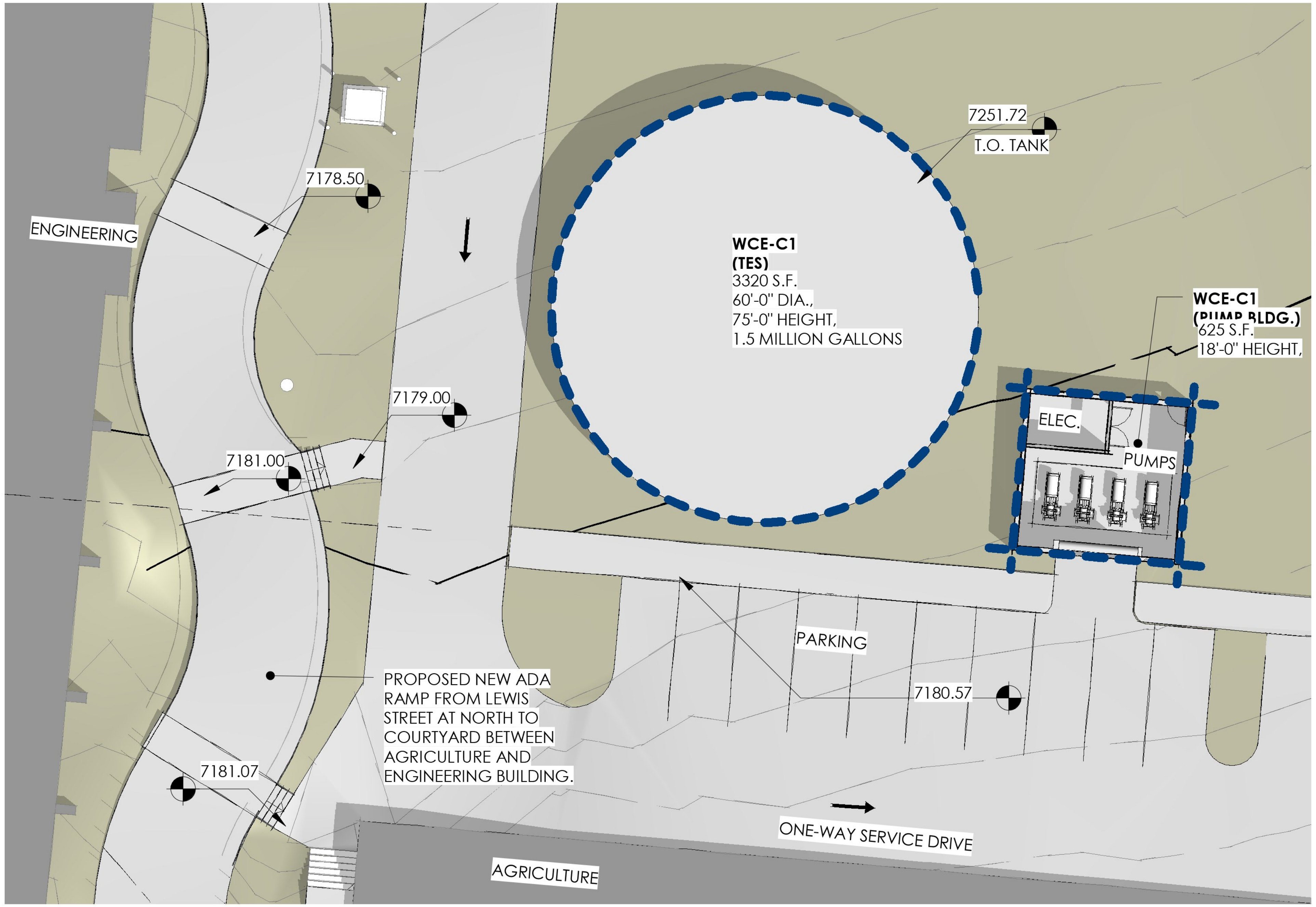
03 West Campus Expansion Options

WCE C-1

Proposed TES tank to be 3,320 s.f. footprint at 60'-0" diameter and 75'-0" tall with 1.5 million gallons storage capacity. Adjacent to the TES tank is a 625 s.f. pump building that includes a pump room and electrical room.



1 WCE-C1 ISOMETRIC VIEW



1 WCE-C1 ENLARGED PLAN
1" = 20'-0"

03 West Campus Expansion Options

WCE C-1

Proposed TES tank to be 3,320 s.f. footprint at 60'-0" diameter and 75'-0" tall with 1.5 million gallons storage capacity. Adjacent to the TES tank is a 625 s.f. pump building that includes a pump room and electrical room.

03 West Campus Expansion Options

WCE-C1

Rendering looking north from Lewis Street with tank height roughly the same height as the adjacent Engineering and Agriculture building's lower roofs.

Both the tank and pump room are located in the southwest corner of the existing site to allow for future pedestrian/transit corridor and green space.

WCE-C1 TES TANK PERSPECTIVE VIEW FROM LEWIS STREET LOOKING SOUTH

03 West Campus Expansion Options

WCE-C1

Rendering looking west along Lewis Street with tank height roughly the same height as the adjacent Engineering and Agriculture building's lower roofs.

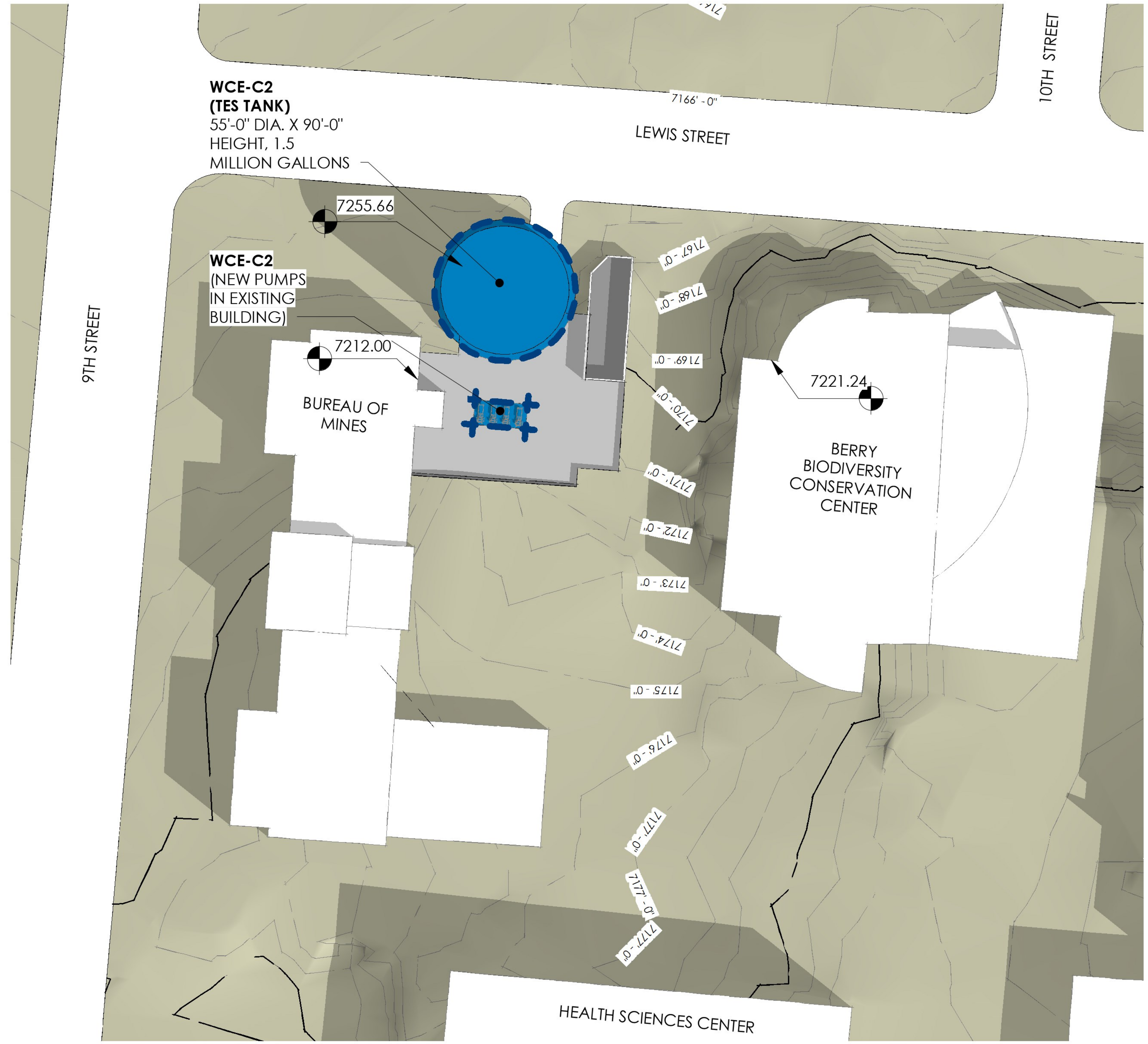
Both the tank and pump room are located in the southwest corner of the existing site to allow for future pedestrian/transit corridor and green space.

WCE-C1 TES TANK PERSPECTIVE VIEW FROM LEWIS STREET LOOKING WEST

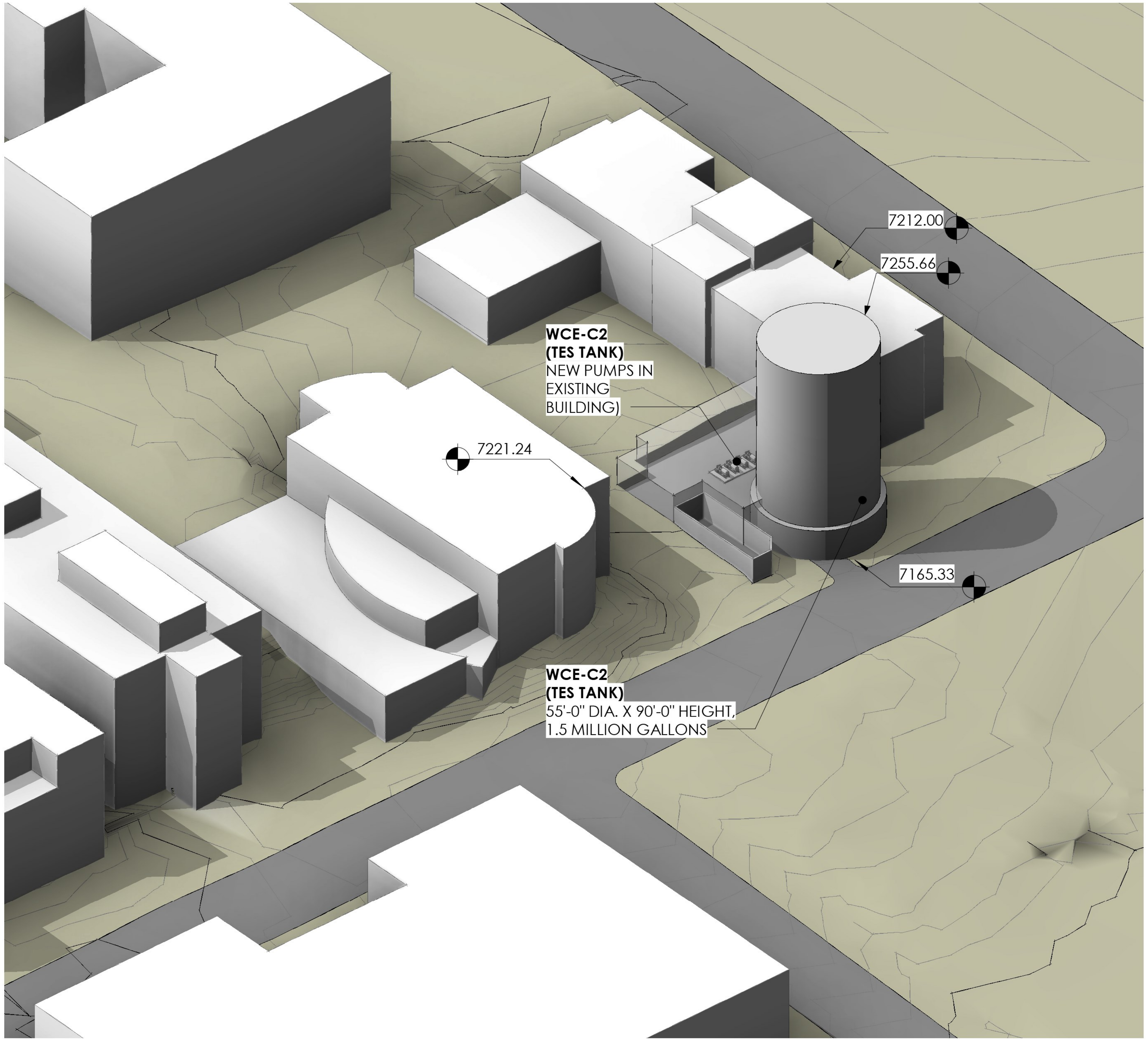
03 West Campus Expansion Options

WCE C-2

The proposed new TES at the Bureau of Mines location would be 55'-0" diameter and 90'-0" tall with a footprint of 2,375 s.f. and with a storage capacity of 1.5 million gallons. The associated pumps and electrical equipment would be located within the existing 1 story building directly south (exact location to be determined). Partial demolition of the north side of the existing 1 story building would be required.



1 WCE-C2 SITE PLAN
1" = 50'-0"



1 WCE-C2 ISOMETRIC VIEW

03 West Campus Expansion Options

WCE C-2

The proposed new TES at the Bureau of Mines location would be 55'-0" diameter and 90'-0" tall with a footprint of 2,375 s.f. and with a storage capacity of 1.5 million gallons. The tank would stand roughly 30 feet taller than the adjacent buildings.

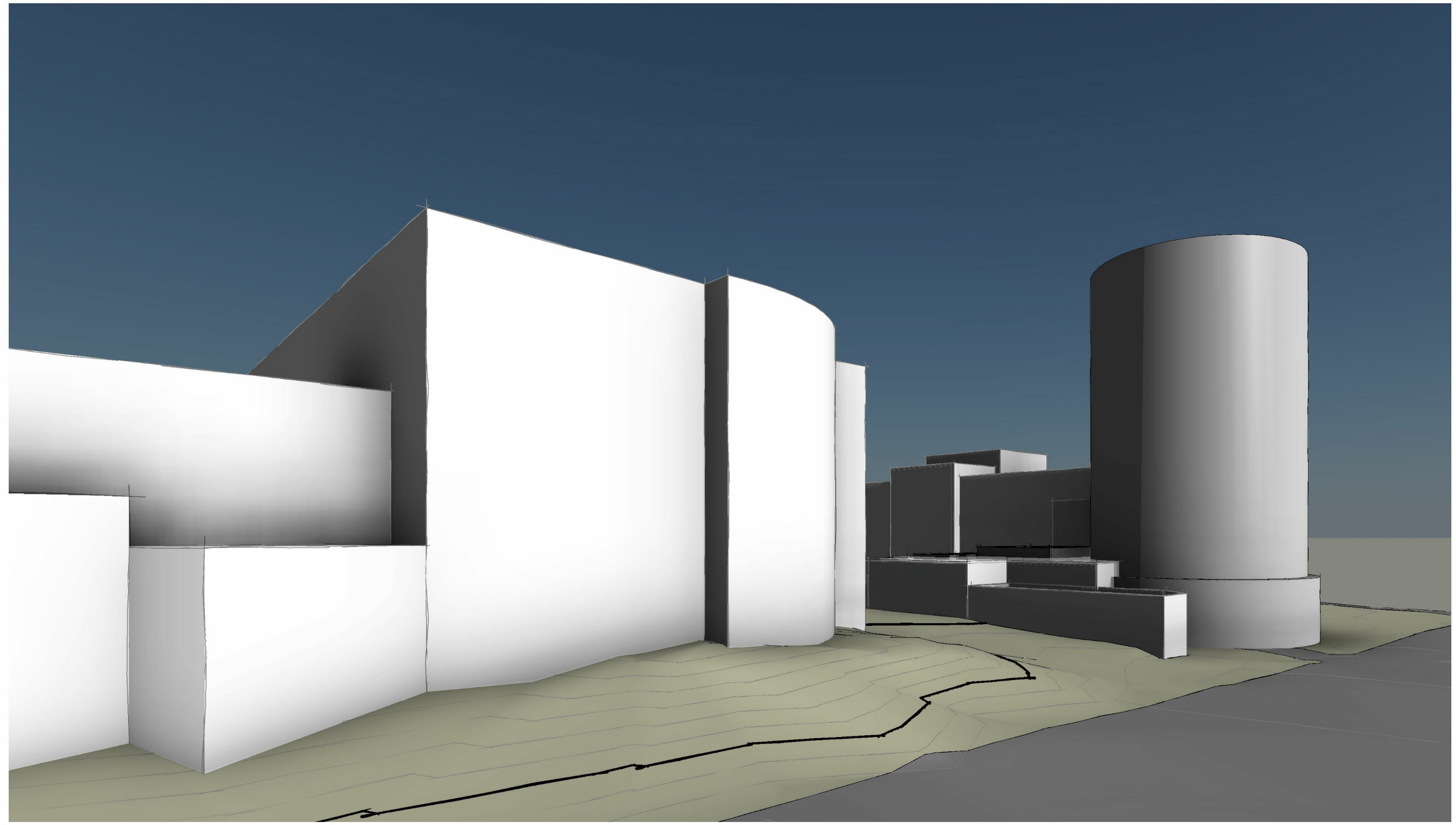
The associated pumps and electrical equipment would be located within the existing 1 story building directly south (exact location to be determined). Partial demolition of the north side of the existing 1 story building would be required.

03 West Campus Expansion Options

WCE C-2

The proposed new TES at the Bureau of Mines location would be 55'-0" diameter and 90'-0" tall with a footprint of 2,375 s.f. and with a storage capacity of 1.5 million gallons. The tank would stand roughly 30 feet taller than the adjacent buildings.

The associated pumps and electrical equipment would be located within the existing 1 story building directly south (exact location to be determined). Partial demolition of the north side of the existing 1 story building would be required.



WCE-C2 TES TANK PERSPECTIVE VIEW FROM LEWIS STREET LOOKING SOUTHWEST

Satellite Plant Options SAT-1 and SAT-2 Technical Summary

West Campus Satellite Energy Plant Options SAT-1 and SAT-2 are very similar. The plant in either location would consist of chilled and heating water production and distribution equipment spread out over several floors. Campus distribution piping is not included in the costs associated with either of these options. Major components of the SAT Options include:

- Utility extensions to the site including power, chilled water, natural gas, steam/condensate, communications, sewer, water
- (2) 700 ton chillers and pumps
- (2) 700 ton cooling towers with remote sumps and pumps
- (2) 500 ton plate and frame heat exchangers
- (6) 5,000 MBH hot water boilers and pumps
- Plant chilled, condenser, and heating water piping
- Steam to HW heat exchangers

Each of these options will require at least 1500 kW of new chiller, boiler and auxiliary loads. We would size the electrical gear to full build-out load. The initial construction will leave space for future boilers but will not account for physical expansion of the satellite plant since the long-term plan is to build multiple plants as funds and needs arise. The new service board will be single-ended and normally fed from the West Campus Substation. In the event of normal power loss, the campus loop configuration will allow the East Campus Substation to feed the plant. One generator will be sized to support the load. Since we will be able accurately assess the final build-out load, we should be able to size the generator precisely to avoid requiring load-shedding switchgear. Emergency lighting will be accomplished with battery wall packs. Any emergency back-up for fire alarm or other required systems will require its own batteries to comply with NEC 700.

The SAT-1 satellite plant location would be constructed in the vacant lot north of agriculture. There are existing underground utilities and tunnels to contend with. We expect to add a pad-mounted S&C Style PME-9 (2-load, 2-line switch) or approved equivalent adjacent to existing Switch 'N' on the west side of the open space with a new transformer. The new switch would intercept the medium voltage feeders near Manhole 20W-1 to maintain the existing campus loop, to provide one load for the plant and one spare for any future building requirements.

The SAT-2 satellite plant option would be constructed at the north-east corner of the Bureau of Mines building, south of Lewis. Demolition of the single story portion of the Mines building would be required for this option. It will require precise physical measurements to contend with the existing site

constraints. Electrical and mechanical design is similar to SAT-1. The north edge of the new plant may conflict with the existing Rocky Mountain feeder which terminates in the outdoor enclose just to the northeast of the existing Bureau of Mines. If the new footprint does conflict, we will need to coordinate the relocation of the Rocky Mountain duct bank with the power company. This utility coordination is not included in the cost estimate, since we hope that it can be avoided. There does not appear to be an available load from an existing pad-mounted switch, so we expect to propose a new PMH-9 and identify a location – perhaps near existing switches S-1 and S-2.

03 West Campus Expansion Options

Narrative

03 West Campus Expansion Options

Narrative

SAT-1-Energy Plant at Agriculture Site

SAT-2-Energy Plant at Bureau of Mine Site

Underground Summary-North of Agriculture

Description: Plant would be located on a portion of the parking lot north of the Agriculture Building.

Adjacent Utilities:

- Water – 10" line just north of Agriculture building which connects into 14" line in Lewis and 6" line south of Ag Bldg, 6" and 14" lines in Lewis Street
- Sanitary – (2) 10" lines north of Ag Bldg that connect to 12" line at Lewis Street and runs north up 12th Street
- Storm – 10" line north of the Agriculture Building that turns north and connect into a 16" line in front of Engineering

Soil Conditions: Red clayey soil with deeper claystone (15-20'), possible striations of gypsum, relatively deep groundwater, and soil should accommodate spread footers or caissons but further geotechnical investigation would need to be performed

Drainage: Site generally drains from southeast to northwest and runoff is conveyed west down Lewis Street where it eventually dumps into the storm sewer main located in 11th Street
Additional Civil Challenges: None determined at this time.

Underground Summary-Bureau of Mines

Description: Plant would be located on the northeast corner of the lot where an existing piece of the Bureau of Mines Building resides

Adjacent Utilities:

- Water – 8" line in 9th Street, 10" and 14" lines in Lewis Street
- Sanitary – 8" line in 9th Street, 8" line starting in Lewis Street and running north in alley between 9th and 10th Street
- Storm – 12" line in 9th Street, (2) 12" lines in Lewis Street

Soil Conditions: Red clayey soil with deeper claystone (15-20'), possible striations of gypsum, relatively deep groundwater, and soil should accommodate spread footers or caissons but further geotechnical investigation would need to be performed

Drainage: Site generally drains from southeast to northwest and runoff is conveyed into Lewis and 9th Street where it gets into the City's storm infrastructure via storm inlets at the intersection of 9th and Lewis
Additional Civil Challenges: Being located off Lewis, parking could again be an issue for this location as well as being in close proximity to residential lots could trigger higher landscaping/screening requirements.

03 West Campus Expansion Options

West Campus Satellite Plants Site Locations

SAT-1

North of Agriculture

Located in the north portion of the West Campus this site is centrally for the current and future loads . It is a previously developed that is now open area. A portion of the site is designated for future open space as primary pedestrian pathway. The location does not require demolition of any existing structures. It is in close proximity to an existing transformer and underground tunnels.

SAT-2

East of Bureau of Mines

Located on the western edge of the West Campus it is less centrally located than the SAT-1 location. The location is currently occupied by a single story storage area that will required demolition. To the south is a developed courtyard that will need to protected during construction. Co-located at this site are two primary transformers and underground feeders that will need to be protected.

Section 1
Section 2
Section 3
Section 4
Section 5

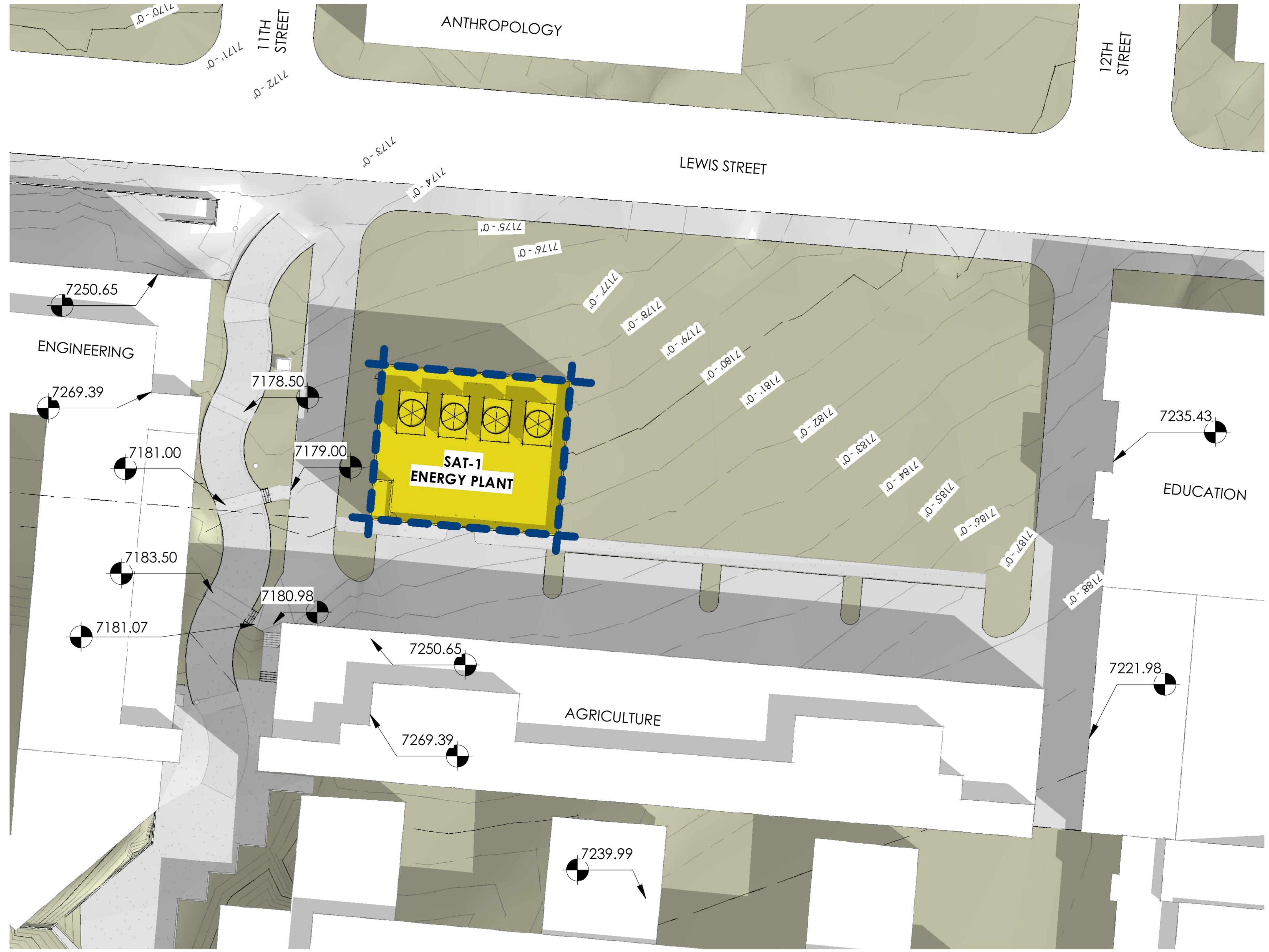
03 West Campus Expansion Options

West Campus Energy Satellite Plant 1 SAT-1

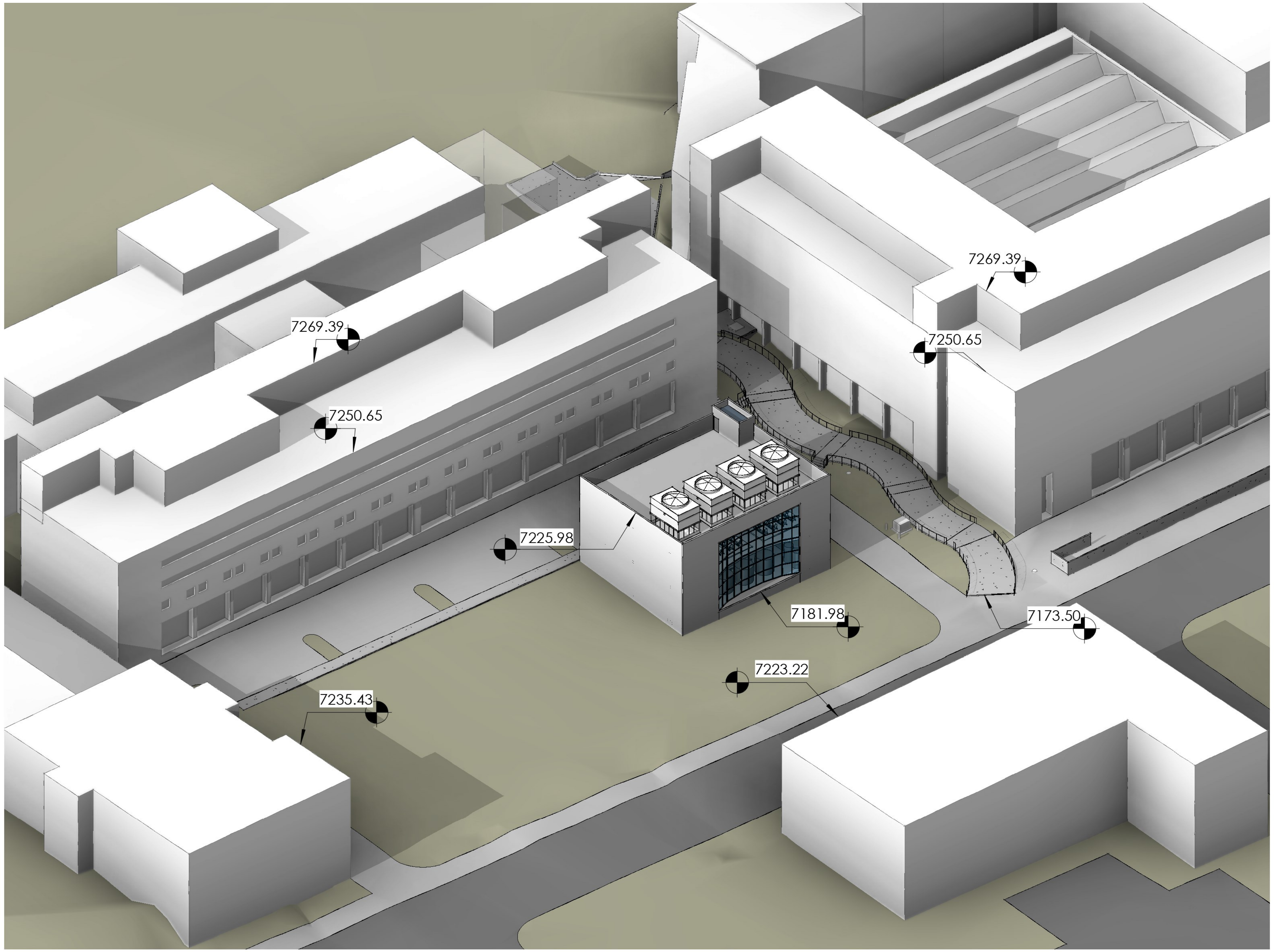
Site Plan

Building Area: 10,560 GSF
Roof Area: 5,580 GSF
Floor to Floor Ht.: 18 feet
Parapet Screen enclosure: 8 feet
Cooling Towers on Roof

Plant location allows for enhancement of the pedestrian pathway as an ADA accessible route between Agriculture and Engineering. Maintains existing utility transformer in place. Accommodates space to the north for pedestrian open space in keeping with the Long Range Development Plan goals.



1 SAT-1 SITE PLAN
1" = 50'-0"



1 SAT-1 ISOMETRIC VIEW

03 West Campus Expansion Options

West Campus Energy Satellite Plant 1 SAT-1

Site Plan

Building Area: 10,560 GSF
Roof Area: 5,580 GSF
Floor to Floor Ht.: 18 feet
Parapet Screen enclosure: 8 feet
Cooling Towers on Roof

The location of SAT-1 allows for future pedestrian/ transit corridor and green space. Glazed walls at north and south facades provide natural daylight and educational opportunities for pedestrians.

The height of SAT-1 is less than the adjacent Agriculture and Engineering buildings, but similar in height to the Anthropology and Education buildings.

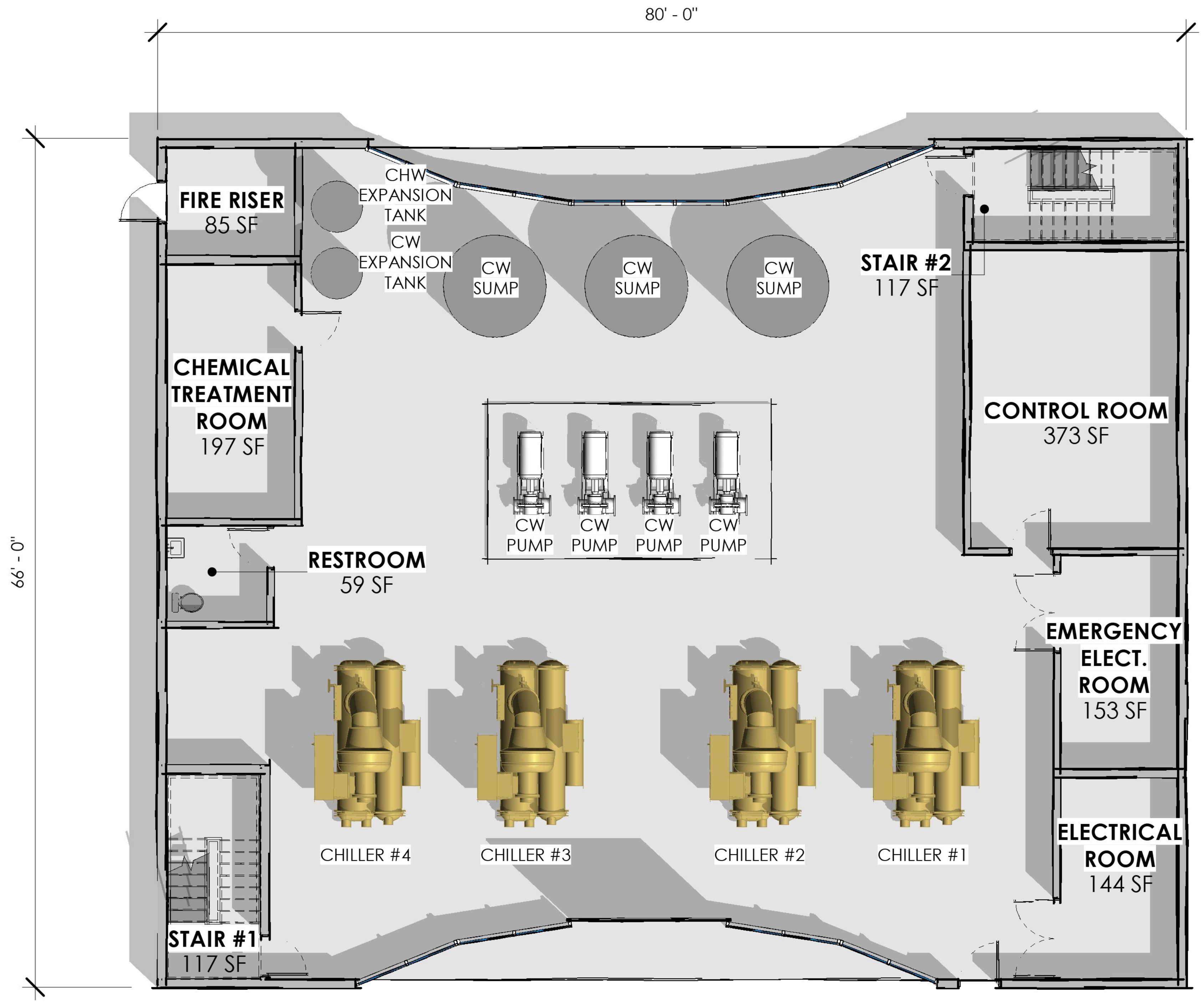
03 West Campus Expansion Options

West Campus Energy Satellite Plant 1 SAT-1

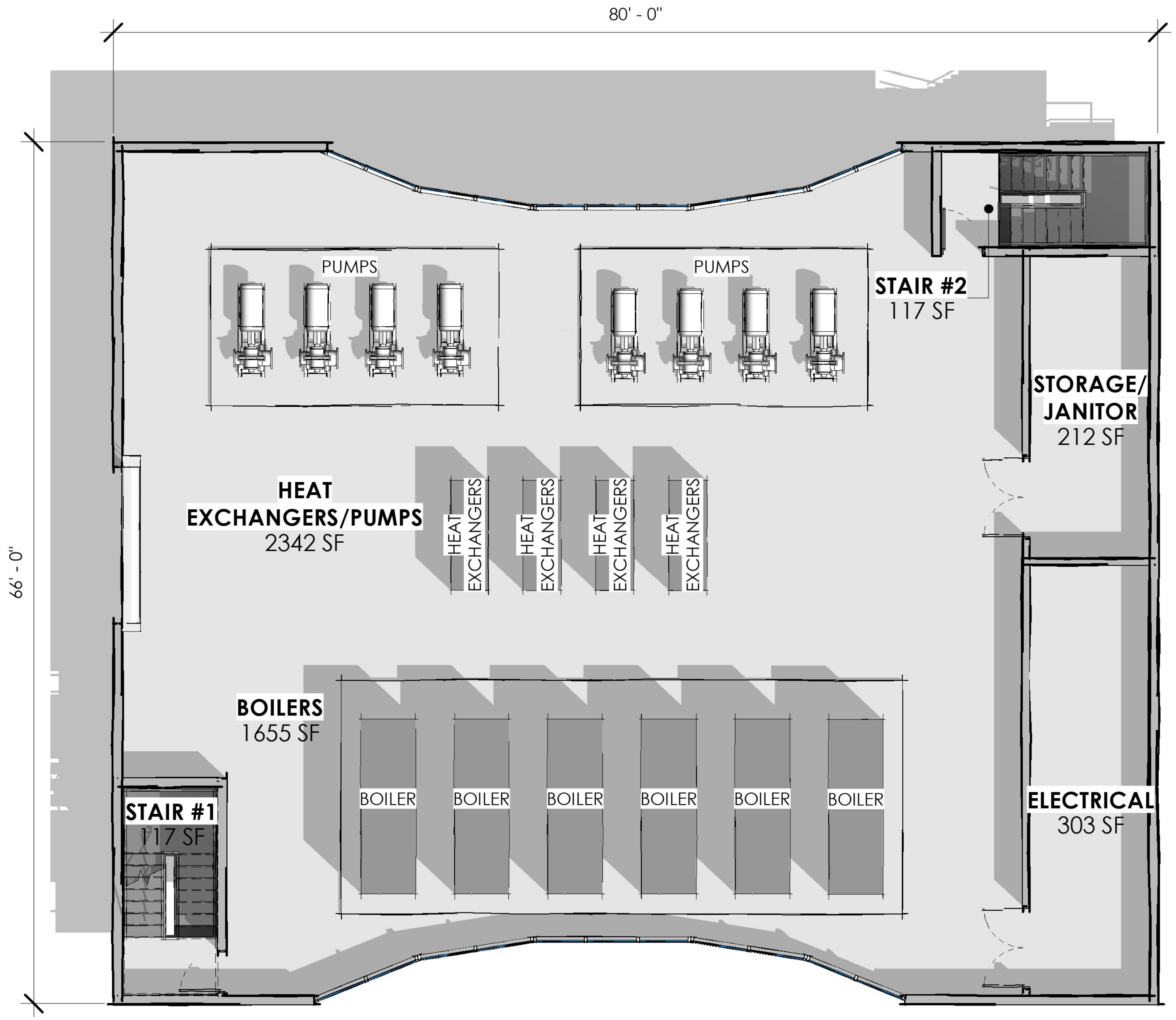
1st Floor Plan

Floor Area: 5,280 GSF
Floor to Floor Ht.: 18 feet

The first floor holds the chillers, pumps and sumps, as well as a control room, chemical treatment room, restroom, and electrical rooms. The north and south facades are enclosed by full height glazed walls that provide natural daylighting. Large equipment can be replaced through the south facing overhead door that abuts the service drive.



1 1ST FLOOR
3/32" = 1'-0"



1 2ND FLOOR
3/32" = 1'-0"

03 West Campus Expansion Options

West Campus Energy Satellite Plant 1 SAT-1

2nd Floor Plan

Floor Area: 5,280 GSF
Floor to Floor Ht.: 18 feet

The 2nd floor holds the boilers, heat exchangers and pumps. Also located on the 2nd floor is an electrical room and storage/janitorial space. A west facing overhead door allows access for large equipment to be replaced along the service drive.

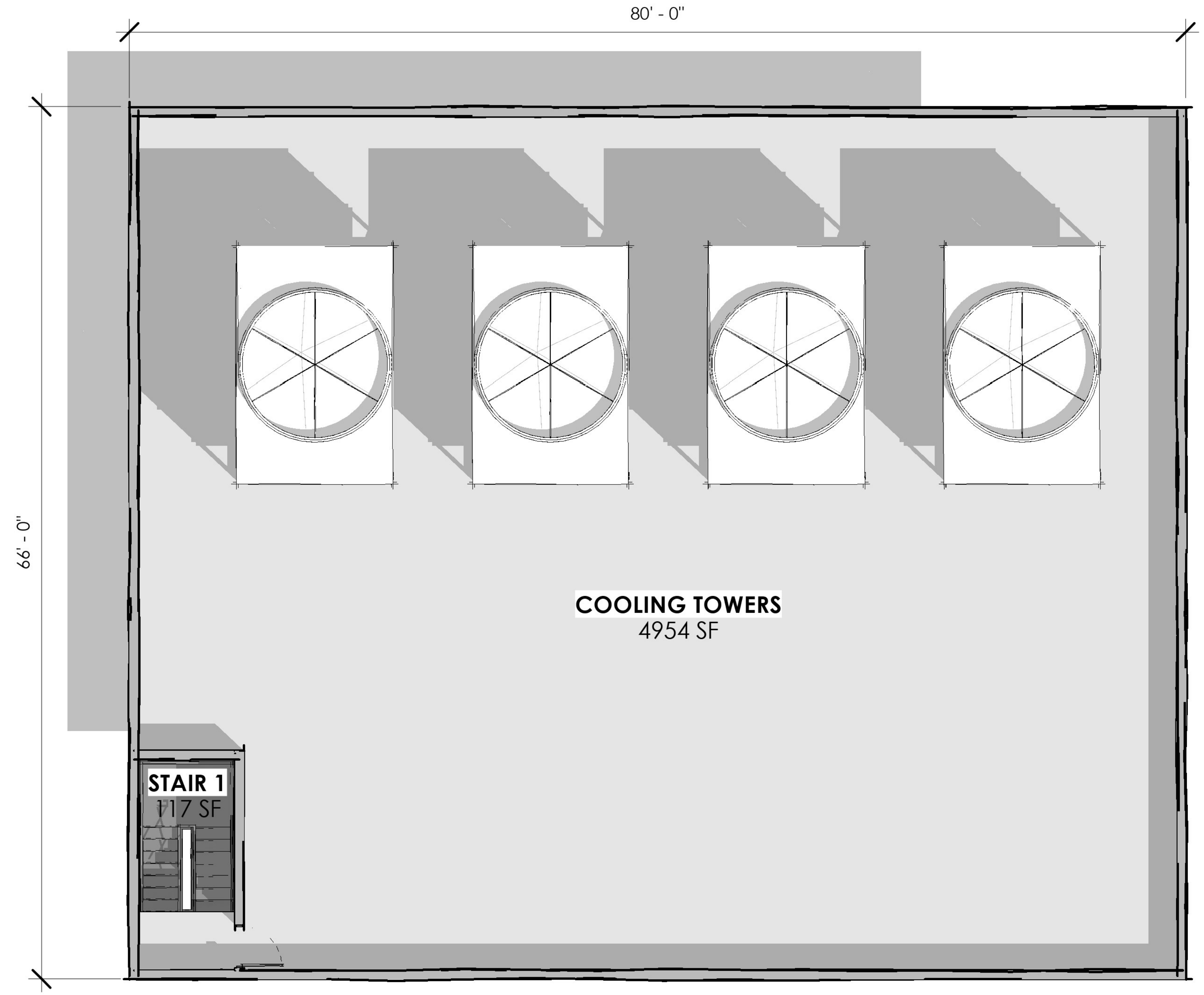
03 West Campus Expansion Options

West Campus Energy Satellite Plant 1 SAT-1

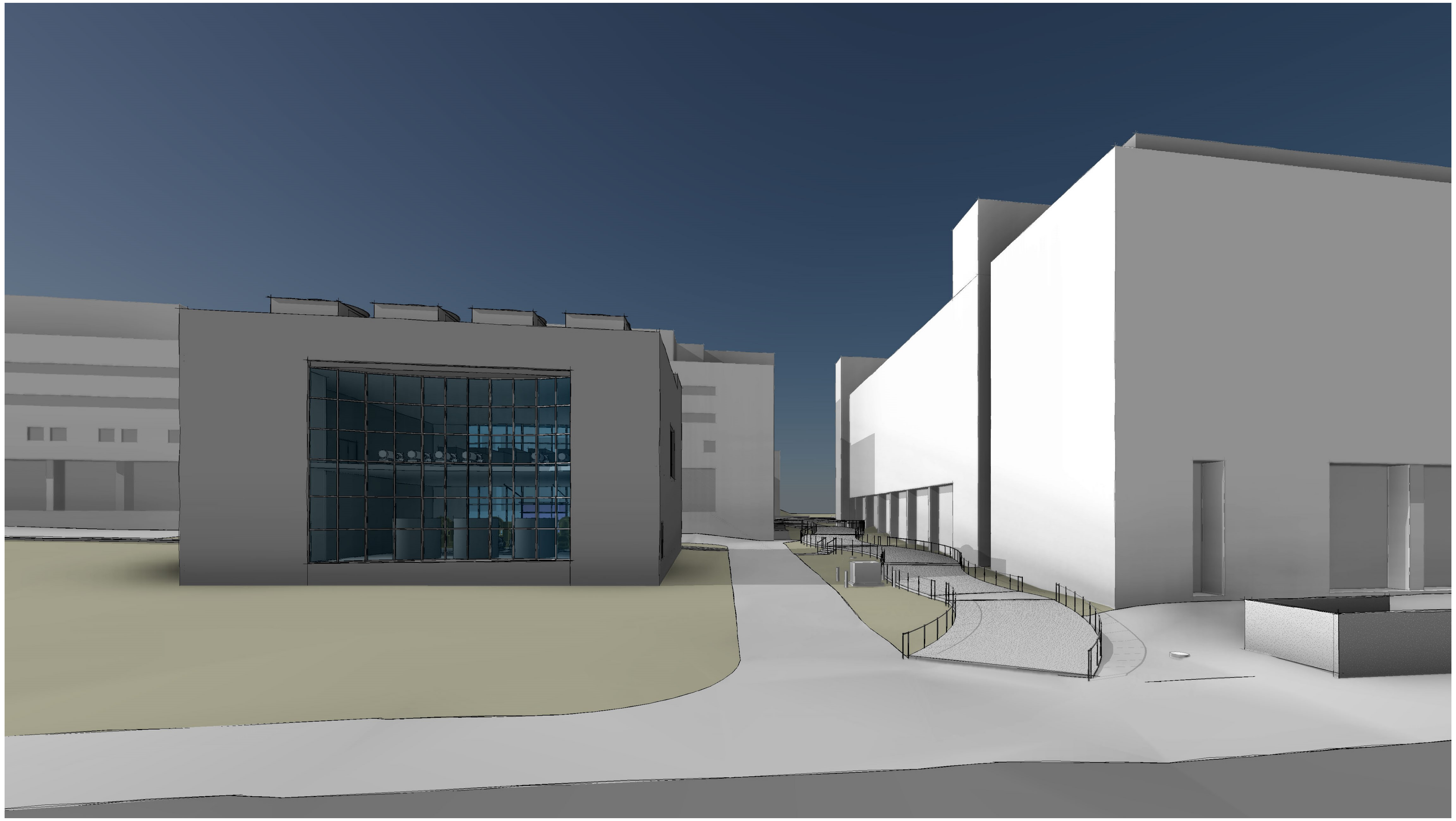
Roof Plan

Roof Area: 5,280 GSF

The roof supports 4 cooling towers and includes additional space for rooftop mechanical equipment. The southwest stair provides access to the roof.



1 ROOF PLAN
3/32" = 1'-0"



PERSPECTIVE VIEW OF SAT-1 FROM LEWIS STREET LOOKING SOUTH.

03 West Campus Energy Satellite Plant 1 SAT-1

Perspective View

The SAT-1 Plant perspective depicts a massing and opportunities for daylighting. The view into the plant can be used as an opportunity for education for students on the function of a Chiller/Boiler plant in support of the campus and human comfort.

Depicted also is the possibility of providing an enhanced pedestrian pathway with ADA compliant access between Agriculture and Engineering.

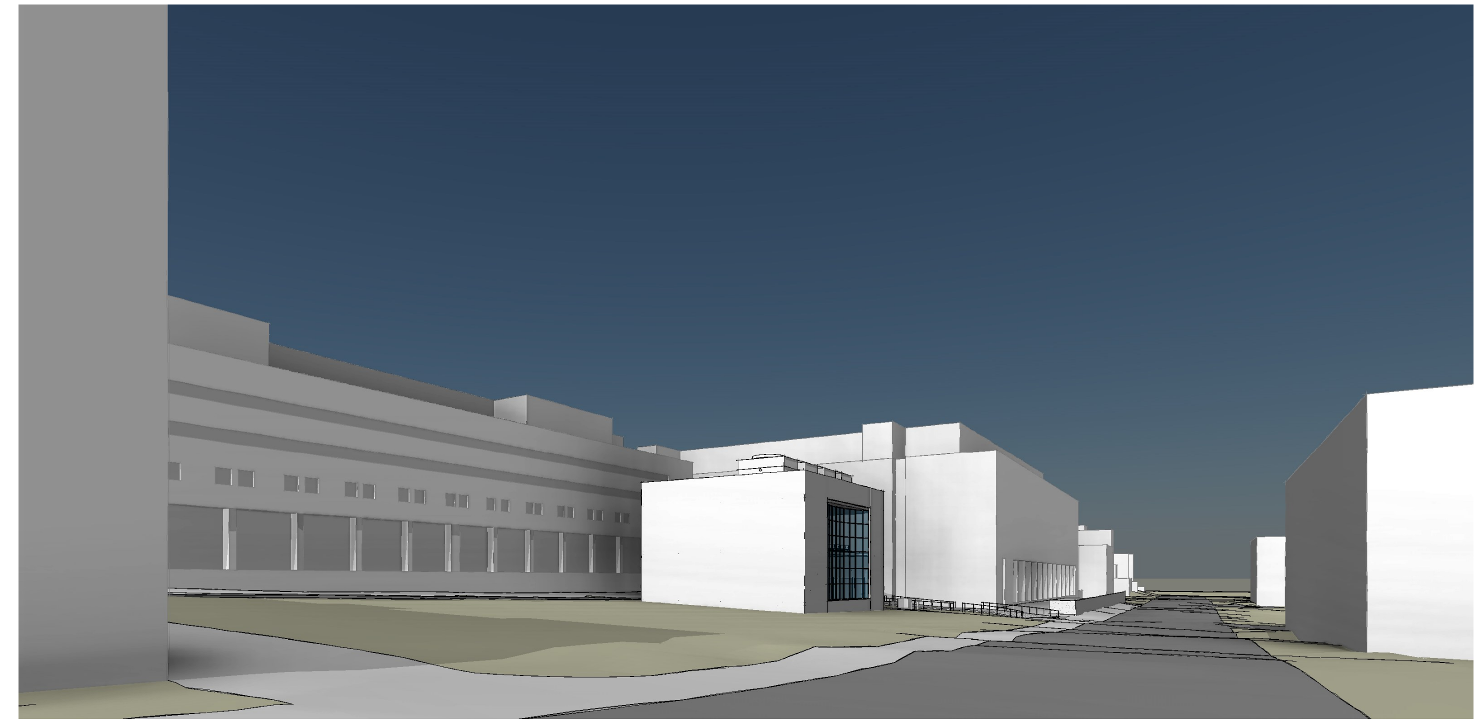
03 West Campus Expansion Options

West Campus Energy Satellite Plant 1 SAT-1

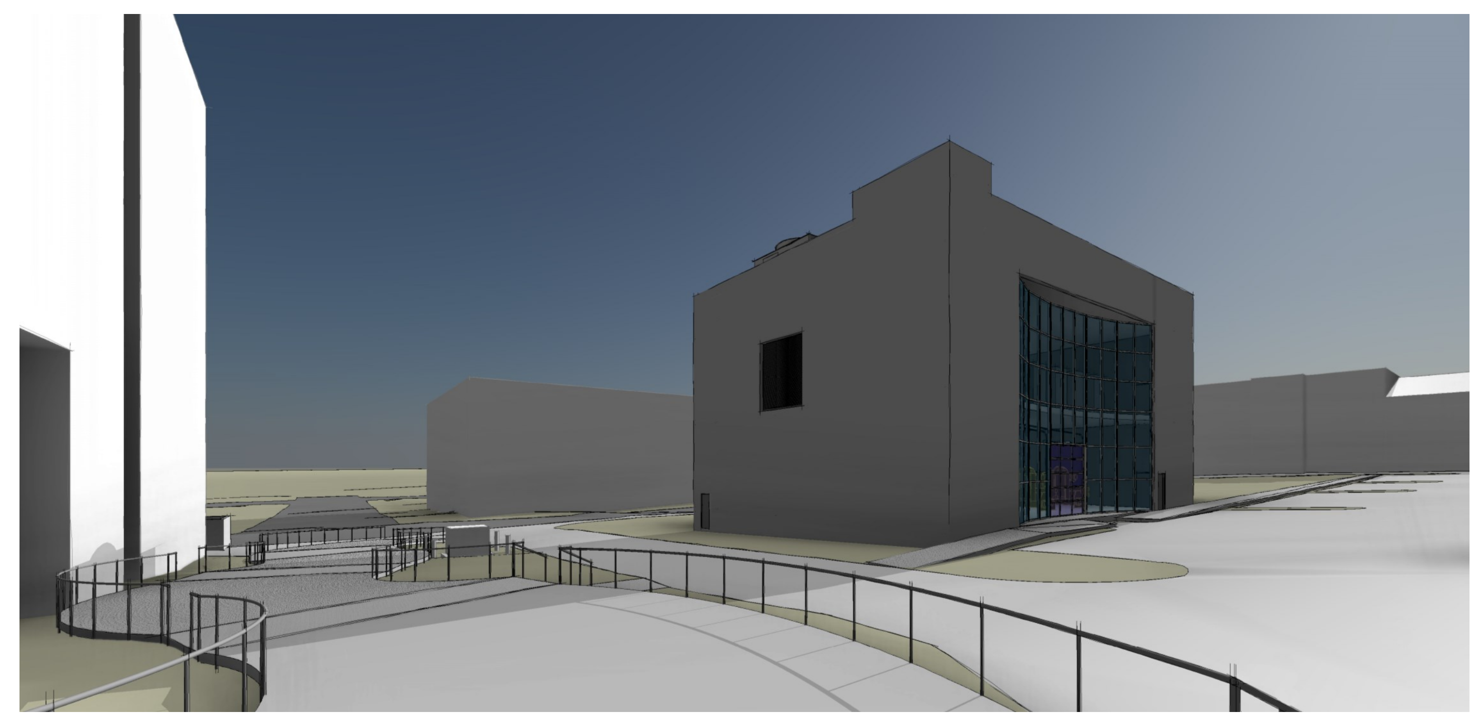
Perspective View

The SAT-1 Plant perspective depicts a massing and opportunities for daylighting. The view into the plant can be used as an opportunity for education for students on the function of a Chiller/Boiler plant in support of the campus and human comfort.

Depicted also is the possibility of providing an enhanced pedestrian pathway with ADA compliant access between Agriculture and Engineering.



PERSPECTIVE VIEW OF SAT-1 ALONG LEWIS STREET LOOKING WEST.



PERSPECTIVE VIEW OF SAT-1 FROM PROPOSED NEW RAMP LOOKING NORTHEAST.

1 SAT-2 SITE PLAN

03 West Campus Expansion Options

West Campus Energy Satellite Plant 1 SAT-2

Site Plan

Building Area: 9,214 GSF
Roof Area: 4,607 GSF
Floor to Floor Ht.: 18 feet
Parapet Screen enclosure: 8 feet
Cooling Towers on Roof

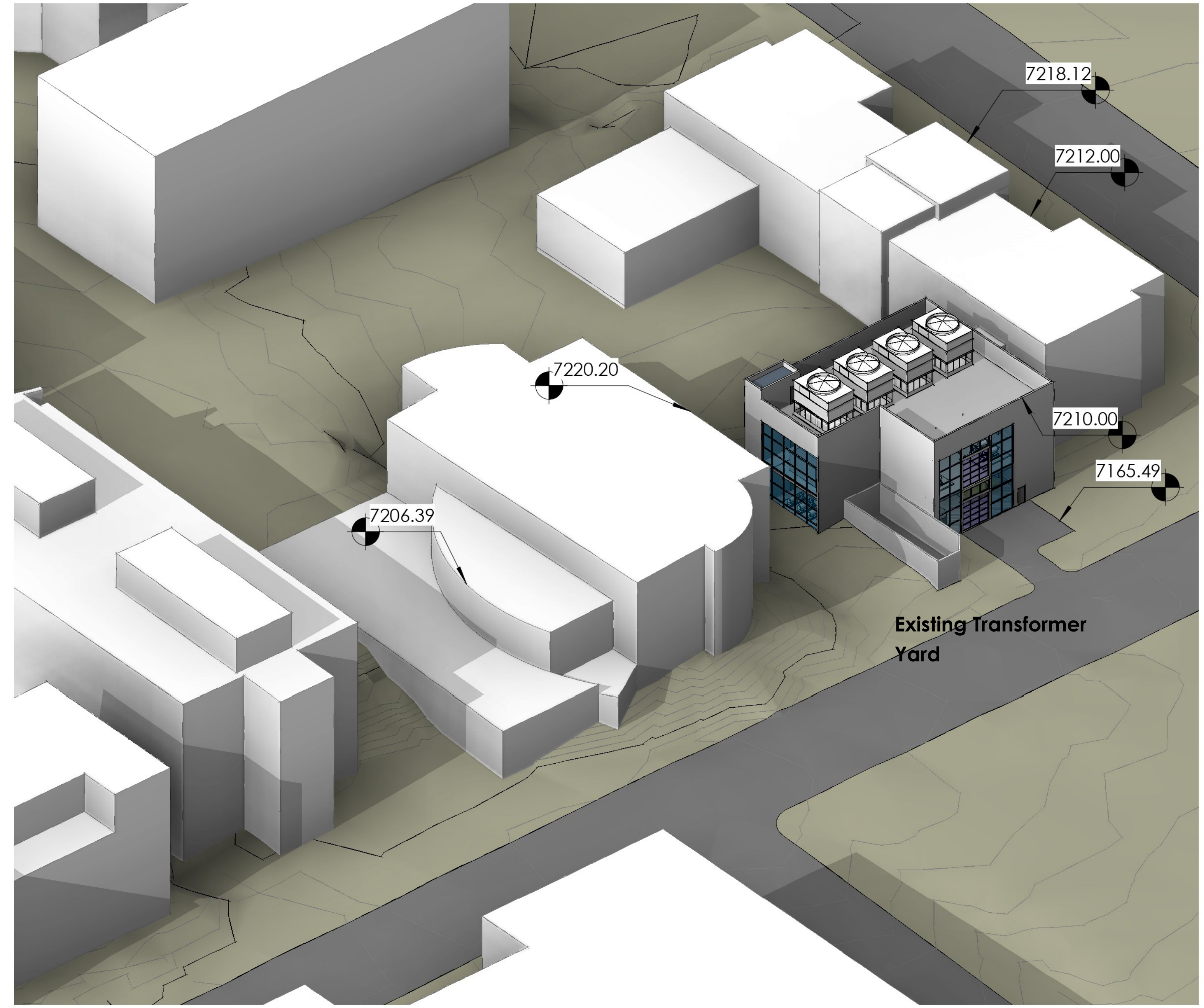
Section 1
Section 2
Section 3
Section 4
Section 5

03 West Campus Expansion Options

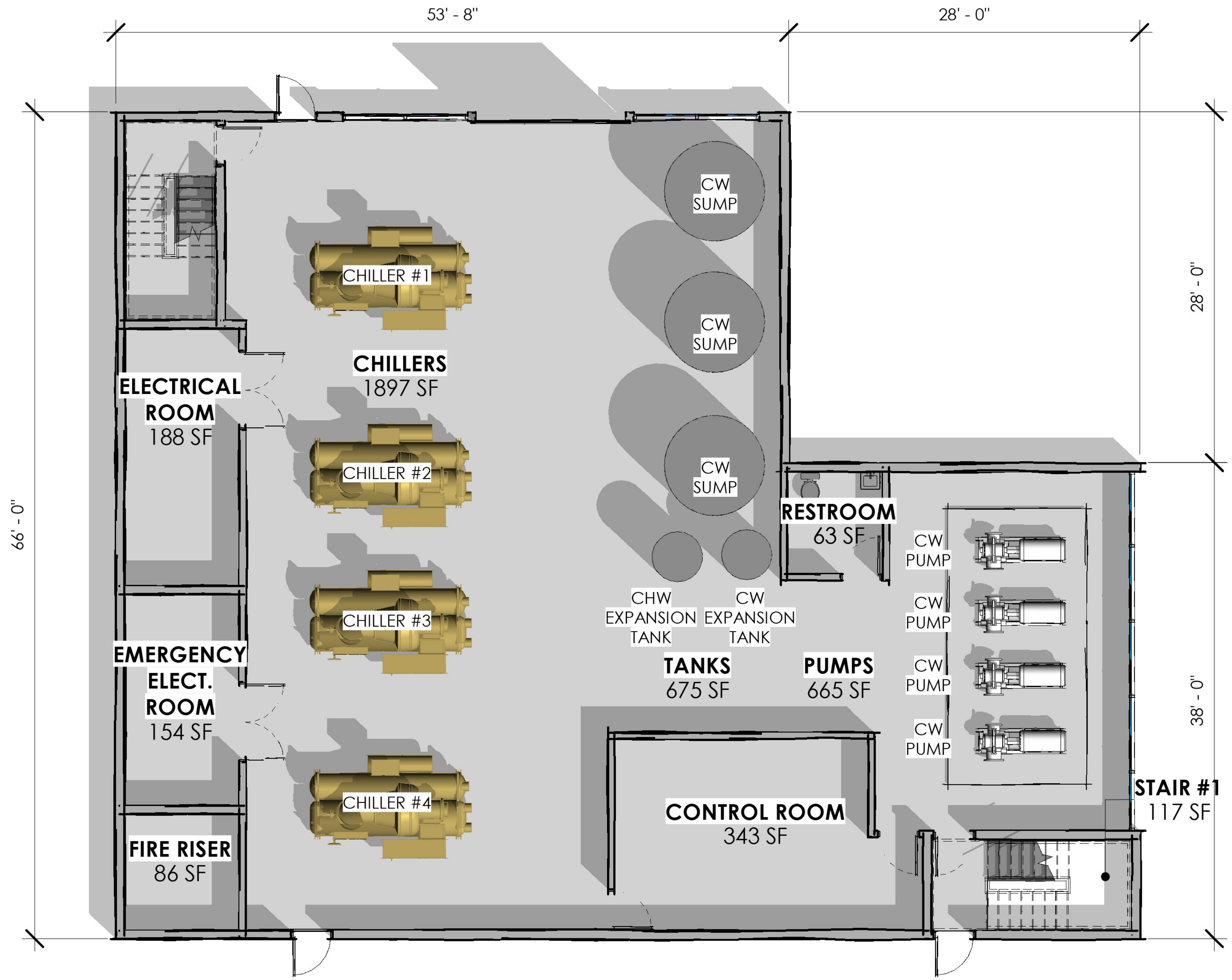
West Campus Energy Satellite Plant 1 SAT-2

Site Plan

Building Area: 9,214 GSF
Roof Area: 4,607 GSF
Floor to Floor Ht.: 18 feet
Parapet Screen enclosure: 8 feet
Cooling Towers on Roof



1 SAT-2 ISOMETRIC VIEW



1 1ST FLOOR
3/32" = 1'-0"

03 West Campus Expansion Options

West Campus Energy Satellite Plant 1 SAT-2

1st Floor Plan

Floor Area: 4,607 GSF
Floor to Floor Ht.: 18 feet

The first floor holds the chillers, pumps and sumps, as well as a control room, restroom, electrical rooms, and fire riser room. The north and east facades are enclosed by full height glazed walls that provide natural daylighting. Large equipment can be replaced through the north facing overhead door that faces Lewis Street.

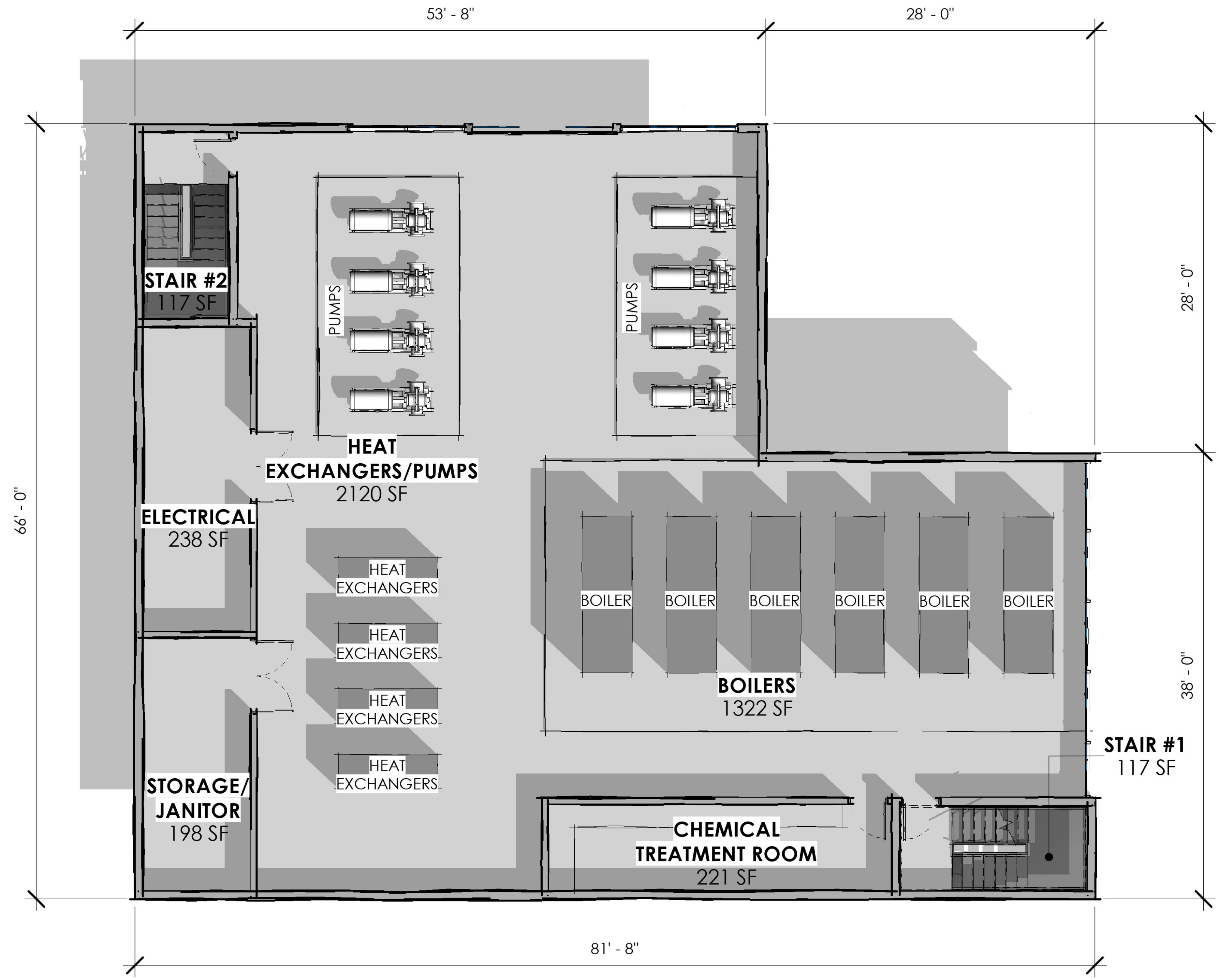
03 West Campus Expansion Options

West Campus Energy Satellite Plant 1 SAT-2

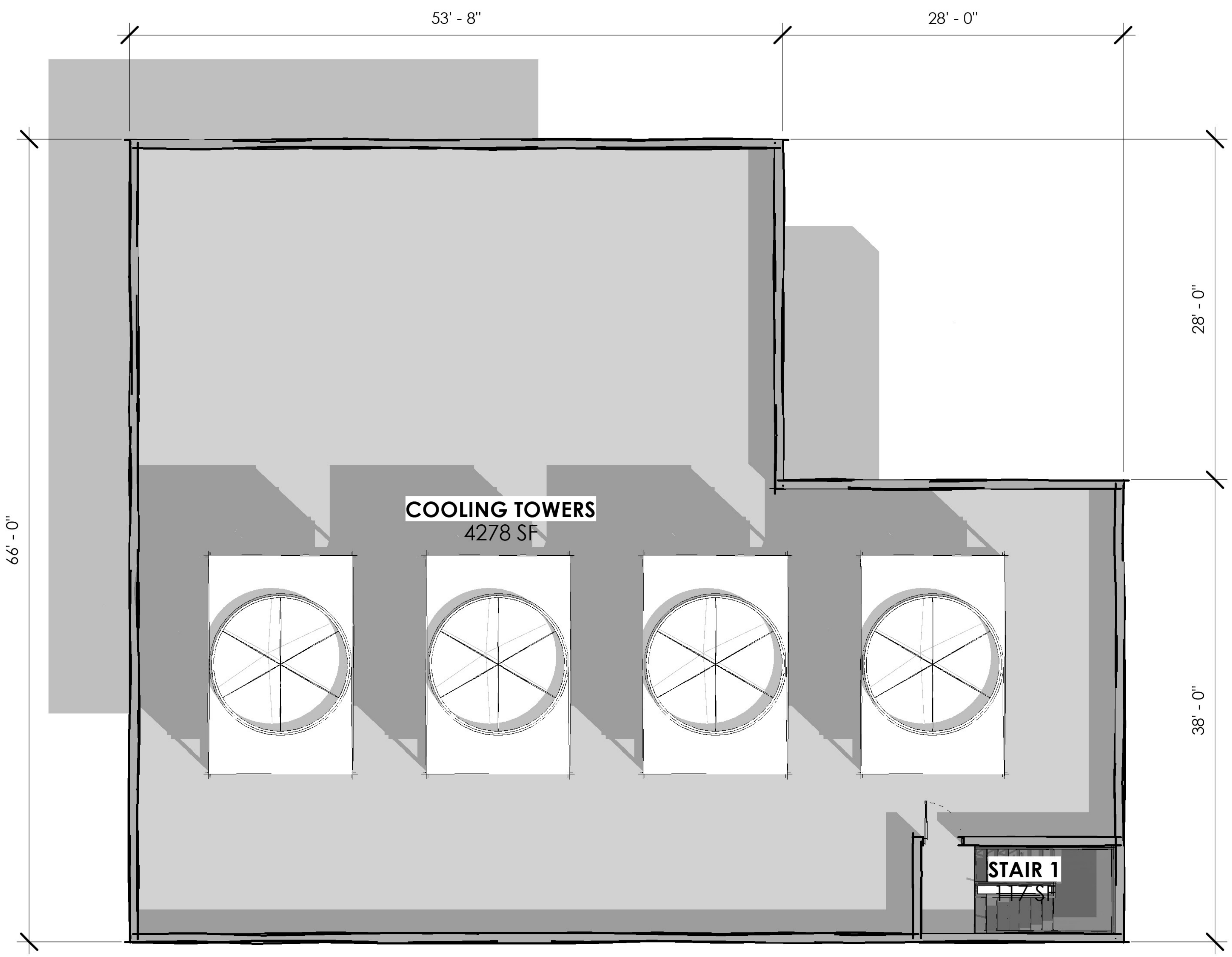
2nd Floor Plan

Floor Area: 4,607 GSF
Floor to Floor Ht.: 18 feet

The 2nd floor holds the boilers, heat exchangers and pumps. Also located on the 2nd floor is an electrical room , storage/janitorial space, and a chemical treatment room. A north facing glazed overhead door allows access for large equipment to be replaced along Lewis Street.



1 2ND FLOOR PLAN
3/32" = 1'-0"



1 ROOF PLAN
3/32" = 1'-0"

03 West Campus Expansion Options

West Campus Energy Satellite Plant 1 SAT-2

Roof Plan

Parapet Screen enclosure: 8 feet
Cooling Towers on Roof

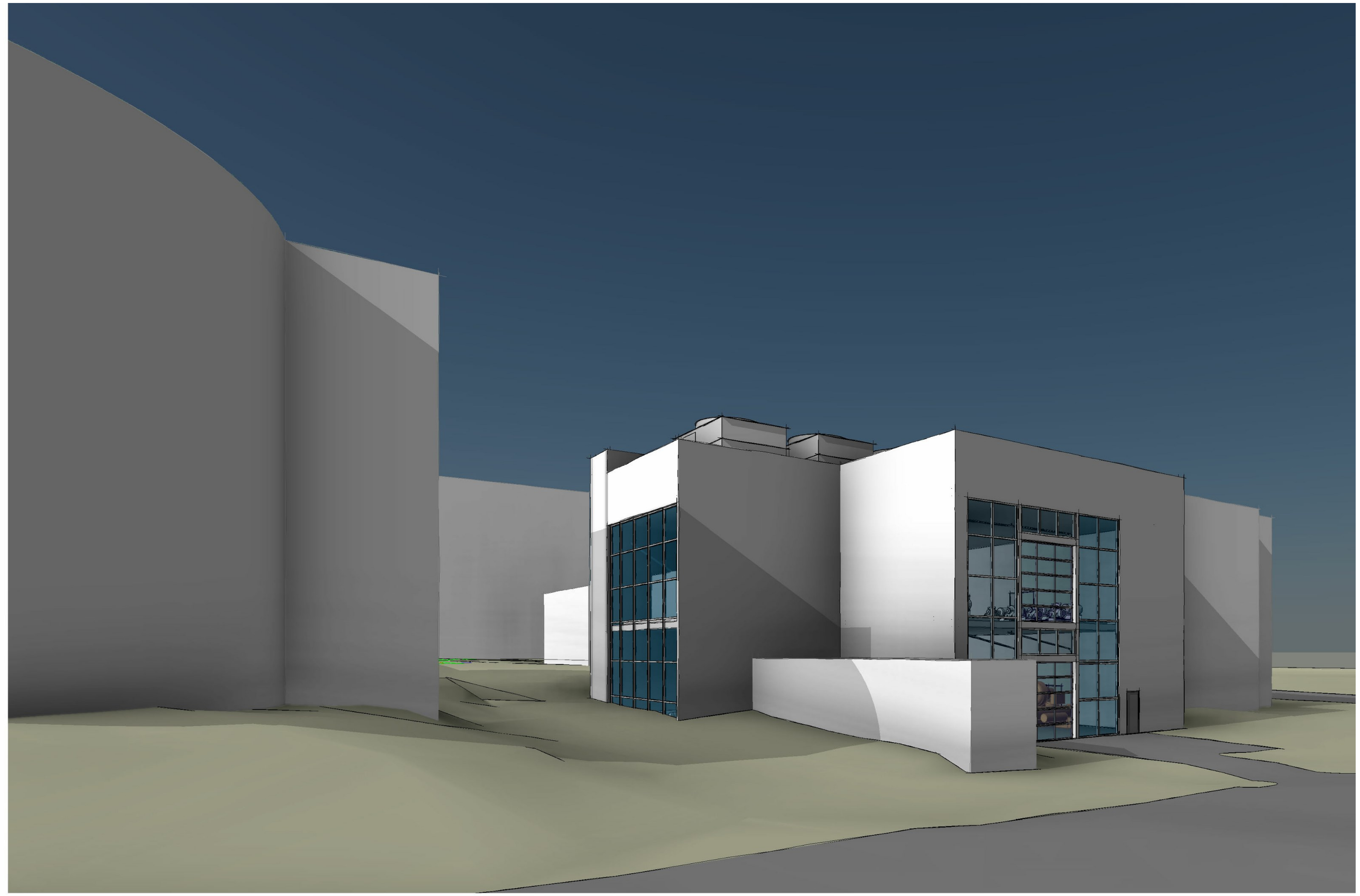
The roof supports 4 cooling towers and includes additional space for rooftop mechanical equipment. The southeast stair provides access to the roof.

03 West Campus Expansion Options

West Campus Energy Satellite Plant 1 SAT-2

Perspective View

The massing of SAT-2 is similar in height and scale to the Bureau of Mines building, and would be designed to reflect it's historic character and that of the older campus building but also integrate current technology. It's location along the future Lewis Street pedestrian/transit corridor provides educational opportunities to pedestrians.
Glazed north and east facades also provide natural daylighting to the interior spaces of the building.

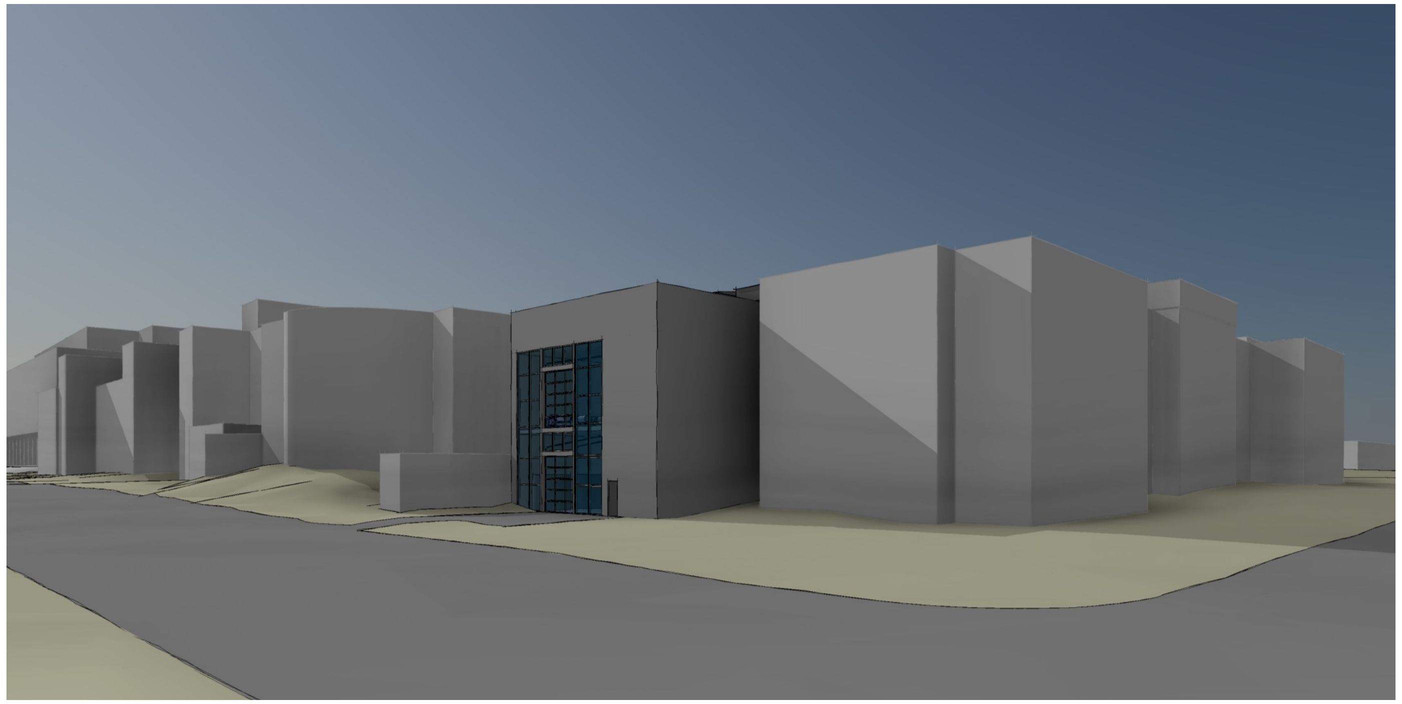


SAT-2 ENERGY PLANT PERSPECTIVE VIEW FROM LEWIS STREET LOOKING SOUTHWEST

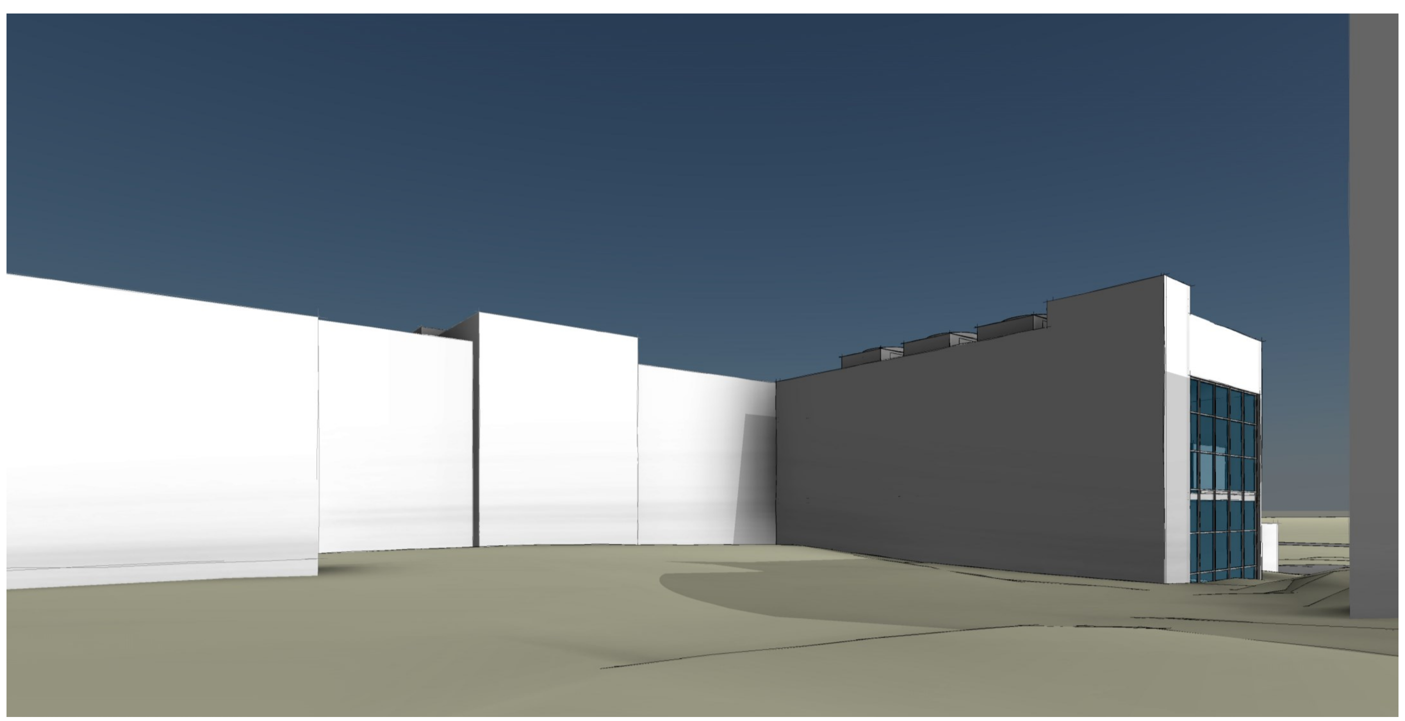
03 West Campus Expansion Options

West Campus Energy Satellite Plant 1 SAT-2

Perspective View



PERSPECTIVE VIEW OF SAT-2 ALONG LEWIS STREET LOOKING SOUTHEAST.



PERSPECTIVE VIEW OF SAT-2 FROM BUREAU OF MINES COURTYARD LOOKING NORTHWEST.

Section 1
Section 2
Section 3
Section 4
Section 5

03 West Campus Expansion Options

Comparison Matrix

Satellite Plant 1 and 2 (SAT-1 & SAT 2)

Page 1

COMPARISION

	Item	SAT-1	North of Agriculture	SAT-2	Bureau of Mines
A0	**Site Facts**				
A1	**Area**	2	Site area is flexible at this location	0	Site is limited, plant constructed between existing bldg. and electrical transformers
A2	Adjacent Bldgs	1		0	
A3	Adjacent Hts	-1	Existing bldgs higher than plant	1	Existing bldgs about the same height as plant.
A4	**Open Space**	2	Works with planned open space	1	No adverse impact with planned open space
A5	**Historic context**	0	Existing bldgs adjacent lack architectural context to existing campus. Newly constructed on east and north are compatible with the campus guidelines		Existing bldgs newer and older and fit with architectural context of existing campus.
A6	**Materials**	0	Engineering and Agriculture - Exterior stucco system	1	Bureau of Mines - Sandstone and Brick
A7	**Forms/Visual image**	0	Engineering and Agriculture are monolithic and generic in form	1	Bureau of Mines details reflect the older campus bldgs.
B0	**Site Environment**				
B1	**Drainage / topography**	0	No or minimal impact to existing drainage	0	No or minimal impact to existing drainage
B2	**Wind**				
B3	Cooling tower drift	-1	Toward Lewis St/vehicles, pedestrians, Anthropology	1	Toward Lewis St/vehicles, pedestrians, less impact at this location
B4	Intake	-2	Possible intakes impact on Anthropology	0	None Known
B5	Exhaust				
B6	**Solar access**	-1	Mostly shaded in winter months	1	Solar access throughout the year
B7	**Solar energy production**	0	Two story plant does not allow room for solar panels on roof	0	Two story plant does not allow room for solar panels on roof
B8	**Daylighting**	2	Good potential for daylighting facility	2	Good potential for daylighting facility
B9	**Orientation**	2	No significant orientation issues	2	No significant orientation issues
B10	**Noise internal/external**	0	Separated bldg. minimizes impact to adjacent structures	-1	With bldg. directly adjacent to existing structure sound attenuation will be required.
B11	**Future development**				
B12	Em Generator/Fuel Tank	1	Adequate site area or located on roof	0	Adequate site area or located on roof
B13	CoGen	1	Adequate site area or located on roof	0	

03 West Campus Expansion Options

Comparison Matrix

Satellite Plant 1 and 2 (SAT-1 & SAT 2)

Page 2

COMPARISION

Site Options

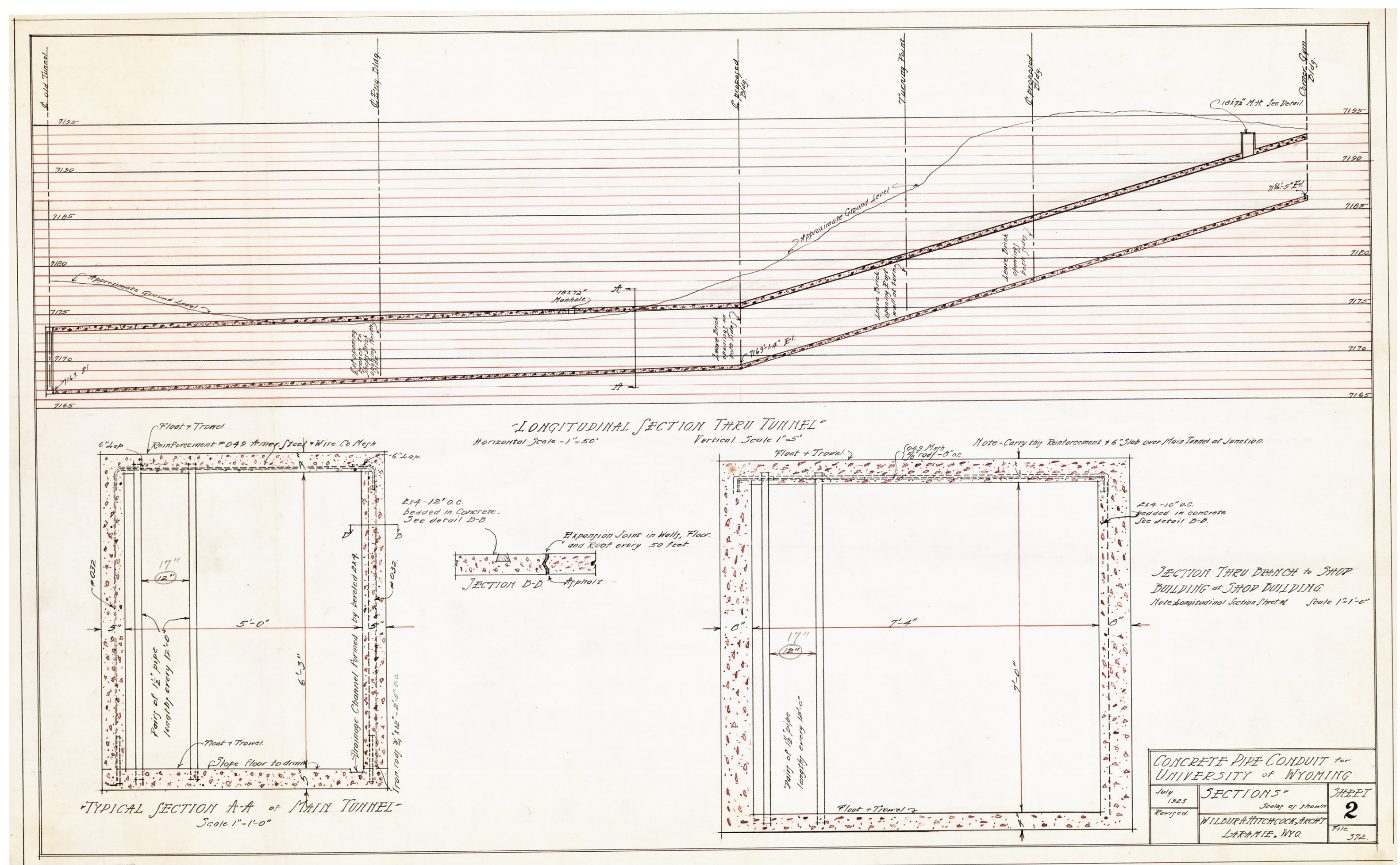
	Item	SAT-1	North of Agriculture	SAT-2	Bureau of Mines
B14	**Views**	1	Create views to new landscaped areas possible.	1	Create views to existing landscaped areas possible.
C0	**Utilities**				
C1	**Tunnels**	0	Existing to E and S of Bldg	0	Existing to the S of bldg entering BofM
C2	**Electric**	0	Fed from existing west campus substation (1300 ft)	1	Fed from existing west campus substation (500ft)
C3	**Gas**	0	Avail in Lewis	0	Avail in Lewis
C4	**Steam**	1	10" Avail. Close to site	0	10" Avail. 450 ft. to site
C5	**Chilled water lines**		New line required in Lewis		New line required in Lewis
C6	**Sewer**	0	2 - 10" lines avail.	0	8" line avail.
C7	**Storm water**	0	10" line avail.	0	12" lines avail.
C8	**Water**	0	10" line avail.	0	8" line avail.
C9	**Data**	0	Avail.	0	Avail.
D0	**Environmental**				
D1	**Previous uses**	-1	Previous developed area, some sub surface features may be present	-1	Demolition of existing structure some known and unknown conditions.
D2	**Archeology**	0	None known	0	None known
D3	**Contamination**	0	None known	0	None known
E0	**Access/Traffic**				
E1	**Vehicular**				
E2	Service	2	Service access on 2 sides of structure	2	Service access on 2 sides of structure
E3	Maintenance	2	Maintenance easily accessible	1	Maintenance accessible
E4	Waste/Trash	1	Waste/Trash in close proximity	1	Waste/Trash in close proximity
E5	**Bicycles**	1	Area available for bicycle parking	1	Area available for bicycle parking
E6	**Pedestrian**	1	Adequate access and does not impede current circulation	1	Adequate access and does not impede current circulation
E7	**On-site parking**	1	Adequate space for on-site parking	0	Limited space for on-site parking but parallel parking avaiable on the street
	Total	**11**		**12**	

04 Tunnel Condition

The University of Wyoming's subterranean tunnel system is approximately 3.5 miles in length. It is comprised mostly of walking tunnels with a few sections that are short and narrow trenches. The earliest portions of tunnel date back to the early 1920s. See accompanying drawing from 1924 showing the original tunnel layout on west campus.

These tunnels mostly convey steam and condensate piping. There are some other utilities such as chilled water, telecom, power, compressed air, and waste that are routed through some portions but the majority is heating system related.

As initially identified in the 2009 Utility Master Plan, several sections of the of the older tunnel system are deteriorating. There are many high priority structural and life safety issues that have led to partial collapses in the recent past.



Flow Simulations

Introduction

Simulations of existing and future Chilled Water (CHW), Hot Water (HW), and steam utility expansions on the University of Wyoming (U.W.) campus were performed. The flow simulation software, PipeFLO, was used to create a flow model to provide a better understanding of the system's hydraulic performance as well as its constraints in response to the projected UW campus cooling and heating load growth. The current existing system consists of an 800 ton and 1200 ton chiller, three CHW pumps, miscellaneous building pumps, piping, coils, and control components. The existing Central Energy Plant (CEP) will soon be over taxed: the projected 5 year peak cooling load is approaching 2000 tons and increasing over the next 30 years. Similarly, the current steam distribution system currently exhibits a calculated load demand of approximately 130,000 lb/hr, with a projected increase of 20,200 lb/hr. Due to rising costs, as well as steam and condensate return energy losses, a proposal to begin transitioning part of the buildings served by the steam distribution to a new Hot Water distribution system was considered. The flow models provide both visual and quantitative data to determine which proposed CHW and steam expansion best satisfies projected load growth.

Simulation

PipeFLO Professional is comprehensive distribution piping analysis software that takes an in depth look at the interaction of pumps, control valves, and other system components to provide the user with a complete picture of modelled piping distribution systems. The flow modelling software can help design individual piping system components or simulate an entire piping system. For this project, models of the existing utility distribution systems were created to understand their hydraulic performance and further to evaluate proposed future engineering modifications.

Flow models of existing UW utility distribution systems were created using PipeFLO Professional. The flow model was necessary in determining system constraints and in exploring different accommodations to future cooling and heating demands. Several different options were explored in the software, providing both visual and quantitative data for reference.

Procedure

GLHN Architects and Engineers, Inc. utilized the University's Utility Master Plan to provide base approximations for the load data. The current CHW and steam piping layouts, sizing, and materials were also provided by the University. The data was categorized into the following phases: Existing, Projected 5 year, and Projected 30 year outlook.

Building cooling load data was translated into the required volumetric CHW flow-rates by way of the fundamental heat transfer equation.

$$Load\ (tons) = \frac{GPM\ \times dT\ (°F)}{24}$$

Existing CHW pumps at the CEP were modelled as a single "sizing pump" to simplify the simulation. In large distribution systems which circulate a considerable amount of flow, pumps are often placed in parallel. Pumps are described as operating in parallel when they receive liquid from the same suction manifold, and discharge into a common discharge manifold. Two pumps placed in parallel will halve the total flow seen by each while maintaining the same head, making them more attractive for low head-large flow systems. The modelled sizing pumps thus represent the actual head required for each existing/future pump.

Each phase acts as a baseline from which to compare the proposed system evolutions. Three alterations from the baseline were considered as options to satisfy projected cooling loads:

1. Buildout option 1 - CEP to west campus CHW loop interconnect
2. New CHW plant - West campus equipment addition (TES or satellite plant)
3. Buildout option 2- BioSci-Student Health interconnect

Pipes in the CHW flow models were color coded to represent varying flow velocity (green being the lowest velocity and red being the highest within the system) to provide a visual representation for possible physical constraints the system may experience as it is subject to phased loading. Using the continuity equation,

$$v = \frac{4}{\pi}\frac{w}{\rho D^2}$$

it is shown that the average pipe flow velocity is related to the pipe's internal pipe diameter (D), mass flow rate (), and fluid density (). The increase in mass flow rate and decrease in pipe diameter size results in an increase of flow velocity.

05 Flow Modeling

A maximum velocity of 9ft/s is typically used to minimize the possibility of erosion by solids, excess noise, and water hammer. As more build-out occurs and load demand increases the mass flow rate must increase to satisfy system loads, and existing pipes will prove to become a major physical constraint to future growth.

It is worth noting that a majority of current load demand and project load growth occur at the south and west ends of campus, while the CEP resides on the far northeast corner of campus.

Results

CHW

Table 1: CHW Utility Growth by Phase

Phase	Cooling Area (ft²)	Cooling Capacity Requirements (tons)	Required CHW Flow @ ΔT = 12°F
Existing (2016)	1,587,532	1,448	3,861
Phase 1: 5 years	2,014,143	1,998	5,327
Phase 2: 30 years	2,853,756	3,292	8,778

Table 1 shows the projected cooling loads and their respective CHW volumetric flow at a 10 °F temperature differential. According to the projected loads, Phase 1 will surpass CEP capacity, reaching a cooling load requirement of 1,998 tons. The increase in CHW load demand also corresponds in a direct increase in volumetric flow rate, which can begin to impose physical limits on system performance. Overall, CHW load is expected to increase from 1,440 tons to 3,400 tons by the year 2045. Table 2 provides a more detailed look at the load growth expected to occur on campus, per building and per phase.
One of the main concerns of the flow model was to evaluate system performance and capacity as load demand increased. Tables 3-5 provide results for pumping capacity at the CEP and proposed new CHW plant. Pumping capacity at a given volumetric flow rate was calculated for each phase and for each buildout option. The existing CHW flow model acts as the main baseline from which to build upon and compare options to satisfy increasing load. The piping system was modelled based upon the info of current and future CHW piping layouts, sizing and materials provided to GLHN.

Figures 1-9 give a visual representation of the existing system flow and the future buildouts. The figures are color coded to provide a look at how flow velocity changes as load demand increases, and can be used as a look into the physical constraints in the system- pipes with very large flow velocity are usually too small for the required

Table 2: Cooling Square Footage & Phasing Data for a 12°F Differential

Phase	UW Building Name	Area Cooled (ft²)	Q_{total} (tons)	V_{dot} (gal/min)
Existing (2016)	Ag. C	3,400	3.3	8
	Education Annex	27,840	18.1	43
	Education (LRC)	6,000	50.1	120
	Half Acre Gymnasium	81,034	83	194
	Earth Sciences	65,000	50.1	120
	Anthropology (AARF)	52,499	35.7	86
	Centennial Complex	126,200	97.2	233
	WY Technology Business Center	31,793	37	89
	Biological Sciences	81,200	62.6	150
	Health Sciences Complex	124,348	95.8	230
	Classroom Building	96,061	62.4	150
	College of Business	61,081	87.8	211
	Geology	12,220	9.1	22
	Cheney International Center/ Student Health	32,013	41.5	100
	Coe Library	185,676	175.5	421
	Coe Library - ILLC Addition	92,876	110	263
	Physical Sciences	65,157	61.8	148
	Wyoming Union	68,480	30.4	73
	Knight Hall	14,056	9.8	24
	WY State Geological Survey	23,171	16.2	39
	Information Technology (IT) Center	86,664	150	360
	Law Building	69,805	48.9	117
	Fine Arts	180,958	112.3	270
	Existing Totals	**1,587,532**	**1,448**	**3,475**

Phase	UW Building Name	Area Cooled (ft²)	Q_{total} (tons)	V_{dot} (gal/min)
Future: 5 yr projection	*Engineering Building (North of Lewis) (2018)*	96,388	*107*	257
	UW Science Initiatiive (North of Lewis) (2019)	*125,842*	*140*	336
	High Bay Research Facility (2017)	*79,701*	*106*	255
	New Natatorium (2020)	55,000	*165*	396
	Arena II (2017)	14,680	*7*	16
	Rochell II (Addition to RAC I) (2018)	*55,000*	25	60
Future (5yr) Totals		**2,014,143**	**1,998**	**4,795**

05 Flow Modeling

Table 3: Modelled Existing (2016) CHW System Pumping Requirement

Building pump	Operating Flow (gpm)	Head $(ft)_{H2O}$
CEP	3,900	168.2

Table 4: Pumping Requirements to Satisfy 5 Year Projection

Pumps	Baseline		Buildout 1 (West Campus Inter-connect)		New CHW plant or West Campus TES		New CHW plant w/ South-West Interconnect	
	Operat-ing Flow (gpm)	Head $(ft)_{H2O}$	Operat-ing Flow (gpm)	Head $(ft)_{H2O}$	Operat-ing Flow (gpm)	Head $(ft)_{H2O}$	Operat-ing Flow (gpm)	Head $(ft)_{H2O}$
CEP	5,000	**211.8**	5,000	137.2	2,500	**90.33**	2,500	**86.74**
TES	N/A	N/A	N/A	N/A	2,500	**97.21**	2,500	**93**

Table 5: Pumping Requirements to Satisfy 30 Year Projection

Pumps	Baseline		Buildout 1 (West Campus Inter-connect)		New CHW plant or West Campus TES		New CHW plant w/ South-West Interconnect	
	Operat-ing Flow (gpm)	Head $(ft)_{H2O}$	Operat-ing Flow (gpm)	Head $(ft)_{H2O}$	Operat-ing Flow (gpm)	Head $(ft)_{H2O}$	Operat-ing Flow (gpm)	Head $(ft)_{H2O}$
CEP	8,500	**379.7**	8,500	**237**	4,250	149.6	4,250	**129.5**
TES	N/A	N/A	N/A	N/A	4,250	158.6	4,250	**133.5**

Existing (2016)

For a 10°F CHW temperature differential, the existing system requires 4,000 gal/min of CHW volumetric flow. Currently the CEP cooling capacity meets the 1,400 ton cooling requirement following a chiller upgrade done by GLHN in 2007. Figure 1 shows a simulated flow model of the existing CHW distribution system. While the cooling load requirements have not yet surpassed CEP capacity, it can be seen from the figure that there are a few physical constraints which hinder future growth, namely pipe size and the location of the CEP plant in relation to the rest of the piping distribution system. Table 3 results indicate a pumping head requirement of 168 ftH2O. The magnitudes of these results are comparable to those of a CHW system similar in size and will act as a baseline to which future growth simulation data will be compared.

As more and more flow is imparted to buildings along the piping layout, the mass flow rate decreases as does the pressure drop at each building. As load growth and future build-outs occur, the CEP Mains will either have to be upsized or some flow capacity will have to be provided by a new satellite plant closer to the growth projected to occur on the west campus.

Existing (2016)

For a 10°F CHW temperature differential, the existing system requires 4,000 gal/min of CHW volumetric flow. Currently the CEP cooling capacity meets the 1,400 ton cooling requirement following a chiller upgrade done by GLHN in 2007. Figure 1 shows a simulated flow model of the existing CHW distribution system. While the cooling load requirements have not yet surpassed CEP capacity, it can be seen from the figure that there are a few physical constraints which hinder future growth, namely pipe size and the location of the CEP plant in relation to the rest of the piping distribution system. Table 3 results indicate a pumping head requirement of 168 ftH2O. The magnitudes of these results are comparable to those of a CHW system similar in size and will act as a baseline to which future growth simulation data will be compared.

As more and more flow is imparted to buildings along the piping layout, the mass flow rate decreases as does the pressure drop at each building. As load growth and future build-outs occur, the CEP Mains will either have to be upsized or some flow capacity will have to be provided by a new satellite plant closer to the growth projected to occur on the west campus.

Phase 1: Projected 5 Year Growth

Figure 2 models the growth expected to occur during the next 5 years, which includes a partial CHW loop build-out on the west end of campus, and multiple new building loads to be services. New buildings added to the loop include the future Engineering Building (North of Lewis) (2018), UW Science Initiative (North of Lewis) (2019), the High Bay Research Facility (2017), the New Natatorium (2020), Arena II (2017) and the Rochell II (Addition to RAC I) (2018). Table 2 lists these additions as well as their respective cooling load requirements.

The new buildings demand a total additional cooling load of 550 tons, corresponding to an additional CHW flow demand of 1,320 gpm and increasing the total system flow demand to 4,800 gpm (for simulation purposes the flow was rounded up to 5,000 gpm). The increase in CHW demand will bring the total campus cooling load demand to 2,000 tons, matching the system's current capacity.

Three options were considered as possible solutions to the projected growth, and compared to the baseline option in Table 4. The largest head requirement occurs for the baseline case (211.8 ft_{H2O}) where the CEP is modelled to have received no further improvements. From figure 3, 05 Flow Modeling

it can be seen that the implementation of a future interconnect has a noticeable impact on the CEP pump head: the west campus interconnect is shown to facilitate CHW distribution and in turn reduce the pumping capacity required to feed the CHW system in its entirety to 137.2 ft_{H2O}.

Figure 4 explores the addition of a new CHW plant on the west end of campus which further reduced the pumping head requirement and volumetric flow rate seen at the CEP. Results from Table 4 indicate a required pumping capacity of 86.74 ft_{H2O} at the CEP with 93 ft_{H2O} pump head seen at the new CHW plant. Better CHW distribution to the west side of campus also significantly decreases the need to upsize piping or for the immediate build-out of future loops and interconnects, which is observed by the overall reduced average flow velocity throughout the system.
Phase 2: Projected 30 Year Growth

The long-term growth expected to occur of the UW campus is considered in Phase 2. A completed west campus CHW loop buildout and numerous future load blocks contribute to the increase in cooling demand, resulting in 1,550 added tons. The projected load demand was split into several blocks to represent different sections of campus where the estimated cooling demand is projected to increase over the course of the next 30 years.

The calculated results from Table 1 dictate total cooling and pumping requirements of 3,550 tons and 8,500 gal/min. Assuming a baseline case in which no further buildouts nor improvements have been made to the CHW system or CEP respectively (other than those described above), in order to satisfy the future cooling requirements the pumps at the CEP would require a head of 380 ftH2O. The existing distribution piping acts as the main physical constraint in this scenario, with currently sized pipes simply too small for the volumetric flow rate required to adequately satisfy the system.

The buildout options presented in Phase 1 were then applied to the Phase 2 baseline and simulated. When exploring the various buildouts, while the buildout of an additional loop interconnect or a new CHW plant were each shown to reduce the pumping capacity, it was the integration of future loops along with a new CHW plant which
provided the most promising results. Table 5 lists the simulated options and their respective results.

Steam and HW Distribution

Table 6: Steam Utility Growth by Phase

Phase	Heating Area (ft^2)	Campus Diversified Steam Load (lb/hr)
Existing (2016)	5,594,099	132,159
Phase 1: 5 years	6,031,322	143,930
Phase 2: 30 years	6,933,835	164,140

Existing and projected heating loads are listed in Table 6. The existing steam distribution system (Figure 10) already serves a considerable amount of campus, demanding a current load of 132,159 lb/hr and expected to increase to 164,140 lb/hr over the next 30 years. To satisfy this load, numerous improvements and additions to the current distribution piping and Central Energy Plant were considered; after life cycle cost analysis however, it was determined that a transition to a new alternative Hot Water utility loop would be more cost effective and greatly improve fuel-to-heat efficiency. A majority of the projected load growth consists of the expansion of the west core campus. Currently, a majority of the west campus buildings (Table 7) are steam supplied and hot water heated- these buildings utilize CEP steam and convert to hot water locally in mechanical rooms via shell and tube heat exchangers. The proposal to transition to a Hot Water heating loop would include the transition of these buildings from steam-hot water to hot water-hot water heating. Due to the relatively high cost of building system changeover, approximately ten buildings residing on the west core campus which are currently 100% steam heating will remain as such.

The phased transition will begin with the interconnection into approximately 30 existing buildings, which are presented in Table 7 along with their respective existing steam heating loads and prospective HW loads. Simulated models of the phased transition are presented in figures 11-13. Results from the simulations indicate an initial pump head requirement of 139 ftH2O at an operating flow of 4,050 gpm to satisfy the new HW system.

The phased buildout of the HW loop will follow that of the prospective west campus CHW loop, and will interconnect into future buildings. Results from the 5 year projected simulation indicate a small increase in required pumping capacity (141.7 ftH2O) with the increased buildout. The final phase, or 30 year growth projection, additionally indicates a required head of 141.7 ftH2O to satisfy the 6.1 MMBTUH load increase. The lack of increase in pumping head is due to the increased feasibility with HW distribution as additional piping loops were interconnected.

Table 7: HW Phase 1 Building data

UW BUILDING NAME	% Build-ing: Steam	Total Heating Load (BTUH)	HW Flow (gpm)	Proposed Building Load On New HW System (BTUH)
Engineering and Applied Science	30%	9,212,150	430	6,448,505
Ag C	50%	2,109,950	70	1,054,975
Ag C Addition		3,192,950	213	3,192,950
Education Annex (Vocational)		548,150	37	548,150
Half Acre Gymnasium		4,629,350	309	4,629,350
Half Acre Gym Addition (HAG)		1,415,086	94	1,415,086
Earth Sciences		1,808,800	121	1,808,800
Berry Center		783,104	52	783,104
Anthropology (AARF)		1,034,550	69	1,034,550
Enzi STEM		2,860,688	191	2,860,688
Energy Innovation Center		1,647,063	110	1,647,063
Biological Sciences (includes Science Library Annex)		5,715,200	381	5,715,200
Health Sciences Complex		3,593,139	240	3,593,139
Classroom Building		1,892,400	126	1,892,400
College of Business		1,221,700	81	1,221,700
College of Business Addition		2,120,921	141	2,120,921
Geology	30%	1,086,800	51	760,760
Cheney International Cen-ter/Student Health		630,800	42	630,800
Hoyt Hall		589,950	39	589,950
Coe Library - 1977 addition	33%	1,688,150	75	1,131,061
Coe Library	33%	2,353,150	105	1,576,611
Coe Library ILLC Addition	33%	1,915,782	86	1,283,574
Aven Nelson		646,950	43	646,950
Physical Sciences		5,977,400	398	5,977,400
Wyoming Union 2002 addi-tion	30%	574,750	27	402,325
Wyoming Union	30%	3,159,700	147	2,211,790
Knight Hall	50%	1,609,300	54	804,650
Ross Hall		1,935,150	129	1,935,150
Aven Nelson - Williams Con-servatory	20%	313,791	17	251,033
WY State Geological Survey		456,950	30	456,950
Existing Subtotals		**76,752,921**	**3,908**	**58,625,582.86**

05 Flow Modeling

Table 8: HW Phase 2 Building data

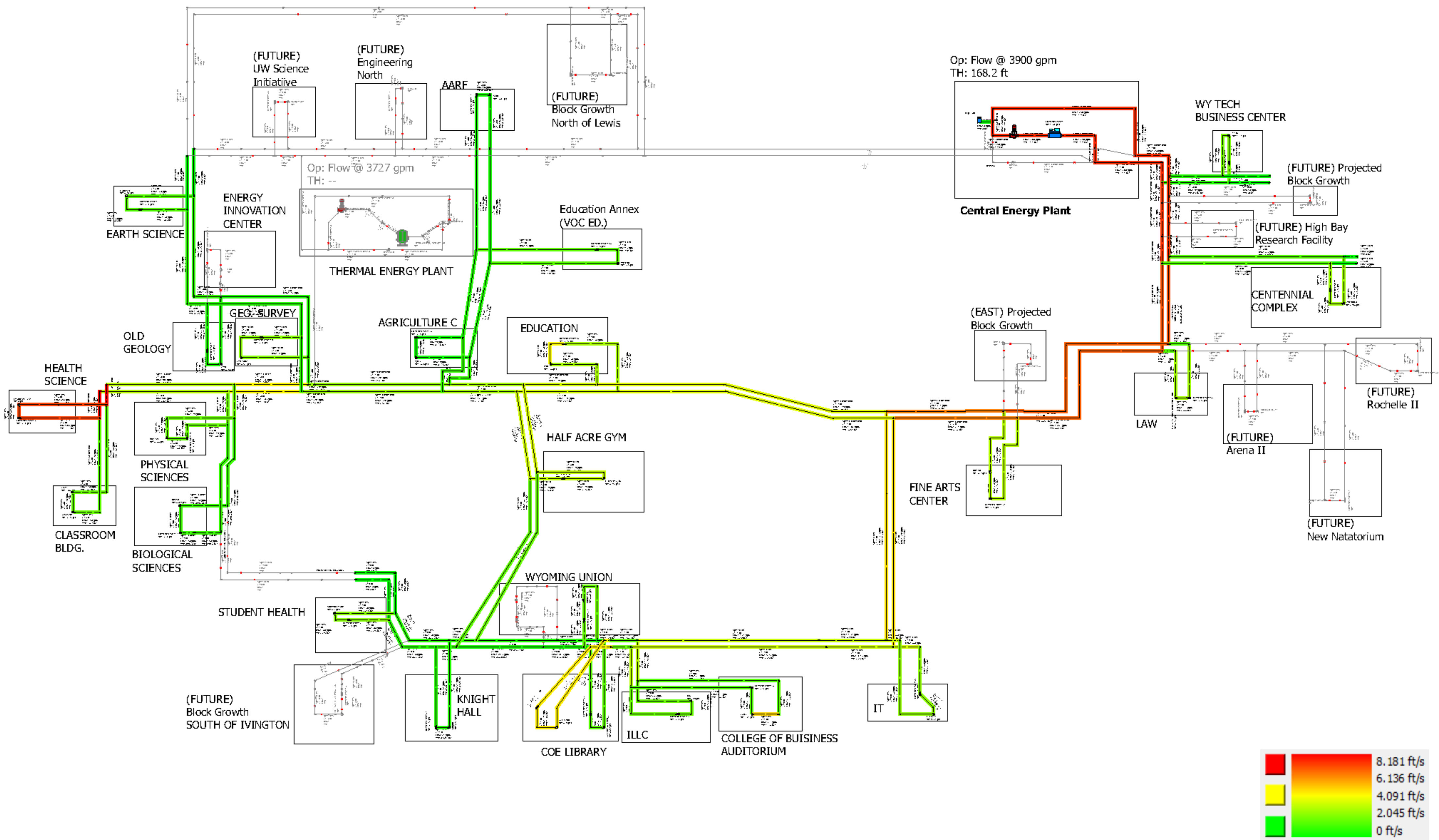
Phase	UW Building Name	HW flow (gpm)	Proposed 5 Year Building Load On New HW System (BTUH)
Future: 5 yr projection	Engineering Building (North of Lewis) (2018)	206	3,091,854
	UW Science Initiatiive (North of Lewis) (2019)	242	3,636,309
Future (5yr) Totals		***4,357***	***32,151,383***

Table 9: HW Phase 3 Building data

Phase	UW Building Name	HW flow (gpm)	Proposed 30 Year Building Load On New HW System (BTUH)
Future: 30 yr projection	*Block Growth (Estimated 2% per year after initial 5 years) North of Lewis*	128	1,917,372
	Block Growth (Based on UMP Projections)	275	4,125,463
Future (30yr) Totals		**4,760**	**71,396,582**

Phase	Required Pump Capacity (ft_{H2O})	Operative flow (gpm)
1: Initial	139.3	4050
2: 5 year Projection	141.7	4500
2: 30 year Projection	141.7	5000

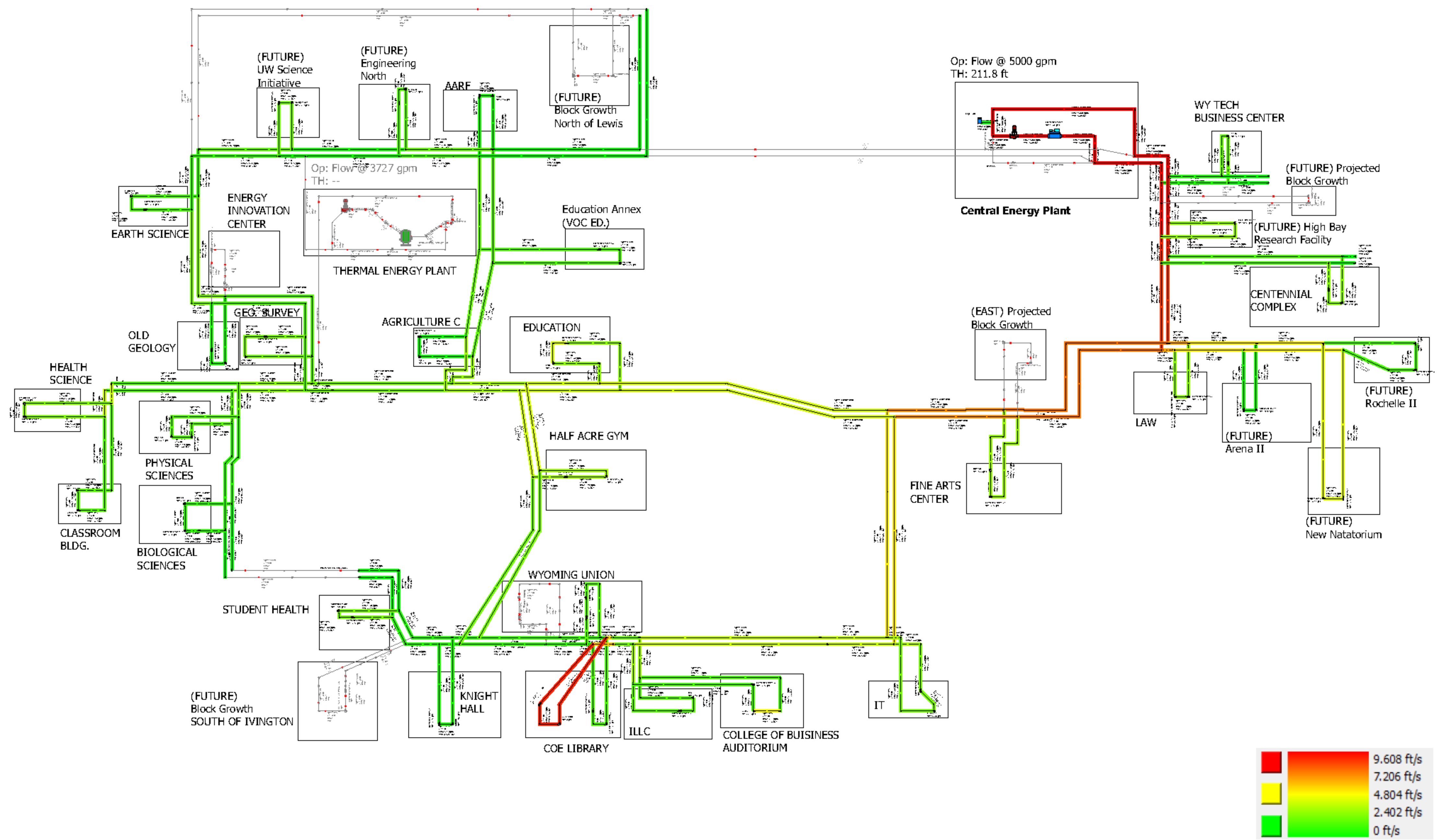
The chilled and heating water differential temperatures or the temperature difference between water leaving and entering the central plant assumed are realistic for the current conditions. These existing conditions include the witnessed CEP chilled water temperatures and the building internal hot water loop temperatures. The higher the delta T of a system, the less water flow required which directly reduces the piping losses and pumping horsepower. It would be in the University's best interest to continuously increase system differential temperatures as much as possible to reduce utility distribution costs. This can be achieved by calibrating water control valves, reducing the flow through any system bypasses, and increasing coil sizes within air handling units. These ideas should be kept in mind during any equipment replacement projects performed on campus.

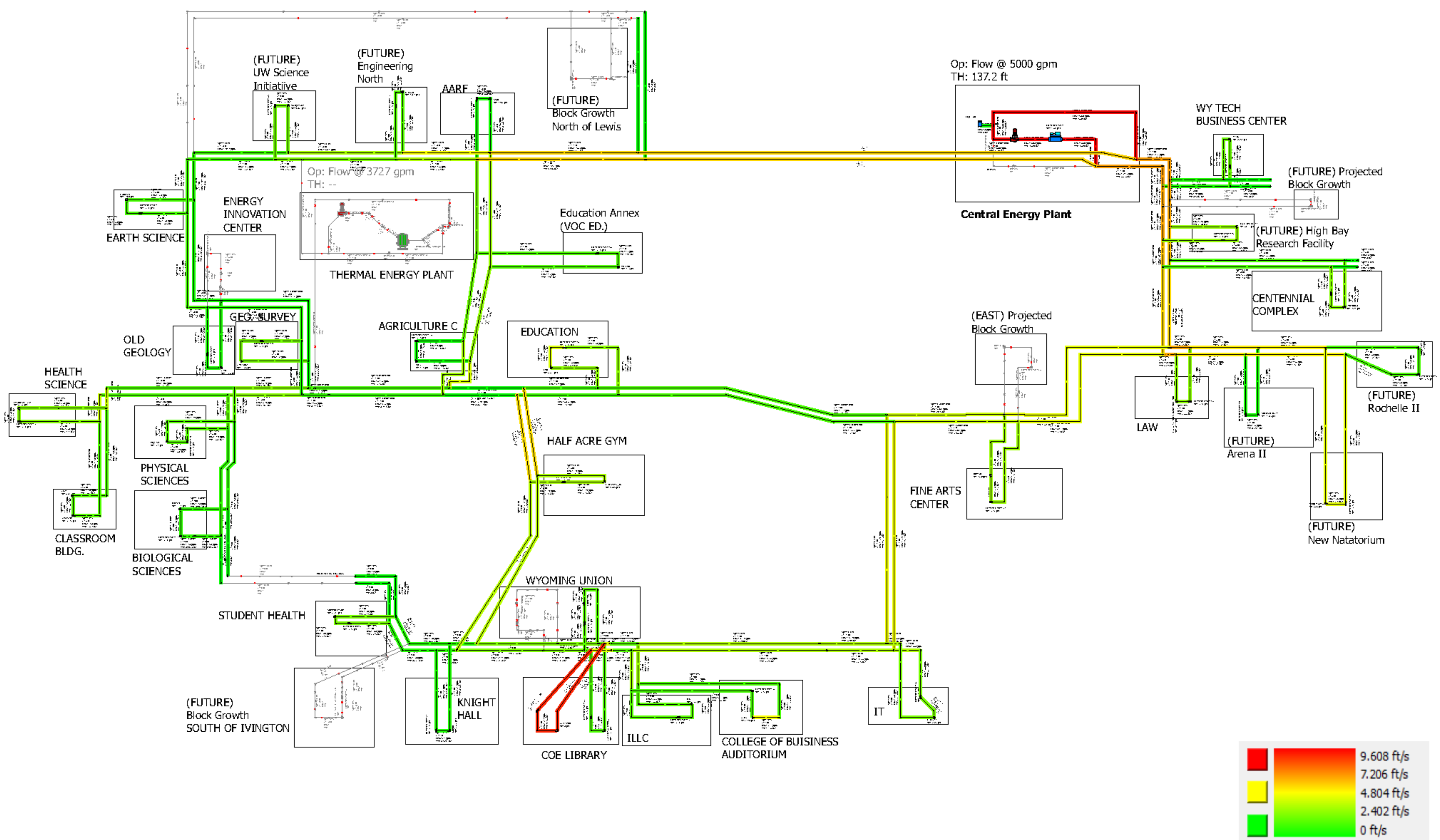


05 Flow Modeling

Section 1
Section 2
Section 3
Section 4
Section 5

05 Flow Modeling





05 Flow Modeling

FIG 1 Chilled Water Flow Model-Existing

FIG 2 Chilled Water Flow Model-5 year with no Improvements

FIG 3 Chilled Water Flow Model-5 year with New Interconnect Piping

FIG 4 Chilled Water Flow Model-5 year with New West Campus Insertion

FIG 5 Chilled Water Flow Model-5 year with New West Campus Insertion and south-west interconnect

FIG 6 Chilled Water Flow Model-30 years with no further improvements

FIG 7 Chilled Water Flow Model-30 years with New Interconnect Piping

FIG 8 Chilled Water Flow Model-30 years with New West Campus Insertion

FIG 9 Chilled Water Flow Model-30 year with New West Campus Insertion and south-west interconnect

FIG 10 Steam Flow Model-Existing

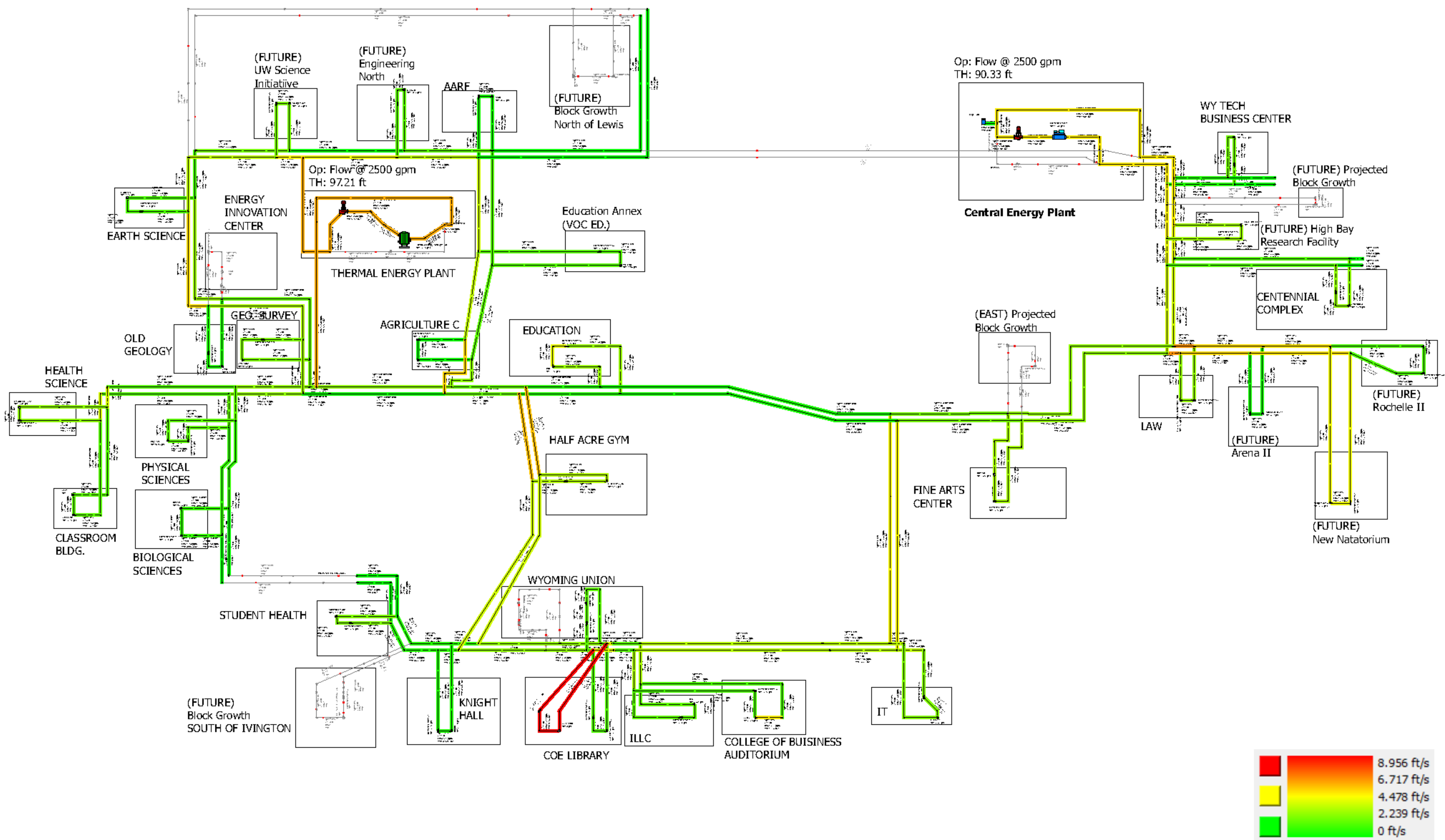
FIG 11 Hot Water Flow Model - Initial phase

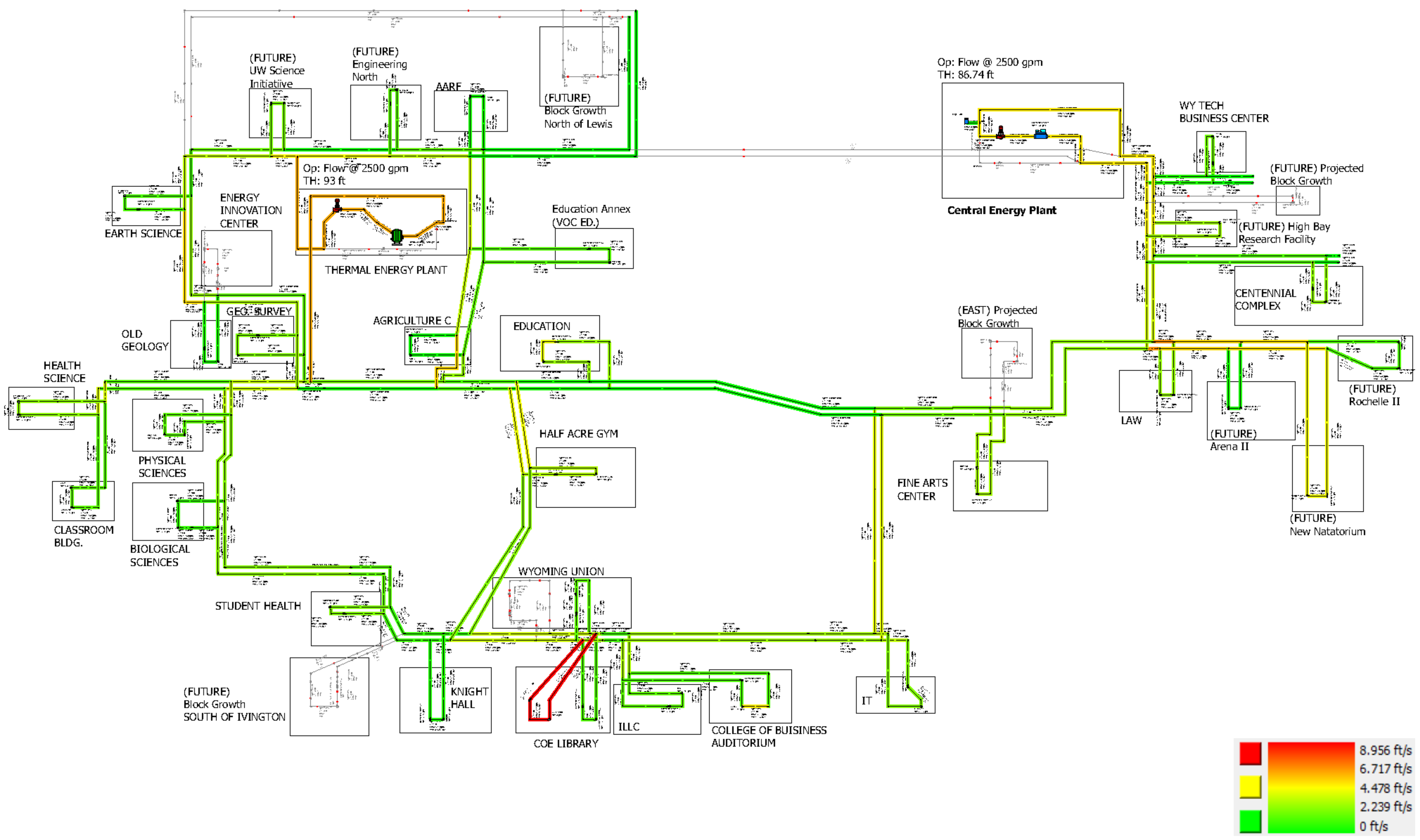
FIG 12 Hot Water Flow Model - 5 year load projection

FIG 13 Hot Water Flow Model - 30 year load projection

05 Flow Modeling

FIG 1 Chilled Water Flow Model-Existing
FIG 2 Chilled Water Flow Model-5 year with no Improvements
FIG 3 Chilled Water Flow Model-5 year with New Interconnect Piping
FIG 4 Chilled Water Flow Model-5 year with New West Campus Insertion
FIG 5 Chilled Water Flow Model-5 year with New West Campus Insertion and south-west interconnect
FIG 6 Chilled Water Flow Model-30 years with no further improvements
FIG 7 Chilled Water Flow Model-30 years with New Interconnect Piping
FIG 8 Chilled Water Flow Model-30 years with New West Campus Insertion
FIG 9 Chilled Water Flow Model-30 year with New West Campus Insertion and south-west interconnect
FIG 10 Steam Flow Model-Existing
FIG 11 Hot Water Flow Model - Initial phase
FIG 12 Hot Water Flow Model - 5 year load projection
FIG 13 Hot Water Flow Model - 30 year load projection





05 Flow Modeling

FIG 1 Chilled Water Flow Model-Existing

FIG 2 Chilled Water Flow Model-5 year with no Improvements

FIG 3 Chilled Water Flow Model-5 year with New Interconnect Piping

FIG 4 Chilled Water Flow Model-5 year with New West Campus Insertion

FIG 5 Chilled Water Flow Model-5 year with New West Campus Insertion and south-west interconnect

FIG 6 Chilled Water Flow Model-30 years with no further improvements

FIG 7 Chilled Water Flow Model-30 years with New Interconnect Piping

FIG 8 Chilled Water Flow Model-30 years with New West Campus Insertion

FIG 9 Chilled Water Flow Model-30 year with New West Campus Insertion and south-west interconnect

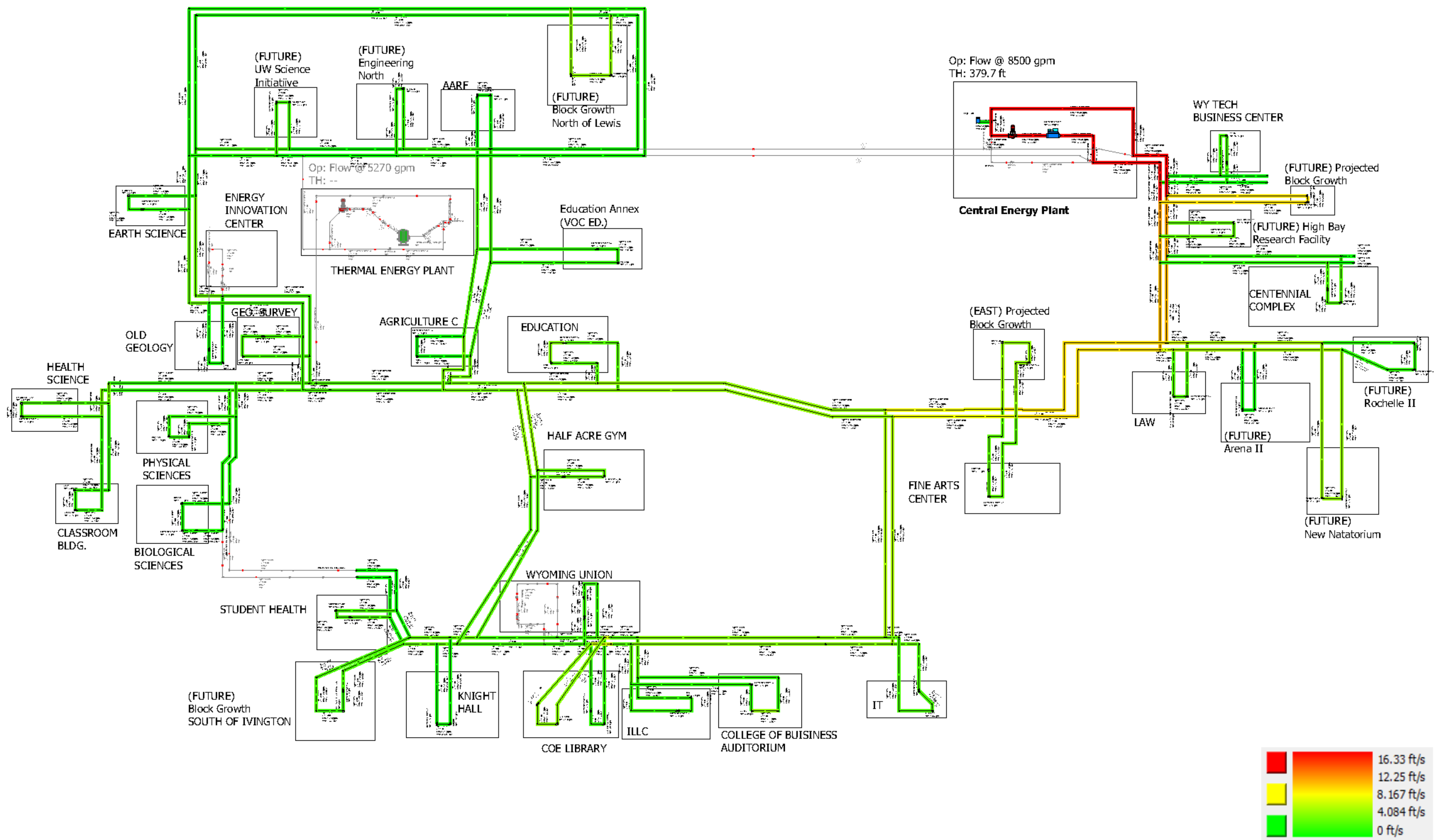
FIG 10 Steam Flow Model-Existing

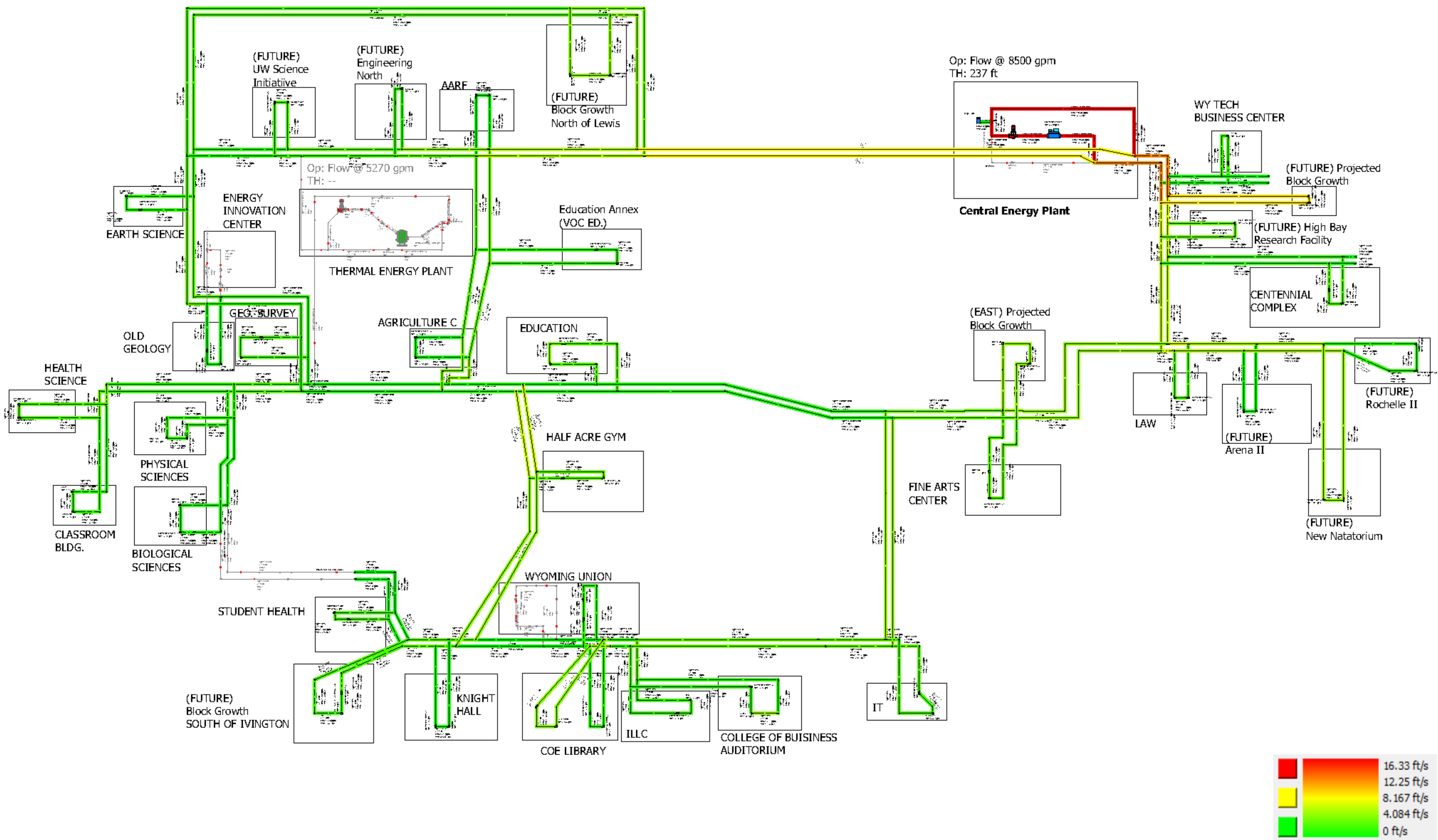
FIG 11 Hot Water Flow Model - Initial phase

FIG 12 Hot Water Flow Model - 5 year load projection

FIG 13 Hot Water Flow Model - 30 year load projection

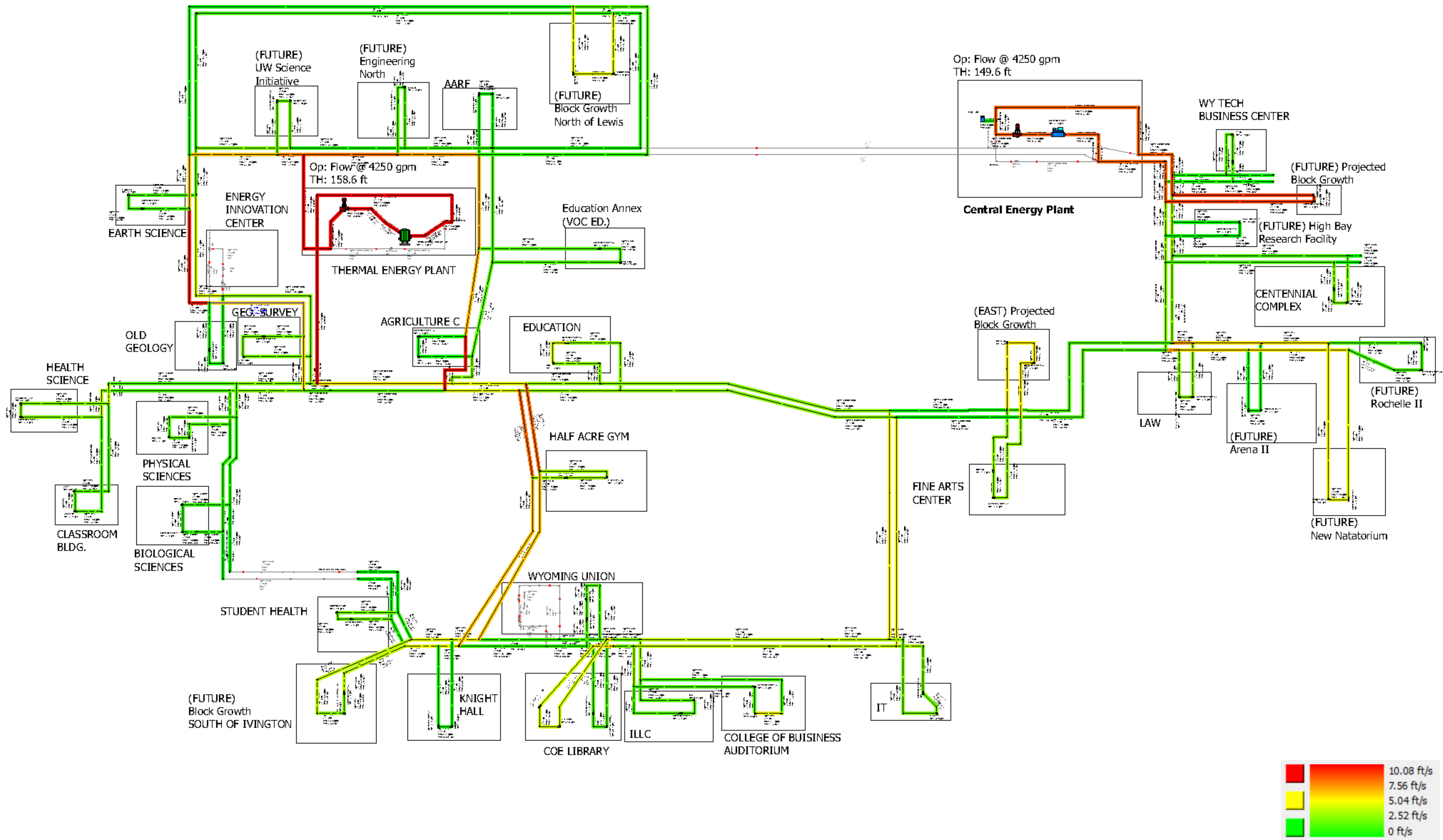
05 Flow Modeling

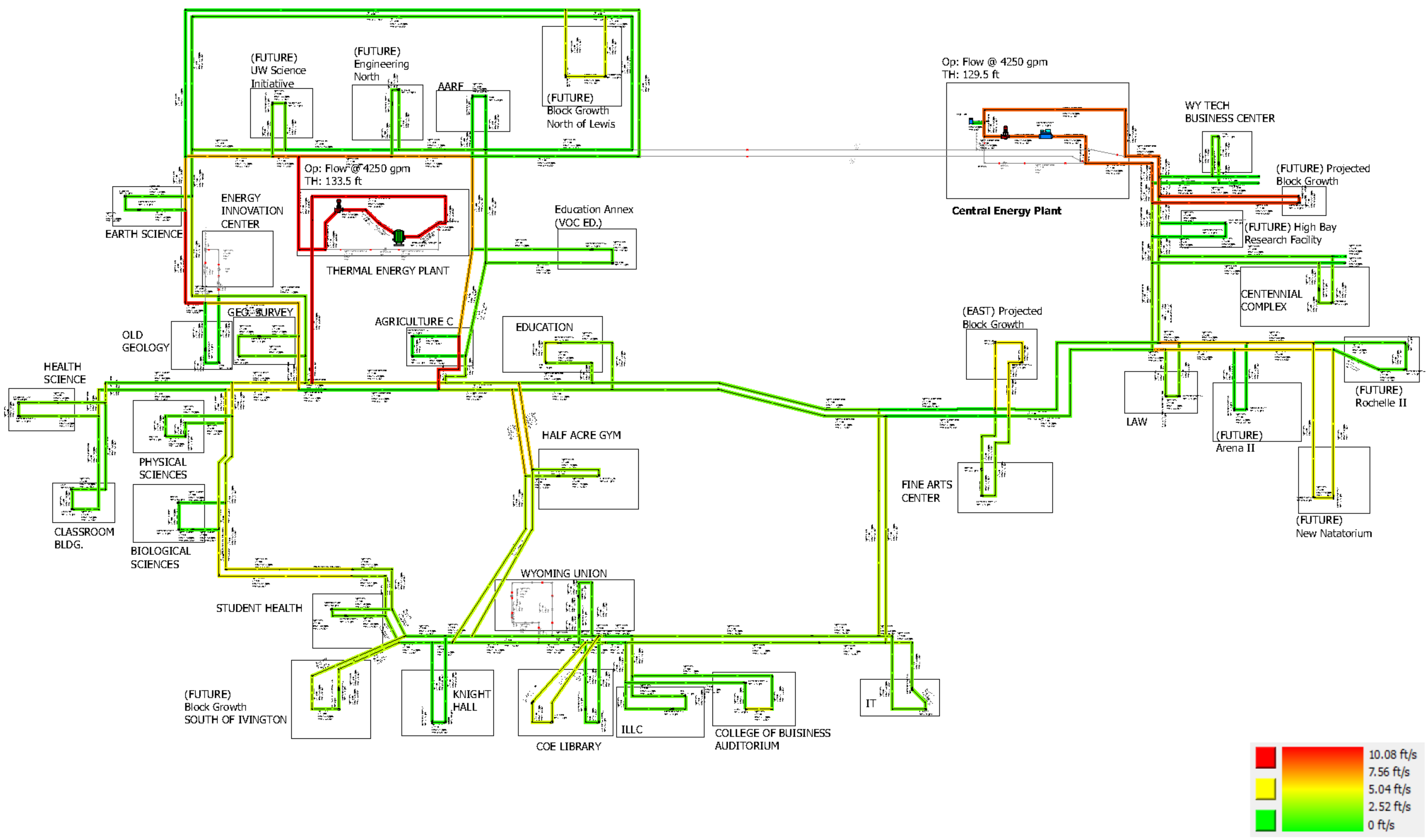




05 Flow Modeling

05 Flow Modeling





05 Flow Modeling

FIG 1 Chilled Water Flow Model-Existing

FIG 2 Chilled Water Flow Model-5 year with no Improvements

FIG 3 Chilled Water Flow Model-5 year with New Interconnect Piping

FIG 4 Chilled Water Flow Model-5 year with New West Campus Insertion

FIG 5 Chilled Water Flow Model-5 year with New West Campus Insertion and south-west interconnect

FIG 6 Chilled Water Flow Model-30 years with no further improvements

FIG 7 Chilled Water Flow Model-30 years with New Interconnect Piping

FIG 8 Chilled Water Flow Model-30 years with New West Campus Insertion

FIG 9 Chilled Water Flow Model-30 year with New West Campus Insertion and south-west interconnect

FIG 10 Steam Flow Model-Existing

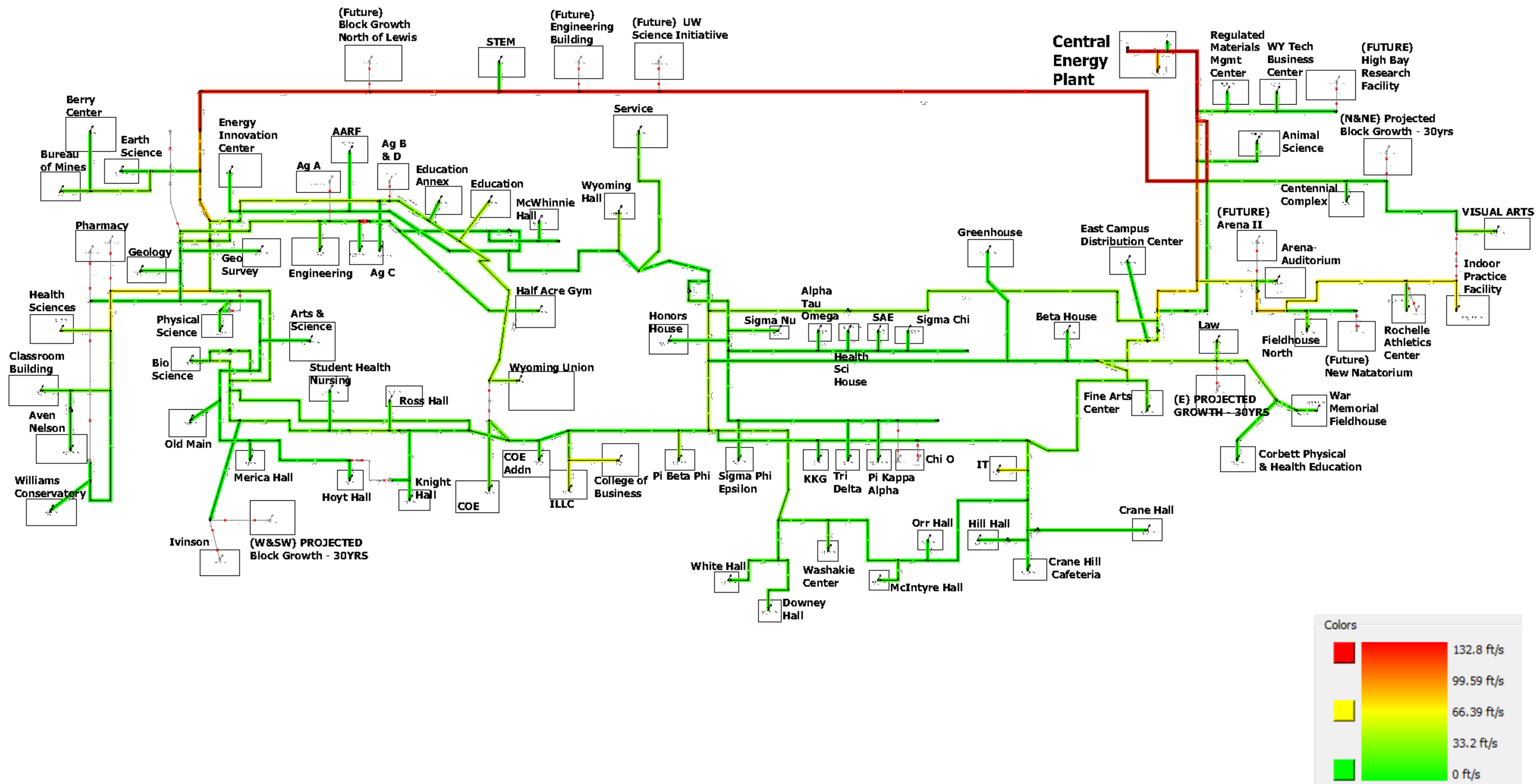
FIG 11 Hot Water Flow Model - Initial phase

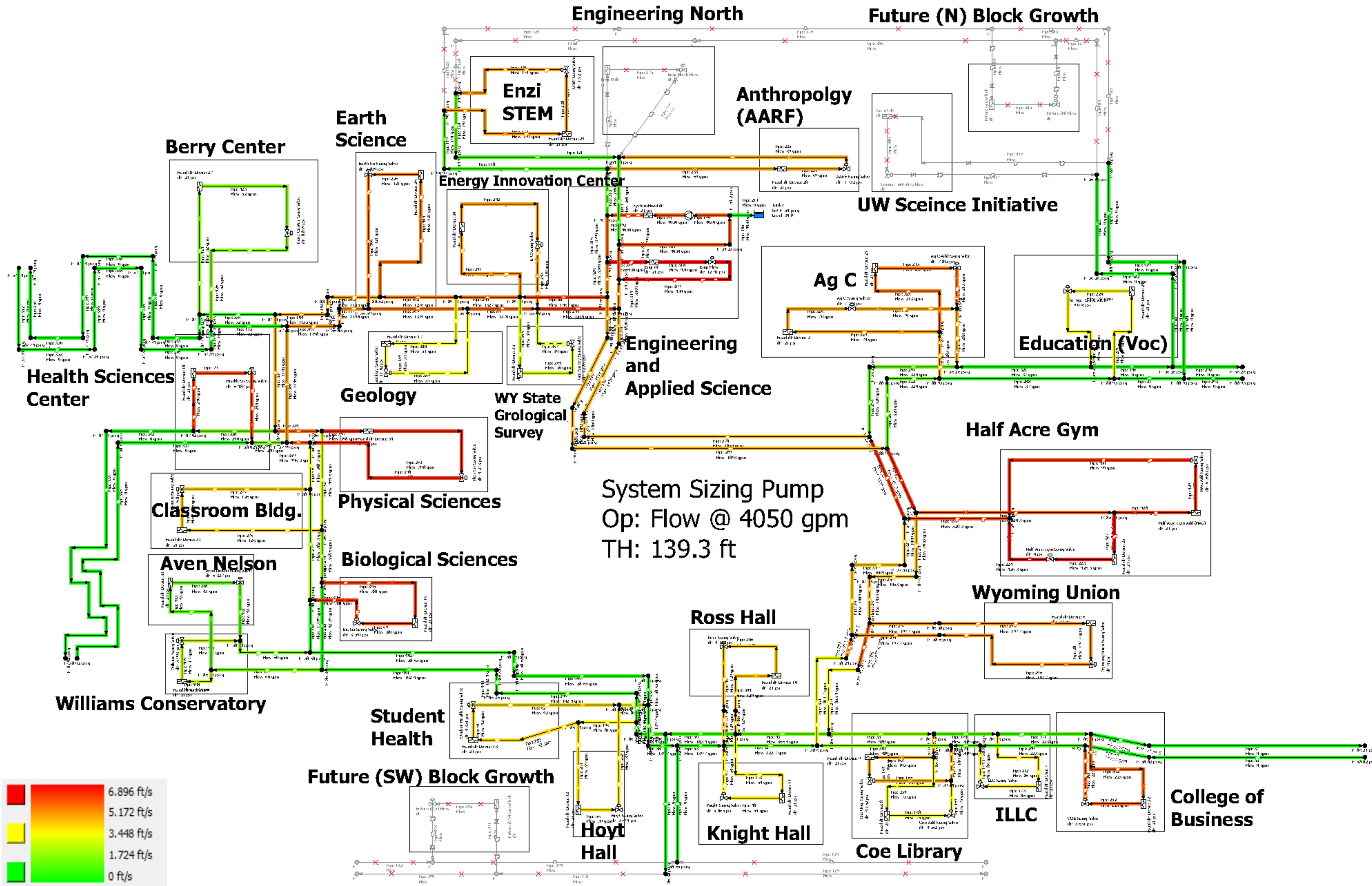
FIG 12 Hot Water Flow Model - 5 year load projection

FIG 13 Hot Water Flow Model - 30 year load projection

05 Flow Modeling

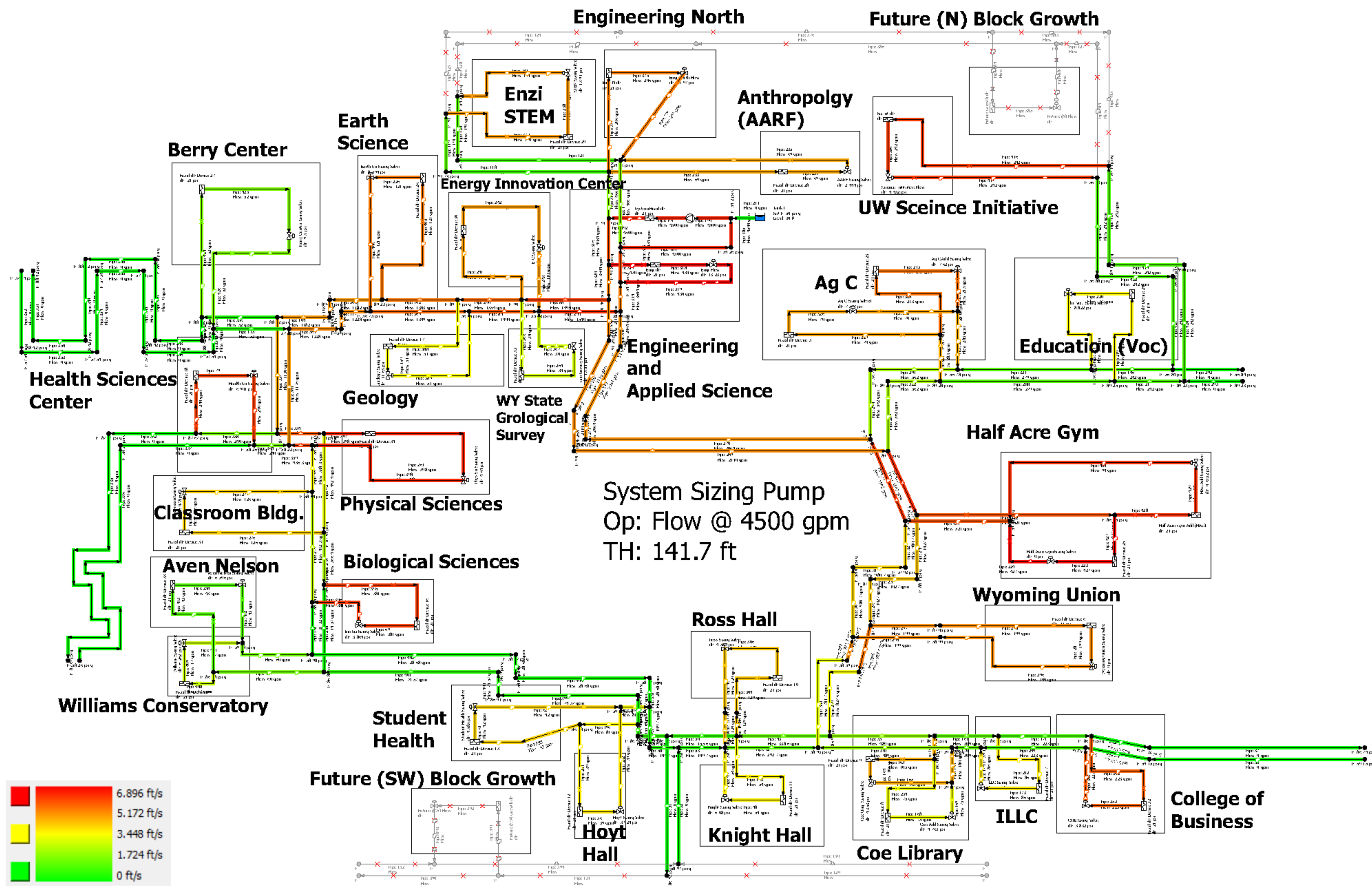
FIG 1 Chilled Water Flow Model-Existing
FIG 2 Chilled Water Flow Model-5 year with no Improvements
FIG 3 Chilled Water Flow Model-5 year with New Interconnect Piping
FIG 4 Chilled Water Flow Model-5 year with New West Campus Insertion
FIG 5 Chilled Water Flow Model-5 year with New West Campus Insertion and south-west interconnect
FIG 6 Chilled Water Flow Model-30 years with no further improvements
FIG 7 Chilled Water Flow Model-30 years with New Interconnect Piping
FIG 8 Chilled Water Flow Model-30 years with New West Campus Insertion
FIG 9 Chilled Water Flow Model-30 year with New West Campus Insertion and south-west interconnect
FIG 10 Steam Flow Model-Existing
FIG 11 Hot Water Flow Model - Initial phase
FIG 12 Hot Water Flow Model - 5 year load projection
FIG 13 Hot Water Flow Model - 30 year load projection

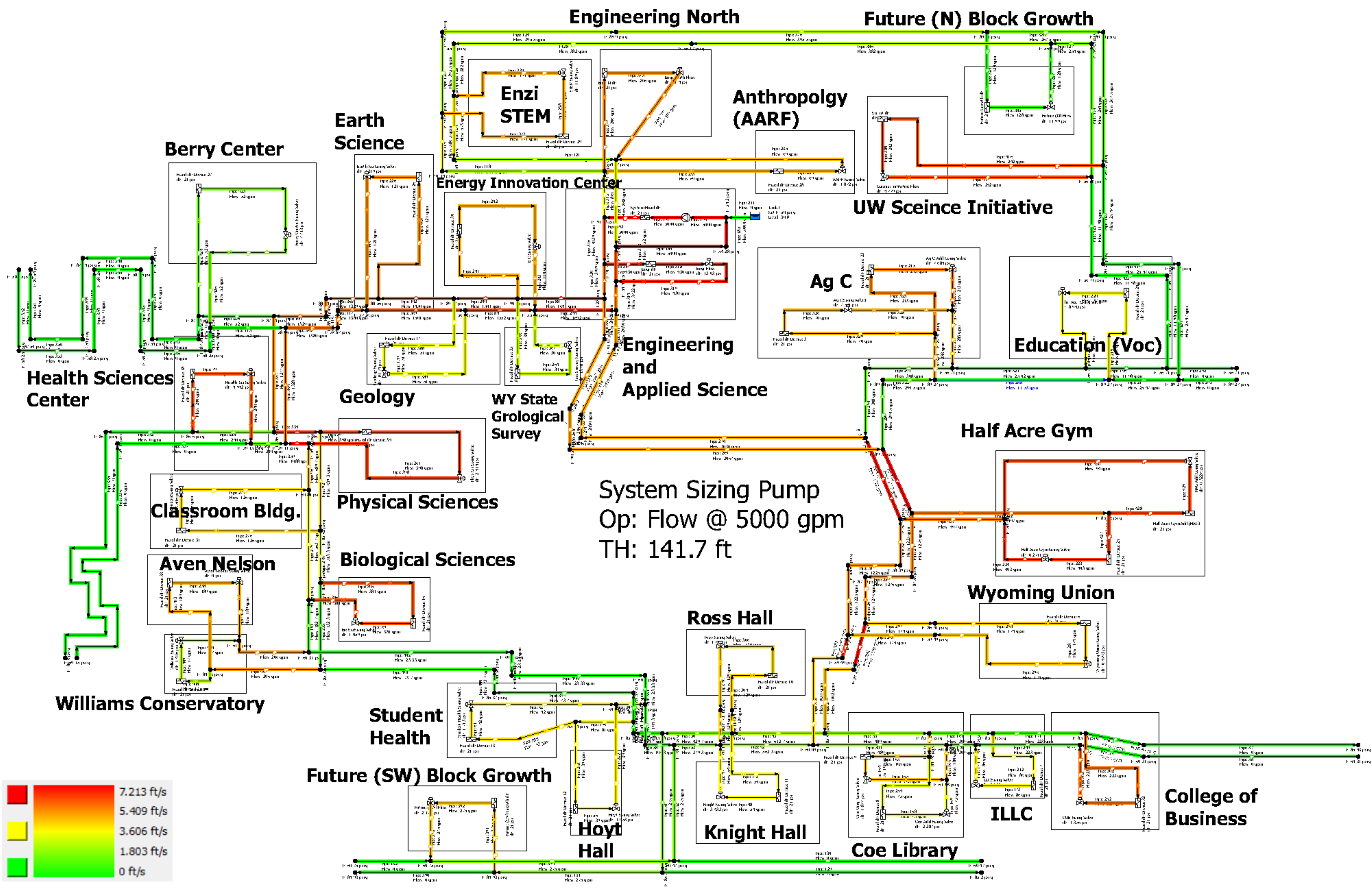




05 Flow Modeling

05 Flow Modeling





05 Flow Modeling

End of Section 4

Section 5: Proposed West Campus Options

Section 1
Section 2
Section 3
Section 4
Section 5

ARCHITECTURAL NARRATIVE:

General

The new Thermal Storage Energy Plant located at the University of Wyoming Campus in Laramie, Wyoming is a 8,500 square foot facility comprised of two primary levels with a utility equipment platform designed to house various mechanical and electrical equipment along with a 1.5 million gallon thermal storage tank. The Architectural design aesthetic will extend upon the current design motifs utilized on nearby campus works such as stone veneers, concrete, and masonry.

Architectural Components

Exterior Wall system

The exterior wall system is comprised of 12" CMU clad in a GFRC (Glass-Fiber-Reinforced Concrete) panel rainscreen system with an "ashlar" Natural Sandstone veneer accent at the lower portion of the wall. The finish and color of the cladding will reflect similar tones and textures of neighboring works on the campus. Below grade, the facility is comprised of reinforced concrete which is visible in portions of the exterior above grade. Below is a breakdown of the system components.

Above Grade: (Number 1 is the outermost, exterior side)
1. GFRC Panel system with partial height Sandstone Ashlar veneer wainscot.
2. Weather membrane
3. 2-3" of Polyiso Rigid insulation (R-6 per inch).
4. 12" CMU structural wall

Below Grade: (Number 1 is the outermost, exterior side)
1. Drainage wall material
2. Weather membrane
3. 2-3" of Polyiso Rigid Insulation (R-6 per inch)
4. 12" Reinforced concrete.

Fenestration

Natural light is a key component to minimizing excessive dependency on artificial light and reducing energy usage. With that said, this design utilizes aluminum framed curtainwall systems on the North and East facades which maximize daylighting as well as allow the space to be viewed from the provided exterior courtyard.

Interior Partitions

The areas provided within the facility will be composed of gypsum board over metal framed partitions with exposed ceilings. The one area to receive a ceiling is the control room which is an acoustic tile ceiling in a t-grid system along with acoustic batt insulation.

Interior Finishes

All exposed surfaces on the interior side will be painted with latex paint while the exposed concrete floors will be sealed with a transparent high-performance coating. Piping and piping equipment will be color coded with a high performance epoxy based paint.
Stairs and Miscellaneous metals The stairwell provided in the facility will be steel with concrete filled, metal pan treads. The equipment deck is an open metal grate deck over metal joists with a metal pipe guardrail. Both the equipment deck and stairwell will receive the same type of metal pipe guardrail whit the stair receiving the additional handrail per IBC requirements. Also provided in this facility is a caged metal access ladder from the basement up to the first level which is separated via floor access hatch.

Doors and Frames

All doors and frames in the facility will be hollow metal and factory primed to receive paint on the field.

Roofing System

This facility will receive a single ply Polyvinyl Chloride roofing system per the recommended guidelines provided by the University of Wyoming design manual. The membrane will be carried up and over the full height of the parapet and met with a sheet metal counter-flashing/reglet.

Design

This facility will be designed in compliance to the International Building Code, International Fire Code, and 2010 ADA guidelines.

Laramie Building Codes:

International Building Code (2012)
International Residential Code (2012)
International Mechanical Code (2012)
International Plumbing Code (2012)
International Fuel Gas Code (2012)
International Fire Code (2012)
International Energy Conservation Code (2012)
National Electrical Code (2014)
Laramie Municipal Code
City of Laramie Standard Details

The following pages outlines the preliminary code review for the project

Code Review

IBC 2012
USE: Satellite Utility Plant

BUILDING CLASSIFICATION
(Per IBC Chapters 3,4,5 And 6)

Basic Occupancy Group(S)
(Per IBC Chapter 3)

Occupancy Group: S-1 (Moderate Hazard Storage)
Occupancy Group: S-2 (Low Hazard Storage)
Occupancy Group: B (Business)

Construction type

(Per IBC chapter 6 and table 503)

Construction type: **VB**
Basic allowable area (GSF)
(per IBC table 503)

Occupancy group: S-1	9,000
Occupancy group: S-2	13,500
Occupancy group: B	9,000
Actual Area:	**8,480**

Building height allowed (Stories / Ht. in feet.)

Occupancy group: S-1	1 / 40
Occupancy group: S-2	2 / 40
Occupancy group: B	2 / 40
Actual Stories:	**2 / 25**

505.3 Equipment platforms.
Equipment platforms in buildings shall not be considered as a portion of the floor below. Such equipment platforms shall not contribute to either the building area or the number of stories as regulated by Section 503.1. The area of the equipment platform shall not be included in determining the fire area in accordance with Section 903. Equipment platforms shall not be a part of any mezzanine and such platforms and the walkways, stairs, alternating tread devices and ladders providing access to an equipment platform shall not serve as a part of the means of egress from the building. **COMPLIES**

505.3.1 Area limitation.
The aggregate area of all equipment platforms within a room shall be not greater than two-thirds of the area of the room in which they are located. Where an equipment platform is located in the same room as a mezzanine, the area of the mezzanine shall be determined by Section 505.2.1 and the combined aggregate area of the equipment platforms and mezzanines shall be not greater than two-thirds of the room in which they are located. **COMPLIES**

505.3.2 Automatic sprinkler system.
Where located in a building that is required to be protected by an automatic sprinkler system, equipment platforms shall be fully protected by sprinklers above and below the platform, where required by the standards referenced in Section 903.3. **COMPLIES**

505.3.3 Guards.
Equipment platforms shall have guards where required by Section 1013.2.

508.3 Nonseparated occupancies.
Buildings or portions of buildings that comply with the provisions of this section shall be considered as nonseparated occupancies.

508.3.1 Occupancy Classification.
Nonseparated occupancies shall be individually classified in accordance with Section 302.1. The requirements of this code shall apply to each portion of the building based on the occupancy classification of that space. In addition, the most restrictive provisions of Chapter 9 which apply to the nonseparated occupancies shall apply to the total nonseparated occupancy area.

508.3.2 Allowable building area and height.
The allowable building area and height of the building or portion thereof shall be based on the most restrictive allowances for the occupancy groups under consideration for the type of construction of the building in accordance with Section 503.1.

508.3.3 Separation.
No separation is required between nonseparated occupancies.

Minimum Fire Resistive Requirements
(Per IBC Section 403.2.1.1 and Table 601)

Element	**Rating**
Bearing Walls (Exterior)	0hr
Bearing Walls (Interior)	0hr
Non-Bearing Walls (Ext)	0hr 10'≤ X≤30', 1hr <5' / 5'≤ X ≤ 10'
Structural Frame	0hr
Shaft Enclosures	1hr (See 713.4 less than 4 stories)
Floor Construction	0hr
Roof Construction	0hr
Stairway Construction	1hr (See 1009.3 Exception 1)
Exit Passage	1hr
Horizontal Exit	1hr

Maximum Travel Distance to Exits
Occupancy Group: S-1 250'
Occupancy Group: S-2 400'
Occupancy Group: B 300'
Maximum Dead End Distance
(with Fire Suppression System Throughout)
Occupancy Group: S-1 50'
Occupancy Group: S-2 50'
Occupancy Group: B 50'
Maximum Common Path of Travel
Occupancy Group: S-1 100'
Occupancy Group: S-2 100'
Occupancy Group: B 100'

Fire Suppression
The Facility Is Protected By a Supervised Automatic Sprinkler Suppression System Per NFPA 13.
Hand Held Fire Extinguishers Will Be Provided Per NFPA 10 at 75' Travel Distance And Maximum Floor Area of 3,000sf.

Occupant Load Calculations
(Per IBC Chapter 10 And Table 1004.1.2)
Occupant Load Factor (Sf / Person)

Office Areas:	100 Gross
Storage, Mech, Electrical Areas:	300 Gross

Occupant Load

Basement:	15 Occupants
First Level:	14 Occupants
Equip Platform:	0 Occupants
Roof Level:	0 Occupants
Total	**29 Occupants**

1009.3 Exit access stairways.
Floor openings between stories created by exit access stairways shall be enclosed.

Exceptions:
In other than Group I-2 and I-3 occupancies, exit access stairways that serve, or atmospherically communicate between, only two stories are not required to be enclosed.

Stories with One Exit or Access to One Exit for Other Occupancies
Table 1021.2(2)
First Story or Basement, Use **B and S**,
Maximum Occupants per Story: **49** Occupants,
Travel distance: **75 Feet** (**100 Feet** with Automatic Fire Sprinkler System.)

Section 5: Proposed West Campus Options

STRUCTURAL NARRATIVE:
The new University of Wyoming Energy Plant is an approximately 9,000 sqft, two story structure. The structure will consist of a basement area, second floor area, a equipment, and a 1.5 million gallon thermal storage tank (separate from the building).

Building Structural System Components

ROOF FRAMING
The roof framing consists of 1-1/2" type B, 20 ga. steel deck supported on steel wide flange joists spaced 5'-4" to 6'-8" on center. The roof joists will vary in depth from 8" to 12" and vary in span from 14'-0" to 22'-0". The roof joists will bear on two interior beam column lines and on the exterior masonry walls. The support beams along the interior beam columns lines will be wide flange steel beams varying in depth from 12" to 16", and varying in span from 16'-0" to 20'-0".

EQUIPMENT PLATFORM FRAMING
The equipment area will be approximately 24'-0" x 60'-0". The equipment framing consists of 1-1/4" x 1/8" steel bar grating supported on steel wide flange joists spaced at 4'-0" on center. The equipment joists will vary in depth from 8" to 12" and vary in span from 14'-0" to 22'-0". The roof joists will bear on two interior beam column lines and on the exterior masonry walls. The interior support beam for the equipment will be 12" deep steel wide flange beam.

FLOOR and FRAMING
The floor framing consists of 1-1/2" type B, 18 ga. composite steel deck with 4-1/2" of concrete, for a total deck plus concrete depth of 6". The steel deck will be supported on steel wide flange joists spaced 4'-0" to 5'-0" on center. The floor joists will vary in depth from 12" to 16" and vary in span from 14'-0" to 22'-0". The floor joists will bear on two interior beam column lines and on the exterior masonry walls. The support beams along the interior beam columns lines will be wide flange steel beams varying in depth from 18" to 21", and varying in span from 16'-0" to 20'-0". There will be a 10'-0"x10'-0" hatch in the floor framing for access to the basement. The typical floor will be concrete slab on grade construction. The slab on grade will be 6 inches thick reinforced with #4 bars at 24" o.c. each direction. Equipment in the basement will sit on 12" thick minimum equipment pads isolated from the floor slab.

WALL SYSTEMS
The basement walls will be 12 inch thick reinforced concrete walls. The walls above the first level will be 12 inch thick reinforced and grouted concrete block (CMU). All lintels in the masonry walls will be reinforced CMU lintels.

COLUMNS
Interior support columns will be W8 wide flange columns.

LATERAL SYSTEMS

The building lateral loads generated by either wind or earthquake forces will be resisted by a combination of masonry block shear walls and reinforced concrete wall. The shear walls will be laterally braced by the horizontal metal deck roof and floor diaphragms.

FOUNDATIONS

A geotechnical report for this project has not yet been completed, however we anticipate the footings for this project will be conventional concrete foundations; square spread footings at columns; and continuous strip footings at bearing walls bearing on native soil (unless the soils report recommends an alternate foundation system). We estimate the bearing wall footings will 3'-0" to 3'-6" wide and 12" thick, and the column footings to be 6'-6" square by 16" thick. The 1.5 million gallon thermal storage tank will bear on a 2'-6" thick concrete pad with a double layer of reinforcement.

SITE

There will various retaining wall around the building and the thermal storage tank. The retaining walls will vary in height from 2'-0" up to 15'-0". The retaining wall will consist of 12" thick reinforcement concrete wall and footings.

RAIL HOIST

A 2.5-ton rail hoist will be installed above the floor hatch.

Design Criteria

All structural design will be in accordance with the 2012 Edition of the International Building Code.

Roof Design Loads:
Typical Dead Load = 30 psf
Typical Live Load = 30 psf (snow load)

Equipment Design Loads
Typical Dead Load = 20 psf
Typical Live Load = 60 psf

Floor Design Load
Typical Dead Load = 83 psf
Typical Live Load = 150 psf

Wind Load:
V_{3S} = 115 mph, Exposure C

Earthquake:
Site Classification: B S_S=0.237 S_1=0.068
Occupancy Category Iv
Importance Factor I_S = 1.5
Seismic Design Category = B

Lateral Force Resisting System:
Ordinary Reinforced Masonry Shear Walls and Reinforced Concrete Shear Walls

Foundation Allowable Bearing:
Pending soils report

Hot Water System

The recommendation to satisfy the projected heating loads on west campus is to transition from a steam distribution system to a hot water production and distribution system. Currently, the majority of buildings on west campus are steam supplied and hot water heated. These buildings utilize CEP steam and convert to hot water locally in mechanical rooms. This project would transition these buildings from steam-hot water to hot water-hot water via replacement of the existing shell and tube heat exchangers and installation of new plate and frame heat exchangers. There are approximately 30 different buildings that will make this transformation. Approximately ten (10) buildings on West Campus that are currently 100% steam will remain on steam and no changes in heating will occur as part of this project. On average, (1) new plate and frame heat exchanger with an exchange capacity of 1.5 mmbtu for heating water and (1) domestic hot water heat exchanger with a capacity of 0.35 mmbtu will be required per building. Existing building loop pumps will be reutilized in the new design.

An existing, fairly extensive underground tunnel system is in place and operational on West Campus. There are several portions of this system that are very old, some areas near collapse. Most of the existing steam distribution system, in forms of various sizes and operational pressures of steam and condensate piping, are located within these tunnels. The poor sections of tunnels and piping will be demolished, some of which contain ACM. Approximately 1,000' of tunnel and corresponding contents are being considered for demolition or abandonment. A majority of the tunnels will be used to house the new hot water supply and return piping. A single steam line will be required to be operational to supply the few steam buildings on west campus.

A new west campus plant would house up to (10) high efficient natural gas condensing boilers and distribution pumps. Boilers would be sized for approximately 5 mmbtu each, with pumps at 50HP each. A 30 mmbtu steam to water heat exchanger package will be installed as a backup system with steam supplied from the CEP. Up to (8) variable speed direct primary distribution pumps would be installed within the plant to circulate water. 14" North and south plant entrances would be metered and provided with air/dirt separators. A modulating draft control system will be implemented to allow the combination of (5) boilers to utilize one stack. Both stacks would run the height of the adjacent thermal energy storage tank and terminate. A new hot water, bladder type expansion tank will be installed at the plant to compensate for system volume expansion.

Existing utilities that require extension into the new plant would interconnect into the existing utility corridor routed along Lewis Street. All utilities will be direct buried and include:

-6" Natural Gas
-10" High Pressure Steam.
-6" steam condensate
-8" Domestic Cold Water/Fire Sprinkler
-6" Sanitary sewer
-2" Compressed Air
-Communications
-Fire Alarm
-Power

There will be two HW distribution loops with the intent that a future hot water plant be interconnected as the loads increase. The first loop is the North of Lewis loop. This 10" direct buried loop will originate at the new plant and route north of Lewis, west to 11th Street, north along 11th to approximately half way between Bradley and Flint Streets. The routing will then continue east until 12th street where it turns southerly. It will run south until halfway between Bradley and Lewis and then head west past 13th street. From here it will work its way back to the plant. Total North of Lewis Loop distance is approximately 3,575'.

The West Campus Main Loop will be 12" and begin/terminate at the new plant. From the plant it will intersect the tunnel under Old Engineering. It will follow the tunnel piping through Knight, head south past Physical Sciences and head east direct buried at Biological Sciences. It will turn south and interconnect the exiting tunnel again around Ross Hall. Piping will run east until Wyoming Union where 12" branch piping will continue north. The eastern branch piping will head to the Business Building where 12" taps will be left for future connection from the East. On the North Branch, the existing tunnel will be utilized from Wyoming Hall through Half Acre. North of Half Acre, the direct burried piping will head west and run along the northern edge of Prexy's Pasture. The Pathway between Old Engineering and Agriculture will be utilized to get back to the plant. The length of West Campus Main Loop supply/return piping that will utilize an existing tunnel is approximately 2,700'. The length of new piping within the West Campus Main Loop that will be direct buried is approximately 1,650'. Various branches off the main loop will be required to extend hot water supply and return piping to buildings distant from the main loop. These legs include a 6" set over to the Berry Center, 6" to the Health Sciences Center/Class Room Building/and Aven Nelson, and a pair of 6" lines to Mcwhinnie Hall and Wyoming Hall.

Chilled Water System

The recommended solution for the chilled water system deficiencies requires several areas of work around campus. The first area will be the construction of a 1.5 million gallon chilled water thermal energy storage (TES) tank within the vacant area north of the Anthropology building. This tank will allow for the storage of approximately 11,000 ton-hrs of chilled water. This installation will reduce the need to upsize campus distribution piping and allow for the generation of chilled water to occur during nighttime conditions when the energy cost is lower and the ambient conditions are more conducive to cooling tower operation. The location of the proposed system will be within close proximity of the center of the projected future cooling load. A 60' diameter, 75' tall steel field constructed tank will be internally epoxy coated and externally insulated and jacketed to minimize the energy loss to atmosphere. Internal upper and lower flow diffusers will be required to reduce fluid mixing during operation. The base will be 15' below grade, helping to reduce the visual impact on the campus. Conformance to AWWA D100 will be required. Three TES chilled water pumps would accompany this tank and provide the necessary pressure differential to distribute the stored water. Dual pressure sustaining valves will be required to maintain system pressure and reduce unnecessary pumping losses. All chilled water piping shall be standard weight, welded steel piping sized per accompanying flow diagrams. All major valves shall be butterfly in type, Nibco model LD-2000.

The interconnection into the existing chilled water system will occur between the new West Campus Plant and the 14" main direct buried distribution piping on the north end of Prexy's Pasture (approx. 450 linear feet of piping). New 14" chilled water supply and return piping shall be direct buried and routed in a north-south orientation between the Agriculture and Engineering Buildings. This piping shall be HDPE with fusion joints, insulation and external wrap.

Approximately 1,800 linear feet of new 14" chilled water supply and return piping will be installed along Lewis Street between 9th Street and 14th Street to facilitate future growth in this quadrant of campus. This will set the base for a future loop that would run east-west north of Bradley. New distribution piping shall be HDPE with fusion joints, insulation, and external wrap. There are numerous existing utilities under Lewis Street so extreme care/caution must be provided during installation.

There is a chilled water supply/return interconnect that was proposed in the 2009 Utility Master Plan located between Biological Sciences and Merica Hall. This interconnect has not been installed to date. It is recommended that this piping be installed as system distribution efficiency will benefit. This would include approximately 180 linear feet of direct buried 8" supply/return chilled water piping. .

The replacement of chiller #1 at the CEP from an 800 Ton machine to a 1,200 Ton machine and the installation of additional plate and frame heat exchanger capacity is the final recommended scope to be completed. This replacement will provide an increase to the campus's chilled water production capabilities and increase the chilled water firm capacity to 1,200 tons.

This Page Intentionally Left Blank

Electrical System

Intercept the existing feeder loop at Manhole 20W-1 (just to the south of existing Switch 'N') and provide new 15 kV feeders to extend the loop to the east roughly 50 feet to a new pad-mounted S&C Style PME-9 (2-load, 2-line switch) or approved equivalent. Provide one load to the new service 750 kVA oil-filled transformer adjacent to the switch. One load compartment will be spare.

New service board 'SES' will be single-ended and normally fed from the West Campus Substation. In the event of normal power loss, the campus loop configuration will allow the East Campus Substation to feed the plant. One generator will be sized to support the load. Our current intent is to avoid the need for an ATS by providing controls (Cummins DMC1500 or equivalent) for master paralleling. The switchgear will most likely be 4-section, roughly 16' wide x 4' deep in total.

Emergency lighting will be accomplished with battery wall packs. Any emergency back-up for fire alarm or other required systems will require its own batteries to comply with NEC 700.

All aboveground conduits will be galvanized rigid steel. All conductors are stranded copper- either THHN-THHW or XHHW-2. To save on cooling requirements, all VFDs will be located in the electrical room. Please refer to the electrical sketches and drawings for further explanation.

Section 1
Section 2
Section 3
Section 4
Section 5

Civil Narrative

The proposed West Campus Boiler Plant location is a vacant portion of land, void of any existing structures, north of the existing Agriculture Building, just south of the Lewis Street corridor. It is current use is surplus parking, storage, and project staging. This piece of property is located within the core campus and is completely owned by the University of Wyoming. Given these existing property ownership conditions, it is not anticipated that there will be any legal encumbrances that would either delay or preclude this project from moving forward.
This type of development project would require attainment of the following permits:
City of Laramie Building Permit
Requires a Site Plan Review prior to submittal
All permits (electrical, mechanical, and plumbing) would be included in the building permit submittal

Wyoming Department of Environmental (WDEQ) Permit to Construct
Covers any public utilities (water and sanitary sewer) that are constructed, modified, or upgraded as part of a project

WDEQ Small Construction General Permit (SCGP)
Covers small construction (less than 5 acres) stormwater discharge permitting
A "no-application" permit
Requires a Stormwater Pollution Prevention Plan (SWPPP) to be developed and maintained on-site

WDEQ Air Quality Construction Permit (AQCP)
Any new facility that is deemed a "major air pollution source" would have to apply for a AQCP

Title V Permit
Annual operational permit required by U.S. EPA Clean Air Act for major sources of air pollutants

Environmental Conditions
Based on the proposed location of the West Campus CEP being located within core University of Wyoming property and given that this area is almost entirely urban developed which includes a previous development/structure on the subject property, it anticipated that there will be no findings of significant impact (FONSI) and as a result no site specific environmental impact study (EIS) would need to be performed.

It is expected that subsurface geology conditions will be similar to that experienced on recent adjacent projects, that being the S.T.E.M. Building, Anthropology Building, and Engineering Building (under construction). Historically soil conditions in this area of campus are suitable and compatible for this type of building construction and it is likely that the proposed building site will be no different.
Further subsurface geotechnical exploration is recommended to be performed prior to construction which will give site specific soil conditions allowing for proper foundation and structure design.
The proposed project location is not located within the Casper Aquifer Protection Zone (CAPZ) but the encountering of ground water is typical in this area but can be addressed through normal best management practices.

Building Code and City of Laramie Planning Requirements
The West Campus Boiler Plant project, at a minimum, would need to meet the following developmental code requirements:
International Building Code (IBC)
The current version of the IBC at the time of construction would govern over the design and construction of the proposed west campus satellite CEP

City of Laramie Unified Development Code (UDC)
The current version of the COL UDC, at the time of construction, would apply to this project where applicable
Includes relevant Fire Code, Uniform Plumbing Code, and National Electrical Code

University of Wyoming Long Range Development Plan (LRDP)
Design and development will need to meet requirements laid forth by the LRDP

Open Space and Landscaping
Currently the proposed vacant lot has no designated open space or landscaping to speak of, however the University of Wyoming Long Range Development Plan (LRDP) and City of Laramie Unified Development Code (UDC) both have landscaping and open space requirements that will have to be satisfied. The site design of the West Campus CEP will need to meet the highest demanding requirements between these two documents if in fact both govern over this project.

Geotechnical Summary:
As previously described, it is expected that subsurface geology conditions will be similar to that of recent adjacent building projects which experienced pockets of gypsum mixed within a majority of suitable (red clay) material as well as a potential for encountering groundwater. As a result, the majority of new building construction in this area utilizes relatively deep drilled pier foundation systems and it is likely that the proposed building site will be no different.
Further subsurface geotechnical exploration is recommended to be performed prior to construction which will give site specific soil conditions allowing for proper foundation and structure design.

Surrounding Land Use:
The immediate surrounding land use to the proposed project location is Campus/Education and outside of the campus limits you have single and multifamily residential land use (R3 Zoning).

Possible Impact of Construction on Surrounding Buildings:
Given the location of the proposed CEP and its proximity to several building similar in scale and magnitude, visually there will be little to no impact on any surrounding buildings. There will be some potential impact on accessibility and mobility for students, faculty, and staff but can be minimized if proper construction management practices are utilized. Noise and air pollution is always a possible concern when mixing mechanical/industrial buildings with educational facilities and will need to be addressed through the design and permitting process.

University and City Infrastructure needed
The proposed siting for the West Campus CEP is strategically located from a utility access stand point. The Lewis Street Corridor which is adjacent to the subject property is a major utility corridor and will be able to provide the CEP with required water, sanitary and storm sewer, data/fiber, and electrical power utilities.
It is anticipated that the utility capacities of those found in Lewis Street will be able to meet the demands of the proposed CEP as several large buildings projects have been completed along this corridor with no need to upsize any existing utility mains. However, it is recommended that the design and utility demand be coordinated through the University Utility Department to insure all assumptions are correct and proper service can be delivered.

Previously identified underground issues at the site
Beyond previously described geotechnical conditions (red clay mixed with possible striations of gypsum) and the potential for encountering groundwater which can be dealt with as new buildings are and have been constructed all around the existing site, there are no other known underground issues that can be foreseen without further investigation being performed. An old east-west running tunnel identified in the site plans, will have to be considered in the final design.

Section 1
Section 2
Section 3
Section 4
Section 5

Historic Review

The site is located in the **Contemporary Academic West** area of campus. As stated in the Historic Plan, the "**Contemporary Academic West Zone** is rapidly changing from residential to large-scale university facilities. This zone signifies innovation and the prestige of the expanding campus. The Contemporary Academic West Zone is located south of Flint Street and extends slightly south of Lewis from 9th Street to 15th Street. It includes several contemporary buildings facing Lewis Street with plans for large scale buildings in the future." The stated design objectives for the area from the Historic Plan include the following:

- Provide a pleasing campus edge by providing a transitioning or stepping down of the large scale on Lewis Street to a more residential scale on Flint Street.
- Optimize the south elevation of the buildings and provide a more pedestrian scale with inviting entrances and stepped-back.

Contemporary Academic West Requirements and Response

Entrance and Orientation

Requirement: Main entrances should be oriented toward existing and proposed open spaces. South facing whenever possible. All requirements on Building Massing and Articulation also applies.

Response: Building is not public so access in limited to authorized personnel. The new Plant is designed to provide a frontage façade that integrates with the existing structures in the area and provides a place for students to relax and study adjacent to the building. One goal of the project is to provide visual access into the building along with educational information about the function and energy efficiencies gained with this project.

Building Massing and Articulation

Requirement: Five stories maximum with a maximum height of 60 feet on Lewis Street. The building should be step back on the side facing Flint Street. Two story maximum height on Flint Street.

Response: The new Plant in equivalent to a 2 story building. The Thermal Energy Storage (TES) tank is just lower than the surrounding Engineering building to the west and Anthropology building to the south. The Plant / TES is setback from Lewis Street to provide maximum area for future pedestrian area and landscaping as shown in the Long Range Development Plan.

Building Materials

Requirement: Elevations visible from Flint Street or Lewis Street: Primary materials cover at least 60% of the building facade, secondary up to 30% maximum and accent or trim materials up to 10%. Other Elevations: Primary materials cover at least 20% of the building facade, secondary up to 70% and accent or trim materials up to 10%.

Response: As a support utility structure the design of the facades will seek to meet this criteria within the constraints of the budget.

Sustainability

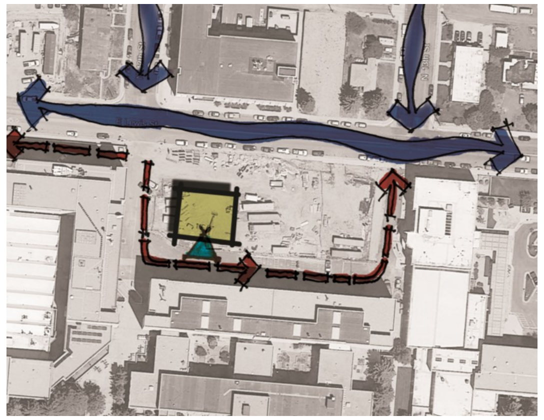
Requirement: Focus on passive solar design and step back building massing from Lewis Street to Flint Street. All requirements on Sustainability/Response to Climate also applies, refer Sustainability section.

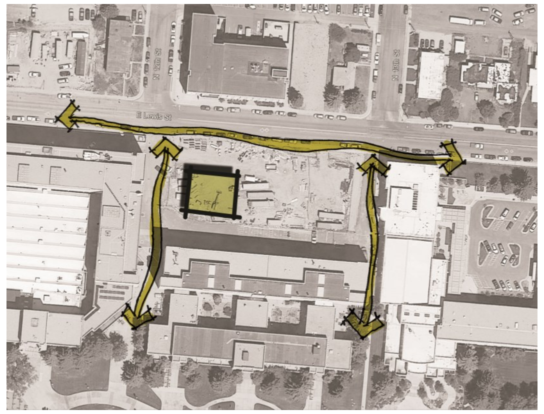
Response: This building, as a producer of energy for the campus, will deliver heating and cooling water to the west side of campus more efficiently and save resources and reduce annual capital expenditures.

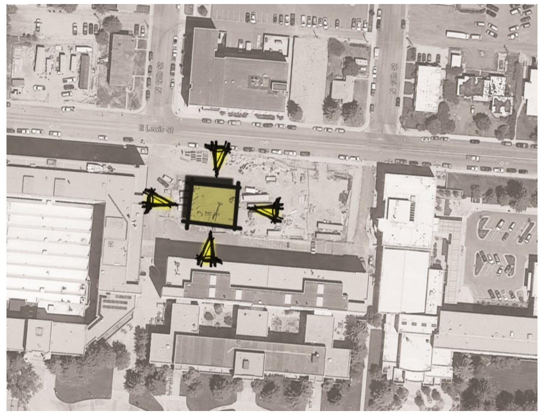
Other

Requirement: No new buildings shall be visible from Prexy's Pasture and should not interfere with existing roof lines on any historic structures.

Response: This project should not have any significant impact to Prexy's Pasture. The placement of the structure and TES is to minimize the visual impact to the area and create a stepping of elements from the lower new structures to the existing higher buildings.



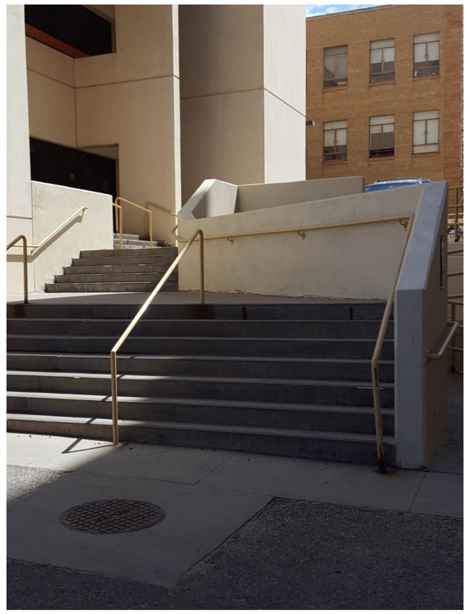


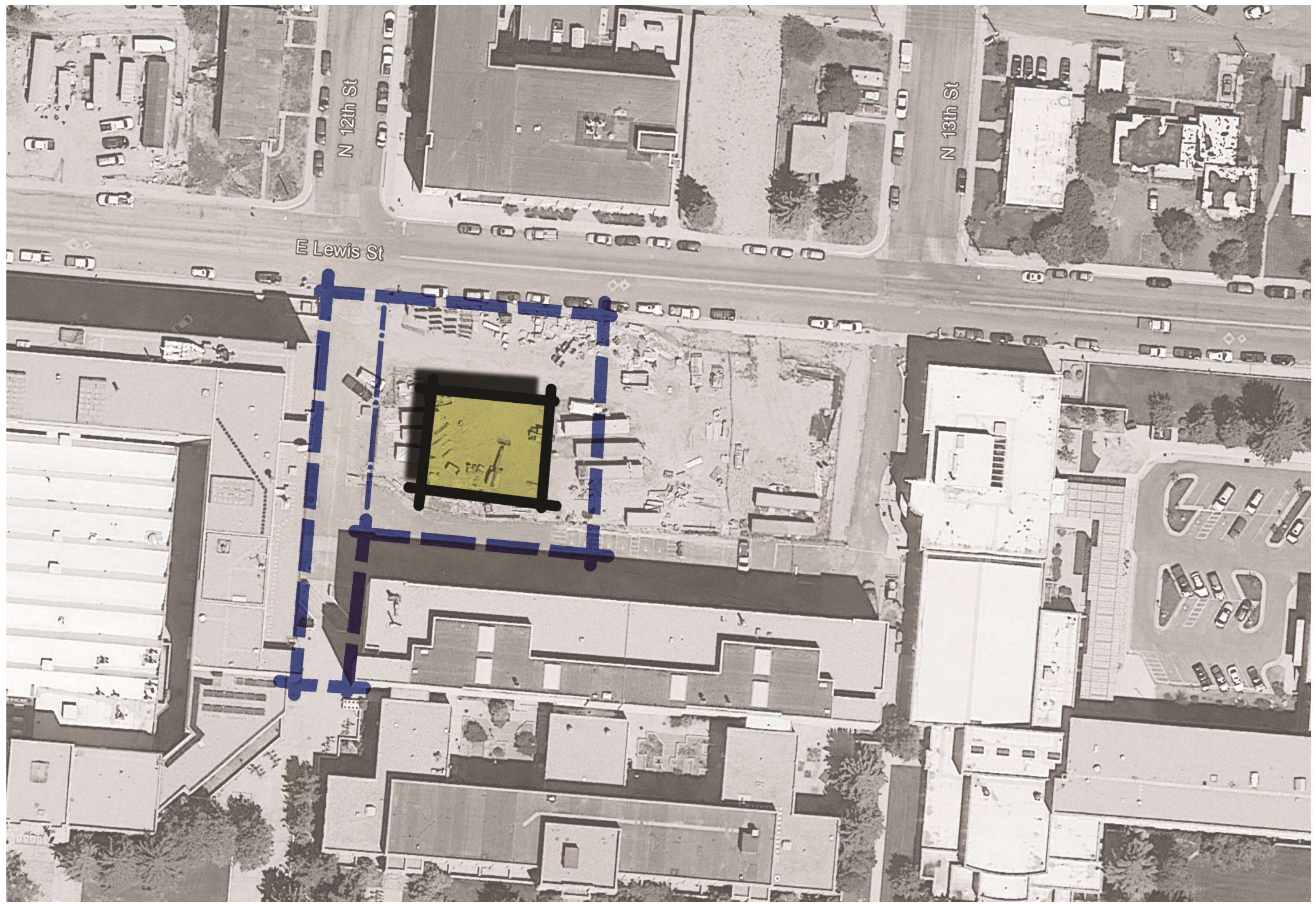


03 Site Analysis

Section 5: Proposed West Campus Options

03 Site Analysis





West Campus Energy Satellite Plant (WEP)

Site Features:

Site area: 14,000 GSF

Pedestrian link area: 10,000 GSF

Total site area: 25,000 GSF

Proposed height to top of roof: 40 ft.

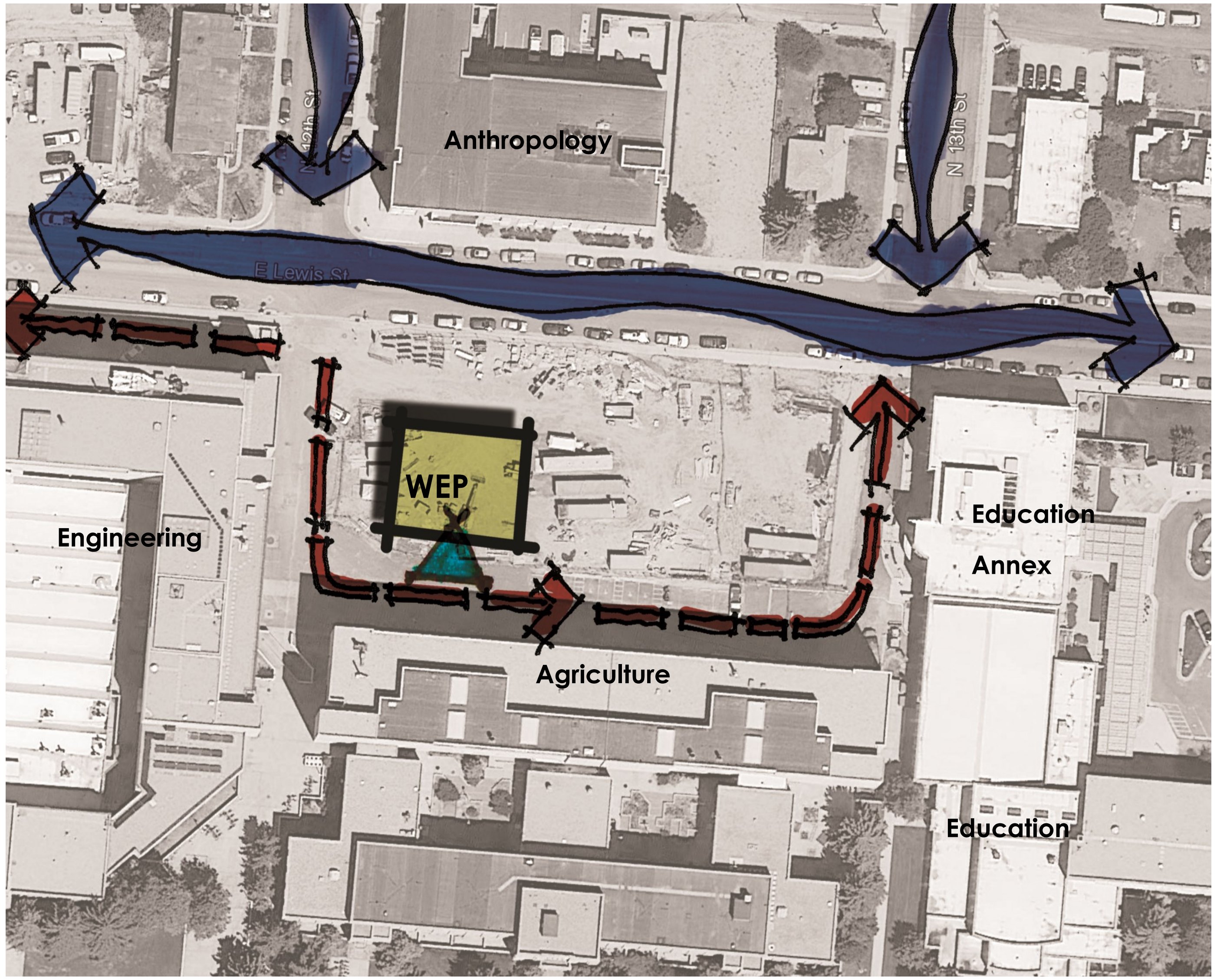
Building area: 10,500 on two floors

Area available for expansion: yes

Adjacent Building Heights:

- Engineering
- Agriculture
- Education Annex
- Anthropology

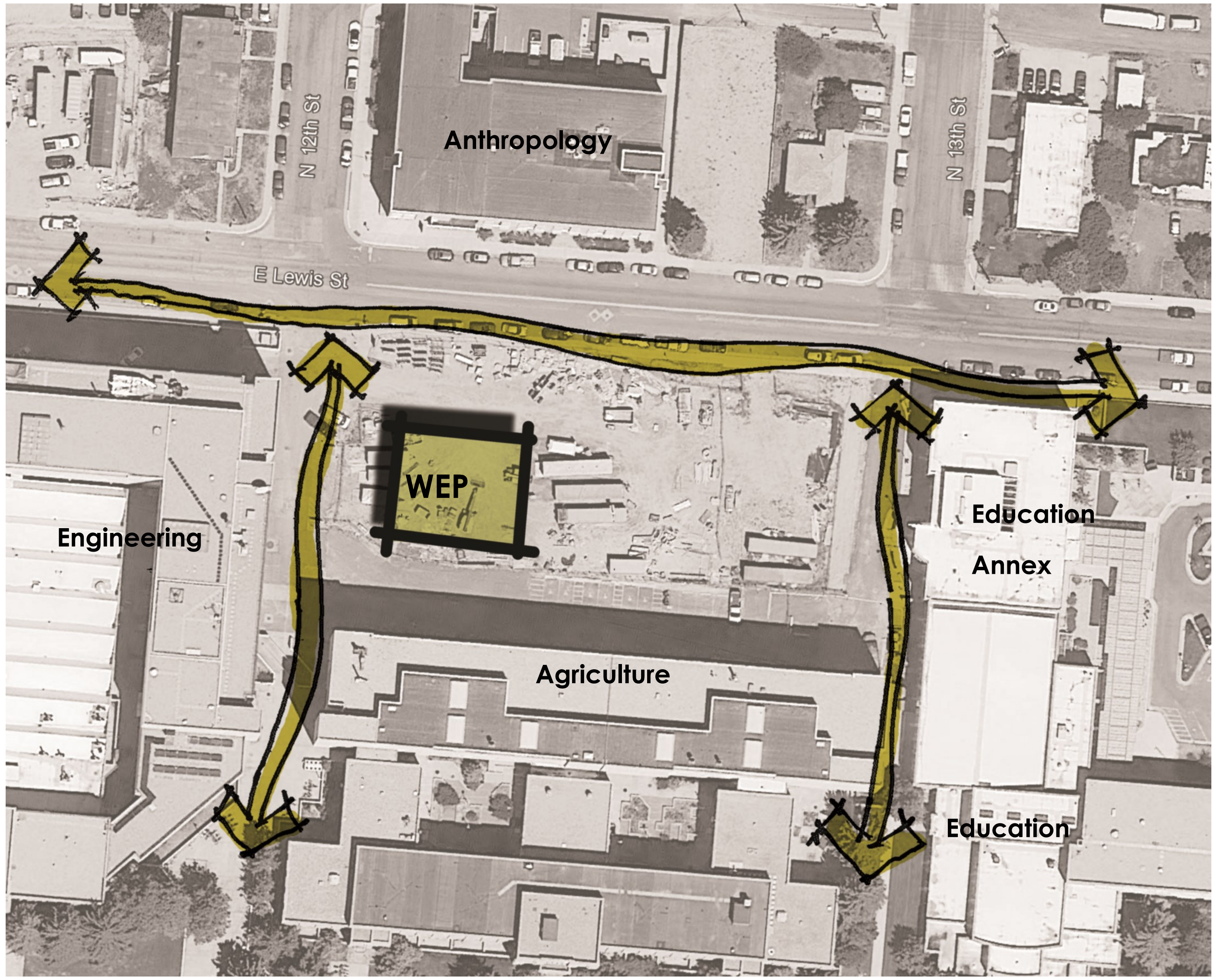
Site surrounded by Engineering, Agriculture, Education/Education Annex, and Anthropology buildings. Engineering and Agriculture were built in the 1980's and are very non-descript architecturally and do not relate to the campus architecture. The Education Annex and Anthropology are newer construction and while more contemporary in design relate back to the older original campus building through the use of stone facades plus newer elements which tie the old part of campus to the newer structures.



Access/Traffic: Vehicular

Primary traffic flow is currently along Lewis street with feeders to Lewis from 12th and 13th streets (Blue). One way vehicular drive (shown in red) provides service, waste and maintenance access around the proposed site. This access drive also serves for drop-off to the Education Annex.

Access to this site in the future will be from 12th street by a limited service driveway across Lewis.



Access/Traffic: Pedestrians

Current primary pedestrian circulation occurs on 3 sides of the site indicated. The east and west locations circulate co-mingled with vehicular traffic in the area. The pedestrian pathway along Lewis is by sidewalks on both the north and south sides of the street.

The Campus Long Range Plan shows Lewis transitioning to a multi-modal pedestrian landscaped area with campus transit mall. Discussions for WEP improvements included the potential for enhancing the pedestrian pathway and ramping along the west portion of the site.

Section 5: Proposed West Campus Options

03 Site Analysis

West Campus Energy Satellite Plant 1 (WEP)

Long Range Development Plan

The location of the WEP plant can work within the context of the Long Range Development Plan (LRDP).

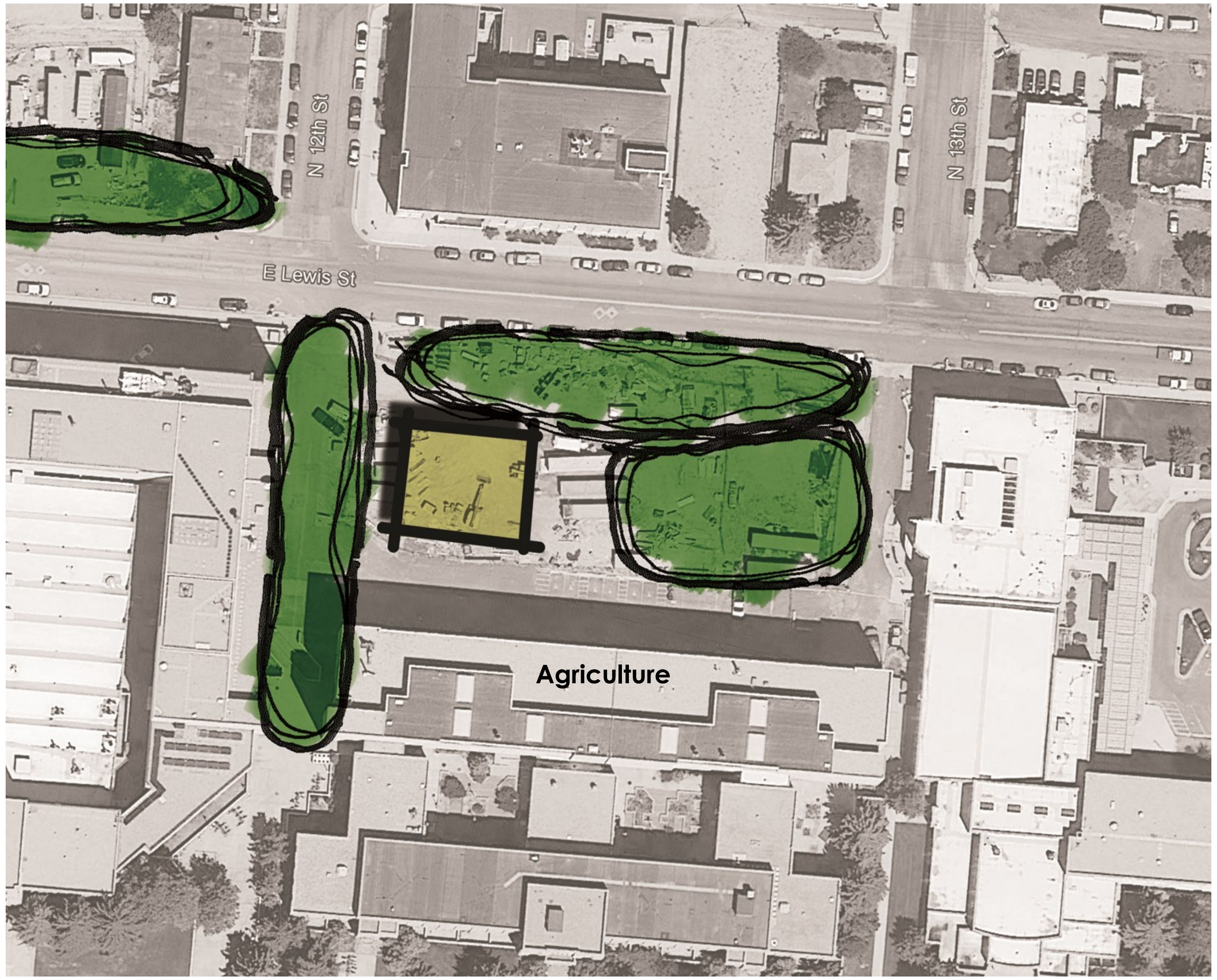
WEP proposed location will fit with the future planned pedestrian and landscaped areas while utilizing the shared service drive for Engineering and Agriculture.

The proposed landscape and pedestrian amenities can be integrated with the new plant and provide opportunities for education about what the plant is, what it does and how it serves the campus.

This area serves as the service side for both Engineering and Agriculture which is compatible with the Satellite Central Plant use.

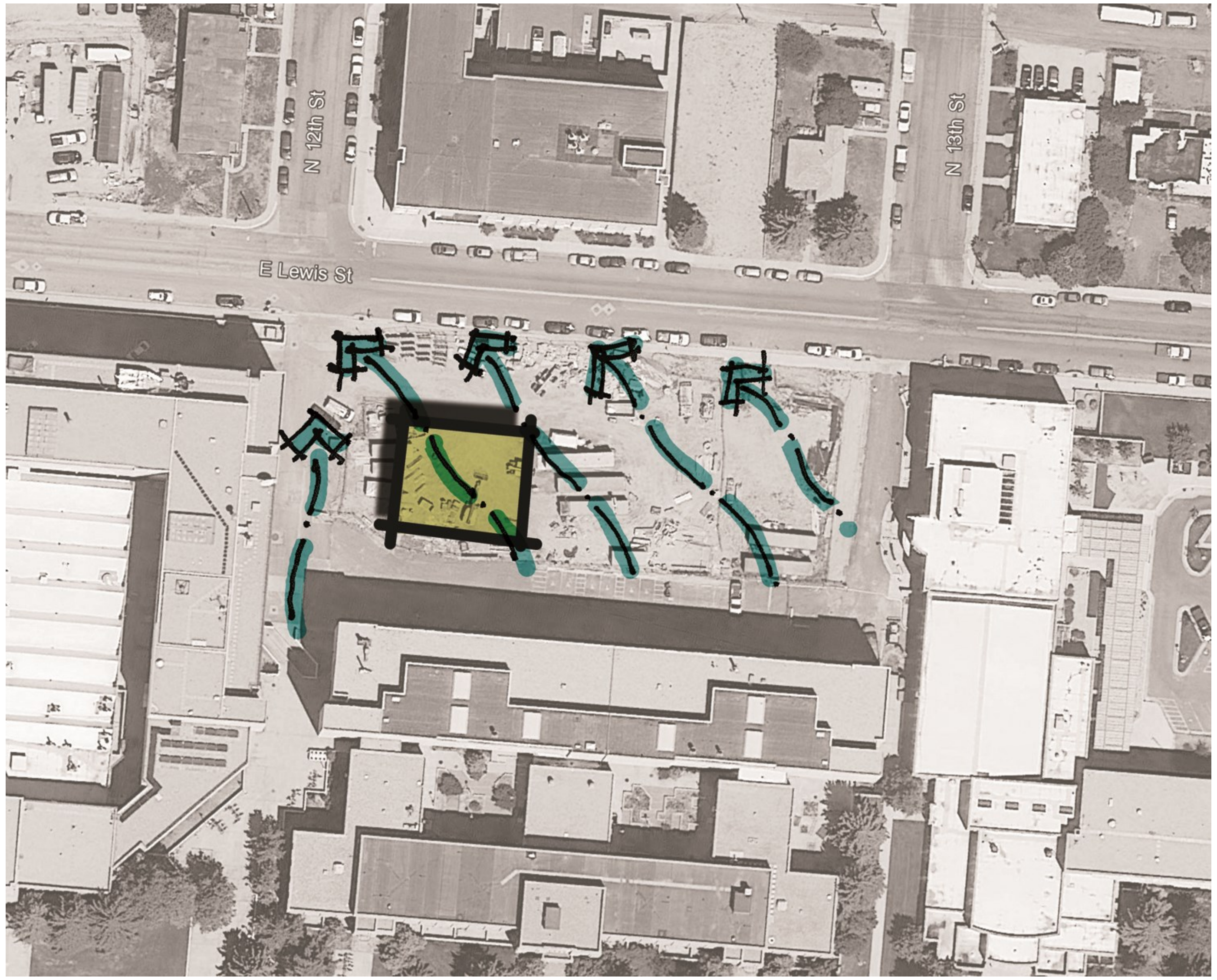
Open Space

The WEP location will allow for the implementation of ideas contained within the Long Range Development Plan. There is adequate open space around the plant site to comply with circulation and landscape planning. Even while Lewis is still used for vehicular traffic, open space could be developed to enhance the student experience.



Drainage and Topography

The drainage on this site flows generally from southeast to northwest. There is a grade differential between the existing buildings and the street of about 5 to 8 feet south to north and 12 to 14 feet southeast to northwest corner . With the plant located on the high side of the slope, drainage flows should be able to be re-directed around the structure.



Section 5: Proposed West Campus Options

03 Site Analysis

Wind (wind rose diagram)

The diagram below depicts graphically the speed and direction the wind. The lines represents winds speeds as follows:

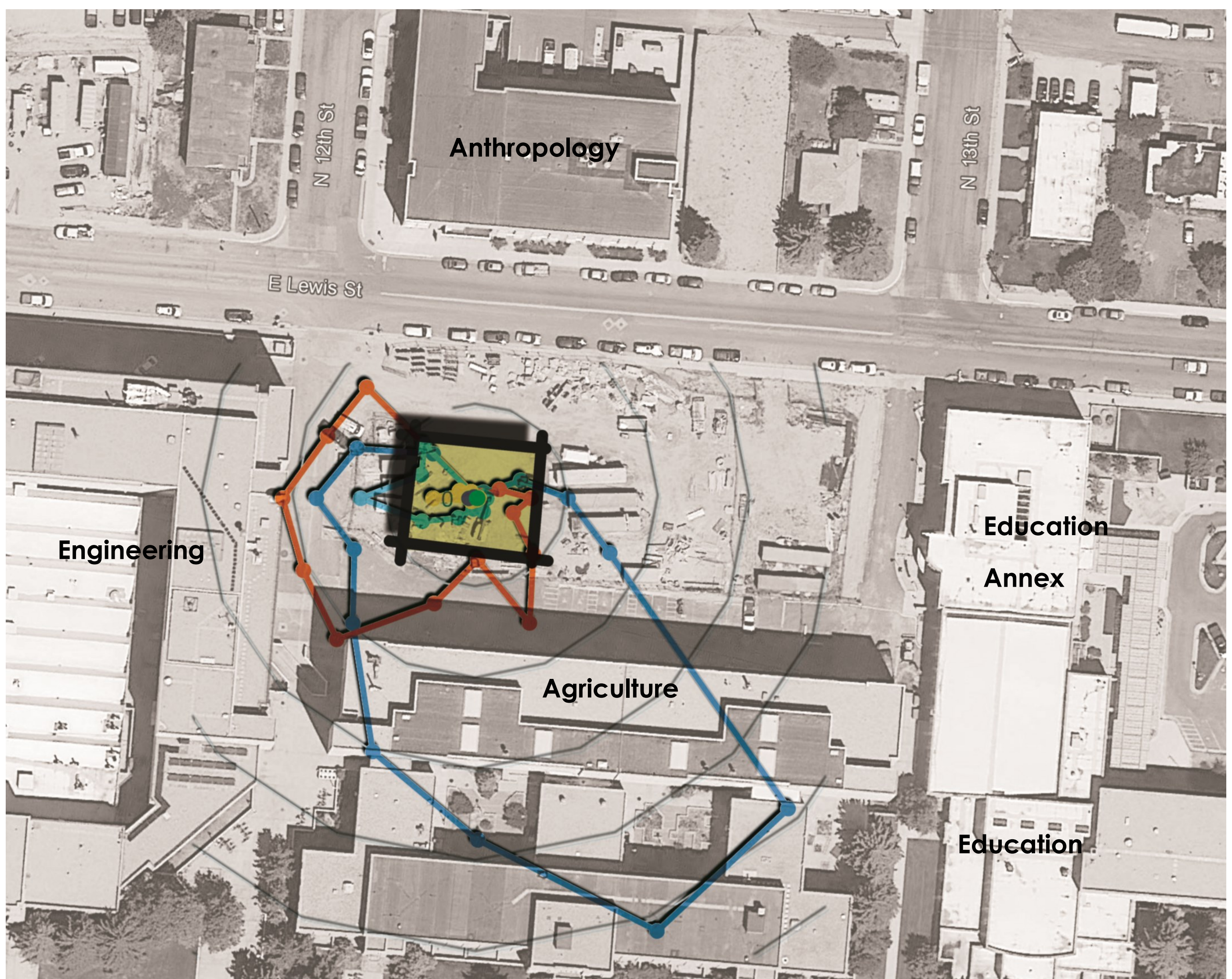
Dark Blue: 0 to 5 mph

Orange: 5 to 10 mph.

Light blue: 10 to 15 mph .

The lower wind speeds generally blow from southeast towards the northwest while most all of the higher winds are generally from the southwest, west and northwest.

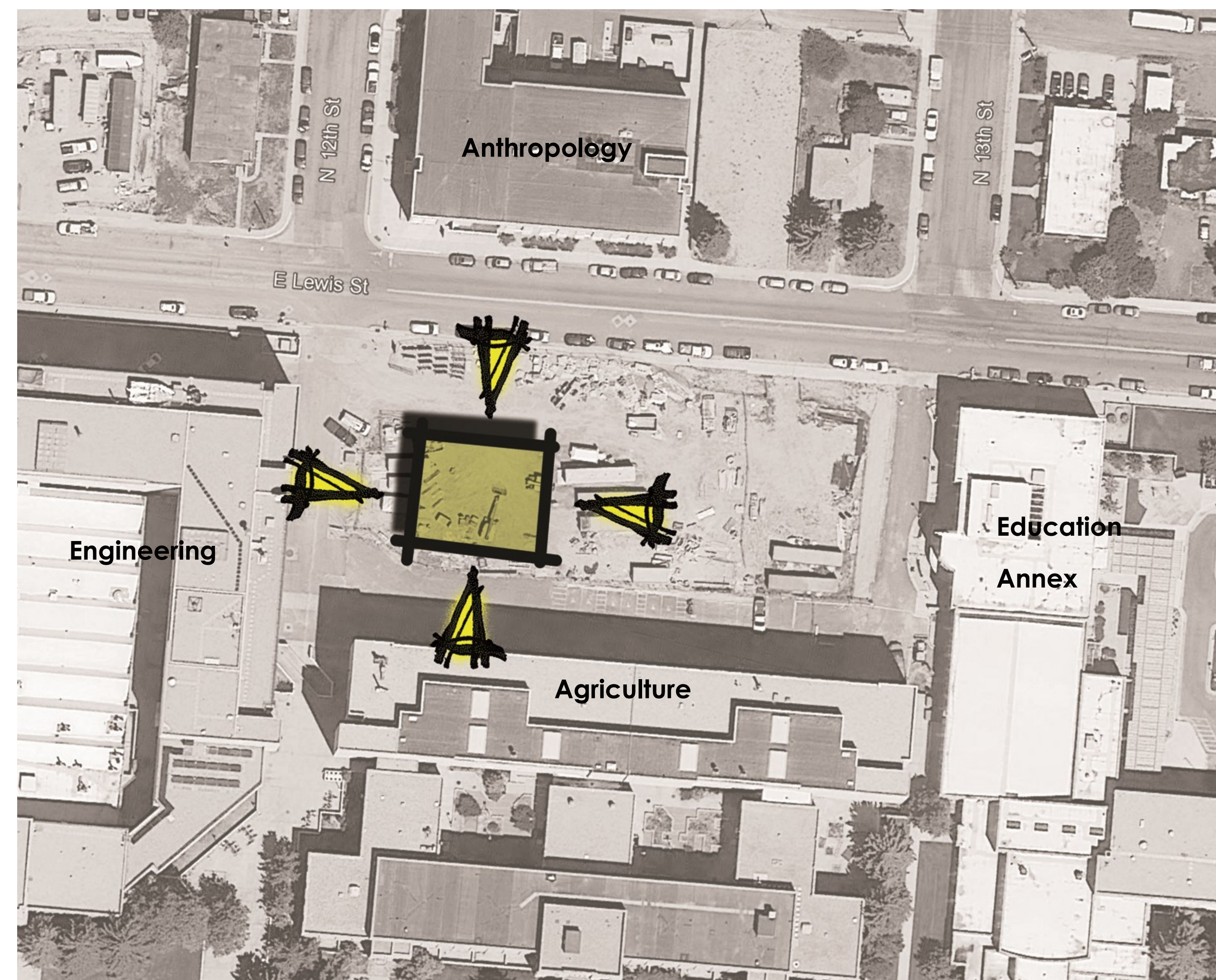
This wind orientation and the height of the adjacent structures create the potential for the leeward side to be in negative pressure creating unique conditions for the WEP plant location. A wind study should be performed to address any issues.



Solar

North and East: This location will allow for north and east daylighting. These orientation could allow for views to the exterior if desirable.

South and West: Because of the close proximately to the six story Engineering and Agriculture buildings view are less positive from these sides. Daylighting could be accomplished through the use of translucent materials.



Engineering Bldg

Looking West from service drive

Agriculture Bldg

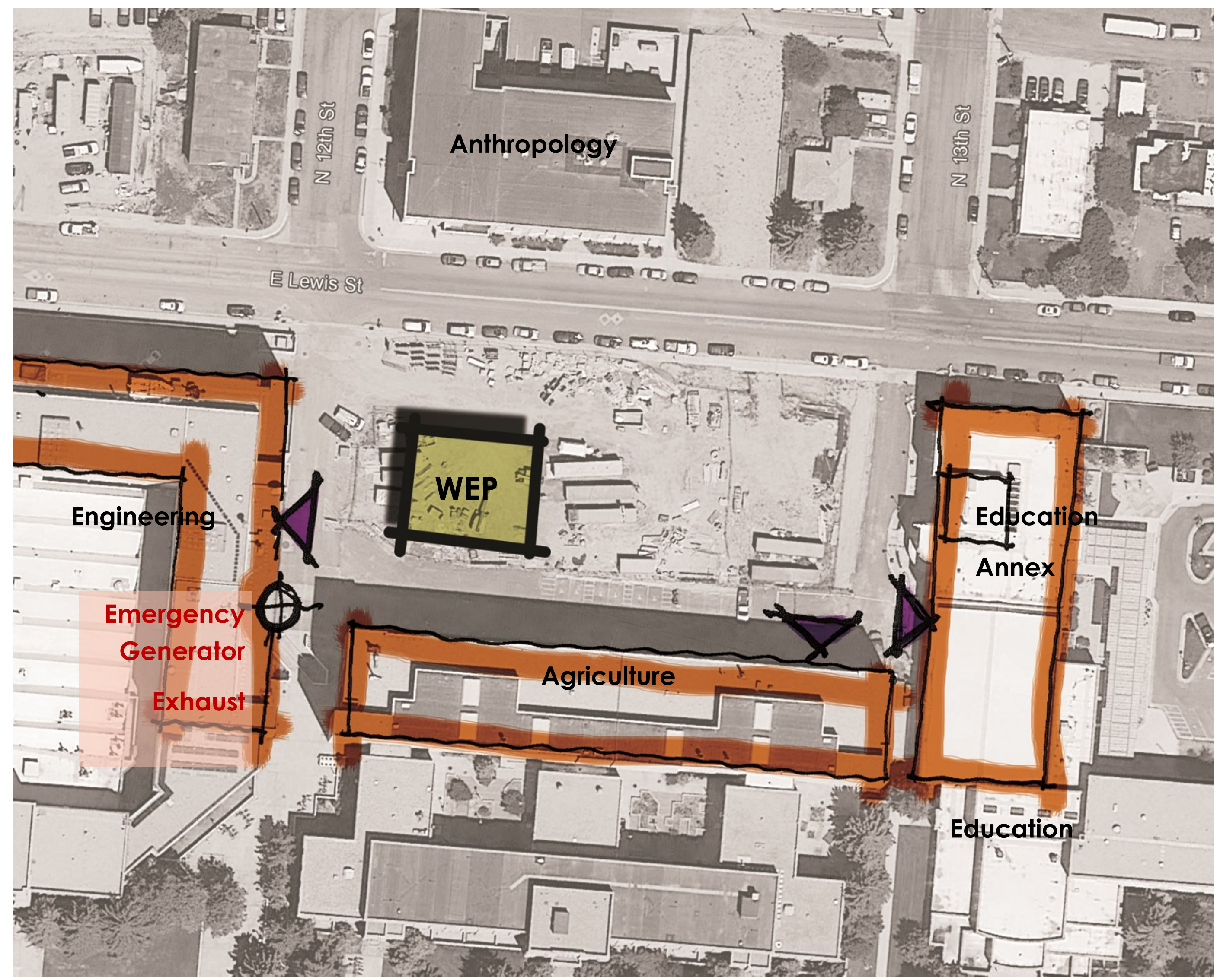
Looking Southeast from across Lewis St.

Education Annex Bldg

Looking East from the service drive

Intake/Exhaust

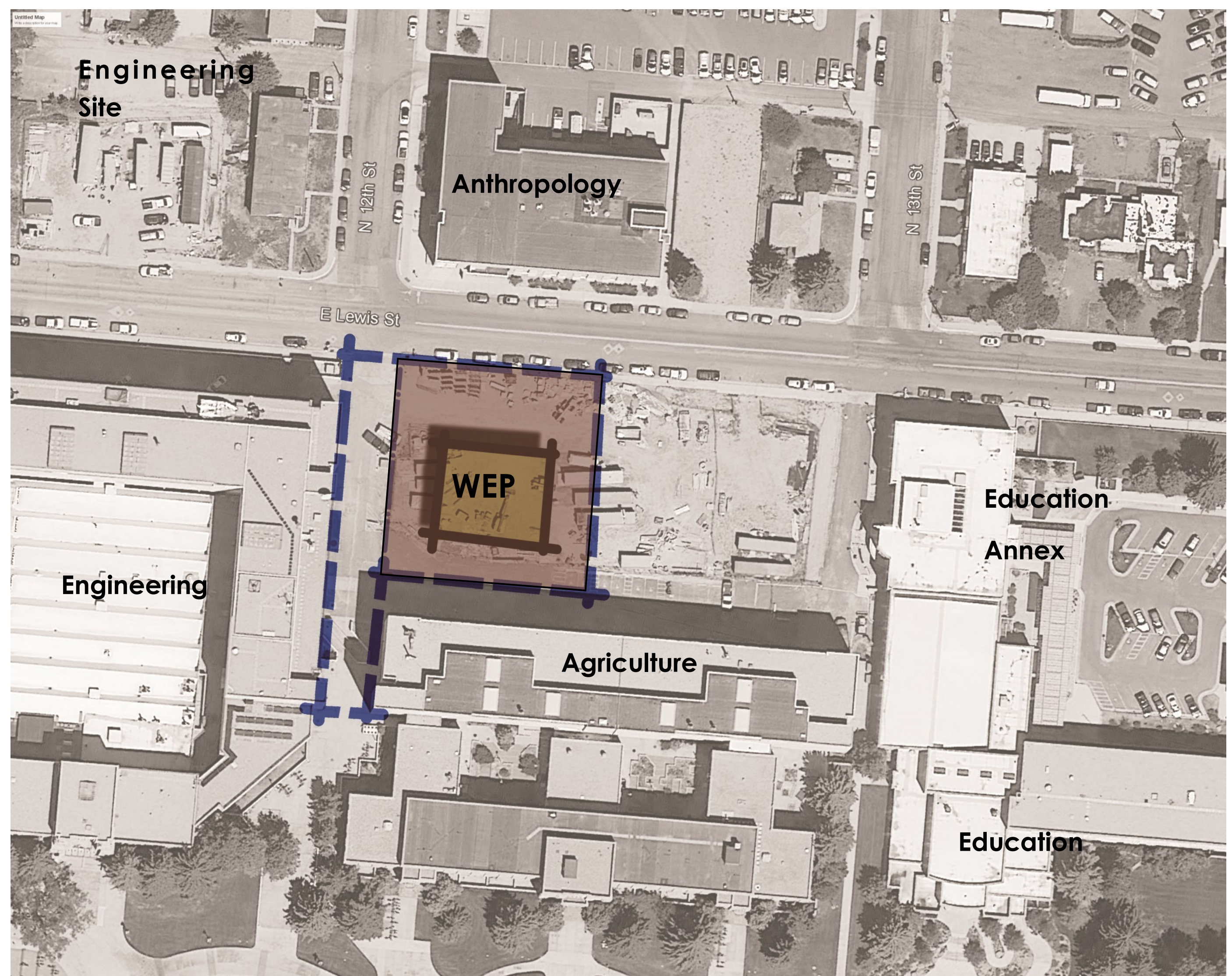
The WEP is surrounded by taller structures that will have and effect on the air flows around the plant. The higher structures have most of their exhaust on the roofs. There is an emergency generator exhaust located at about 12 feet above grade on the east side of the Engineering building that will need to be addressed.



Soils/Environmental

A layer of gypsum was found under the new engineering building site cattycorner to this site. Also in previous projects to the north subsurface water was discovered that required remediation.

Because soils issues are present in adjacent sites, a full geotechnical exploration should be done prior to the design of the structural and storm drainage designs. Since this site contained other structures a review of documents and some subsurface investigation will be desirable prior to completion of any final documents.



Section 1
Section 2
Section 3
Section 4
Section 5

Morning **Noon** **Evening**

December

Site is in the shade throughout the day in the winter from Mid October Thru Mid February.

March/September

Site is mostly in the sun throughout the day in the spring and fall from Mid February thru Mid May and Mid August thru Mid October.

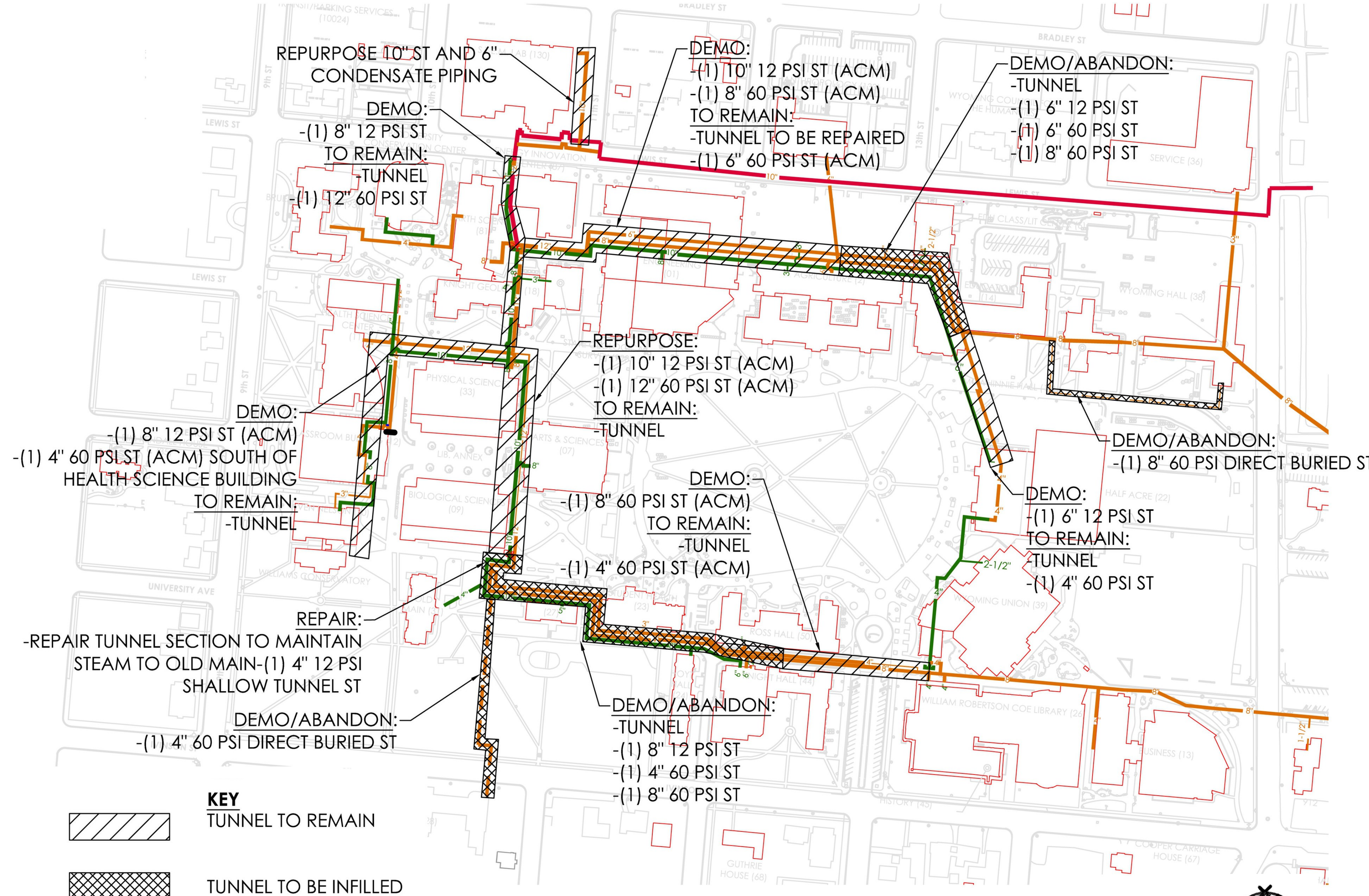
June

Site is fully in the sun throughout the day in the summer from Mid May thru Mid August.

Section 5: Proposed West Campus Options

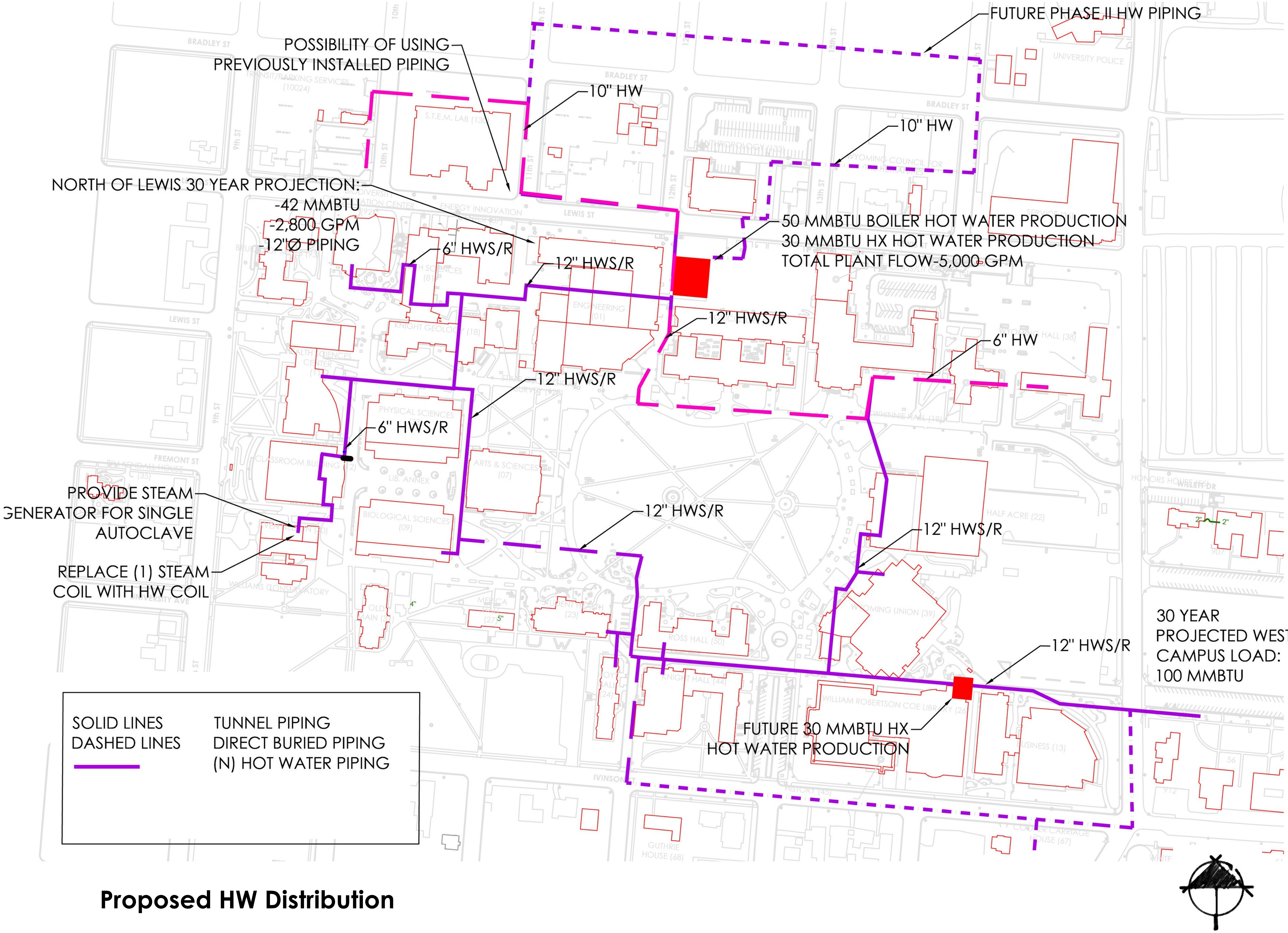
04 Arch/Mech/Elect Drawings and Renderings

- **Site Demolition**
- Proposed HW Distribution
- Proposed Steam Distribution
- Proposed Chilled Water Distribution
- Architectural Drawings
- Mechanical CHW P&ID
- Mechanical HW P&ID
- Mechanical Boiler Exhaust P&ID
- Mechanical Equipment Schedules
- Electrical Satellite Plant Single Line
- Electrical Medium Voltage Single Line



Site Demolition Plan

This Site Demolition Plan provides an overall look at the existing West Campus steam piping and tunnel layout. Several portions of the tunnel system as depicted by the double cross hatched areas, are in extremely poor condition, some of which have already experienced partial collapse. These sections are proposed to be decommissioned. The single hatched portions of tunnel are to be repaired and reutilized for the new HW system. Segment descriptions on each tunnel/piping section identify what steam utilities are present.

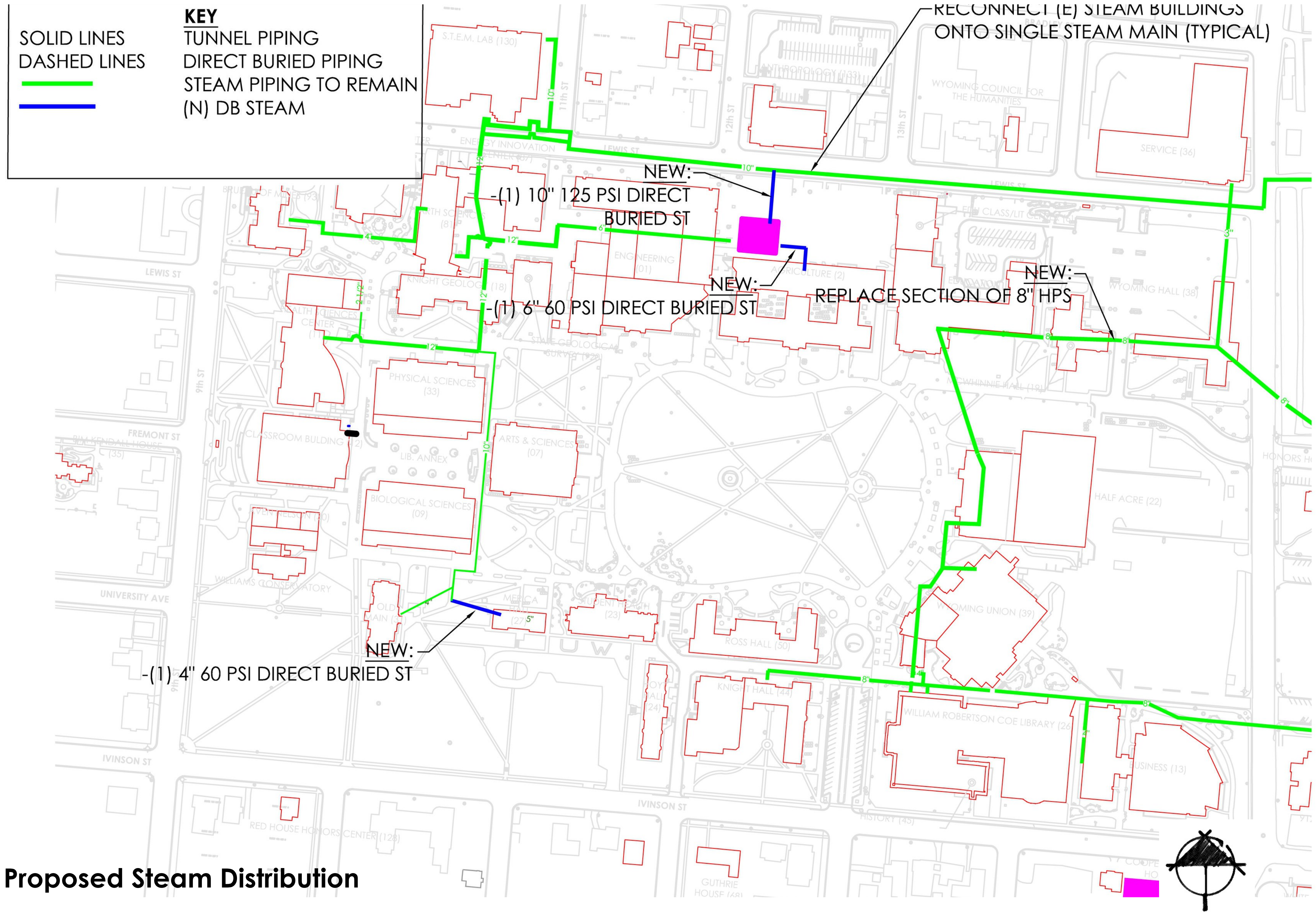


Proposed HW Distribution

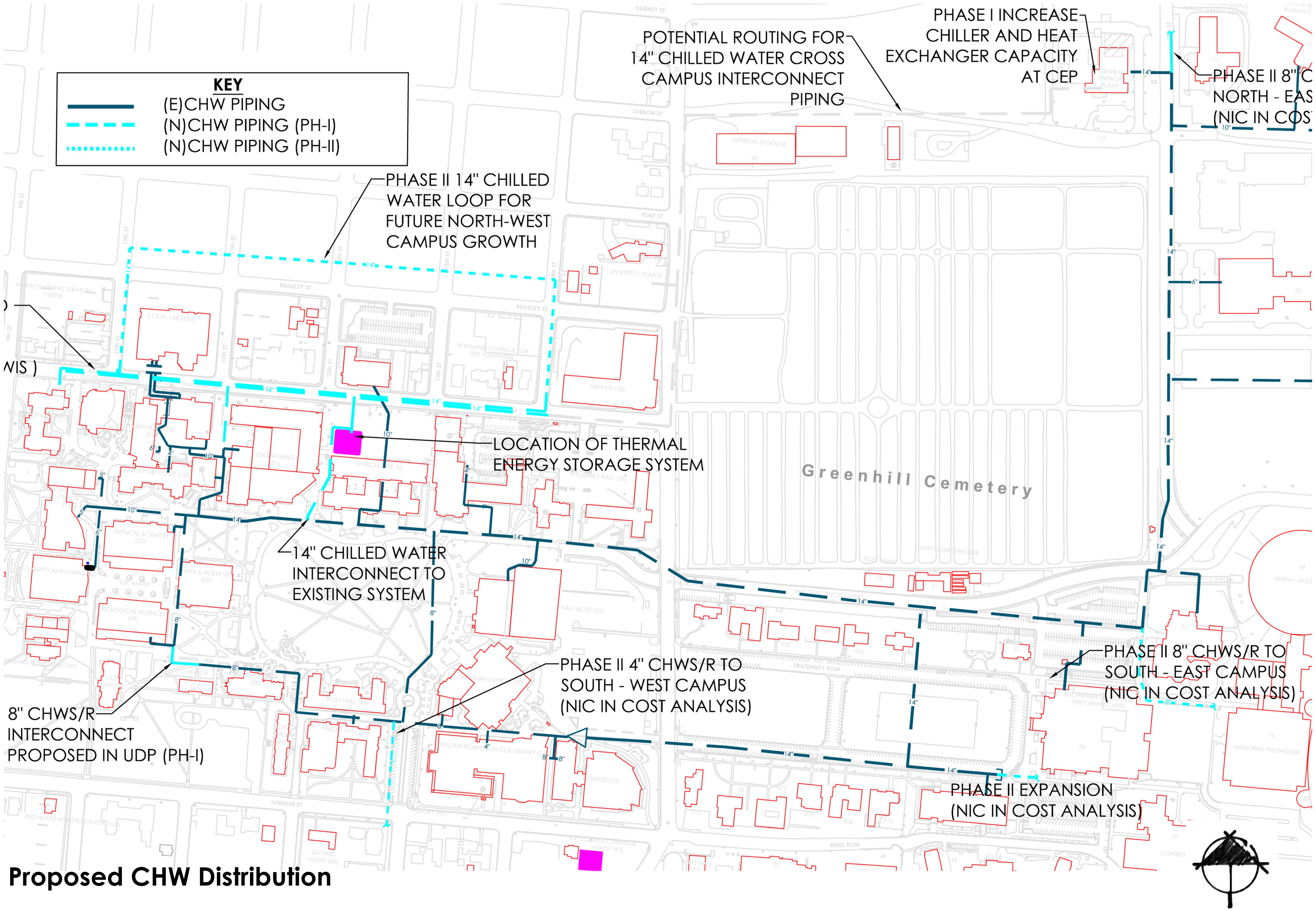
This Proposed Hot Water Distribution Plan identifies the proposed routing and sizes of the new piping. The solid lines represent new HW supply and return piping to be routed in tunnels. The long dashed lines show new direct buried piping. The short dashed lines represent future Phase II piping that would be installed as growth expands into those areas.

Section 1
Section 2
Section 3
Section 4
Section 5

This Proposed Steam Distribution Plan shows the final existing and new steam distribution within West Campus.



Proposed Steam Distribution



Proposed CHW Distribution

The Proposed Chilled Water Distribution Plan identifies the new and existing chilled water routing through campus. The immediate chilled water routing scope would include the start of the new Lewis Loop, and the interconnection of the new Thermal Energy Storage facility with the existing campus chilled water mains.

Programming

Introduction

The programming for a Satellite Plant is different from an student occupied University building in that the functions are arranged not for proximity, noise and associated uses. The primary goal of the design is to produce a facility that optimizes:

- Equipment placement,
- Piping runs
- Efficient exhausting
- Access for maintenance
- Access for services

Space Requirements

As such programming is equipment centric. The layout of the facility begin with the equipment layout in conjunction with the access points to the site. The ease of suppling and replacing material, chemicals and equipment is important in servicing the facility.

This facility has 5 basic components:

- Modular Boilers
- Pumps/Heat Exchangers
- Thermal Energy Storage (TES) Tank
- Electrical room
- HVAC for the facility

Additional requirements:

- Control room for monitoring equipment
- Restroom for staff
- Janitor space

Layout

The design places the modular boilers and electrical equipment on the main floor level for direct access and servicing from the existing service drive. The smaller pumps and heat exchangers are located on the basement level and serviced through a floor access hatch via a monorail crane. A equipment platform level is provided for locating the HVAC equipment to serve the plant main and lower levels. The equipment platform will also allow for inspection and service of portions of the boiler flue piping. All equipment will require housekeeping pads.

Boiler Area
3200 NSF
- 10 Modular Boilers
- Exterior Access from service drive
- Visible from control room
- Access to lower level for equipment replacement
- Stair access to lower level for staff
- Access to Janitor Closet

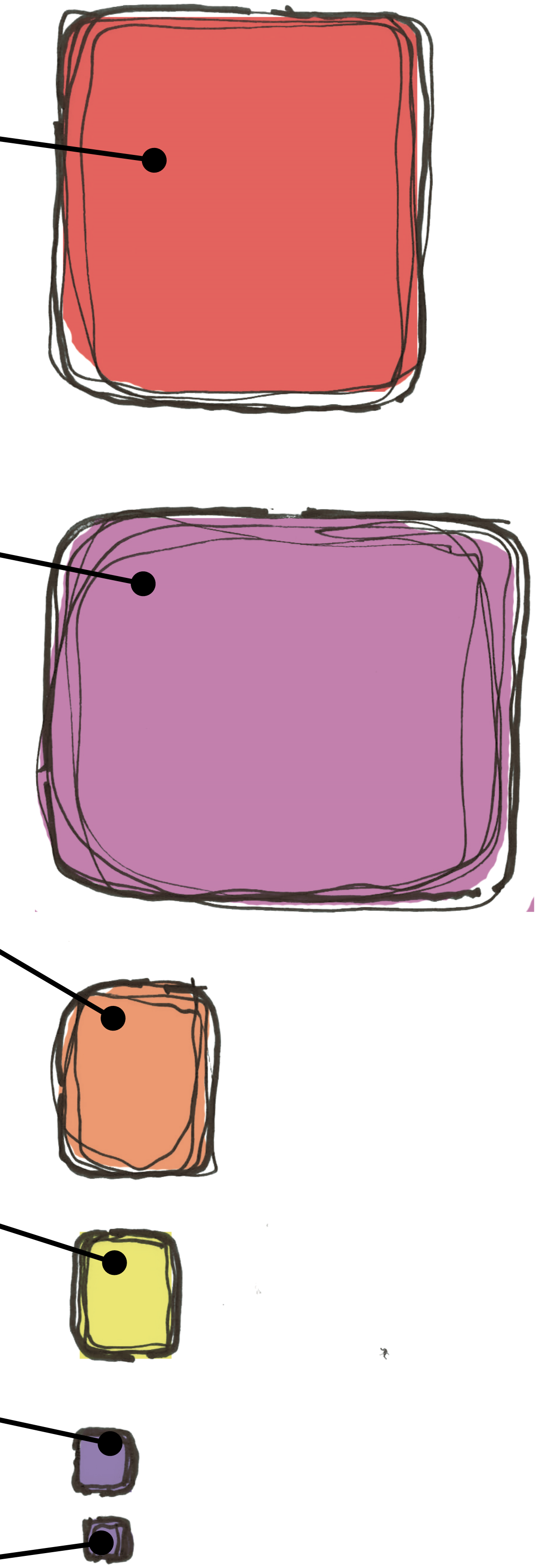
Pump Area
4100 NSF
- 8 Hot water pumps
- 3 Chilled water pumps
- 3 Heat Exchangers
- Piping for HHW and CHW supply and return
- Hot Water expansion tank
- Air compressor equipment
- Storage for spare parts.

Electrical Equip. Room
500 NSF
- Service Entrance
- 2 Stepdown Transformers
- 480v Panels
- 208v Panels
- EM Transfer switches
- Motor VFDs

Control Room
200 NSF
- Acoustically isolated
- Counter for computer monitoring equipment
- Drinking fountain

Restroom
50 NSF
- Wall Sink
- Water Closet
- Accessories, SD,TPD,PTD, WR, MIR
- Non-Absorbent finishes

Janitor
20 NSF
- Service Sink
- Small Storage



Exiting
Egress for the lower level is provided via a standard type stair for ease of personnel access. In addition an emergency ladder is provided at the opposite side of the basement level from the egress stair. The ladder is provided with a floor hatch at the first level. This is a secondary means of egress for service personnel.

Emergency Generator
In support of the facility an emergency generator is required for backup power. The location and service is critical for this equipment. The unit is located within a service yard and exhaust is located to maintain gases away from public areas.

Accessibility
As a utility service building accessibility is less critical than other public campus buildings; nevertheless, to the extent possible the facility will provide accessibility for staff and visitors.

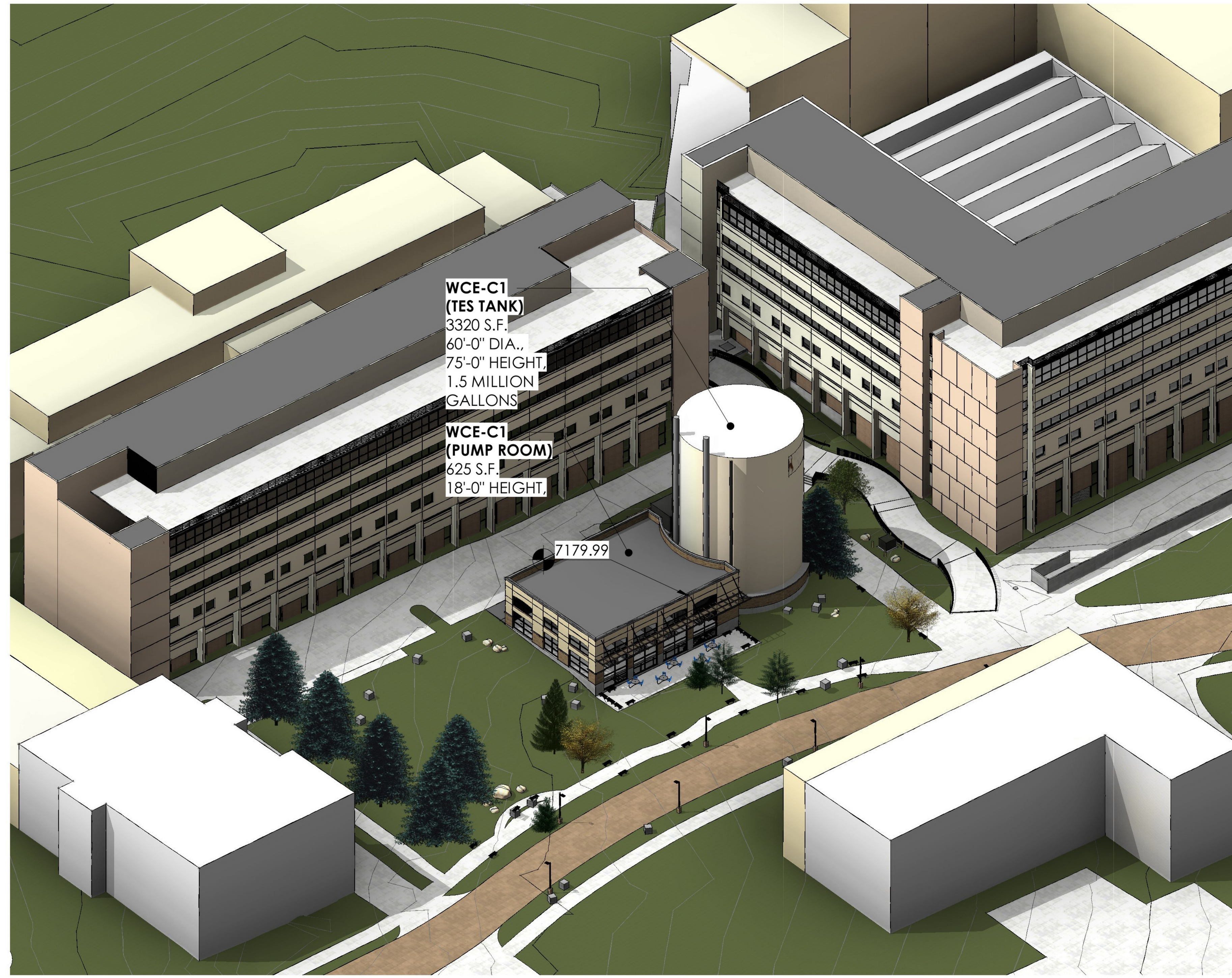
Security
This facility requires unique security features to allow plant staff and managers access but limits public access through means of car key access points designated by staff.

Site
The building is located on the sloped site in such a manner that the basement is partially exposed on the north side. This allows for direct access to the main level from the elevated service drive on the south side of the building. On the north side of the building, there are windows to allow natural daylighting into the facility including the basement. These windows also allow for students to view the equipment and piping that help to feed the west campus. This will also allow an opportunity to provide educational material in the area so students and staff can learn about the function of this new plant in the efficient heating and cooling of the campus.

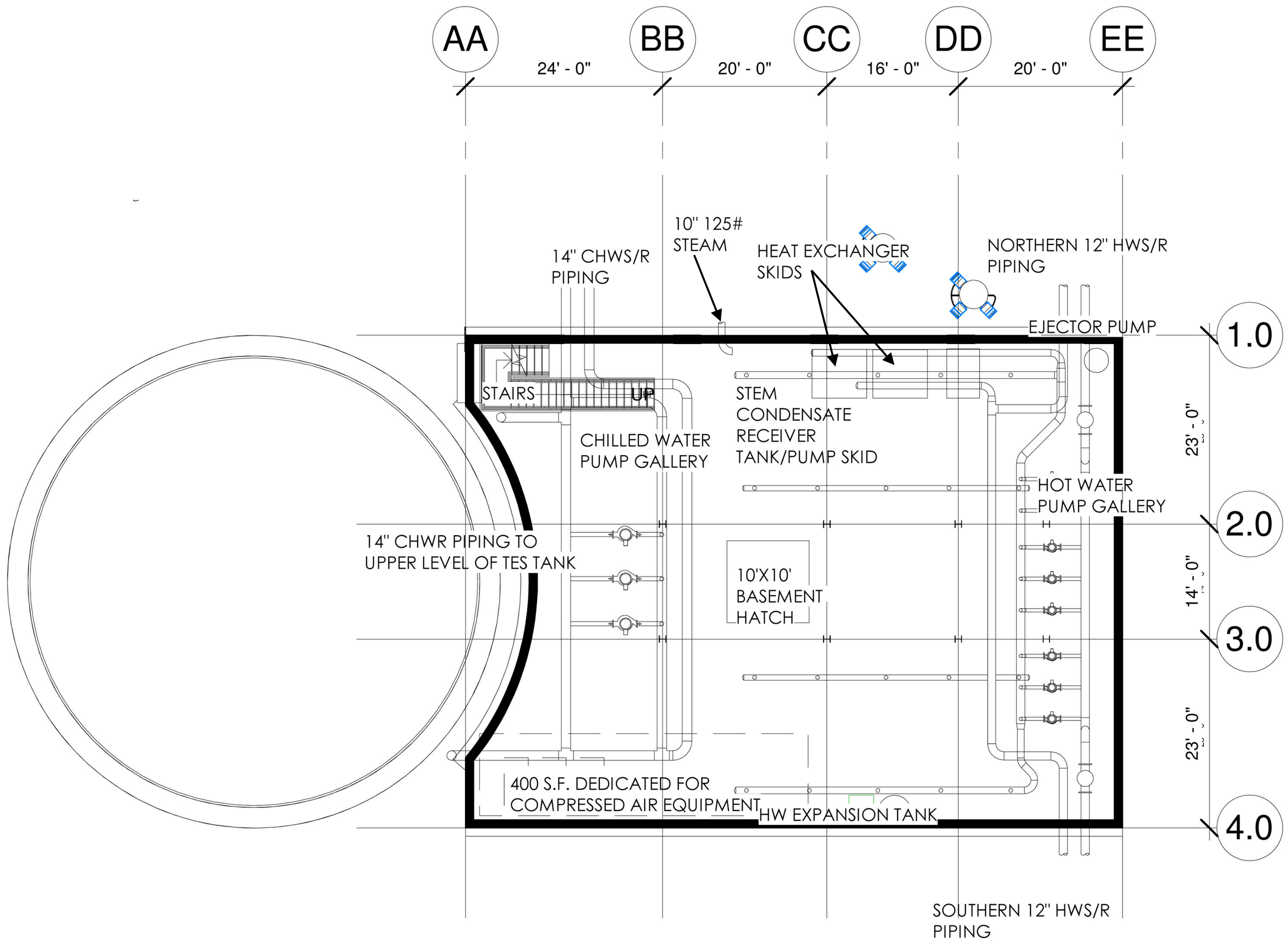
ADA Site enhancement
Along with the building improvements, piping upgrades will necessitate the disturbance of the walkway between the Engineering building and the new Plant. This is an opportunity to create a better ADA compliant ramp to transition from Prexy's Pasture down to Lewis Street. The plans are to relocate the existing driveway to the east. The drive will still provide access to service functions and parking for Anthropology. This allow for a series of ramps to start at the area between Anthropology and Engineering and traverse the slope down to Lewis Street. Care will be given to provide access to the Engineering Building utilities and doors along this path.

Parking
Parking for the new plant is minimal for operation. There is adequate spaces available to provide for this facility.

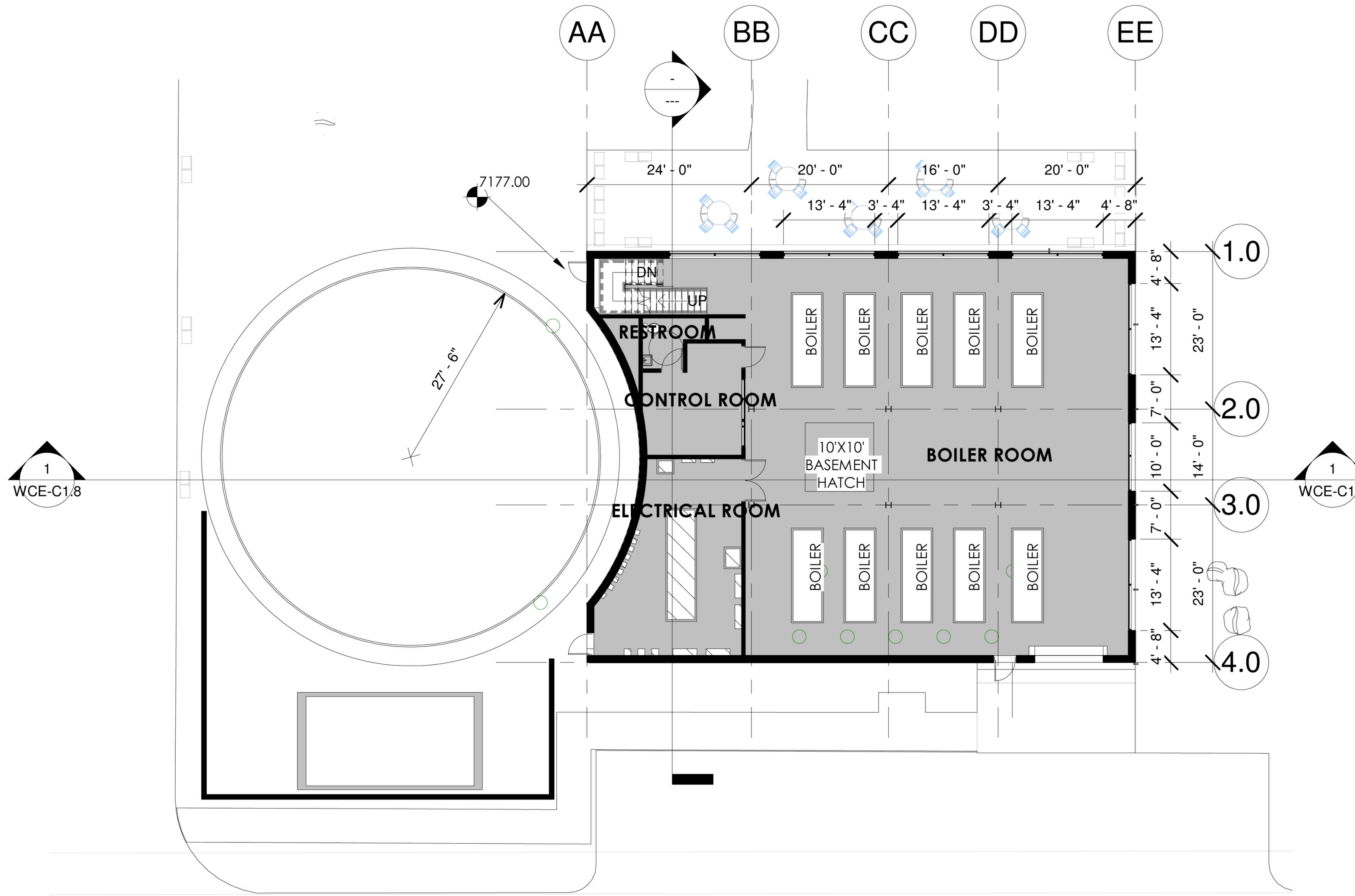
Section 5: Proposed West Campus Options



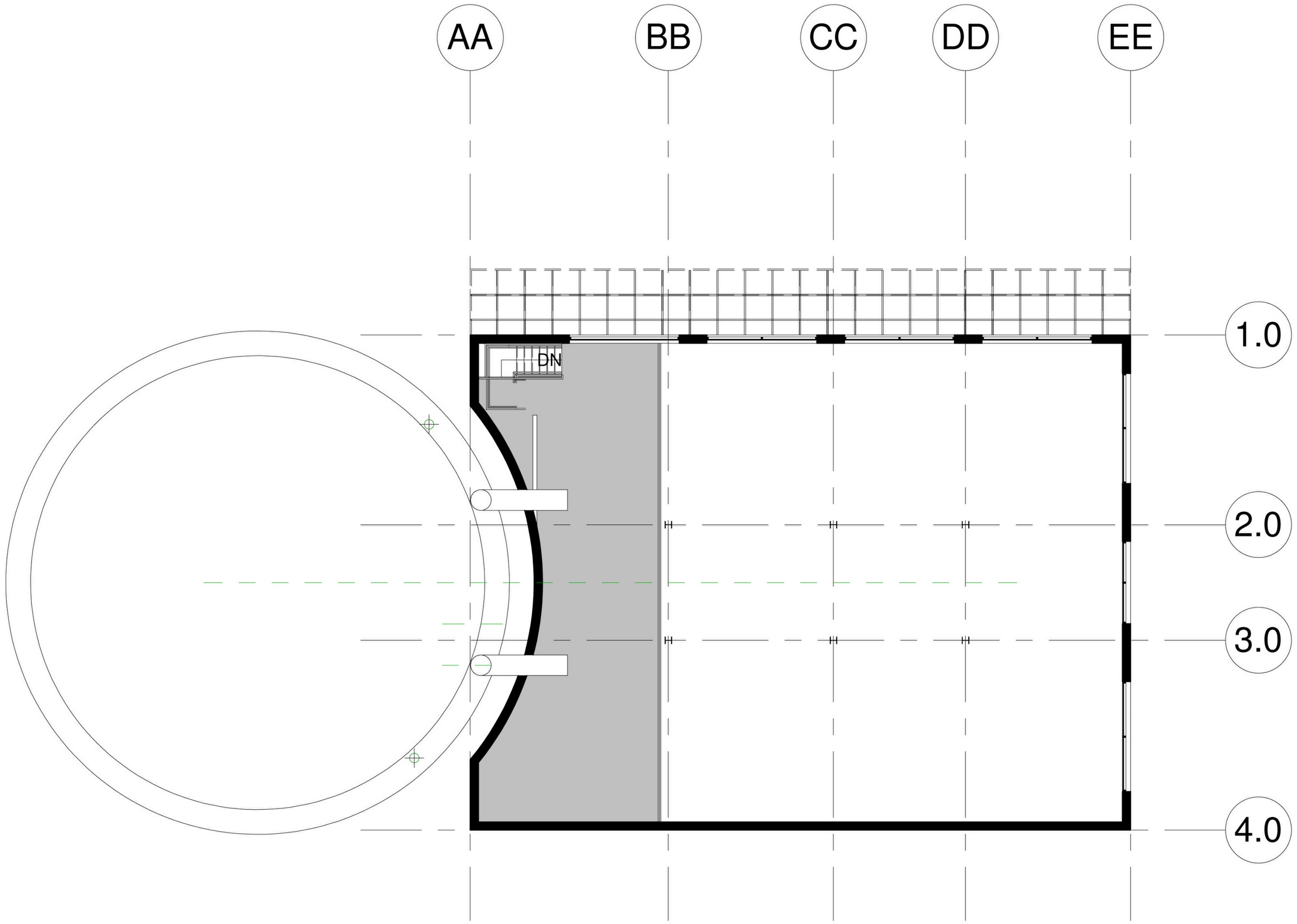
1 WCE-C1 ISOMETRIC VIEW



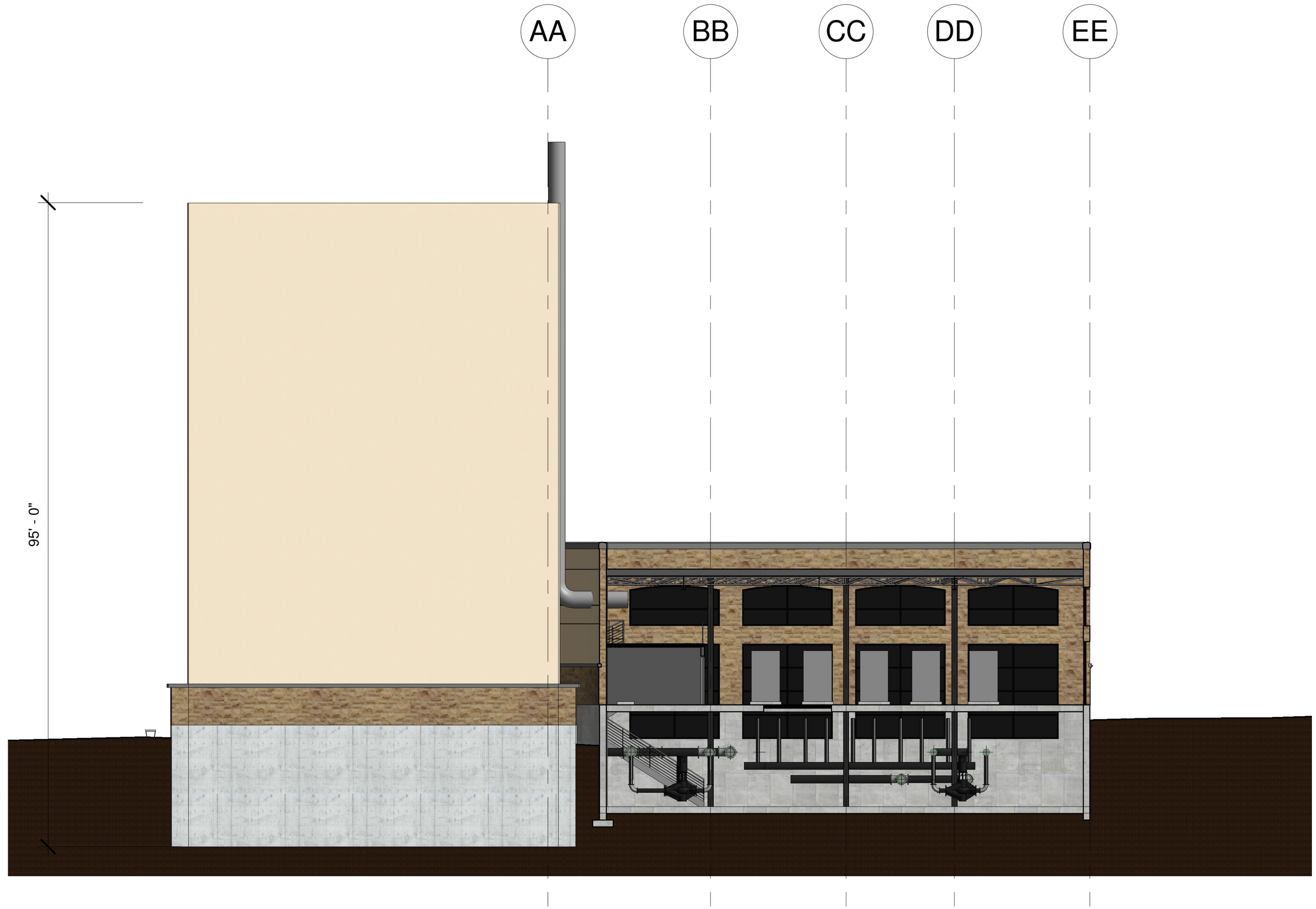
1 BASEMENT NEW PLANT
1/16" = 1'-0"



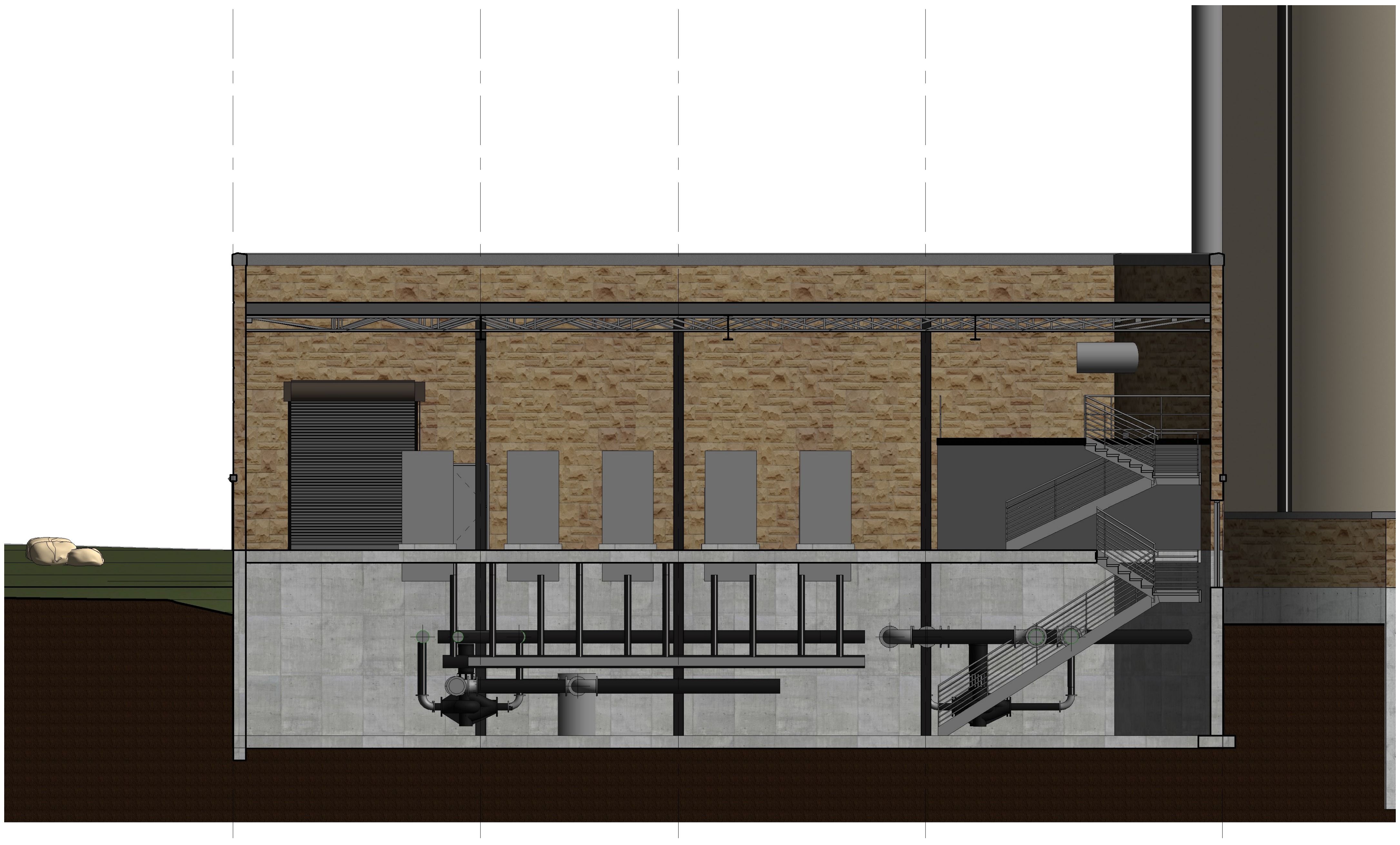
1 FIRST LEVEL NEW PLANT
1/16" = 1'-0"



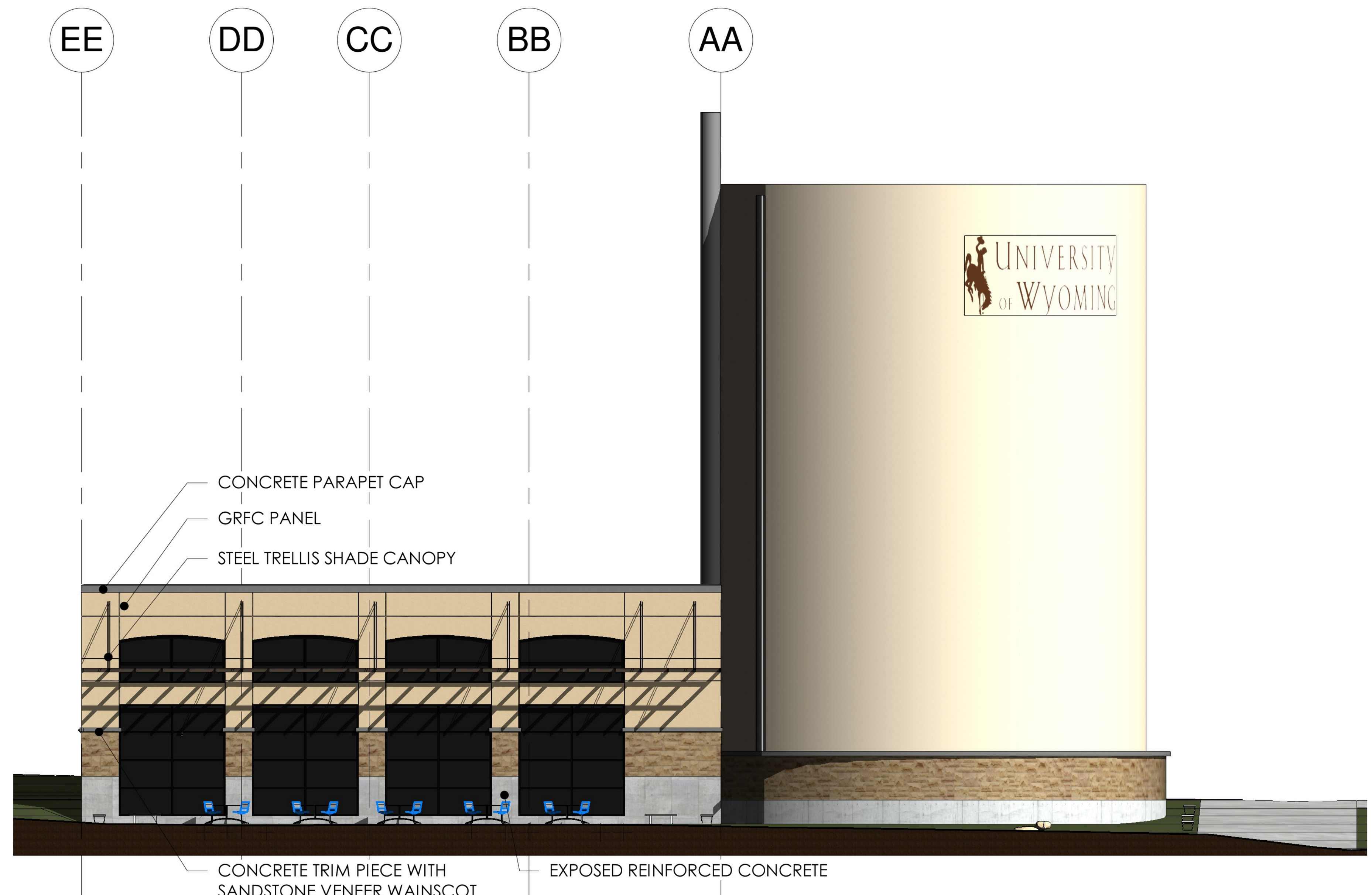
1 EQUIPMENT PLATFORM NEW PLANT
1/16" = 1'-0"



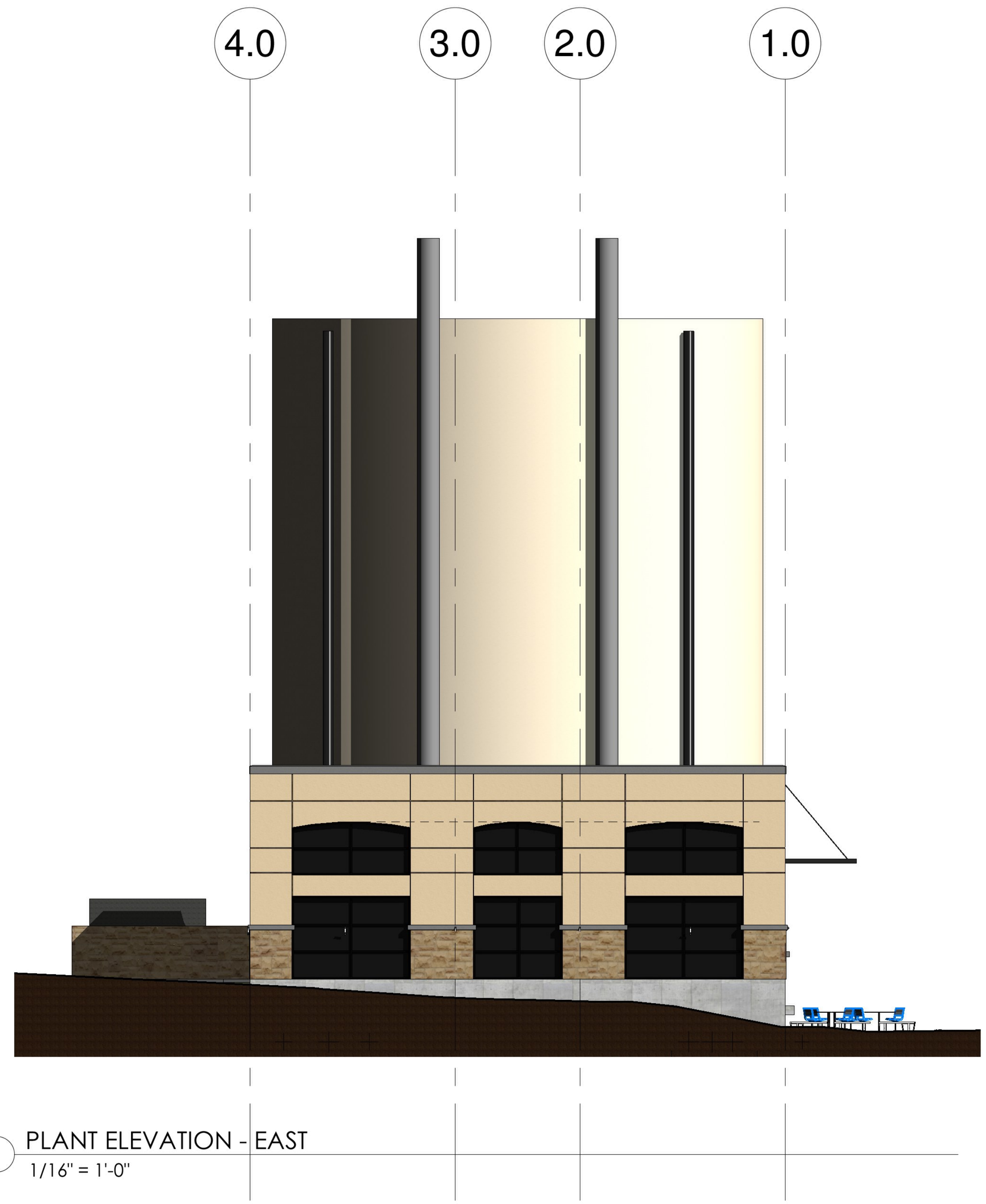
Building Section Looking North



Building Section Looking South



1 PLANT ELEVATION - NORTH
1/16" = 1'-0"



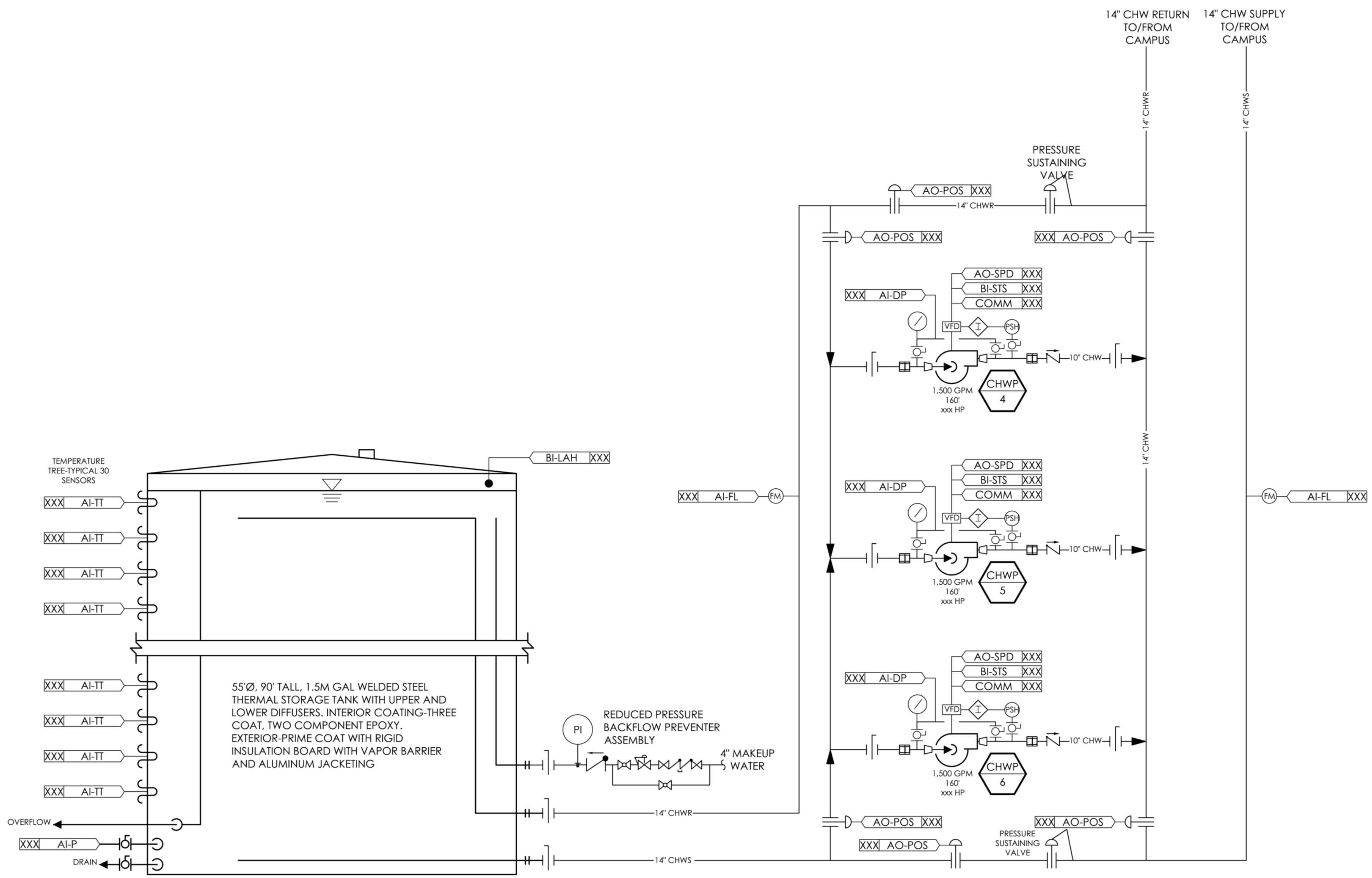
1 PLANT ELEVATION - EAST
1/16" = 1'-0"

Section 5: Proposed West Campus Options

Perspective looking southwest

Perspective looking southeast

This Page Intentionally Left Blank

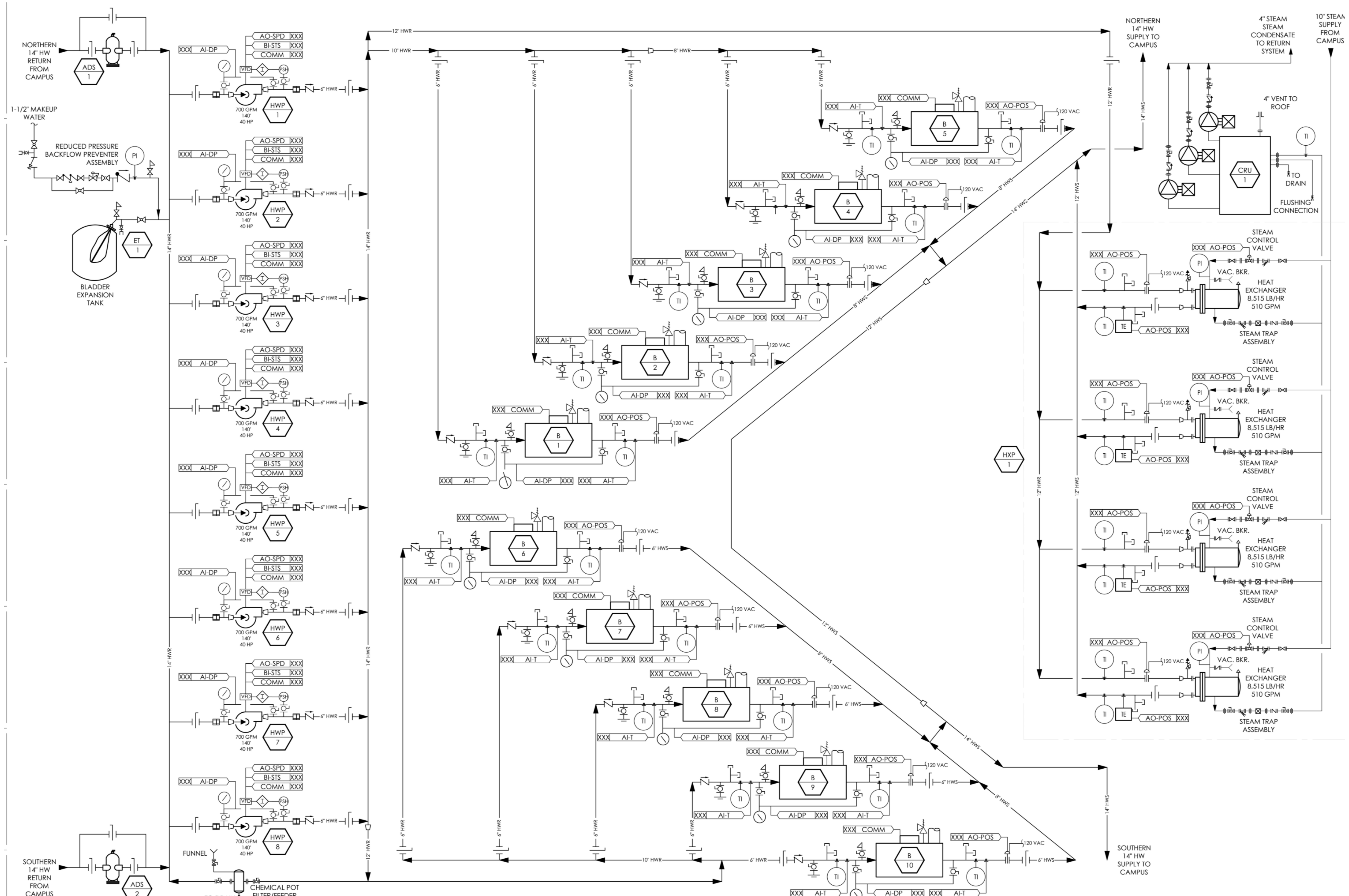


PIPING AND INSTRUMENTATION DIAGRAM
THERMAL ENERGY STORAGE
CHILLED WATER SYSTEM
A4
SCALE:NTS

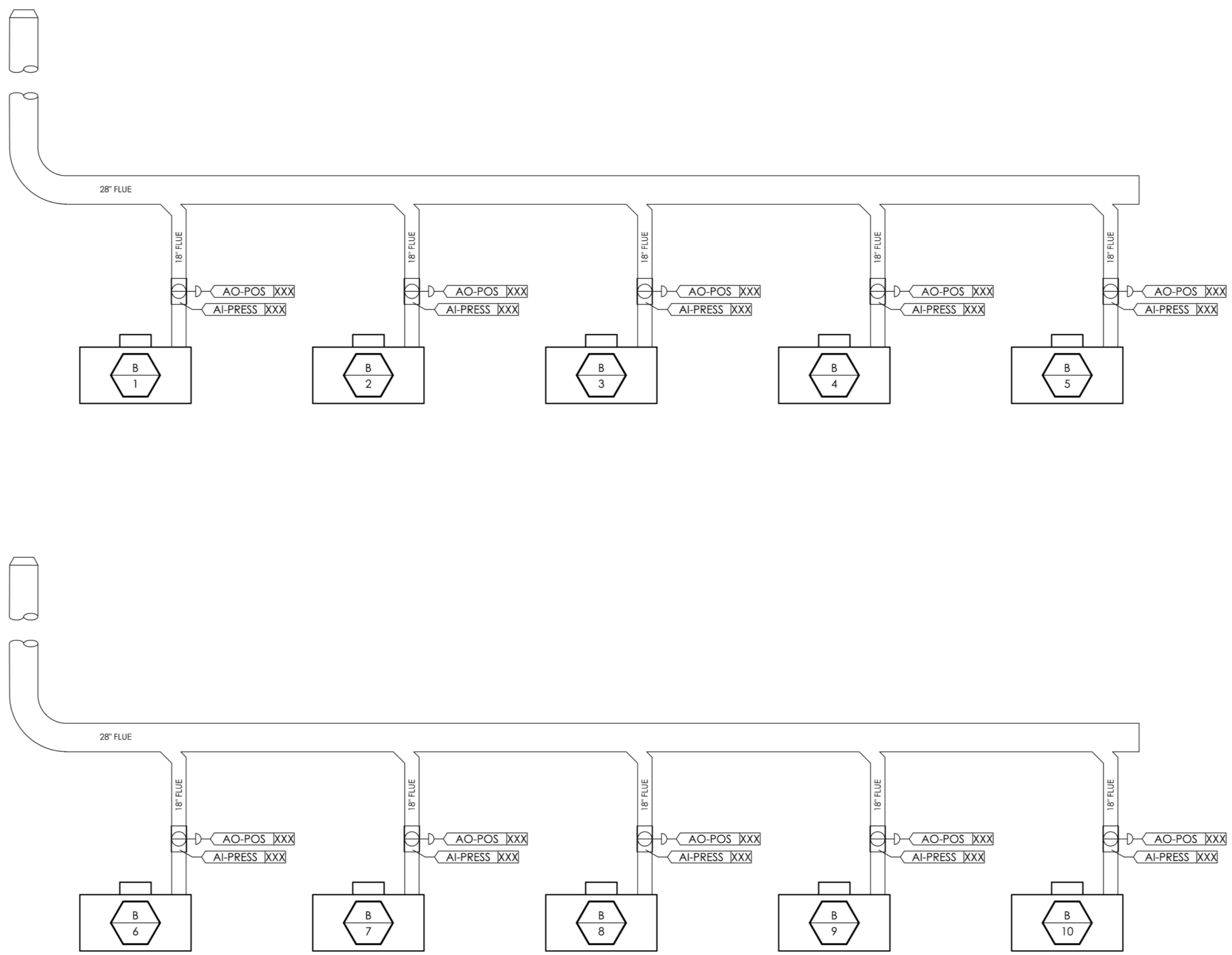
This is the proposed chilled water Thermal Energy Storage system flow diagram. Three new chilled water pumps and corresponding valving arrangement would pull cold water from the bottom of the 1.5 million gallon storage tank and return warm water to the upper nozzles of the tank during discharge mode. During recharge mode, warm water would be pulled form the upper portion of the tank and sent to the CEP for cooling. Cold water would then be returned into the bottom of the tank to take advantage of thermal stratification.

Section 1
Section 2
Section 3
Section 4
Section 5

This hot water and steam diagram represents the new heating equipment and piping configuration within the new West Campus Plant. (8) variable speed hot water pumps will provide the necessary pumping energy to circulate water throughout the new west campus loop. (10) high efficiency hot water boilers would utilize natural gas as a fuel source to provide approximately 50 MBH of heating. A new 30 MBH steam to hot water converter will be located at the new plant for backup.



A3 PIPING AND INSTRUMENTATION DIAGRAM
HEATING HOT WATER SYSTEM
SCALE: NTS



A4 **PIPING AND INSTRUMENTATION DIAGRAM**
BOILER EXHAUST SYSTEM
SCALE:NTS

Banks of (5) boiler exhausts can be headered together into single exhaust stack risers.

AIR/DIRT SEPARATOR SCHEDULE

MARK	SYSTEM AND/ OR SERVICE	TYPE	AIR SEPARATOR				OPERATING WEIGHT	BASIS OF DESIGN	NOTES
			SIZE IN	FLOW	WPD	BUILT-IN STRAINER REQ'D			
			IN	GPM	FT		LBS		
ADS-1	HEATING WATER	AIR/DIRT COMBINATION	14	2,530	3	YES	1,320	SPIROTHERM VDT1400	
ADS-2	HEATING WATER	AIR/DIRT COMBINATION	14	2,530	3	YES	1,320	SPIROTHERM VDT1400	

EXPANSION TANK SCHEDULE

MARK	LOCATION	SYSTEM AND/OR SERVICE	TYPE	APPROX SYSTEM VOLUME	SYSTEM TEMPERATURE RANGE		MIN VOLUME TANK	MIN BLADDER VOLUME	PIPE SIZE TO TANK	COLD WATER FILL SIZE	FILL WEIGHT	BASIS OF DESIGN	NOTES
					MIN	MAX							
				GAL	°F	°F	GAL	GAL	IN	IN	LBS		
ET-1	WEST CAMPUS PLANT	HEATING HOT WATER	BLADDER	85,000	60	180	370		1.50	1.5	4,000	BELL & GOSSETT MODEL B-1400	
ET-2	WEST CAMPUS PLANT	HEATING HOT WATER	BLADDER	85,000	60	180	370		1.50	1.5	4,000	BELL & GOSSETT MODEL B-1400	

HOT WATER HEATING BOILER SCHEDULE

MARK	LOCATION	SYSTEM AND/OR SERVICE	TYPE	FLUID			BOILER			% EFF	NATURAL GAS SUPPLY PRESSURE	FUEL	ELECTRICAL			OPERATING WEIGHT	BASIS OF DESIGN
				FLOW	EWT	LWT	HEATING SURFACE	OUTPUT GENERATED	MAX HEAT INPUT				POWER	PHASE	VOLT		
				GPM	°F	°F	SQFT	MBH	MBH		IN WG		HP			LBS	
B-1	WEST CAMPUS PLANT	HEATING HOT WATER	HOT WATER CONDENSING	345	150	180	670	5,171	5,443	95	2	NATURAL GAS	5.5	3	230	11,500	PARKER MODEL TC1450
B-2	WEST CAMPUS PLANT	HEATING HOT WATER	HOT WATER CONDENSING	345	150	180	670	5,171	5,443	95	2	NATURAL GAS	5.5	3	230	11,500	PARKER MODEL TC1450
B-3	WEST CAMPUS PLANT	HEATING HOT WATER	HOT WATER CONDENSING	345	150	180	670	5,171	5,443	95	2	NATURAL GAS	5.5	3	230	11,500	PARKER MODEL TC1450
B-4	WEST CAMPUS PLANT	HEATING HOT WATER	HOT WATER CONDENSING	345	150	180	670	5,171	5,443	95	2	NATURAL GAS	5.5	3	230	11,500	PARKER MODEL TC1450
B-5	WEST CAMPUS PLANT	HEATING HOT WATER	HOT WATER CONDENSING	345	150	180	670	5,171	5,443	95	2	NATURAL GAS	5.5	3	230	11,500	PARKER MODEL TC1450
B-6	WEST CAMPUS PLANT	HEATING HOT WATER	HOT WATER CONDENSING	345	150	180	670	5,171	5,443	95	2	NATURAL GAS	5.5	3	230	11,500	PARKER MODEL TC1450
B-7	WEST CAMPUS PLANT	HEATING HOT WATER	HOT WATER CONDENSING	345	150	180	670	5,171	5,443	95	2	NATURAL GAS	5.5	3	230	11,500	PARKER MODEL TC1450
B-8	WEST CAMPUS PLANT	HEATING HOT WATER	HOT WATER CONDENSING	345	150	180	670	5,171	5,443	95	2	NATURAL GAS	5.5	3	230	11,500	PARKER MODEL TC1450
B-9	WEST CAMPUS PLANT	HEATING HOT WATER	HOT WATER CONDENSING	345	150	180	670	5,171	5,443	95	2	NATURAL GAS	5.5	3	230	11,500	PARKER MODEL TC1450
B-10	WEST CAMPUS PLANT	HEATING HOT WATER	HOT WATER CONDENSING	345	150	180	670	5,171	5,443	95	2	NATURAL GAS	5.5	3	230	11,500	PARKER MODEL TC1450

Section 1
Section 2
Section 3
Section 4
Section 5

STEAM CONDENSATE RETURN PACKAGE

MARK	LOCATION	SYSTEM AND/OR SERVICE	TYPE UNIT	FLOW EACH PUMP	DISCHARGE PRESSURE	MIN RE-CEIVER SIZE	MOTOR				OPERATING WEIGHT	BASIS OF DESIGN	RE-MARKS
							NOMINAL POWER (3) EACH	PHASE	VOLT	RPM			
				GPM	PSIG	GAL	HP				LBS		
CRU-1	WEST CAM-PUS PLANT	STEAM CONDEN-SATE	TRI-PLEX	35	75	100	3	3	480	3,500	1,500	WATSON MCDANIEL	----

STEAM TO HOT WATER HEAT TRANSFER PACKAGE

MARK	LOCATION	SYSTEM AND/ OR SERVICE	TYPE	SHELL AND TUBE HEAT EXCHANGER QUANTITY	STEAM			WATER				TOTAL PACK-AGE HEAT TRANS-FER	STREAM TRAPS			SKID LENGTH/ WIDTH/ HEIGHT	OPERAT-ING WEIGHT	BASIS OF DESIGN	RE-MARKS
					PRES-SURE	FLOW (EACH HX)	LWT	EWT	LWT	FLOW (EACH HX)	WPD		QUAN-ITITY	TRAP TYPE	TRAP SIZE				
					PSI	LB/HR	°F	°F	°F	GPM	FT	MBTUH			IN	IN	LBS		
HXP-1	WEST CAM-PUS PLANT	HEATING HOT WATER	HEAT EX-CHANGER SKID	4	125	8,515	180	150	180	510	1.5	30,000	4	FLOAT AND THERMO-STATIC		104"X95"X104	8,300	ARM-STRONG	

PUMP SCHEDULE

MARK	LOCATION	SYSTEM AND/OR SERVICE	TYPE	CIRCULATING FLUID: FLUID	CIRCULATING FLUID: FLOW (GPM)	CIRCULATING FLUID: HEAD (FT)	CIRCULATING FLUID: MAXIMUM NPSH REQUIRED (FT)	CIRCULATING FLUID: TEMPERATURE (°F)	CIRCULATING FLUID: SP GR	MIN % EFF	ELECTRICAL MOTOR: NOMINAL POWER (HP)	ELECTRICAL MOTOR: PHASE	ELECTRICAL MOTOR: VOLT	ELECTRICAL MOTOR: MAX RPM	ELECTRICAL MOTOR: SPEED CONTROL	OPERATING WEIGHT (LBS)	BASIS OF DESIGN	REMARKS
CHWP-4	WEST CAMPUS PLANT	CHILLED WATER	SPLIT COUPLED VERTICAL INLINE	WATER	1,500	160	20	60	1	80	100	3	460	1800	VFD	1,700	TACO MODEL KS8016	
CHWP-5	WEST CAMPUS PLANT	CHILLED WATER	SPLIT COUPLED VERTICAL INLINE	WATER	1,500	160	20	60	1	80	100	3	460	1800	VFD	1,700	TACO MODEL KS8016	
CHWP-6	WEST CAMPUS PLANT	CHILLED WATER	SPLIT COUPLED VERTICAL INLINE	WATER	1,500	160	20	60	1	80	100	3	460	1800	VFD	1,700	TACO MODEL KS8016	
HWP-1	WEST CAMPUS PLANT	HEATING WATER	CLOSE COUPLED VERTICAL INLINE	WATER	700	140	15	180	1	75	50	3	460	1800	VFD	1,000	TACO MODEL KS6013	
HWP-2	WEST CAMPUS PLANT	HEATING WATER	CLOSE COUPLED VERTICAL INLINE	WATER	700	140	15	180	1	75	50	3	460	1800	VFD	1,000	TACO MODEL KS6013	
HWP-3	WEST CAMPUS PLANT	HEATING WATER	CLOSE COUPLED VERTICAL INLINE	WATER	700	140	15	180	1	75	50	3	460	1800	VFD	1,000	TACO MODEL KS6013	
HWP-4	WEST CAMPUS PLANT	HEATING WATER	CLOSE COUPLED VERTICAL INLINE	WATER	700	140	15	180	1	75	50	3	460	1800	VFD	1,000	TACO MODEL KS6013	
HWP-5	WEST CAMPUS PLANT	HEATING WATER	CLOSE COUPLED VERTICAL INLINE	WATER	700	140	15	180	1	75	50	3	460	1800	VFD	1,000	TACO MODEL KS6013	
HWP-6	WEST CAMPUS PLANT	HEATING WATER	CLOSE COUPLED VERTICAL INLINE	WATER	700	140	15	180	1	75	50	3	460	1800	VFD	1,000	TACO MODEL KS6013	
HWP-7	WEST CAMPUS PLANT	HEATING WATER	CLOSE COUPLED VERTICAL INLINE	WATER	700	140	15	180	1	75	50	3	460	1800	VFD	1,000	TACO MODEL KS6013	
HWP-8	WEST CAMPUS PLANT	HEATING WATER	CLOSE COUPLED VERTICAL INLINE	WATER	700	140	15	180	1	75	50	3	460	1800	VFD	1,000	TACO MODEL KS6013	

Section 1
Section 2
Section 3
Section 4
Section 5

GENERAL NOTES

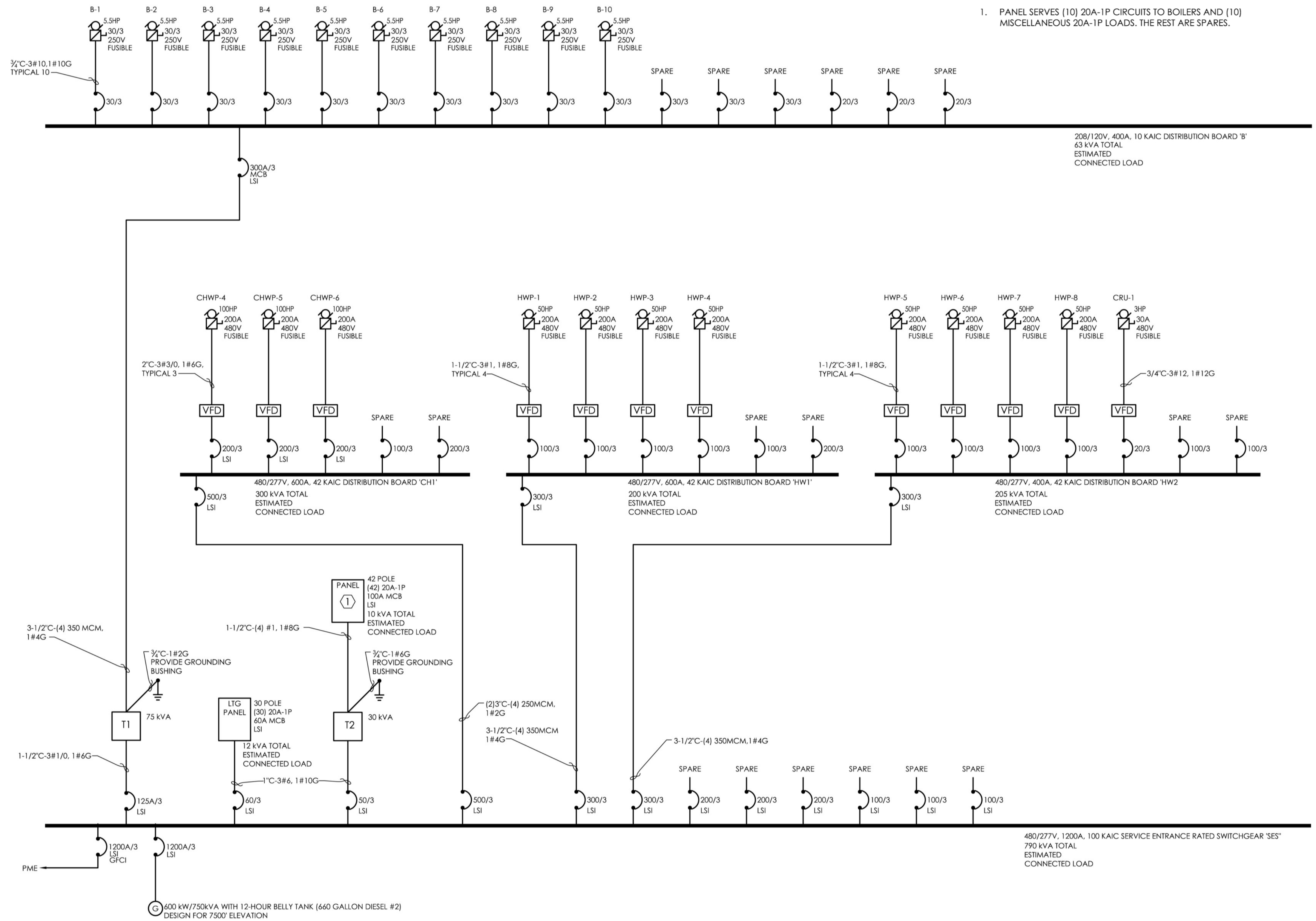
A. ALL CONDUIT IS EMT.

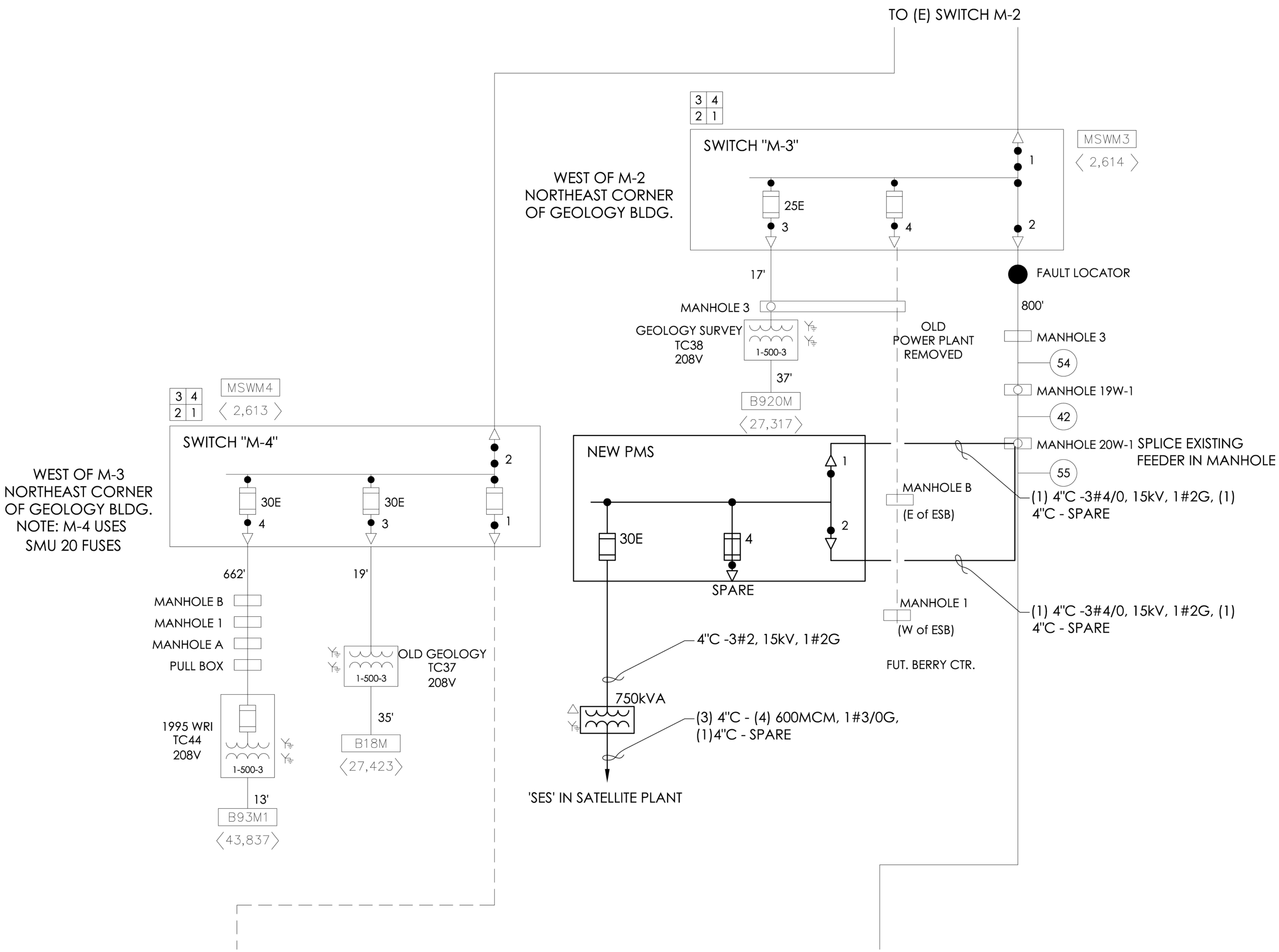
B. CONDUCTORS ARE STRANDED COPPER THHN AND XHHW-2.

C. VFDS ARE WITHOUT INTEGRAL BYPASS.

KEYNOTES

1. PANEL SERVES (10) 20A-1P CIRCUITS TO BOILERS AND (10) MISCELLANEOUS 20A-1P LOADS. THE REST ARE SPARES.




TO (E) SWITCH M-2
SWITCH "M-3"
MSWM3
2,614
WEST OF M-2
NORTHEAST CORNER
OF GEOLOGY BLDG.
25E
FAULT LOCATOR
17'
800'
MANHOLE 3
GEOLOGY SURVEY
TC38
208V
1-500-3
OLD
POWER PLANT
REMOVED
MANHOLE 3
54
MANHOLE 19W-1
42
37'
B920M
27,317
MANHOLE 20W-1
SPLICE EXISTING
FEEDER IN MANHOLE
55
MSWM4
2,613
SWITCH "M-4"
WEST OF M-3
NORTHEAST CORNER
OF GEOLOGY BLDG.
NOTE: M-4 USES
SMU 20 FUSES
30E
30E
NEW PMS
30E
SPARE
MANHOLE B
(E of ESB)
(1) 4"C -3#4/0, 15kV, 1#2G, (1)
4"C - SPARE
662'
19'
MANHOLE B
MANHOLE 1
MANHOLE A
PULL BOX
MANHOLE 1
(W of ESB)
(1) 4"C -3#4/0, 15kV, 1#2G, (1)
4"C - SPARE
OLD GEOLOGY
TC37
208V
1-500-3
4"C -3#2, 15kV, 1#2G
FUT. BERRY CTR.
750kVA
(3) 4"C - (4) 600MCM, 1#3/0G,
(1)4"C - SPARE
1995 WRI
TC44
208V
1-500-3
35'
B18M
27,423
13'
B93M1
43,837
'SES' IN SATELLITE PLANT

Section 5: Proposed West Campus Options

05 West Campus Heating Loads

This is a list of West Campus buildings and associated areas and heating requirements. The Building names in red represent a building in which steam is utilized within the space. These buildings are assumed to remain on CEP steam service.

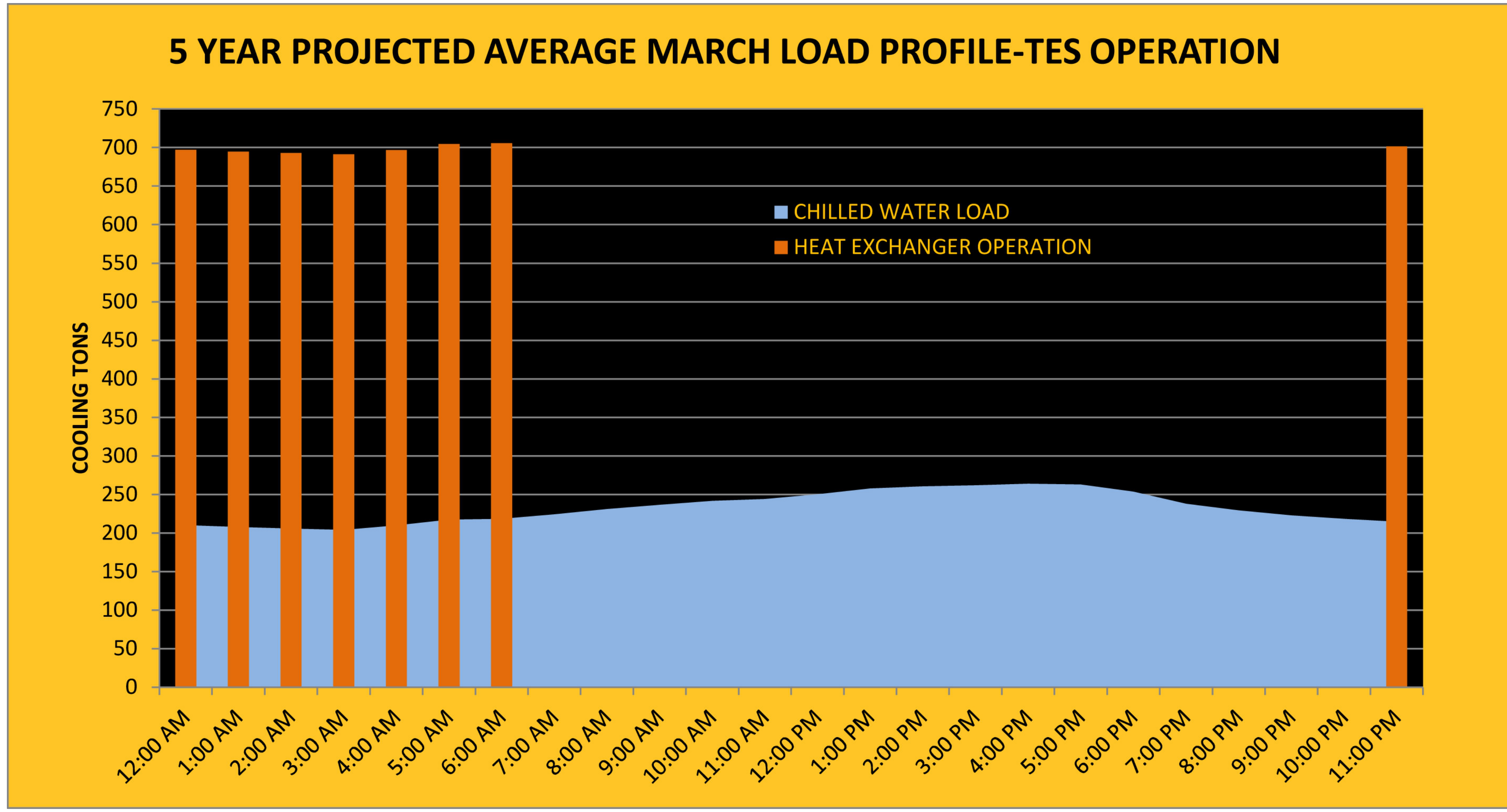
UNIVERSITY OF WYOMING BUILDINGS HEATING LOAD		STEAM HEATING				
UW BUILDING NAME	UW BUILDING #	Area Conditioned by Steam (sq-ft)	Peak Steam Load (lb/hr)	Diversified Steam Load (lb/hr)	Diversified Heating BTU/sqft	2016 Building Data Average Peak Month BTU/sqft
						NORTH-WEST CAMPUS
Existing						
Engineering and Applied Science 1927/59/83	1	309,365	15,446	9,697	34	10
Agriculture C	2	107,053	3,854	2,221	22	12
Agriculture C Addition	2	114,726	5,354	3,361	32	12
Education Annex (Vocational)	6	27,840	1,002	577	22	40
Education (LRC)	14	123,674	4,452	2,565	22	10
McWhinnie Hall	19	26,625	959	552	22	9
Half Acre Gymnasium w/o 2014 addition	22	119,306	7,249	4,873	44	-
Half Acre Gym Addition (HAG)		75,034	2,223	1,490	21	-
Service Bldg Orig w/1956 & 60 additions	36	81,268	2,117	1,219	16	-
Wyoming Hall	38	69,579	2,505	1,443	22	12
Earth Sciences	81	65,000	3,033	1,904	32	-
Berry Center (39081sf)	92	39,081	1,230	824	23	24
Bureau of Mines	93	77,916	3,247	2,370	33	39
Anthropology (AARF)	133	52,499	1,890	1,089	22	8
Enzi STEM		99,000	4,125	3,011	33	9
Energy Innovation Center (ERC, EIC)	87	57,000	2,375	1,734	33	19
Existing Subtotals		**1,444,966**	**61,061**	**38,930**	**29**	
Projected 5 Year Growth North of Lewis						
(Future) Engineering Building (North of Lewis) (2018)		*107,000*	*4,458*	*3,255*	*33*	
(Future) UW Science Initiatiive (North of Lewis) (2019)		*125,842*	*5,243*	*3,828*	*33*	
5 Year Projected Totals		**1,677,808**	**70,763**	**46,012**	**30**	
Projected 30 Year Totals						
Block Growth (Estimated 2% per year after initial 5 years) North of Lewis		*66,355*	*2,765*	*2,018*	*33*	
Projected 30 Year Totals		**1,618,321**	**68,284**	**44,203**	**29**	
						WEST AND SOUTH-WEST CAMPUS
Arts & Sciences	7	66,186	2,317	1,335	22	12
Biological Sciences (includes Science Library Annex)	9	205,350	9,583	6,016	32	6
Health Sciences Complex (Bio-Chem; Pharmacy; HS in 07)	11	124,348	5,181	3,782	33	11
Classroom Bldg w/2007 addn	12	96,061	2,852	1,992	22	17
College of Business w/o auditorium (demo 2008)	13	61,081	2,232	1,286	23	7
College of Business Addition	13	102,821	3,332	2,233	23	7
Geology w/ 56 addn	18	57,771	2,080	1,144	21	4
Cheney International Center/Student Health	23	32,013	1,152	664	22	14
Hoyt Hall	24	29,939	1,078	621	22	-
Coe 1977 addition	26	85,676	3,084	1,777	22	9
Coe 58 orig and History	26	119,390	4,298	2,477	22	9
Coe Library ILLC Addition	26	92,876	3,010	2,017	23	9
Merica Hall	27	17,651	635	366	22	-
Aven Nelson	30	32,832	1,182	681	22	-
Old Main	31	34,089	1,227	707	22	17
Physical Sciences	33	179,777	9,798	6,292	38	16
Wyoming Union 2002 addition	39	25,000	1,050	605	26	8
Wyoming Union w 79 additions	39	137,418	5,772	3,326	26	8
Knight Hall 41 orig/46 addn/50 food ser	44	81,671	2,940	1,694	22	11
Ross Hall	50	90,665	3,536	2,037	24	11
Aven Nelson - Williams Conservatory	82	15,443	472	330	23	-
WY State Geological Survey	920	23,171	834	481	22	-
Existing Subtotals		**1,711,229**	**67,645**	**41,863**	**26**	
Projected 30 Year Totals						
Block Growth (Based on UMP Projections)		*200,000*	*6,481*	*4,343*	*23*	
Projected 30 Year Totals		**1,911,229**	**74,127**	**46,205**	**26**	

HOT WATER HEATING							
% Building on Steam Heat (Existing)	Existing Local Steam Building Load (BTUH)	Existing Local HW Building Load (BTUH)	Total Building Load (BTUH)	Existing HW Building Flow (gpm)	Proposed Immediate Building Load On New HW System (BTUH)	Proposed 5 Year Building Load On New HW System (BTUH)	Proposed 30 Year Building Load On New HW System (BTUH)
NORTH-WEST CAMPUS							
30%	2,763,645	6,448,505	9,212,150	430	6,448,505		
50%	1,054,975	1,054,975	2,109,950	70	1,054,975		
	0	3,192,950	3,192,950	213	3,192,950		
	0	548,150	548,150	37	548,150		
100%	2,436,750	0	2,436,750	0	0		
100%	524,400	0	524,400	0	0		
	0	4,629,350	4,629,350	309	4,629,350		
	0	1,415,086	1,415,086	94	1,415,086		
100%	1,158,050	0	1,158,050	0	0		
100%	1,370,850	0	1,370,850	0	0		
	0	1,808,800	1,808,800	121	1,808,800		
	0	783,104	783,104	52	783,104		
100%	2,251,448	0	2,251,448	0	0		
	0	1,034,550	1,034,550	69	1,034,550		
	0	2,860,688	2,860,688	191	2,860,688		
	0	1,647,063	1,647,063	110	1,647,063		
	11,560,118	***25,423,219***	***36,983,337***	***1,695***	***25,423,219***		
	0	3,091,854	3,091,854	206		3,091,854	
	0	3,636,309	3,636,309	242		3,636,309	
	11,560,118	***32,151,383***	***43,711,501***	***2,143***		***32,151,383***	
	0	1,917,372	1,917,372	128			1,917,372
	11,560,118	***34,068,755***	***45,628,873***	***2,271***			***34,068,755***
WEST AND SOUTH-WEST CAMPUS							
100%	1,268,250	0	1,268,250	0	0		
	0	5,715,200	5,715,200	381	5,715,200		
	0	3,593,139	3,593,139	240	3,593,139		
	0	1,892,400	1,892,400	126	1,892,400		
	0	1,221,700	1,221,700	81	1,221,700		
	0	2,120,921	2,120,921	141	2,120,921		
30%	326,040	760,760	1,086,800	51	760,760		
	0	630,800	630,800	42	630,800		
	0	589,950	589,950	39	589,950		
33%	557,090	1,131,061	1,688,150	75	1,131,061		
33%	776,540	1,576,611	2,353,150	105	1,576,611		
33%	632,208	1,283,574	1,915,782	86	1,283,574		
100%	347,700	0	347,700	0	0		
	0	646,950	646,950	43	646,950		
100%	671,650	0	671,650	0	0		
	0	5,977,400	5,977,400	398	5,977,400		
30%	172,425	402,325	574,750	27	402,325		
30%	947,910	2,211,790	3,159,700	147	2,211,790		
50%	804,650	804,650	1,609,300	54	804,650		
	0	1,935,150	1,935,150	129	1,935,150		
20%	62,758	251,033	313,791	17	251,033		
	0	456,950	456,950	30	456,950		
	6,567,220	***33,202,364***	***39,769,584***	***2,213***	***33,202,364***		
	0	4,125,463	4,125,463	275			4,125,463
	6,567,220	**37,327,827**	**43,895,047**	**2,489**			**37,327,827**

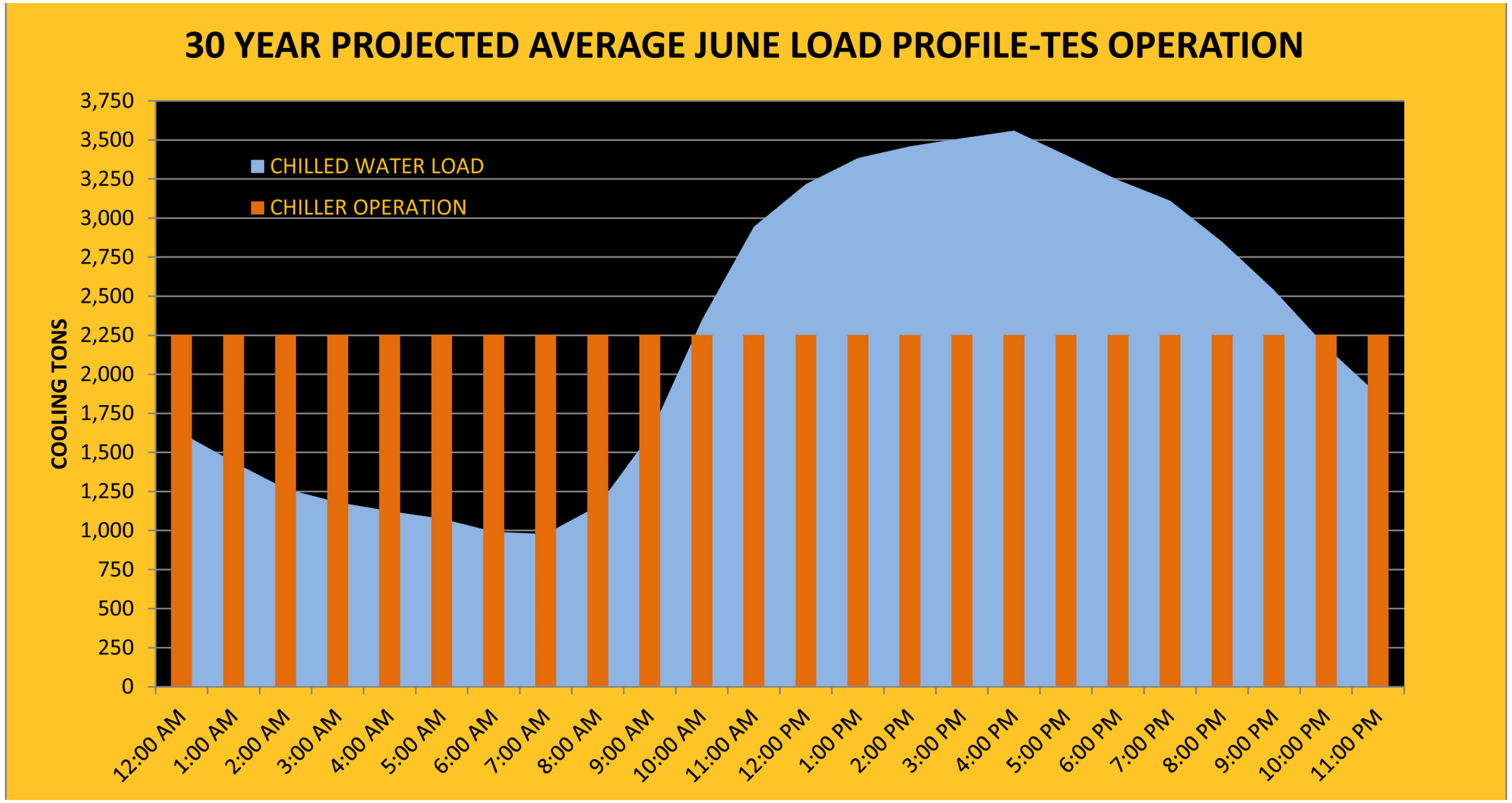
06 Thermal Energy Storage Comparisons

Winter Operation

Summer Operation



This graph shows the use of hydronic economizer heat exchangers paired with the TES tank during the nighttime hours to satisfy the projected 5 year chilled water load for a typical March day



This graph shows the use of the CEP chillers paired with the TES tank to satisfy the projected 30 year chilled water load for a typical June day

07 Natural Gas Supply

Natural Gas Narrative

For the modular hot water plant concept to occur, a natural gas source needs to be secured. The current gas provider is Black Hills Corp (BHC). Through discussions with BHC representatives, an additional 20MBtuh would be available for purchase beyond the current purchased quantity. This available quantity equates to approximately (3) new modular type boilers if there is no reduction in CEP use. Any quantity of gas over this limit will not be able to be provided to the University with the current BHC infrastructure. Additional analysis by BHC is required to determine future availability.

Another source of natural gas is through a private provider. The University is in discussion with Energy Operations Management (EOM) regarding the possibility of a new gas line between the University and the Kinder Morgan Colorado Gas Interstate Pipeline, approximately seven miles away. The possibility for a reduced unit cost is available. Preliminary highlights of a potential agreement are as follows:

- EOM would propose a Pipeline Development and Natural Gas Purchase and Sale Agreement (PSA). This agreement would consist of two phases:
  - Phase I-A feasibility study to understand the design and permitting requirements, obtain pipeline Right of Way, and develop a firm project budget. This phase would also develop a capital plan through either financing or upfront payment.
  - Phase II would consist of the actual build out and construction.
- EOP would construct, own, maintain, and operate the project in a turnkey manner.
- If financed, the pipeline capital cost would be amortized over a 3-5 year period until payout after which the amortization charge would cease.

The estimated cost for the feasibility portion of this project is approximately $200K. The estimated construction cost of this pipeline is $6.7M.

See the Comparative Cash Flow analysis within Section 5 of this report for additional information regarding natural gas costs and the impact on the system life cycle.

Wind Analysis Narrative

When wind collides with the face of a building its flow is forced in various directions. The mean flow patterns and turbulence caused by wind passing over a building can recirculate exhaust gases to air intakes- as airflow separates at the building edges, it creates recirculation zones over downwind surfaces, extending the downwind wake (ASHRAE Fundamentals 2013).

Looking at the overlay of the wind rose over the campus map, it is seen that a majority of the wind will blow in over the Agriculture building, as well as some gusts flowing from the Engineering building's direction. Due to the proximity of the new CHW tank to either of the buildings, both will obstruct airflow and generate their own recirculation air zones that must be considered when designing the new satellite plant's exhaust stacks.

In order to begin stack design, the new CHW tank's structure and wind characteristics had to be simplified. The simplification of the building and its surroundings allows for the ASHRAE method of stack design to be utilized, but this simplification does not come without drawbacks. Because of the simplification, many flows created by unique building geometries are not analyzed. These unanalyzed flows could potentially cause differences in the ASHRAE model and what is actually needed on site. ASHRAE Fundamentals 2013 states: "Buildings having even moderately complex shapes, such as L- or U-shaped structures, can generate flow patterns too complex to generalize for design," much like shape formed by the buildings surrounding the proposed site.

By simplifying the surrounding building structures into simple cubic shapes, their wake recirculation zones can be estimated. After drawing the wake recirculation zones, a 1:5 sloped line is added, which can be seen in Figure 1 and Figure 2. The line represents the minimum stack height required to just clear the recirculation zones. The minimum stack height, measured from the roof below, should be at least 21' and placed on the north edge of the tank. It is recommended that exhaust velocity is within the range of 2,000-3,000 feet per minute to eliminate stack wake downwash, reduce energy usage, and minimize noise issues.

Concentration and dilution are two very important factors in safe stack design. Boiler exhaust gas, which has high concentrations of toxic substances, is vented outside for dilution. For our purposes, dilution is the process of mixing exhaust gas, which has a high concentration of toxic substances, with outside air. The goal of dilution is to bring down the concentration of toxic substances, below the allowable limit, before interacting with receptors. If it is discovered that the exhaust gas is not diluted enough before it reaches a receptor, then additional filters, scrubbers, or collectors may be added to the stack to maintain acceptable air quality.

While simplifying the shape of the new TES tank is convenient for general stack design, it does not account for unique flow patterns that develop in the real world. Because of this inaccuracy, as well as the toxic nature of the exhaust gas, we recommend that a more accurate wind study is performed, such as the wind tunnel study done by Ambient Air Technologies on the ENZI building.

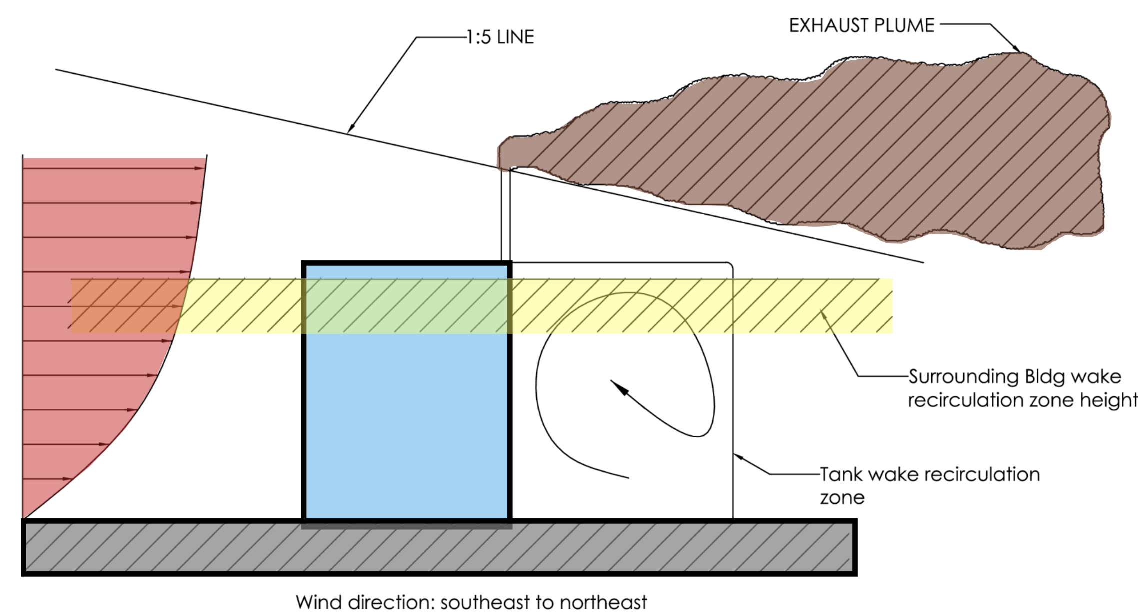


Figure 1 – Example Stack

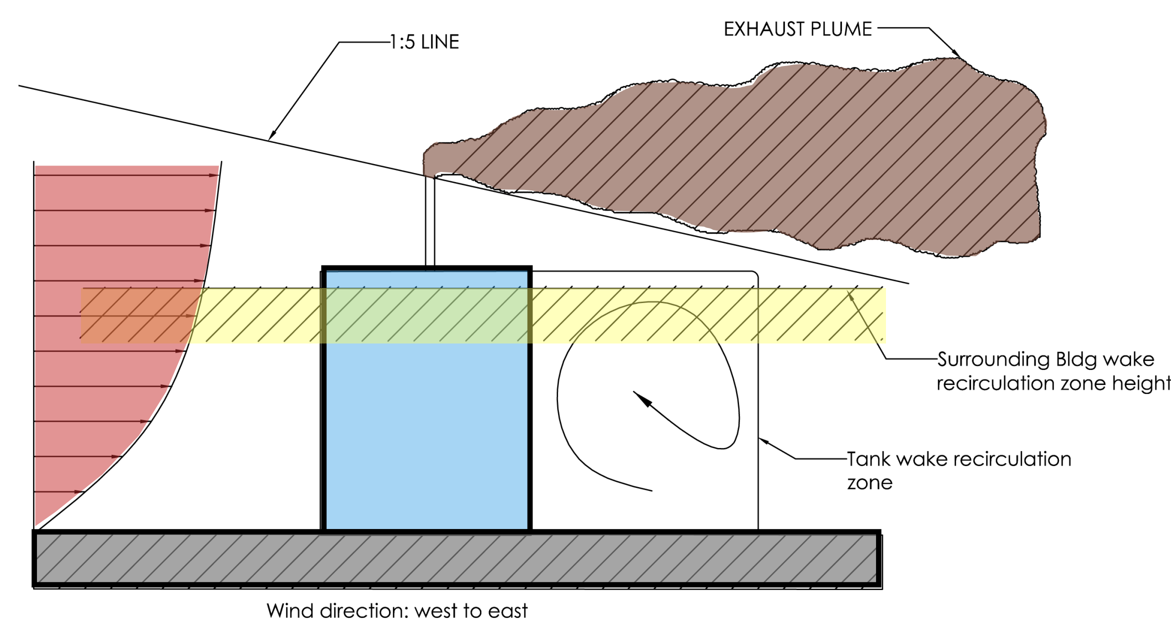


Figure 2 – Example Stack

Life Cycle Cost Evaluation

Remain on CEP steam vs, Transition to Modular HHW

Qualitative Description of Alternatives

Projected campus growth and diminishing steam plant peak capacity is one of three primary reasons to consider an alternative approaches to heating and cooling the University of Wyoming Laramie Campus. Other reasons include capital cost to address risk and reliability associated with an aging steam production, distribution and terminal use infrastructure, and the annual operating costs associated with the poor thermal efficiency of the distribution system and the high technical labor burden to operate the plant. Two alternatives were considered.

Remain on CEP Steam & Water Chilling

The Remain on CEP Steam alternative represents "business as usual" over the next 30 years. The projected near term heating capacity shortfall would be addressed by the installation of an additional water tube steam boiler, fired on natural gas and located in a new bay at the North of the existing CEP. Aging distribution infrastructure would be addressed through two major steam tunnel replacement projects (Knight to BioSciences, and Education to Engineering) and a series of tunnel and tunnel piping repair and renewal projects. Replacement of the building steam converters, regulating stations and condensate return units would continue to occur in response to age and condition related failures. The thermal efficiency of the five miles of steam supply/condensate return piping within the tunnel system would not substantially improve under this alternative. The labor necessary to properly staff full CEP plant operations would remain as is.

Campus load growth, particularly in research and academic laboratory facilities at the West Campus drives a need to improve campus chilled water campus capacity. An additional 1,200 ton electric driven water chiller would be installed in a bay extension to the north of the existing chiller bay, and new chilled line extension routed to the vicinity of Lewis and 14th.

Transition to Modular HHW

The transition to modular HHW alternative shifts from steam production at the CEP, distribution through the campus utility tunnel system and ultimate conversion to heating water within buildings, to a heating hot water production and distribution system within west campus. A new natural gas fired heating water boiler plant, using modular package units would now supply heating water to 30 buildings in the vicinity of Prexy's Pasture and to the North of Lewis. The heat supplied from the West Campus Satellite plant through this new distribution system will correspond to approximately 60% of current campus annual heating load. The remaining 40% of existing load including residence halls, athletics, fine arts and facilities east of the Union and in the vicinity of the CEP, would continue to be served through the existing steam distribution, supplied by the CEP, and firing boilers on the most economical combination of natural gas or coal.
The oldest steam tunnels on campus, are in greatest risk of structural failure and would be stabilized and permanently abandoned. New building heating water components would be installed in the 30 buildings affected, eliminating deferred maintenance and renewal costs for pressure regulating, heat transfer and condensate return components. Significant improvements in both thermal efficiency and operating labor in this alternative drive the annual operating cost savings.

Investment in the Transition to Modular HHW does not eliminate the ongoing beneficial use of the CEP, which will continue to serve 40% of the campus load. The existing CEP capacity can continue to serve the west campus through a relatively new (and well insulated) 14" steam supply main in Lewis that can supply in the new heating water plant. These heat exchanger units are sufficiently sized to enable either supplemental or full steam heat to west campus, providing multiple fuel reliability and the potential to restore a higher utilization of coal as the campus fuel, should clean coal/carbon sequestration technologies, regional energy economics, and/or solid fuel plant labor requirements change over the next 30 years.
A lower cost alternative to the increasing chilled water production capacity and extending new piping from the CEP to campus is proposed in this alternative. A 1.5 Million gallon thermal storage tank, integrated into design and construction of the west campus satellite modular boiler plant will enable existing CEP water chillers and existing distribution piping to operate more continuously at lower load and at night (under off-peak electrical rates) to store cooling energy, in close proximity to the west campus demand. This alternative is attractive from both a first cost and operating cost perspective.

Quantitative Cost Analysis

A side-by-side comparative Life Cycle Cost Evaluation (LCCE) was prepared to consider quantitative differences between projected University expenditures for these two alternatives.

Capital Expense

The capital construction costs developed for each of the alternatives include plant facility and equipment, distribution and tunnel improvements, and building connection and renewal elements and they are summarized in the accompanying table. Construction for either alternative was assumed to occur over a six year period, representing three two year funding biennials. Cost estimates carry a 9% escalation factor to cover phasing. Planning and design of the entire project and construction of CEP extension or HHW plant would occur in the first phase, installation of distribution and connections to buildings would occur in phases two and three. Improvements to the natural gas supply to UW are needed in both alternatives. Initial discussions with both the current utility provider (Black Hills) and a pipeline services contractor have not yet yielded quantitative cost projections. The comparative cost model assumes that, in either case, cost of the new pipeline would be negotiated along with a commitment to additional annual volume.

Remain on Steam

Estimated Net Cost

Central Energy Plant and Steam Tunnel Improvements				estimated net
chilled water improvements	GLHN			$ -
boiler bay expansion	GLHN			$ 1,200,000
40MBH boiler & aux	GLHN			$ 1,320,000
underthrow upgrades	GLHN/Henneman			$ 500,000
plant				**$ 3,020,000**
CHW line extension	GLHN			$ 3,600,000
Immediate Tunnel Replace knight biosci	GLHN	1000	$ 2,100	$ 2,100,000
Immediate Tunnel Replace Ag/Engr	GLHN	1300	$ 3,000	$ 3,900,000
Misc Tunnel & Piping Repair/Renewal	GLHN	750	$ 1,000	$ 750,000
distribution				**$ 10,350,000**
Building Steam Equipment Replace/Renev	GLHN	0.5		$ 894,395
buildings				**$ 894,395**
Estimated Net Cost				**$ 14,264,395**

Margins and Adjustments

General Conditions and Temporary Requirements	15.0%	$ 2,139,659
Design Estimating Contingency	20.0%	$ 3,280,811
Escalation	9.0%	$ 1,771,638
Overhead and Profit	5.0%	$ 1,072,825
Bonds and Insurance	2.5%	$ 563,233
State Sales Tax (65% of 6.0%)	3.9%	$ 900,610
Soft Costs	20.0%	$ 4,798,634
		$ 28,791,805

Transition to HHW

Estimated Net Cost

WC Boiler Plant and HHW Distribution		estimated net
Boiler Plant & TES	RLB	$ 6,131,271
TES tank, chw system & foundation	RLB	$ -
underthrow upgrades	GLHN/Henneman	$ 500,000
plant		**$ 6,631,271**
Phase 1 Sitework (30 bldgs)	RLB	$ 8,111,690
distribution		**$ 8,111,690**
New building domestic/HHW HX	RLB	$ 1,788,790
buildings		**$ 1,788,790**
Estimated Net Cost		**$ 16,531,751**

Margins and Adjustments

General Conditions and Temporary Requirements	15.0%	$ 2,479,763
Design Estimating Contingency	20.0%	$ 3,802,303
Escalation	9.0%	$ 2,053,243
Overhead and Profit	5.0%	$ 1,243,353
Bonds and Insurance	2.5%	$ 652,760
State Sales Tax (65% of 6.0%)	3.9%	$ 1,043,764
Soft Costs	20.0%	$ 5,561,387
		$ 33,368,324

Section 1
Section 2
Section 3
Section 4
Section 5

Operating Expense

Annual operating costs were projected for each alternative based on recent plant operating cost data. A spreadsheet model of the composition of costs includes factors for the unit costs of coal, natural gas, electric power (including chilled water production) and water, full time equivalent labor costs, the costs associated with routine maintenance (service contracts, materials, etc.) and the annualized costs associated with major maintenance.

CEP Alternative

Under this alternative, the CEP was assumed to consume 23,000 Tons/yr of coal and 29,250 MMBTU/yr of Natural gas to produce a total campus building load estimated at 249,234 MMBTU/yr. These conditions mimic plant operation behavior in 2013 and essentially represent full coal capability with supplemental natural gas. The annual boiler efficiency is estimated at 75% and the continuous thermal loss through the steam piping system are estimated at 12,000 lb/hr, yielding an overall conversion efficiency (fuel-to-building heat) of 52%. Distribution losses are based on calculation of the piping losses in approximately 25,000 LF of steam and condensate piping, along with estimates for building and condensate return losses. The 12,000 lb/hr value used is corroborated by the plant engineer's observation of system behavior near summer shutdown. An operating labor burden of 17.5 full time equivalents was used to match current operation. A projection of ongoing major maintenance expense for the 36+ year old CEP was annualized from a table of projected plant renewal costs over the next 30 years. Although our observations indicate the plant is in good condition at present, many major components and systems in the abrasive environment of a coal fired steam plant will need to be replaced to maintain safe, reliable operation at current efficiency. We expect ongoing major maintenance expense to average $400,000/yr, remaining similar to historical expense. Under this assumption set, a full cost of first year operation sums to $4,041,687 or $16.22/MMBTU delivered to the buildings.

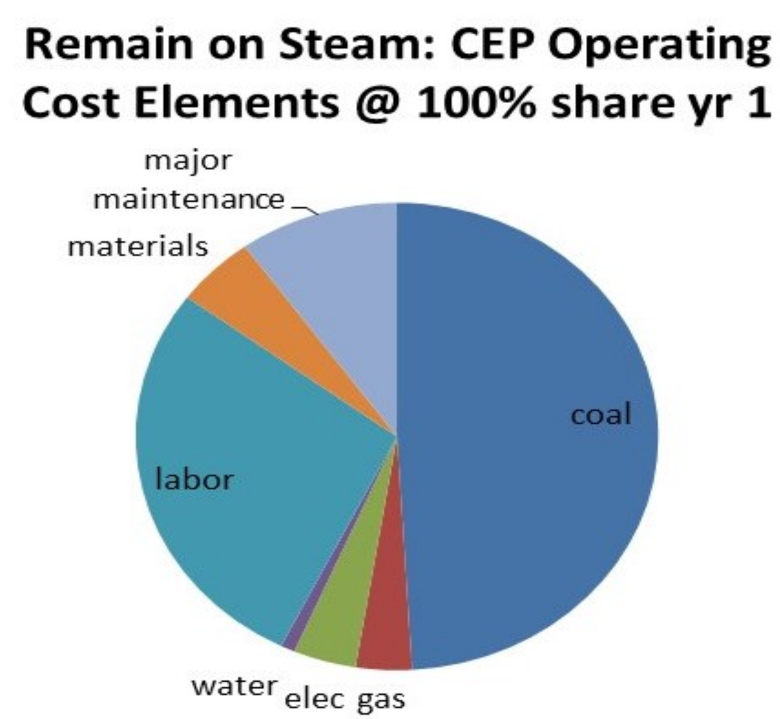
Remain on Steam-CEP @100% Major Maintenance Schedule (projected)

	qty		matl	labor	each	total
Induced draft fan repair	3	2 times	$ 50,000	$ 50,000	$ 100,000	$ 600,000
Induced draft fan replace	3	1 time	$ 160,000	$ 100,000	$ 260,000	$ 780,000
Dump valve replacement	10	3 times	$ 20,000	$ 2,880	$ 22,880	$ 686,400
Boiler Retube & Refractory Repair	3	1 time	$ 200,000	$ 200,000	$ 400,000	$ 1,200,000
Combustion control replacement	3	1 time	$ 250,000	$ 250,000	$ 500,000	$ 1,500,000
Plant control replacement	1	1 time	$ 750,000	$ 750,000	$ 1,500,000	$ 1,500,000
Replace stokers	3	in 30 yrs	$ 500,000	$ 500,000	$ 1,000,000	$ 3,000,000
BOP Replacements	1	5	$ 250,000	$ 250,000	$ 500,000	$ 2,500,000
						$ 11,766,400

	induced draft fan repair	induced draft fan replace	dump valve replacement	Boiler Retube and Refractory Repair	combustion control replacement	plant control replacement	replace stokers	BOP Replacements
2017								
2018								
2019								
2020	$ 300,000							
2021			$ 228,800					
2022								
2023								$ 500,000
2024								
2025				$ 400,000				
2026								
2027					$ 1,500,000			
2028								
2029								$ 500,000
2030		$ 780,000		$ 400,000				
2031			$ 228,800					
2032								
2033								
2034								
2035				$ 400,000				$ 500,000
2036							$ 1,000,000	
2037						$ 1,500,000		
2038								
2039							$ 1,000,000	
2040	$ 300,000							
2041			$ 228,800					$ 500,000
2042							$ 1,000,000	
2043								
2044								
2045								
2046								
2047								$ 500,000
	$ 600,000	$ 780,000	$ 686,400	$ 1,200,000	$ 1,500,000	$ 1,500,000	$ 3,000,000	$ 2,500,000
			Total Major Maintenance					**$ 11,766,400**
			30 year average annual major maintenance					**$ 392,213**

Remain on Steam

CEP	**100%**								
only		annual	249,234	MMBTU/hr					
		peak	127.0	MMBTU/hr					
			1015625	total possible					
			0.25	load factor					
					480,050				
	coal	4.40	$/MMBTU		450,800	MMBTU/yr	$ 1,983,520		
	gas	4.80	$/MMBTU		29,250	MMBTU/yr	$ 140,400		
	elec	0.08	$/kWh		1,965,429	kWh/yr	$ 157,234		
	water	8.50	$/kgal		4,180	kgal	$ 35,532		
	utility cost						**$ 2,316,687**		
	campusheat						249,234	MMBTU	
	raw cost		fte	$/fte			$ 9.30	$/MMBTU	
annual	labor cost	coal plan	17.5	$ 64,286			$ 1,125,000		
annual	materials						$ 200,000		
	major maintenance &materials						$ 400,000		275000
	full cost (no depreciation)						**$ 4,041,687**		12%



										based on	350,000	MMBTU/yr	
dist loss		plant loss						coal input			kWh/yr	kWh/MMBTU	
8000	hrs/yr	90%	return	15psig sat				23000	tons/yr	coal electr	2,000,000	5.71	
12000	lb/hr loss	thermal lo:	35,156,250	lb				9800	BTU/lb	gas electric	500,000	1.43	
12	MMBTU/hr	makeup	50	210		5,273	MBTU	450,800	MMBTU/yr				
96000	MMBTU/hr		316,406,250	lb				gas input					
27%		return	180	210		9,492	MBTU	29,250	MMBTU/yr				
						14,766							
						4.10%	of total						

bldg load	distrib loss	plant steam	plant loss	boiler steam	plant wc	coalsteam	coal eff	gas eff	coal steam	coalsteamr	gas stean	coal elec	gas elec
MMBTU/yr	MMBTU/yr	MMBTU/yr	MMBTU/yr	MMBTU/yr	kgal	MMBTU/yr	%	%	MMBTU	MMBTU	MMBTU	kWh	kWh
249,234	96,000	345,234	14,766	**360,000**	4,180	1,500	75%	80%	338,100	336,600	23,400	1,932,000	33,429

net dist eff 69.2% 351,562,500 lb per year

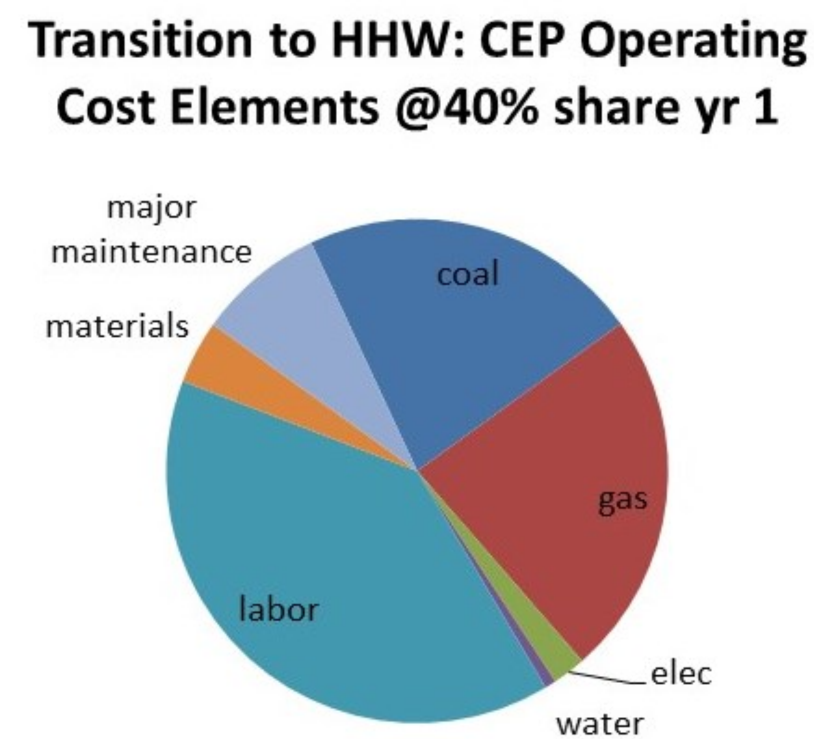
Modular HHW Plant Alternative

The West Campus Modular HHW plant, when connected through a distribution system to 30 buildings, was assumed to supply 60% of total campus heat, with the remaining 40% supplied by the CEP, now operating with 5,000 Tons per year of coal. This assumption is based on relative square footage and the energy use intensity of the building types served. Assumed steam distribution losses scale in proportion. Reducing coal utilization and the associated ongoing maintenance and operation in this alternative would enable a reduction in CEP labor from 17.5 to 12 full time equivalents. In addition, one full time equivalent was assigned to operate the modular heating water plant. The

Transition to HHW

					CEP steam			
CEP	**40%**	annual	99,694	MMBTU/hr	99,693.75	MMBTU/hr		
		peak	127.0	MMBTU/hr				
			1015625	total possible				
			0.10	load factor				
	coal	4.4	$/MMBTU	98,000	MMBTU/yr	$	431,200	
	gas	4.8	$/MMBTU	96,000	MMBTU/yr	$	460,800	
	elec	0.08	$/kWh	522,857	kWh/yr	$	41,829	
	water	8.5	$/kgal	1,672	kgal	$	14,213	
	utility cost					**$**	**948,042**	
	campusheat						99,694	MMBTU
	raw cost					$	9.51	$/MMBTU
	labor cost CEP	12	$	64,286		$	771,429	
	materials					$	80,000	
	materials CEP					$	160,000	
	full cost					**$**	**1,959,470**	
						$	19.65	

building load	249,234	MMBTU
target output		
CEP	99,694	MMBTU
HHW=	149,541	MMBTU



										based on	350,000	MMBTU/yr
dist loss		plant loss						coal input			kWh/yr	kWh/MMBTU
8000	hrs/yr	90%	return					5000	tons/yr	coal elec	2,000,000	5.71
4800	lb/hr loss	thermal loss	14,062,500	lb				9800	BTU/lb	gas electr	500,000	1.43
4.8	MMBTU/hr	makeup	50		210	2,109	MBTU	98,000	MMBTU/yr	3 month/yr		
38400	MMBTU/hr		126,562,500	lb				gas input		44.7 MMMBTU/hr		
27%		return	180		210	3,797	MBTU	96,000	MMBTU/yr	eq of 1 coal boiler 3 month/yr		
					DA total	5,906	MBTU					
						4.10%	of total					

bldg load MMBTU/yr	distrib loss MMBTU/yr	plant steam MMBTU/yr	plant loss MMBTU/yr	boiler steam MMBTU/yr	plant water kgal	coal steam loss MMBTU/yr	coal eff %	gas eff %	coal steam MMBTU	coal steam net MMBTU	gas steam MMBTU	coal elec kWh	gas elec kWh
99,693.75	38,400	138,094	5,906	**144,000**	1,672	1,500	75%	75%	73,500	72,000	72,000	420,000	102,857

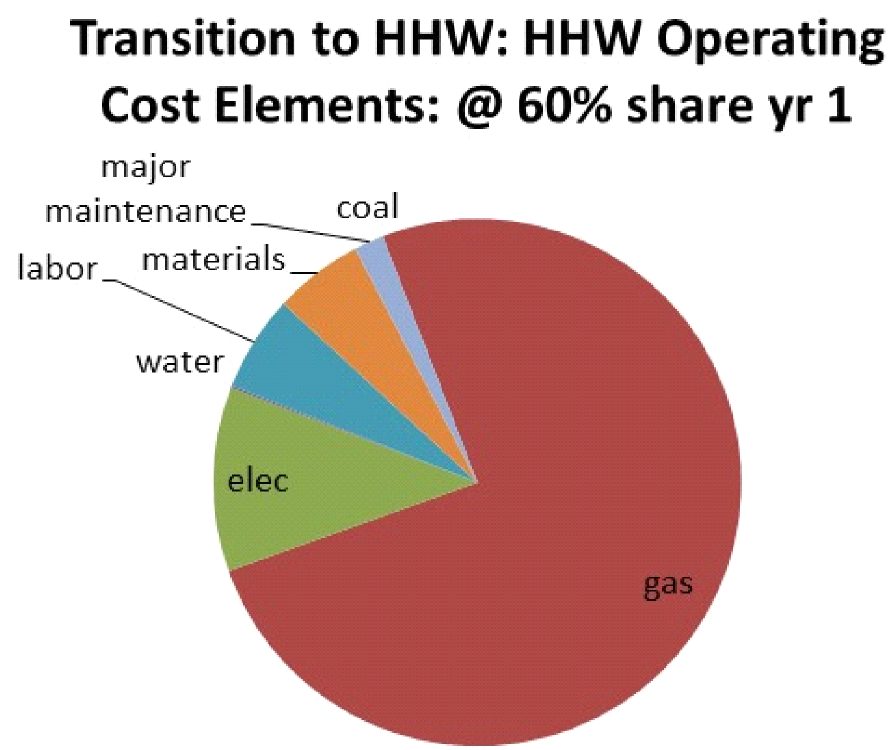
heating water plant operates at a low enough pressure and temperature, and with sufficient digital controls and automated safety interlocks to obviate the need for full-time on-site stationary operation. Once set up and commissioned, the plant could be run remotely from the CEP. The heat transfer efficiency of the boilers and thermal insulation on the lower operating temperature heating water distribution piping provides substantially improved natural gas fuel-in to building heat –out ratio. Under the 40%/60% CEP to modular HHW production mix, full cost to provide the same campus 249,234 MMBTU of building heat was estimated at $3,035,338 or $12.17/MMBTU delivered. The projected 1 million dollar operating cost savings represents a 25% reduction in the annual operating cost.

Transition to HHW

HHW 60%

peak plant capacity	127	MMBTU/hr
load factor	0.26	
annual production	264160	MMBTU
campus load	249,234	MMBTU
HHW plant capacity	50	MBH
baseload hrs	8000	
	400,000	MMBTU/hr
avg % full load	37%	

coal	4.4	$/MMBTU	-	MMBTU/yr	$	-	
gas	4.8	$/MMBTU	172,111	MMBTU/yr	$	826,133	
elec	0.08	$/kWh	1,549,000	kWh/yr	$	123,920	
water	8.5	$/kgal	180	kgal	$	1,529	
utility cost					**$**	**951,582**	
campusheat						149,873	MMBTU
raw cost					$	6.35	$/MMBTU
labor cost HHW only		1 $	64,286		$	64,286	
materials HHW					$	60,000	
major maintenance HHW					$	20,000	
full cost					**$**	**1,075,868**	
					$	7.18	



	based on	350,000	MMBTU/yr
		kWh/yr	kWh/MMBTU
coal elect		2,000,000	5.71
gas electr		750,000	10.00

dist loss		plant loss		
8000	hrs/yr	99%	return	
600	lb/hr loss	thermal loss	1,512,695	lb
0.6	MMBTU/hr	g inlet temp	50	F
4800	MMBTU/hr		227	MBTU
3%			0.15%	of total

gas input
172,111 MMBTU/yr
totalgas
268,111 MMBTU/yr

bldg load MMBTU/yr	distrib loss MMBTU/yr	plant htgwtr MMBTU/yr	plant loss MMBTU/yr	boiler htgwtr MMBTU/yr	plant water kgal	coalstea mloss MMBTU/yr	coal eff %	gas eff %	coal steam MMBTU	coalstea mnet MMBTU	gas htgwtr MMBTU	coal elec kWh	gas elec kWh
149,873	4,800	154,673	227	**154,900**	180	-		90%	-	-	154,900	-	1,549,000
166525.662				172111.1111									

Section 1
Section 2
Section 3
Section 4
Section 5

09 Life Cycle Cost Evaluation (LCCE)

Modelling Assumptions

Three other elements factor into the 30 year life cycle cost projection. These are: campus growth rate, energy and water cost escalation, and the potential of a "carbon tax" that would increase the relative cost of coal (with 215 lbCO2/MMBTU) with respect to natural gas (with 117 lbCO2/MMBTU). The graph adjacent compares year over year operating costs under the baseline assumptions. Note the operating costs for the two options remain the same for the first 6 years, while the construction of the new HHW system is completed.

A separate chilled water analysis, described elsewhere in this section, projects a $20,000/yr electrical energy cost savings associated with the operation of the Thermal Energy Storage system to reduce peak demand charges. These savings, which are not included in the campus heating life cycle cost comparison, are thought to be conservative. Electric rates in Wyoming (and across the Mountain West) are in flux, due in part to increasing pressures from both distributed generation and penetration of renewable energy sources. Peak demand charges (kW) are generally increasing at a higher relative rate than are charges related to consumption (kWh). Chilled water thermal energy storage is essentially a large (and low cost) battery. The opportunity to further reduce electric utility costs by shifting the campus summertime electric demand away from the peak utility rate periods is likely to improve over the next decades.

The three primary drivers to consider when comparing a heating hot water alternative to "business as usual" at the CEP are 1.)the ongoing campus load growth, 2.) risk and reliability of aging infrastructure, and 3.) the potential operating cost savings due to energy and labor efficiency, and macro-economic changes in the regional fuel market . The comparative LCCE was set up to enable the consideration of the relative rates of change in campus square footage, fuel cost, and the possibility that a "carbon tax" is implemented within the 30 year life cycle modelled. Three scenarios were tested:

Operating Cost Model Sensitivity Scenarios

1 most conservative assumptions

fuel cost projection

Coal escalation = EIA, Nat Gas & Elec Power = 150% higher than EIA

coal	0.30%	100%
natural gas	2.40%	150%
electricity	3.60%	150%
labor and material	2.00% CPI	

implementation of "carbon tax"

$	15.00	$/CO2 ton
at year	-	(no "carbon tax")

campus load growth

half of rate observed from yrs 2006-2016

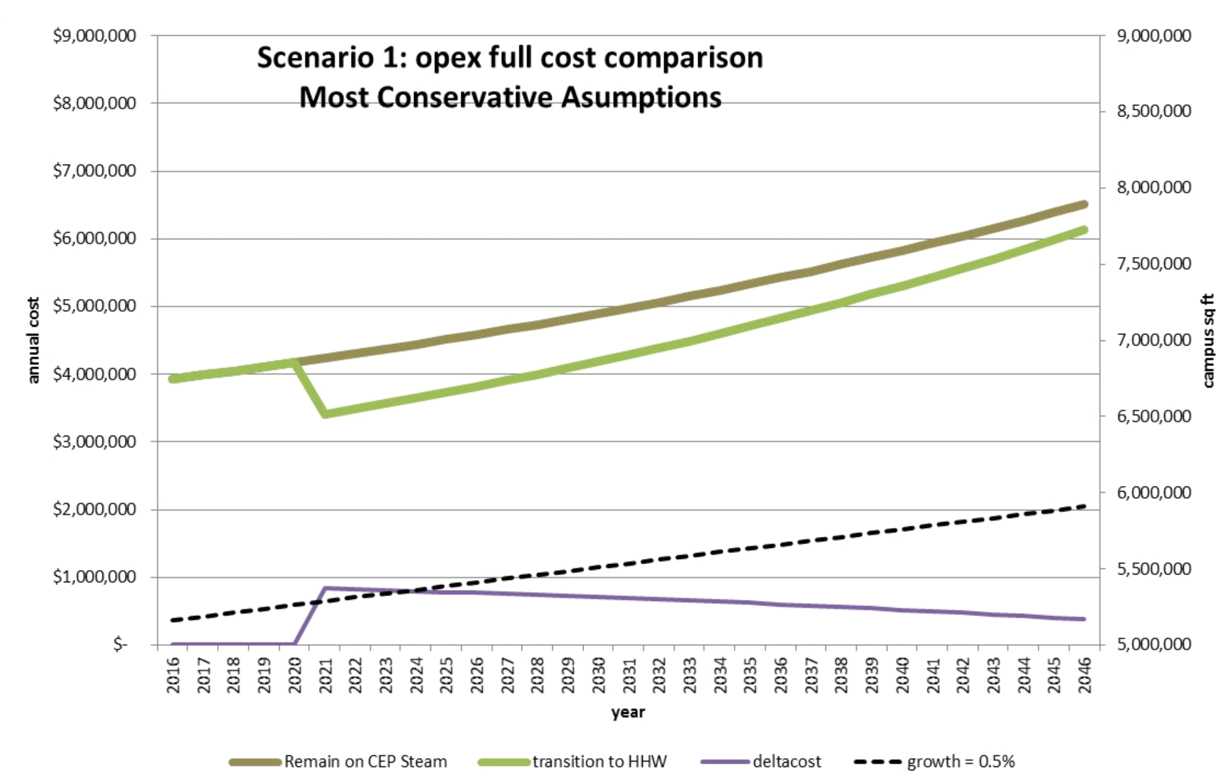
24,000 GSF/SF/yr 50% of recent observed

Remain on Steam vs Transition to HHW

30 yr cummulative operating cost difference

$16,489,469

Most Conservative is based on a combination of factors most likely to favor the "Remain on CEP" alternative. This scenario uses a long term growth rate of 0.5%/yr which is half of recently observed (1.0%/yr), raises the energy cost escalation of natural gas and electricity to 150% of federal government (EIA) projections with respect to escalation in coal, and assumes there will not be any sort of "carbon tax" over the 30 year period. Water, Labor and Materials are all assumed to escalate at a constant "consumer price index" of 2%/yr.



2 baseline assumptions

fuel cost projection

Coal escalation = EIA, Nat Gas & Elec Power = EIA

coal	0.30%	100%
natural gas	1.60%	100%
electricity	2.40%	100%
labor and material	2.00%	

implementation of "carbon tax"

$ 15.00 $/CO2 ton

at year 16 ($15/Ton CO2 at year 16)

campus load growth

equal rate observed from yrs 2006-2016

49,000 GSF/SF/yr 100% load growth/yr

Remain on Steam vs Transition to HHW

30 yr cummulative operating cost difference:

$ 29,493,993

3 least conservative assumptions

fuel cost projection

Coal Escalation 150% higher than EIA,
Nat Gas & Elec Power =EIA

50%	coal	0.45%	##
	natural gas	1.60%	##
	electricity	2.40%	##
	labor and m(	2.40%	

implementation of "carbon tax"

$ 15.00 $/CO2 ton ($15/Ton CO2

at year 12 at year 16)

campus load growth

Rate used in LDRP

65,000 GSF/yr 130% load growth/yr

Remain on Steam vs Transition to HHW

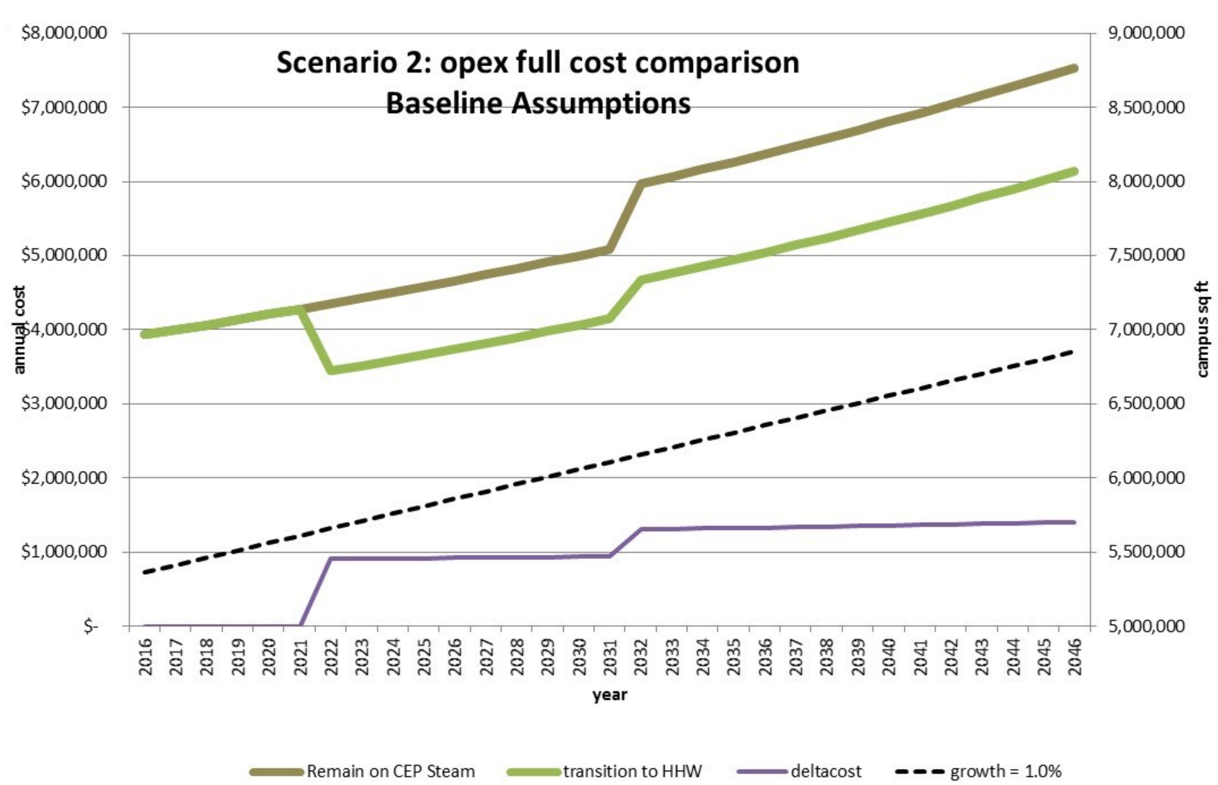
30 yr cummulative operating cost difference:

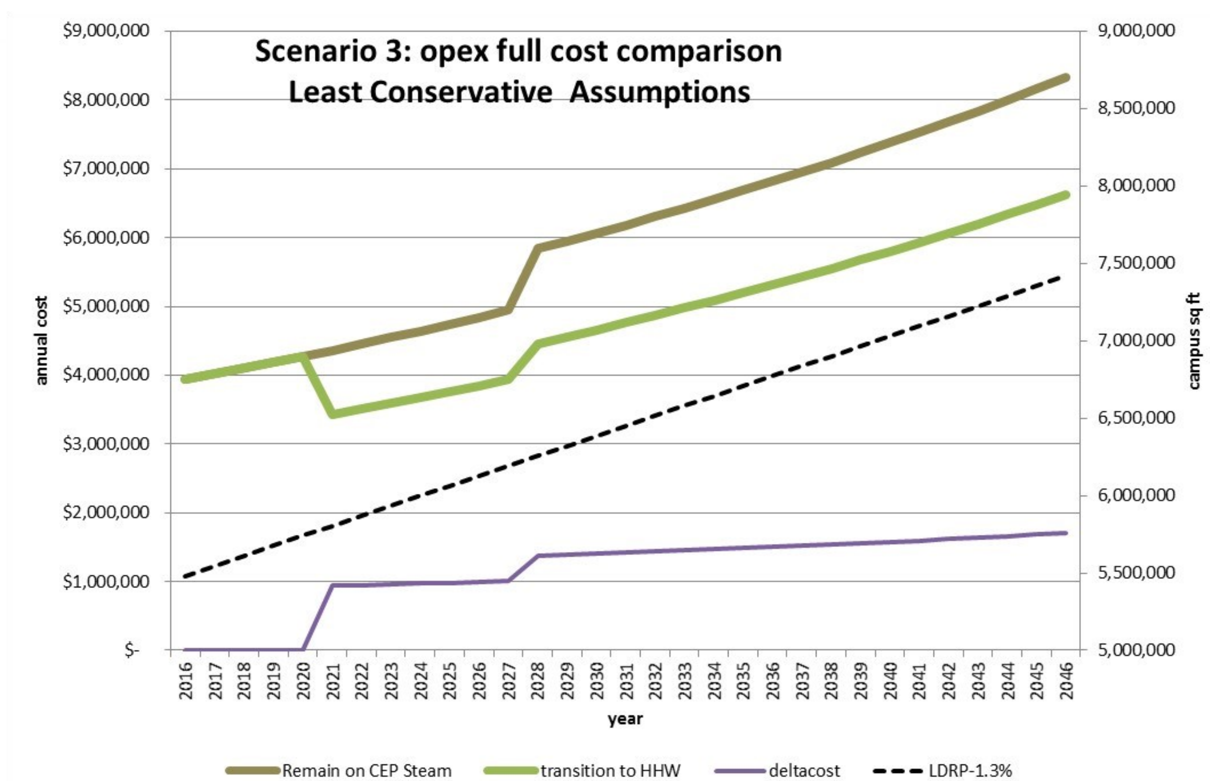
$35,814,620

Baseline extrapolates historical campus growth rates (1.0%/yr), uses EIA energy escalation projections directly and assumes a $15/lbCO2 premium on carbon combustion starting in year 16. Water, Labor and Materials are all assumed to escalate at a constant consumer price index of 2%/yr.

Least Conservative raises the campus growth rate to 1.3%/yr – the value used in the 2006 Utility Development Plant (based on the 2005 Long Range Development Plan), escalates the cost of coal to 150% above EIA projections while holding natural gas and electricity at EIA projections and assumes a $15/lbCO2 premium starting in year 12. Water, Labor and Materials are all assumed to escalate at a constant consumer price index of 2.4%/yr.

Note:
With regard to the potential cost of a possible carbon premium, (visible in the cash flow diagram as a vertical step), the University of British Columbia (UBC), located in Vancouver BC where a carbon tax is legislated, currently incurs a $25/lbCO2 carbon premium on its heating plant combustion expense.





Section 1 Section 2 Section 3 Section 4 Section 5

Section 5: Proposed West Campus Options

09 Life Cycle Cost Evaluation (LCCE)

Life Cycle Cost Narrative

Capital and operating costs are combined into annual cash flows for the two alternatives over a 30 year period. The capital phasing plan is based on equal project allocations at the beginning of each of the next three biennial funding cycles. Operating cost savings do not begin to accrue until the end of year six, when the HHW plant is complete, and commissioned, the majority of the HHW piping in place and the building conversions are underway. We note that major maintenance is treated here as an operating, rather than capital expense and is represented as an annualized operating expense. In reality, the ongoing major maintenance expense in a 36 year old coal heating plant is more likely be non-homogeneous, occurring in response to changing physical conditions, regulations, and available technologies. By year 14 of the 30 year life cycle, a majority of the primary components and systems within the CEP will have been in near continuous operation for 50 years. Estimated useful service life of most mechanical and electrical components of this type is less than 40 years. We believe that annualizing the potential cost of renewal into an estimated $400,000/yr is a conservative approach.

Several financial metrics can be drawn from the side-by-side cash flow comparison.

- The Year 7 annual operating cost difference provides an estimate of the potential impact of the project on university budget.
- The Cumulative operating cost differences can be averaged and used to consider the "simple payback" of the additional investment in lower operating cost
- The Net Present Value Cumulative capital and operating costs are tabulated at the end of the 30 year period and a Net Present Value of total expense computed with a 5% discount rate. Comparison of the NPV of the two cash flow strings provides insight into the quality of investment of today's dollars over the life of the project.
- A comparison of these metrics under different assumption scenarios offers some insight into risks brought on of changing external factors.

LCCE Discussion

Results of the 30 year life cycle modelling suggest that transition to a modular heating hot water concept on West Campus has practical economic value even under a conservative set of assumptions. This approach addresses the three impending campus challenges of load growth and remaining heating/ cooling capacity, costs of renewing aging steam infrastructure, and high cost of service due to poor thermal and labor efficiency.

Over the past 10 years, universities across the US have been under increasing pressure from students, staff and administrators to improve system reliability and building facility control, manage efficiency and operating cost, and reduce campus environmental impact particularly the campus CO_2 emission footprint. Although not directly considered in the quantitative LCCE method, all of these factors are involved in a major campus heating and cooling infrastructure investment decision at the University of Wyoming. Furthermore, our inability to project 30 year future externalities and technologies represent a challenge the certainty of the LCCE results. Will there be a "cost of carbon" at some point in the future? Will CO_2 sequestration technologies become practical at this scale? Will coal gasification or liquifaction alternatives develop enough to enable cost effective use of coal in campus combined heat and power engine systems? Will renewable energy generation, electric battery storage, building load control and efficiency improve to the point that a "decarbonized" campus utility system is economically viable?

A primary recommendation of the 2006 UW Utility Masterplan was future construction of a woody biomass steam boiler and bulk material handling yard at the CEP. This $40M investment was planned to occur between 2015 and 2020. In addition to solving the impending heating capacity/campus growth problem, it would have offered a substantial reduction in the campus carbon footprint by utilizing beetle kill pine forest biomass, projected at that time to be a viable resource.

scenario 1 Most Conservative Assumptions

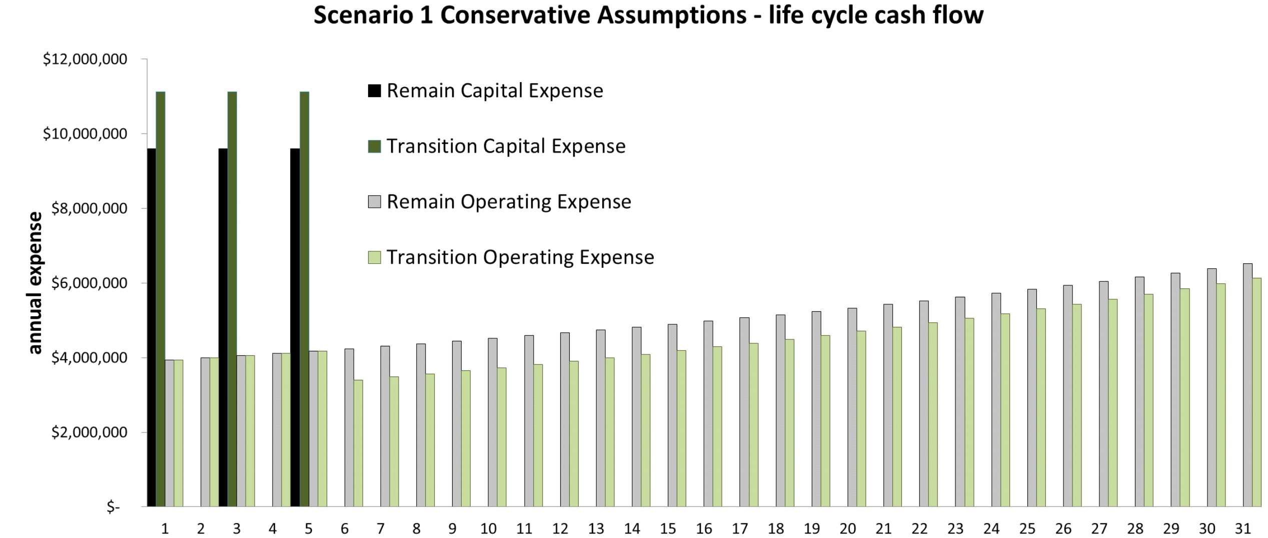
5.0% discount rate

Remain on Steam $ 28,791,805

Transition to HHW $ 33,368,324

yr	Remain Capital Expense	Remain Operating Expense	Remain Total	Transition Capital Expense	Transition Operating Expense	Transition Total
0	$ 9,597,268	$ 3,934,081	$ 13,531,350	$ 11,122,775	$ 3,934,081	$ 15,056,856
1		$ 3,992,207	$ 3,992,207		$ 3,992,207	$ 3,992,207
2	$ 9,597,268	$ 4,051,787	$ 13,649,056	$ 11,122,775	$ 4,051,787	$ 15,174,562
3		$ 4,112,861	$ 4,112,861		$ 4,112,861	$ 4,112,861
4	$ 9,597,268	$ 4,175,471	$ 13,772,740	$ 11,122,775	$ 4,175,471	$ 15,298,246
5		$ 4,239,660	$ 4,239,660		$ 3,404,270	$ 3,404,270
6		$ 4,305,472	$ 4,305,472		$ 3,482,562	$ 3,482,562
7		$ 4,372,953	$ 4,372,953		$ 3,562,911	$ 3,562,911
8		$ 4,442,148	$ 4,442,148		$ 3,645,374	$ 3,645,374
9		$ 4,513,107	$ 4,513,107		$ 3,730,009	$ 3,730,009
10		$ 4,585,878	$ 4,585,878		$ 3,816,874	$ 3,816,874
11		$ 4,660,513	$ 4,660,513		$ 3,906,032	$ 3,906,032
12		$ 4,737,063	$ 4,737,063		$ 3,997,546	$ 3,997,546
13		$ 4,815,583	$ 4,815,583		$ 4,091,480	$ 4,091,480
14		$ 4,896,128	$ 4,896,128		$ 4,187,902	$ 4,187,902
15		$ 4,978,754	$ 4,978,754		$ 4,286,880	$ 4,286,880
16		$ 5,063,522	$ 5,063,522		$ 4,388,484	$ 4,388,484
17		$ 5,150,490	$ 5,150,490		$ 4,492,788	$ 4,492,788
18		$ 5,239,722	$ 5,239,722		$ 4,599,866	$ 4,599,866
19		$ 5,331,281	$ 5,331,281		$ 4,709,795	$ 4,709,795
20		$ 5,425,232	$ 5,425,232		$ 4,822,653	$ 4,822,653
21		$ 5,521,644	$ 5,521,644		$ 4,938,524	$ 4,938,524
22		$ 5,620,586	$ 5,620,586		$ 5,057,489	$ 5,057,489
23		$ 5,722,130	$ 5,722,130		$ 5,179,636	$ 5,179,636
24		$ 5,826,349	$ 5,826,349		$ 5,305,053	$ 5,305,053
25		$ 5,933,320	$ 5,933,320		$ 5,433,831	$ 5,433,831
26		$ 6,043,121	$ 6,043,121		$ 5,566,063	$ 5,566,063
27		$ 6,155,832	$ 6,155,832		$ 5,701,847	$ 5,701,847
28		$ 6,271,535	$ 6,271,535		$ 5,841,282	$ 5,841,282
29		$ 6,390,317	$ 6,390,317		$ 5,984,469	$ 5,984,469
30		$ 6,512,264	$ 6,512,264		$ 6,131,515	$ 6,131,515
	$ 28,791,805	$ 157,021,013		$ 33,368,324	$ 140,531,544	$ 173,899,868
NPV			**$99,034,398**			**$95,321,458**
				avg over life	"SPB"	
		delta opex	$ 16,489,469	$ 549,649	8.3	
		delta capex	$ 4,576,519			
		delta NPV	$3,712,940	discount rate	5.0%	

Scenario 1 Conservative Assumptions - life cycle cash flow



scenario 2 Baseline assumptions

0.05 discount rate

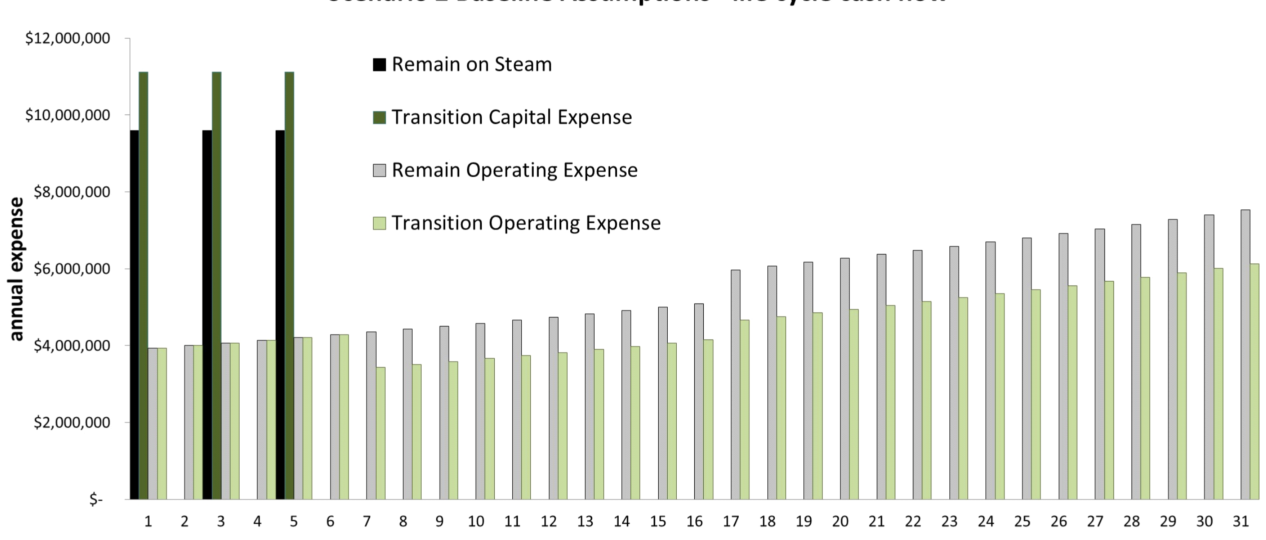
Remain on Steam $ 28,791,805

Transition to HHW $ 33,368,324

yr	Remain Capital Expense	Remain Operating Expense	total	Transition Capital Expense	Transition Operating Expense	Transition Total
0	$ 9,597,268	$ 3,934,081	$ 13,531,350	$ 11,122,775	$ 3,934,081	$ 15,056,856
1		$ 3,999,643	$ 3,999,643		$ 3,999,643	$ 3,999,643
2	$ 9,597,268	$ 4,066,679	$ 13,663,948	$ 11,122,775	$ 4,066,679	$ 15,189,454
3		$ 4,135,221	$ 4,135,221		$ 4,135,221	$ 4,135,221
4	$ 9,597,268	$ 4,205,304	$ 13,802,572	$ 11,122,775	$ 4,205,304	$ 15,328,078
5		$ 4,276,959	$ 4,276,959		$ 4,276,959	$ 4,276,959
6		$ 4,350,223	$ 4,350,223		$ 3,442,132	$ 3,442,132
7		$ 4,425,131	$ 4,425,131		$ 3,513,984	$ 3,513,984
8		$ 4,501,717	$ 4,501,717		$ 3,587,384	$ 3,587,384
9		$ 4,580,020	$ 4,580,020		$ 3,662,367	$ 3,662,367
10		$ 4,660,077	$ 4,660,077		$ 3,738,964	$ 3,738,964
11		$ 4,741,926	$ 4,741,926		$ 3,817,211	$ 3,817,211
12		$ 4,825,607	$ 4,825,607		$ 3,897,142	$ 3,897,142
13		$ 4,911,159	$ 4,911,159		$ 3,978,792	$ 3,978,792
14		$ 4,998,623	$ 4,998,623		$ 4,062,199	$ 4,062,199
15		$ 5,088,041	$ 5,088,041		$ 4,147,399	$ 4,147,399
16		$ 5,970,821	$ 5,970,821		$ 4,666,055	$ 4,666,055
17		$ 6,067,757	$ 6,067,757		$ 4,757,272	$ 4,757,272
18		$ 6,166,778	$ 6,166,778		$ 4,850,399	$ 4,850,399
19		$ 6,267,928	$ 6,267,928		$ 4,945,475	$ 4,945,475
20		$ 6,371,255	$ 6,371,255		$ 5,042,542	$ 5,042,542
21		$ 6,476,806	$ 6,476,806		$ 5,141,641	$ 5,141,641
22		$ 6,584,628	$ 6,584,628		$ 5,242,815	$ 5,242,815
23		$ 6,694,771	$ 6,694,771		$ 5,346,109	$ 5,346,109
24		$ 6,807,285	$ 6,807,285		$ 5,451,566	$ 5,451,566
25		$ 6,922,223	$ 6,922,223		$ 5,559,233	$ 5,559,233
26		$ 7,039,636	$ 7,039,636		$ 5,669,156	$ 5,669,156
27		$ 7,159,577	$ 7,159,577		$ 5,781,382	$ 5,781,382
28		$ 7,282,103	$ 7,282,103		$ 5,895,961	$ 5,895,961
29		$ 7,407,267	$ 7,407,267		$ 6,012,941	$ 6,012,941
30		$ 7,535,129	$ 7,535,129		$ 6,132,374	$ 6,132,374
	$ 28,791,805	$ 172,454,377	$ 201,246,183	$ 33,368,324	$ 142,960,385	$ 176,328,709
NPV			**$ 104,128,903**			**$ 96,389,547**

		avg over life	"SPB"
delta opex	$ 29,493,993	$ 983,133	4.7
delta capex	$4,576,519		
delta NPV	$ 7,739,356	discount rate	5%

Scenario 2 Baseline Assumptions - life cycle cash flow



scenario 3 Least Conservative Assumptions

5% discount rate

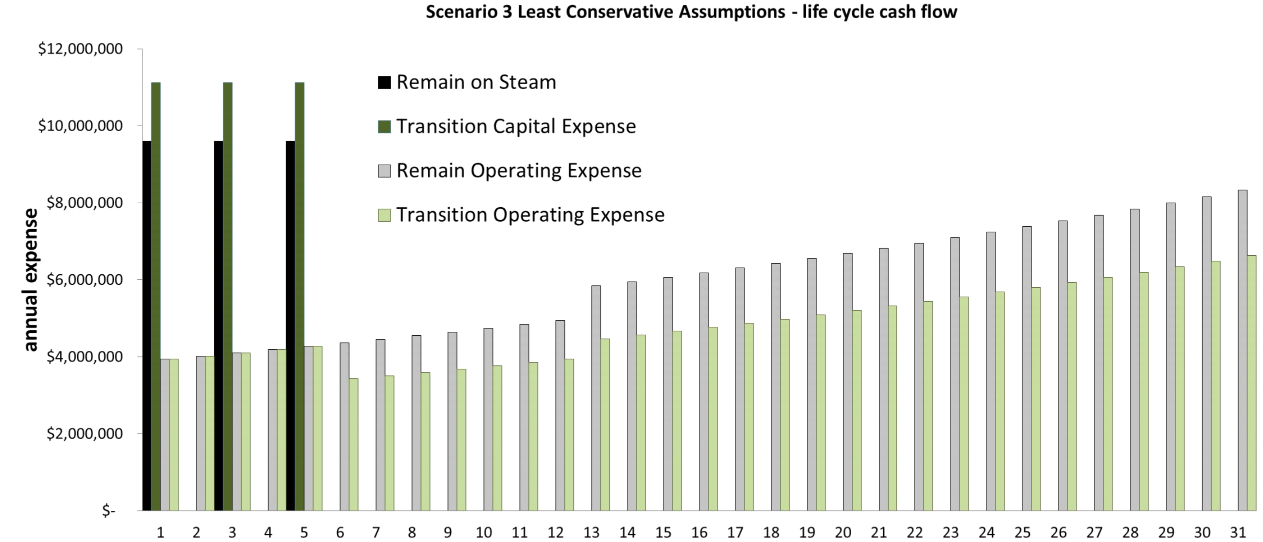
$ 28,791,805

Transition to HHW $ 33,368,324

yr	Remain Capital Expense	Remain Operating Expense	total	Transition Capital Expense	Transition Operating Expense	
0	$ 9,597,268	$ 3,934,081	$ 13,531,350	$ 11,122,775	$ 3,934,081	$ 15,056,856
1		$ 4,015,123	$ 4,015,123		$ 4,015,123	$ 4,015,123
2	$ 9,597,268	$ 4,098,151	$ 13,695,420	$ 11,122,775	$ 4,098,151	$ 15,220,926
3		$ 4,183,214	$ 4,183,214		$ 4,183,214	$ 4,183,214
4	$ 9,597,268	$ 4,270,359	$ 13,867,628	$ 11,122,775	$ 4,270,359	$ 15,393,134
5		$ 4,359,637	$ 4,359,637		$ 3,420,810	$ 3,420,810
6		$ 4,451,098	$ 4,451,098		$ 3,502,044	$ 3,502,044
7		$ 4,544,794	$ 4,544,794		$ 3,585,186	$ 3,585,186
8		$ 4,640,779	$ 4,640,779		$ 3,670,280	$ 3,670,280
9		$ 4,739,106	$ 4,739,106		$ 3,757,369	$ 3,757,369
10		$ 4,839,831	$ 4,839,831		$ 3,846,501	$ 3,846,501
11		$ 4,943,011	$ 4,943,011		$ 3,937,721	$ 3,937,721
12		$ 5,837,497	$ 5,837,497		$ 4,460,990	$ 4,460,990
13		$ 5,950,191	$ 5,950,191		$ 4,559,478	$ 4,559,478
14		$ 6,065,518	$ 6,065,518		$ 4,660,202	$ 4,660,202
15		$ 6,183,542	$ 6,183,542		$ 4,763,212	$ 4,763,212
16		$ 6,304,325	$ 6,304,325		$ 4,868,560	$ 4,868,560
17		$ 6,427,934	$ 6,427,934		$ 4,976,300	$ 4,976,300
18		$ 6,554,434	$ 6,554,434		$ 5,086,486	$ 5,086,486
19		$ 6,683,895	$ 6,683,895		$ 5,199,174	$ 5,199,174
20		$ 6,816,386	$ 6,816,386		$ 5,314,422	$ 5,314,422
21		$ 6,951,979	$ 6,951,979		$ 5,432,287	$ 5,432,287
22		$ 7,090,746	$ 7,090,746		$ 5,552,829	$ 5,552,829
23		$ 7,232,762	$ 7,232,762		$ 5,676,110	$ 5,676,110
24		$ 7,378,105	$ 7,378,105		$ 5,802,192	$ 5,802,192
25		$ 7,526,852	$ 7,526,852		$ 5,931,139	$ 5,931,139
26		$ 7,679,083	$ 7,679,083		$ 6,063,016	$ 6,063,016
27		$ 7,834,880	$ 7,834,880		$ 6,197,890	$ 6,197,890
28		$ 7,994,327	$ 7,994,327		$ 6,335,830	$ 6,335,830
29		$ 8,157,510	$ 8,157,510		$ 6,476,904	$ 6,476,904
30		$ 8,324,516	$ 8,324,516		$ 6,621,185	$ 6,621,185
	$ 28,791,805	$ 186,013,666		$ 33,368,324	$ 150,199,046	$ 183,567,370
NPV			**$ 109,417,681**			**$ 98,887,350**

		avg over life	"SPB"
delta opex	$ 35,814,620	$ 1,193,821	3.8
delta capex	$ 4,576,519		
delta NPV	$ 10,530,331	at	5% discount rate

Scenario 3 Least Conservative Assumptions - life cycle cash flow



This resource has not materialized and the urgency to address impending utility challenges at UW is mounting. A possible lesson to be learned from this is the need to plan utility systems incrementally and in a way that assures flexibility.

Transition to heating hot water on the West Campus provides future flexibility in heating fuel sources and technologies. The new thermal distribution system, sized to operate at substantially lower temperature, pressure and exergy than the current 90 psi steam system and with substantially less energy loss can be served, in future, by a number of production alternatives that could scale from electric heat pumps driven by a renewable energy grid to biofuel driven Combined Heat and Power engine generators, to some future form of campus scale clean coal, carbon sequestration or waste-to -energy technology. Perhaps, some day, an economical source of woody biomass will become available in Laramie. The modular boilers to be installed in the initial phase of the modular HHW alternative are a relatively small element in the overall investment and would serve as redundancy or backup under a future alternative fuel scenario.

The transition to heating water concept could be expanded to other less dense areas of campus over time. Major renovation of residence halls east of the Union might include a buried pipe extension to the west campus system and construction of a second satellite heating plant. Eventual transition of the CEP to less operational maintenance, labor and materials intense heating production equipment would further reduce campus heating costs.

This Page Intentionally Left Blank

Budget Information

During the early stages of the report, at the time the options were being selected, preliminary budget information was assembled for each of the CEP and West Campus options. These budgets were assembled utilizing vendor equipment quotes, RS Means Data Base, and data obtained from similar type projects. These preliminary estimates are included in Section V of the Supporting Documentation volume of this report.

Once the recommended concept was vetted through the University (the proposed concept to construct a new modular type hot water boiler generation and distribution system on West Campus) a preliminary design was completed. Preliminary drawings and narratives were provided to Rider Levett Bucknall, GLHN's third party cost estimating sub consultant. The report in its entirety is included as Supporting Document SD-VI-9 in the accompanying volume. The Results of the report are as follows:

Scope Item	Estimated Cost
Phase I Site work	$19,983,511
New Boiler Plant	$17,569,781
CEP Boiler Stoker Upgrade	$959,000
Total Net Cost Required for this Project	$38,512,292

Note that the Phase II Site work which is the future HW and CHW loops north of Lewis Street, and CEP Energy Plant as identified in the RLB report are not scopes funded by this project. The CEP Boiler Stoker Upgrades quotes are provided in the Supporting Documentation, Section II.

The Scope of work included in the Scope Items above is as follows:

Phase I Site Work

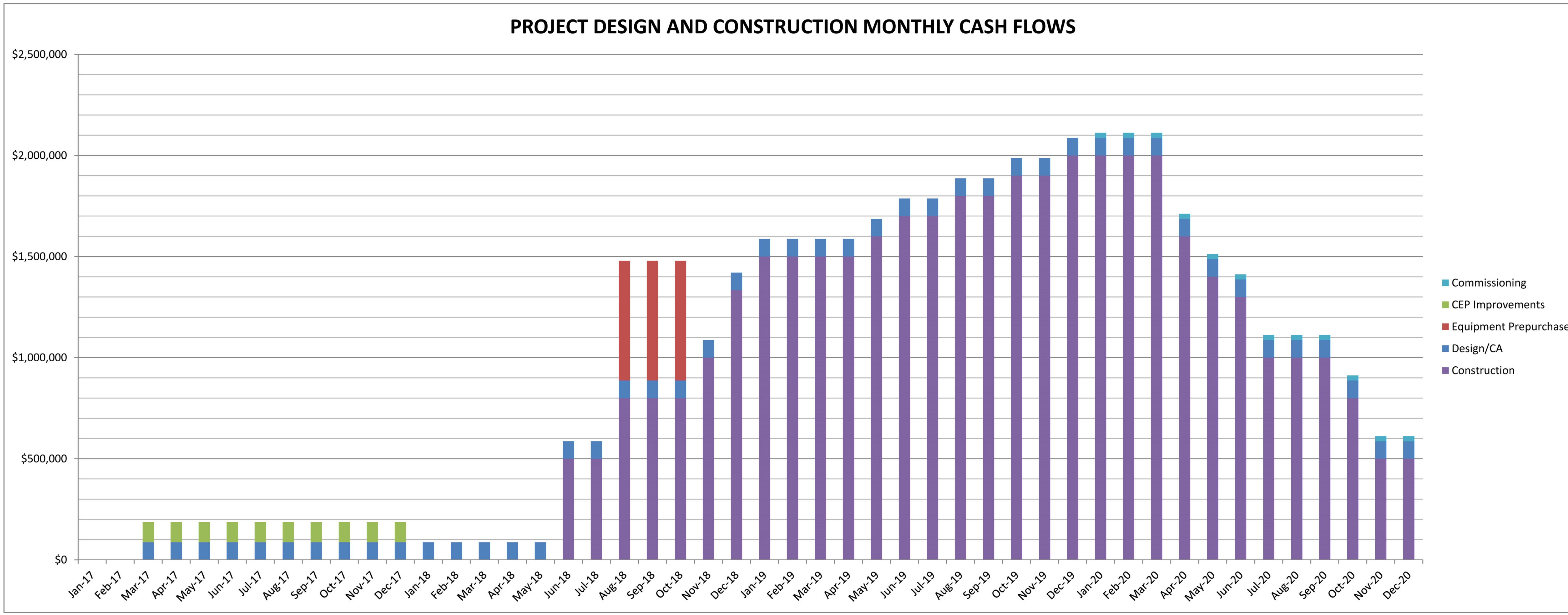
- Replacement of 30 Domestic Water building heat exchangers from shell and tube to plate and frame (equipment, piping, controls, T&B)
- Replacement of 30 Heating Water building heat exchangers from shell and tube to plate and frame (equipment, piping, controls, T&B)
- Abatement allowance for steam tunnel piping
- Infill of decommissioned tunnels
- Allowance for repair of tunnels to be reutilized
- Removal of sections of direct buried piping
- Installation of new HW piping (within tunnels and direct buried)

New Boiler Plant

- New plant structure
- 1.5M gall TES tank
- Utilities to Plant
- Full boiler and HW pump buildout within plant (10)
- Steam to hot water converters located at plant
- Chilled water pumps
- Diesel backup generator for plant

Section 5: Proposed West Campus Options

11 Monthly Cash Flows/Funding Schedule



Section 1
Section 2
Section 3
Section 4
Section 5

PROPOSED PROJECT PHASING AND PRELIMINARY SCHEDULE

ITEM	COMPLETION YEAR	YEAR 1		YEAR 2		YEAR 3		YEAR 4		YEAR 5		YEAR 6		YEAR 7		YEAR 8	
		Jan-17	Jul-17	Jan-18	Jul-18	Jan-19	Jul-19	Jan-20	Jul-20	Jan-21	Jul-21	Jan-22	Jul-22	Jan-23	Jul-23	Jan-24	Jul-24
COMPLETE DESIGN/PERMITTING	2018																
RETROCOMISSIONING OF BUILDINGS-HIGH DT	ONGOING																
SECURE NATURAL GAS SUPPLY	2020																
CEP BOILER IMPROVEMENTS (STOKERS)	2018																
TUNNEL IMPROVEMENTS	2019																
CEP CHILLER REPLACEMENT	2018																
CONSTRUCTION OF TES SYSTEM	2019																
CONSTRUCTION OF BOILER PLANT	2019																
HOT WATER SITE IMPROVEMENTS	2020																
HOT WATER BUILDING CONVERSIONS	2020																
COMMISSIONING	2021																
TES SYSTEM ONLINE	2021																CONT.
NEW BOILER PLANT ONLINE	2020																CONT.
PHASE II WEST CAMPUS HEATING IMPLEMENTATOIN	2024																CONT.

End of Report