Engineer to assist the University with the design of a Utilities Master Plan

CAP#14SOL011

Utilities Master Plan

Oklahoma State University

Stillwater, Oklahoma

Energy Services

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1 Executive Summary

1.1 Introduction

Frankfurt Short Bruza Associates, P.C. (FSB) has been retained by Oklahoma State University (OSU / the University) for professional services to assist the University with a Campus Utilities Master Plan (UMP). The goal of the UMP was to provide OSU a living document that can be updated over time based on the ever-changing and dynamic campus environment. The UMP is the roadmap for the planning of campus utilities over the next twenty years and beyond.

Figure 1, Existing Power Plant

The scope of services for the UMP is as follows:

1. Evaluation of base option for the new Central Plant, proposal of three to four alternate options, and recommendation of most favorable solution
2. Load requirement analysis for steam, chilled water, and electrical to assure the new Central Plant is sized correctly
3. Plan for each system with budgetary costs for years five and twenty.
4. Hydraulic study of the chilled water distribution system
5. Thermodynamic study of the steam distribution system
6. Dynamic models of utilities systems
    a. Electrical Distribution System
    b. Chilled Water Distribution System
    c. Steam Distribution System
7. Services to further develop the University's ESRI GIS utility data for use in models
8. Recommendations of methods and training for OSU staff to maintain utility and GIS models

1.1.1 Project History

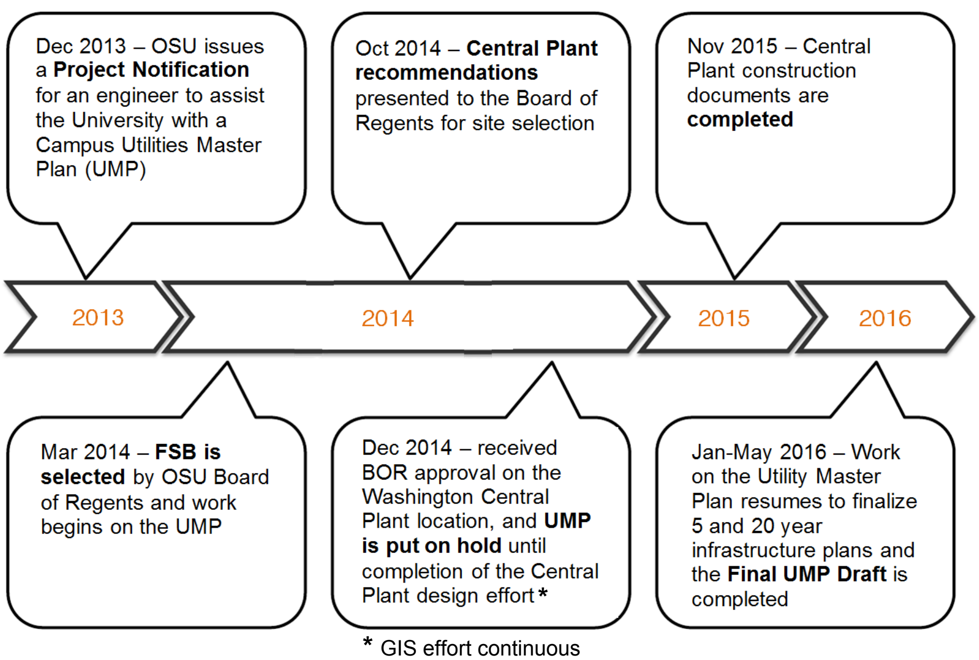


Figure 2, Timeline of Utility Master Plan

1.1.2 Central Plant Program

The overall goals of the Central Plant Program are to modernize utility infrastructure in the most cost effective and energy efficient manner, demolish aging assets, and make valuable campus property available for future use. The first goal is to build the new Central Plant. It will house 12,000 tons of chillers with space for an additional 4,000 tons and 220,000 LB/HR of boilers with space for an additional 60,000 LB/HR. The new plant consolidates the Energy Services department, and provides educational opportunities with a new 80 seat classroom and observation area.

Figure 3, Rendering of New Central Plant

The location and size of the new Central Plant was determined through the UMP process in 2014. Nine potential sites were identified for the location of the new plant and presented to the OSU Board of Regents on October 24, 2014. The Board of Regents selected the site on Washington St. between Connell Ave. and Scott Ave. and design of the Central Plant commenced. Refer to the following sections of the full UMP report for more information: 1.2 Recommendation of New Central Plant.

1.1.3 Chilled Water, Steam, and Electrical Systems

The UMP incorporated input from the OSU Campus Master Plan to understand the utility needs of the growing campus. The campus growth was used to develop the Chilled Water, Steam, and Electrical load analyses used to size the new Central Plant and to predict when additional capacity is needed.

Chilled Water Load Analysis
- Current campus peak demand as of 2016: 15,300 TONS.
- Estimated 5-year campus peak demand: 15,469 TONS
- Estimated 20-year campus peak demand: 18,992 TONS

Steam Load Analysis
- Current campus peak demand as of 2016: 136,000 LB/HR
- Estimated 5-year campus peak demand: 150,000 LB/HR
- Estimated 20-year campus peak demand: 190,000 LB/HR

Electrical Load Analysis
- Current campus peak demand as of 2016: 31,995 kW
- Estimated 5-year campus peak demand: 32,647 kW
- Estimated 20-year campus peak demand: 38,291 kW

Five year plans and twenty year plans have been developed for chilled water, steam and electrical utilities. These plans include additional space in the Central Plant design for "future" boilers, chillers, and electrical equipment based on campus load. These plans outline the upgrades and associated costs to rehabilitate existing systems as well as expand systems to provide required capacity throughout the campus for the next 20 years. Future buildings and resulting loads have been based upon the Campus Master Plan. Refer to Section 1.1.6 of the full UMP report for future building information and associated fiscal year.

1.1.4 Building Dynamic Models for the Future

FSB has studied the OSU campus utilities in depth in conjunction with OSU Energy Services. We have been able to map out the campus utilities in a way that has previously not been possible by building dynamic computer models of the steam, chilled water and electrical utilities. The chilled water study is known as the hydraulic system model, and the steam system is known as the thermodynamic system model. The hydraulic and thermodynamic system model was developed using the KYPipe program. Likewise, the electrical system model was developed using the SKM Power Tools program. These models were used in the load analysis and were the basis of the five and twenty year plans. The models can be updated using KYPipe and SKM Power Tools as the campus grows throughout the years. Refer to the following sections of the full Utility Master Plan for more information: 3.3 Chilled Water Model Development Summary, 4.3 Steam Model Development Summary, and 5.8 Electrical Model Development Summary.

In addition, the GIS system developed as a component of the Utility Master Plan allows University personnel to access a secure website that shows up-to-date maps of the campus and campus utilities. For example, the user will be able to see underground steam piping, chilled water piping, electrical wiring, electrical vaults and transformers, water, wastewater, storm drainage, and natural gas, among others. Refer to Figure 4.

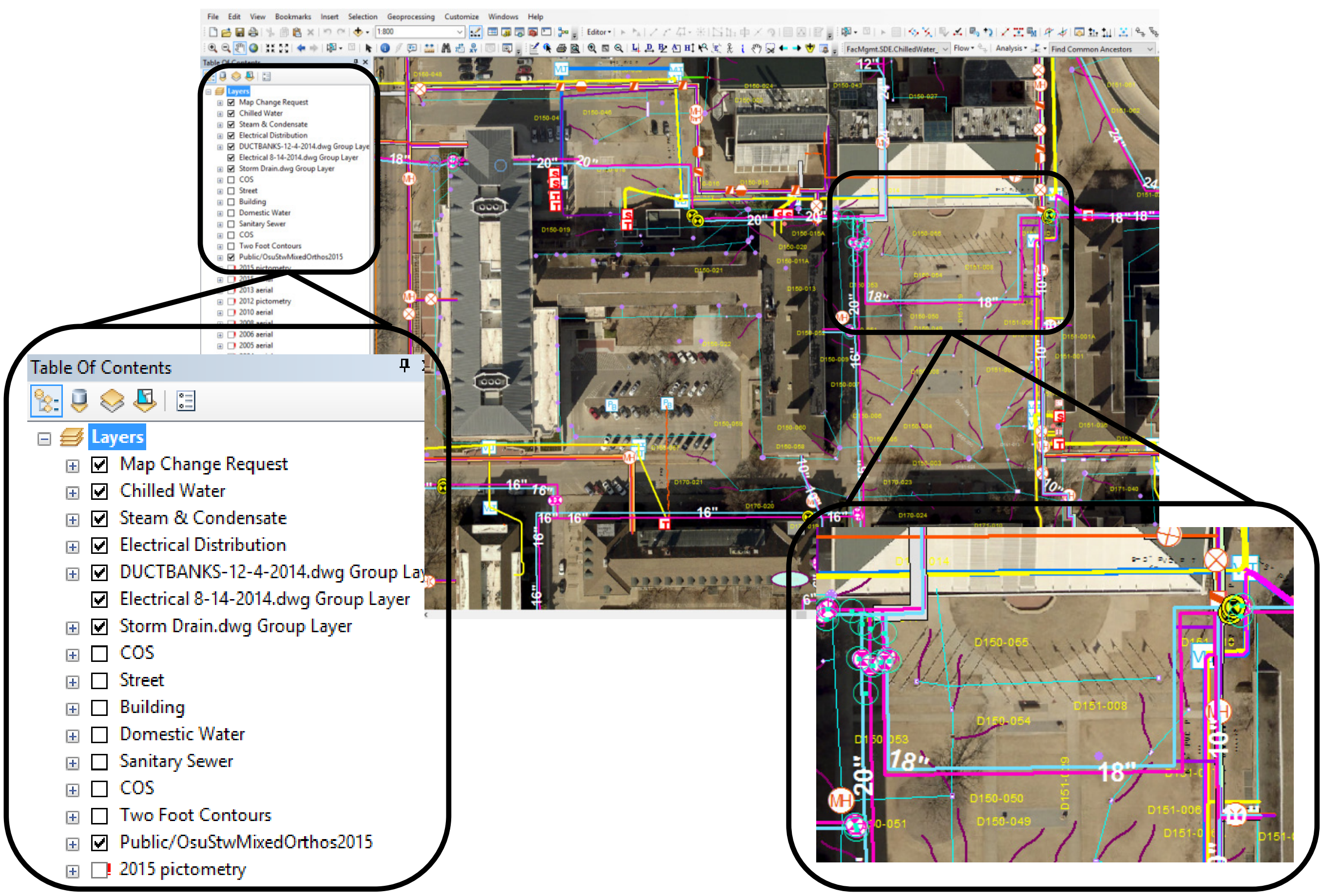


Figure 4, GIS Screenshot

As a goal of this Master Plan, the dynamic models will be turned over to OSU Energy Services. OSU engineers can use these programs to evaluate a number of campus scenarios, anticipate future failures, provide valuable feedback with regard to energy production, and improve campus efficiency.

Refer to the following sections of the full Utility Master Plan for more information: 1.9 Geographic Information System (GIS) & 10 Geographic Information System (GIS)

1.1.5 Summary of Results

The Utilities Master Plan has resulted in many positive developments for Oklahoma State University. A new Central Plant was programmed and sized, and a site was selected from nine potential candidates. Chilled water and steam systems were modeled in KYPipe software, and the electrical system was modeled in SKM Power Tools. A GIS model was developed, and all of these models have been provided to the University to assist in future planning efforts. Future campus utility loads were projected based on the Campus Master Plan capital improvement projects. Subsequently, 5-year and 20-year plans were developed to prepare for OSU Stillwater campus growth. Costs are based on present day dollars and do not take into account escalation or inflation.

The budgetary results of necessary utility upgrades are broken down into a yearly format per fiscal year. Figure 5 below illustrates costs of utility upgrades needed in the next five years, while Figure 6 illustrates costs for years six through twenty. Figure 7 shows the Utility Upgrade Costs by Fiscal Year.

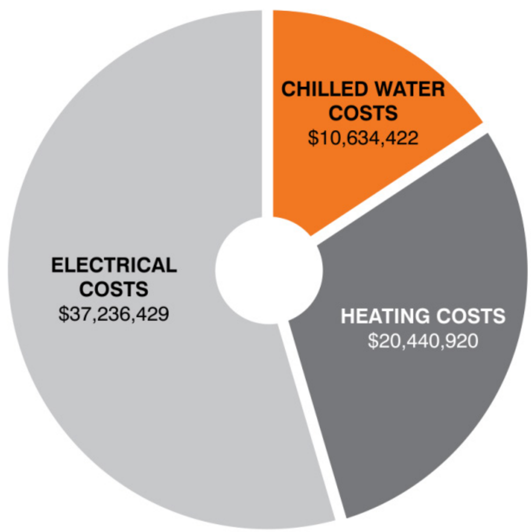


Figure 5, 5-year Utility Upgrade Costs

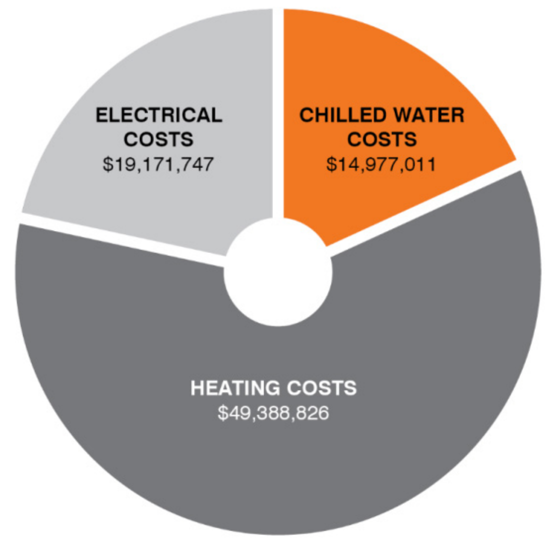


Figure 6, 20-year Utility Upgrade Costs

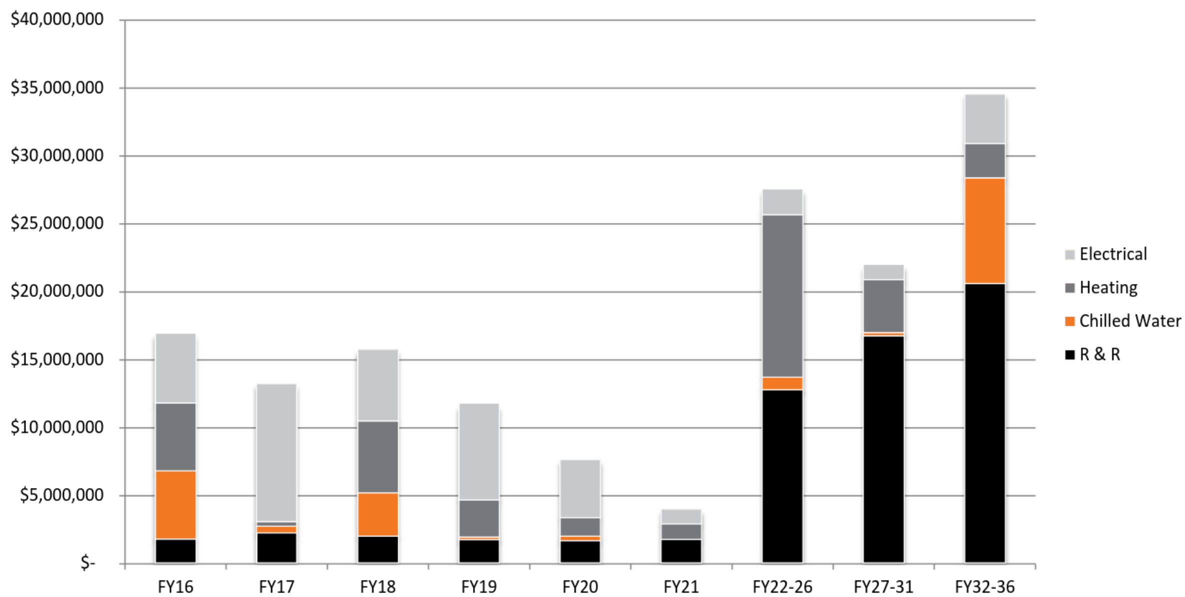


Figure 7, Utility Upgrade Costs by Fiscal Year

1.1.6 Campus Map & Capital Improvement Building List

Utility upgrades are largely dependent on new capital improvement projects. The map in Figure 8, Master Plan Overall Building Map & List shows all buildings for reference within the 20-year plan of this utility master plan. Figure 9 on the following page shows the utility loads associated with each future project.

KEYED NUMBER	BLDG ABBR.	FISCAL YEAR	BUILDING NAME
1	CP	FY16	CENTRAL PLANT
2	BUS	FY17	BUSINESS BUILDING
3	F008	FY17	CEAT LAB BUILDING
4	INT	FY17	INTRAMURAL FIELDS
5	GAR	FY18	PARKING GARAGE
6	PAC	FY18	PERFORMING ARTS CENTER (PAC)
7	SOC	FY18	SOCCER STADIUM
8	NOC	FY18	NOC BUILDING
9	PDC	FY18	POWER DISTRIBUTION CENTER (PDC)
10	BAS	FY19	BASEBALL STADIUM
11	F011	FY20	DASNR BUILDING
12	F005	FY21	FUTURE BUILDING
13	SCPA	FY22-26	SERETEAN CENTER
14	FRC	FY22-26	FAMILY RESOURCE CENTER
15	F004	FY22-26	CLASSROOM BUILDING
16	F009	FY22-26	CLASSROOM BUILDING
17	F017	FY22-26	RESIDENCE HALL
18	F019	FY22-26	MUSEUM
19	MUS	FY22-26	MUSIC SCHOOL
20	LIB	FY27-31	EDMON LOW LIBRARY
21	F006	FY27-31	RESEARCH BUILDING
22	F012	FY27-31	CLASSROOM BUILDING
23	F013	FY27-31	CLASSROOM BUILDING
24	F016	FY27-31	SUPPORT BUILDING
25	NM	FY32-36	NORTH MURRAY
26	AGH	FY32-36	AGRICULTURE
27	F007	FY32-36	RESEARCH BUILDING
28	F010	FY32-36	CLASSROOM BUILDING
29	F014	FY32-36	CLASSROOM BUILDING
30	F015	FY32-36	CLASSROOM BUILDING
31	POL	FY32-36	POLICE BUILDING
32	FIRE	FY32-36	FIRE STATION

Figure 8, Master Plan Overall Building Map & List

KEYED NUMBER	BLDG ABBR.	BUILDING NAME	GROSS AREA (SQ. FT.)	CHILLED WATER LOAD (TONS)	HEATING LOAD (BTU/HR)	ELECTRICAL LOAD (W)
1	CP	CENTRAL PLANT	65,290	233	5,817,000	7,400,000,000
2	BUS	BUSINESS BUILDING	165,000	367	3,300,000	330,000
3	F008	CEAT LAB BUILDING	68,000	194	2,040,000	136,000
4	INT	INTRAMURAL FIELDS[1]	10,000	-	-	20,000
5	GAR	PARKING GARAGE	43,000	-	-	100,000
6	PAC	PERFORMING ARTS CENTER (PAC)[1]	160,000	400	-	480,000
7	SOC	SOCCER STADIUM[1]	30,000	50	-	90,000
8	NOC	NOC BUILDING	58,828	131	1,470,700	224,000
9	PDC	POWER DISTRIBUTION CENTER (PDC)[1]	4,335	30	-	10,450
10	BAS	BASEBALL STADIUM[1]	50,000	-	-	125,000
11	F011	DASNR BUILDING	100,000	222	2,000,000	200,000
12	F005	FUTURE BUILDING	186,000	531	5,580,000	372,000
13	SCPA	SERETEAN CENTER	115,000	288	2,300,000	224,725
14	FRC	FAMILY RESOURCE CENTER[1]	7,185	14	-	14,370
15	F004	CLASSROOM BUILDING	68,000	151	2,040,000	136,000
16	F009	CLASSROOM BUILDING	156,000	347	3,120,000	312,000
17	F017	RESIDENCE HALL[1]	148,000	296	-	296,000
18	F019	MUSEUM[1]	112,000	320	-	224,000
19	MUS	MUSIC SCHOOL[2]	40,000	-	-	80,000
20	LIB	EDMON LOW LIBRARY	262,000	524	6,550,000	511,930
21	F006	RESEARCH BUILDING	72,000	206	2,160,000	144,000
22	F012	CLASSROOM BUILDING	100,000	222	2,000,000	200,000
23	F013	CLASSROOM BUILDING	100,000	222	2,500,000	200,000
24	F016	SUPPORT BUILDING[1]	100,000	200	-	200,000
25	NM	NORTH MURRAY	117,000	334	3,510,000	156,446
26	AGH	AGRICULTURE	230,000	511	4,600,000	290,713
27	F007	RESEARCH BUILDING	150,000	429	4,500,000	300,000
28	F010	CLASSROOM BUILDING	56,000	124	1,120,000	112,000
29	F014	CLASSROOM BUILDING	100,000	22	2,500,000	200,000
30	F015	CLASSROOM BUILDING	64,000	142	1,600,000	128,000
31	POL	POLICE BUILDING[1]	18,000	-	-	36,000
32	FIRE	FIRE STATION[1]	16,000	-	-	40,000

1. Heating load provided by local heating source.
2. Loads are included in PAC loads.

Figure 9, Master Plan Overall Building List and Associated Utility Loads

1.2 Recommendation of New Central Plant

Figure 10, New Central Plant, 2015 - 2018 (Connell Ave. & Washington St.)

A key deliverable of the UMP was to provide a solution to replace the existing Power Plant and to provide recommendations for the location and size of the replacement. This analysis revealed several necessities and opportunities for a new Central Plant.

The plant replacement necessities include:

- Utility production capacity
- Power Plant condition
- Power Plant location
- Stipulations of the wind power purchase agreement between OSU and OG&E

The plant replacement opportunities include:

- Tie to education
- Energy efficiency
- Consolidation of Energy Services department

Reference Section 2 and Appendix I in the full Utility Master Plan for further details on the in depth analysis of the new Central Plant.

1.2.1 Plant Replacement Necessities

Several factors necessitate the need for replacing the Power Plant. The OSU Stillwater campus will outgrow existing utility systems within the next 20 years. The Power Plant is in poor condition and is in need of several repairs. The plant is located in a prominent location, and the architectural style is incompatible with campus Architecture. Finally, the OG&E Wind Power Agreement required construction of a new Central Plant. More detailed discussion of plant replacement necessities follows.

1.2.1.1 Utility Production Capacity

Steam for the entire OSU Stillwater campus is produced at the Power Plant. Required steam capacity for the campus was previously provided in conjunction with electrical production at the Power Plant, but this is no longer viable due to the requirements of the OG&E Wind Power Agreement. Now that the campus is no longer generating electricity as outlined in section 1.5, a more efficient concept for steam generation is needed. The historical steam peak demand for the campus is 150,000 lb/hr, and the demand is anticipated to reach 190,000 lb/hr within the next 20 years based upon the growth forecasted in the Campus Master Plan.

The existing chilled water capacity at the West Chilled Water Plant (WCWP) and the Power Plant is 18,700 tons. Both existing chilled water plants are fully built out, and the projected future growth shows that they will fall short. The West Chilled Water Plant cannot carry the campus historical demand (15,300 tons) alone due to pumping limitations, and an expansion of the WCWP is not viable due to the hydraulic dynamics involved. Either an expansion or replacement of the Power Plant chilled water system is required for more chilled water capacity.

1.2.1.2 Power Plant Condition

The existing Power Plant is comprised of a 67 year old steam plant and a 38 year old chilled water plant, both of which house equipment that has exceeded its life expectancy. The following is a list of condition related issues with the existing Power Plant:

- Equipment replacement parts are hard to find and vendors are often unable or unwilling to risk repairs
- Equipment is inefficient when compared against today's standards
- Equipment is not standardized within the Plant
- East addition is structurally falling away
- Building roof is in need of complete replacement

Figure 11, Existing Power Plant – Constructed 1947

- Building exterior is unsightly and needs refurbishment
- Building interior is inefficiently organized

An analysis was performed that examined opportunities for renovation of the existing Power Plant site as opposed to building a new Central Plant on a separate site. The cost to renovate the existing plant was estimated to be $70,000,000 and the construction was projected to last 60 – 90 months. The new plant building construction cost was $60,000,000. Another major downside of renovating the existing plant is the potential downtime of utilities to the campus, including power, cooling and heating. Significant efforts and expense would be required to maintain campus operation. See Section 2, Appendix I and Appendix V of the full UMP report for more detailed discussion and cost estimates.

1.2.1.3 Power Plant Location

The existing Power Plant is located in a prominent location on OSU Stillwater campus. The following factors make the existing Power Plant site undesirable:

- Existing Power Plant and substation visibility on Hall of Fame Avenue
    - Aesthetic impact in prominent location
    - Architectural compatibility with surrounding facilities
- Existing Power Plant site desired for a future facility
- Existing Poultry Substation site desired for new Agriculture academic building

FSB and the Energy Services team met to determine potential sites for a new central steam and chilled water plant. Any location on the campus map that appeared to have potential for siting the new Central Plant was identified. Nine (9) were identified as being viable candidates, and ultimately the site West of Washington St. between Connell Ave. and Scott Ave. was selected (Figure 12).

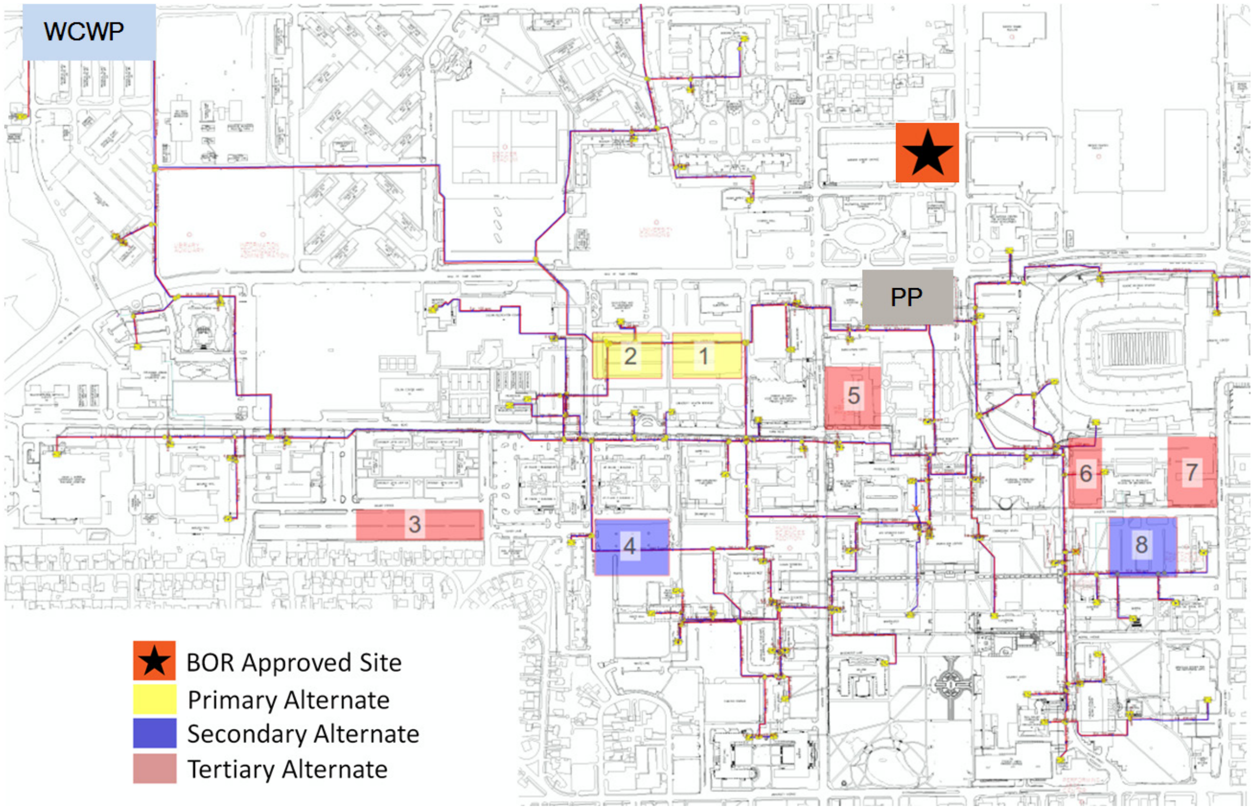


Figure 12, Potential Central Plant Sites

The option to build a new central plant allows the University to demolish the old Power Plant once the new Central Plant is completed. The location of this land is highly desired by the University for other purposes and provides an opportunity to showcase new University buildings. However, due to the electrical switchgear located in the existing plant, the plant cannot be demolished until the electrical low voltage upgrade on campus is completed. The low voltage upgrade projects, which include a new Power Distribution Center outlined in section 1.5, are shown to be constructed in FY17-20. Low Voltage Upgrade Phase 1 is estimated to cost roughly $9,000,000-$10,500,000. Once completed, the Power Plant demolition is estimated to take 12 months at an estimated cost of $3,000,000-$4,000,000. Phase 2 Voltage Upgrades are estimated to cost $2,700,000-$3,500,000. The PDC is estimated to cost $6,000,000-$7,000,000, and once online the Poultry Substation can be demolished.

1.2.1.4 Wind Power Purchase Agreement

2013 was the first year of a 20 year contractual agreement between the University and OG&E to purchase 110,000,000 kW-hr a year of wind generated energy, roughly equivalent to 67% of the Stillwater campus' need, from the new Cowboy Wind Farm in Blackwell, OK (Figure 13). This agreement created better electrical rate predictability for the University, allowed a significant reduction of staff in the Power Plant, and made the University a better steward of the environment. Among other stipulations, as part of their side of the agreement, OG&E would construct a second electrical substation to serve the campus. As part of the University's side of this contract, they would no longer generate power and would build a new

Figure 13, OG&E 60 MW OSU Cowboy Windfarm, Blackwell, OK

Central Plant. For this reason, the University is obligated to build a new Central Plant with a construction completion of December 2017.

The existing Power Plant generates steam to meet most of the heating demands of the Campus. OSU purchases electric power from Oklahoma Gas & Electric Company (OG&E) as well. The Power Plant is no longer generating electricity on a continuous basis; electricity is generated during periods of weather that may potentially interrupt power to vital loads on Campus and this is tested on a monthly basis. The University expects to maintain this capacity until the University substation is built west of campus.

1.2.2 Plant Replacement Opportunities

Construction of a new Central Plant creates many exciting opportunities. The plant has been designed with spaces that provide educational benefits to students. New equipment will be significantly more energy efficient than the existing. Finally, the new plant will reduce the footprint of Energy Services on campus by 42%. Additional discussion on replacement opportunities is provided below.

1.2.2.1 Tie to Education

The new Central Plant will not only serve as a hub for campus utilities, but it will also house a large teaching classroom and have a separate public observation area.

The Energy Services department has coordinated with the College of Engineering, Architecture, and Technology (CEAT) to identify classes to be held at the new plant to include:

- MAE 3223 (Thermodynamics 2)
- MAE 3233 (Heat Transfer)
- MAE 4263 (Energy Conversion)
- MAE 4713 (Thermal Systems)
- MAE 4703 (HVAC)
- MAE 4344 (Sr. Design)

1.2.2.2 Energy Efficiency

Boilers in the new plant will be 21% more efficient than the existing, and chillers will approach an energy efficiency improvement of 31%. Economic calculations have been performed and show that using new, high efficiency boilers, chillers, and pumps will result in $350,000 in annual energy savings. The new equipment is anticipated to provide an additional benefit of $120,000 in annual operation & maintenance savings. These savings are a result of more efficient boilers, chillers, pumps, and supporting equipment.

1.2.2.3 Consolidation of Energy Services Department

The new Central Plant will be the center of the University's heating and cooling distribution and house a state of the art control hub. The Central Plant will also create the opportunity to consolidate Energy Services, thus reducing the campus footprint of the department from 173,138 SF to 103,523 SF, or a 40% reduction. See Figure 14.

ENERGY SERVICES AREA	EXISTING SQFT	PROPOSED SQFT
BUILDING	67,283	64,973
SITE EQUIPMENT	9,275	12,400
EQUIPMENT YARD	81,000	22,400
SUBSTATION	15,580	0
POWER DISTRIBUTION CENTER	0	3,750
TOTAL	173,138	103,523

Figure 14, Breakdown of Energy Services Department Occupied Area, 40% Reduction

The new plant will house all of Energy

Services including:

- Utilities Production
- Distribution Systems
- Utilities Engineering
- Energy Management & Sustainability
- Geospatial Systems

The benefit of this consolidation is to also to functionally create an administration space on the east side of the building to accommodate and promote the Neo Georgian architecture established as the standard on the OSU Stillwater campus. Furthermore, central control of campus utilities is provided in the new plant which offers the following:

- Central Plant, West Chilled Water Plant, and Water Treatment Plant controls integration
- Campus buildings controls monitoring
- Campus buildings meters trending and logging
- After-hours emergency call center
- Emergency operations center during outages

1.3 Chilled Water System

The chilled water system is in relatively good condition compared to other utilities on campus. However, future capital projects will necessitate upgrades to the system as existing infrastructure is outgrown. Construction of the new Central Plant provides an opportunity to increase energy efficiency of chilled water equipment as well as prepare for future growth. The new Central Plant will include three chillers totaling 12,000 tons, with space allocated for an additional 4,000 tons of capacity. The new chillers are 31% more energy efficient than the existing. Chilled water thermal storage is another option which has been considered. Thermal storage could potentially offset the need for the purchase of the fourth chiller until 2050, and simultaneously would create opportunites to reduce energy costs and improve redundancy.

1.3.1 Existing Chilled Water System and Load Growth

The existing chilled water system on campus is fed from two chilled water plants: 1) the Power Plant, and 2) the West Chilled Water Plant. Chilled water production at the Power Plant will be replaced by the Central Plant upon completion of construction. As part of the Central Plant project, piping will be extended from the Power Plant location to the Central Plant. These plants circulate about two million gallons of water that is piped through 20+ miles of chilled water piping. The large underground piping network connects buildings on campus as shown below in Figure 15, Existing Chilled Water Piping System. Likewise, the firm capacity of this existing system is shown in Figure 16 to be 18,700 tons.

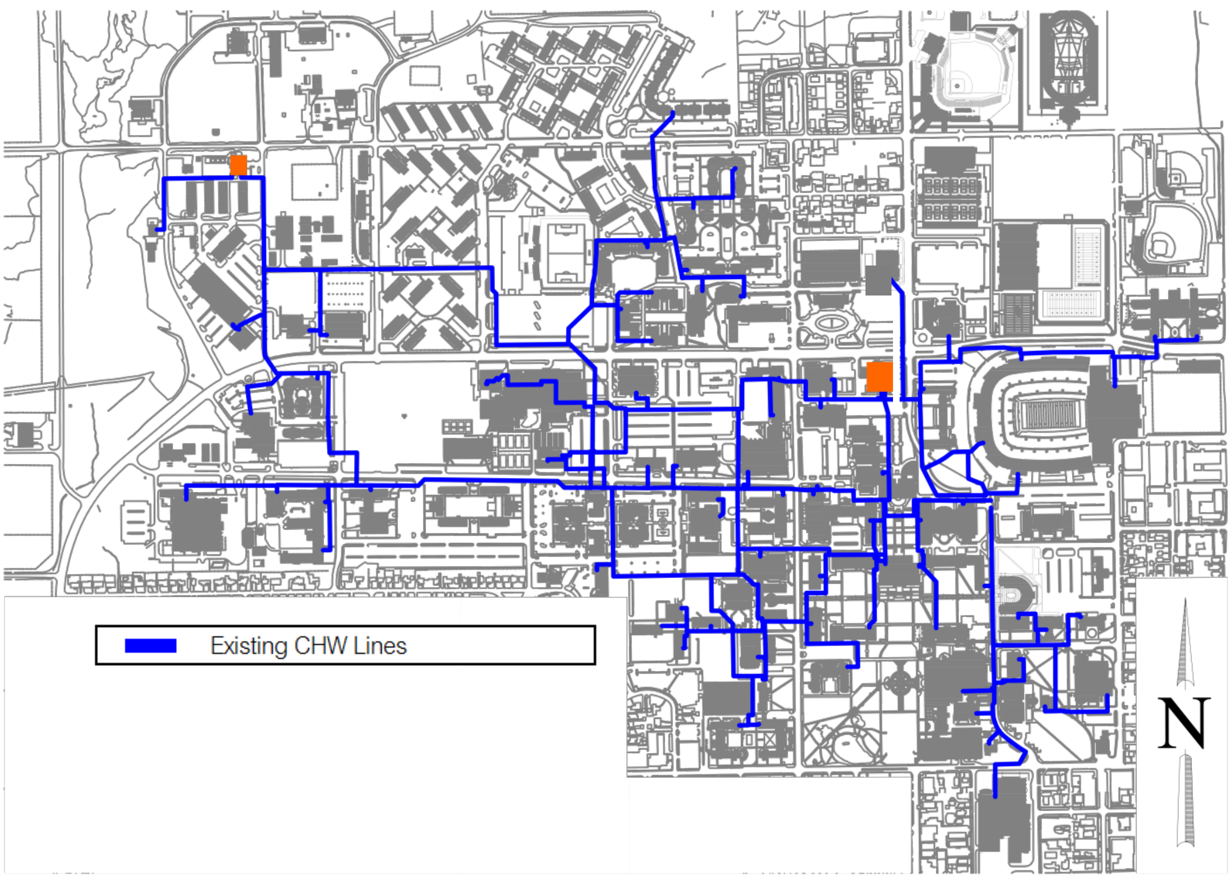


Figure 15, Existing Chilled Water Piping System

As shown Figure 17, the firm capacity of the chilled water system will be 18,000 tons upon completion of the new Central Plant, which is well above the historical peak demand of 15,300 tons. Firm capacity is defined as capacity that is guaranteed to be available in the event of one chiller failure at each plant. Therefore if a chiller fails, or just needs routine maintenance and cannot operate, the campus can still be served with the full load of chilled water for cooling.

EXISTING CHILLED WATER CAPACITY				
PLANT	ENERGY	TYPE	CAPACITY (TONS)	FIRM CAPACITY (TONS)
Existing Power Plant (Hall of Fame Ave.)				
CHILLER 1	Electric	Centrifugal	3,000	3,000
CHILLER 2	Steam	Centrifugal	1,500	1,500
CHILLER 3	Electric	Centrifugal	4,200	4,200
CHILLER 4	Electric	Centrifugal	4,200	-
WCWP - West Chilled Water Plant (McElroy Rd.)				
CHILLER 5	Electric	Centrifugal	4,000	4,000
CHILLER 6	Electric	Centrifugal	4,000	4,000
CHILLER 7**	Electric	Centrifugal	4,000	2,000
CHILLER 8	Electric	Centrifugal	4,000	-
Free Cool HX	N/A	Plate & Frame	4,000	-
TOTAL			32,900	18,700
**Due to existing pumping capacity, the WCWP can only pump 10,000 tons of chilled water equating to a firm capacity of 10,000 tons.				

Figure 16, Existing Chilled Water Capacity

CHILLED WATER CAPACITY WITH NEW PLANT (2018)				
PLANT	ENERGY	TYPE	CAPACITY (TONS)	FIRM CAPACITY (TONS)
Central Plant (Washington & Scott)				
CHILLER 9	Electric	Centrifugal	4,000	4,000
CHILLER 10	Electric	Centrifugal	4,000	4,000
CHILLER 11	Electric	Centrifugal	4,000	-
CHILLER 12	*FUTURE 4,000 TONS*			
WCWP - West Chilled Water Plant (McElroy Rd.)				
CHILLER 5	Electric	Centrifugal	4,000	4,000
CHILLER 6	Electric	Centrifugal	4,000	4,000
CHILLER 7**	Electric	Centrifugal	4,000	2,000
CHILLER 8	Electric	Centrifugal	4,000	-
Free Cool HX	N/A	Plate & Frame	4,000	-
TOTAL			32,000	18,000
**Due to existing pumping capacity, the WCWP can only pump 10,000 tons of chilled water equating to a firm capacity of 10,000 tons.				

Figure 17, Chilled Water Capacity with New Plant

The peak chilled water demand observed to date is 15,300 tons in 2010. Figure 18, Cooling Load Growth Chart below shows the cooling demand and how that demand is projected to grow in the next 20 years.

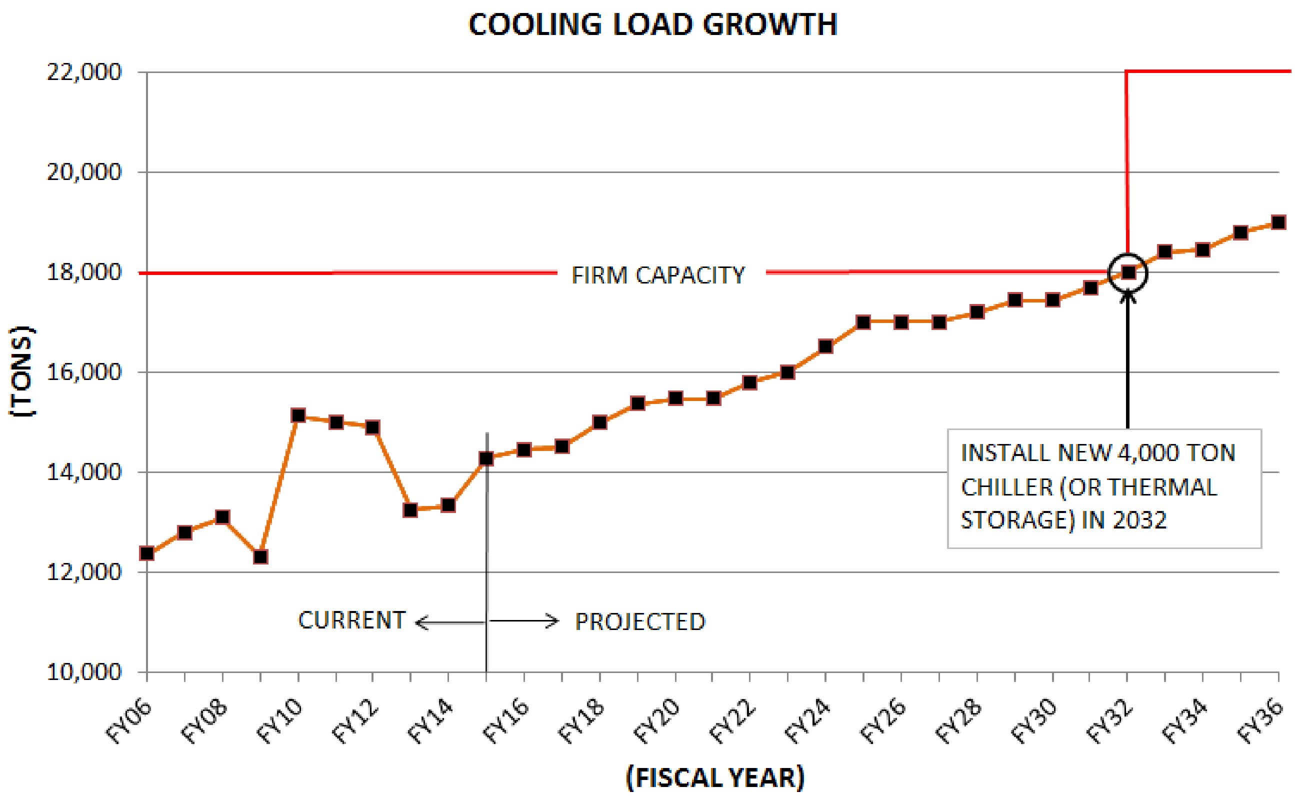


Figure 18, Cooling Load Growth Chart

The 18,000 tons of firm capacity provided by the WCWP and new Central Plant are expected to be exceeded in 2032. When this occurs an additional 4,000 ton chiller will be needed at the Central Plant, or a thermal storage system will be needed at the WCWP. Refer to Section 1.3.1.1 below and Section 3.6 of the full Utility Master Plan for more information regarding Thermal Storage.

1.3.1.1 Chilled Water Thermal Storage

An analysis was performed to determine the potential cost savings benefit of installing a field erected pre-stressed concrete chilled water thermal energy storage tank adjacent to the west chilled water plant. This insulated tank would hold 2,500,000 gallons of chilled water. The potential cost savings would be achieved by shifting 20,000 TON-hours of chilled water production to off-peak hours when electric utility costs are much lower and by utilizing the free cooling capabilities of the west chilled water plant to the extent they are available in the winter to charge the tank. Shown below in Figure 19, West Chilled Water Plant and Recommended Location of Thermal Storage Tank is the proposed location.

- Estimated Cost: $2,215,000
- 20,000 ton-hours capacity
- 2,500,000 gallons
- $95,000 annual energy savings
- Offset future chiller purchase and associated $5,000,000 cost to 2050

Figure 19, West Chilled Water Plant and Recommended Location of Thermal Storage Tank

Based on the results of this analysis, the project has a 17 year simple payback (does not include upgrades to the West Chilled Water Plant such as pumps, and existing system piping upgrades downstream of the plant). The proposed installation would also offset the necessity of installing a future 4,000 ton chiller at the new central plant and defer the associated $5,000,000 in cost until fiscal year 2050, provided that campus growth proceeds at a uniform rate and that improvements are made at the West Chilled Water Plant to distribute chilled water more effectively in the interim. This would likely include upgrading the pumping capacity, upgrading a portion of the campus chilled water piping network, electrical upgrades, etc. A thorough engineering analysis of the West Chilled Water Plant would need to be performed in order to evaluate further and provide a more comprehensive payback.

Figure 20 and Figure 21 show how the chillers would run at night and during off-peak cooling times to charge the thermal storage tank. This chilled water in the tank would then be used the following day during peak cooling times to reduce the electrical loads on the system when energy costs are higher.

Full system description, analysis, recommendations, calculations, weather data, and budgetary estimate documentation are included in Appendix H.

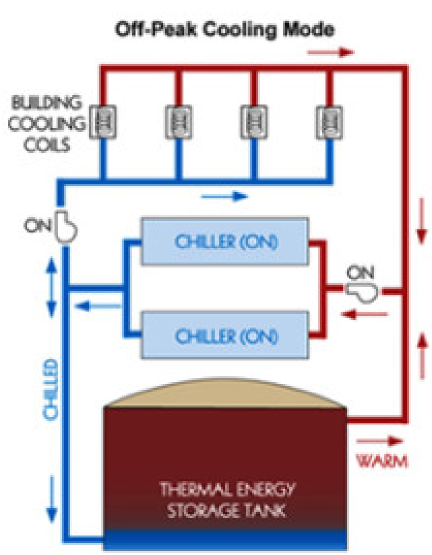


Figure 20, Off-Peak Cooling Mode

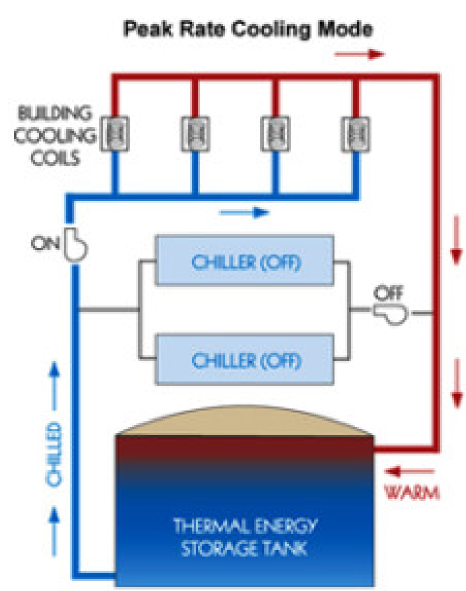


Figure 21, Peak Rate Cooling Mode

1.3.1.2 Chilled Water System Upgrade Costs

The chilled water system is in the best condition of the OSU Stillwater campus utlities. Most upgrades needed in this system in the next 20 years are the result of future campus buildings. If the campus grows as projected, a significant expense will be incurred in the year FY32 when either a new 4000 ton chiller or thermal storage must be added.

The cost of chilled water upgrades needed in the next 5 years is anticipated to be approx: $10,634,422.

Likewise, the cost of the chilled water upgrades needed for the 20-year plan is: $14,977,011.

The cumulative costs for 5-year plan + 20-year plan for chilled water upgrades is $25,611,433.

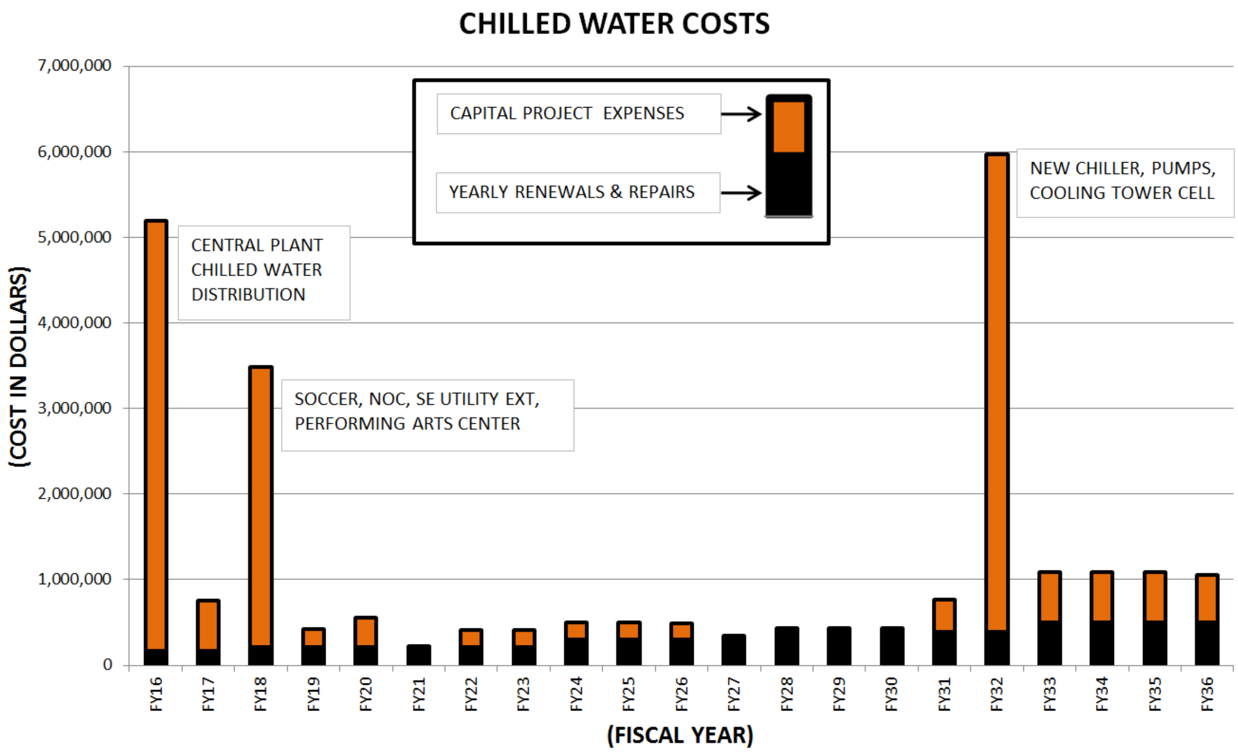


Figure 22, Chilled Water Costs

Figure 22 above shows the yearly estimated cost associated with upkeep and new capital projects. These numbers include the cost of installed chilled water piping, utility design fees, and yearly renewals and replacements.

1.3.2 5-Year Capital Improvement Projects, Chilled Water

In general, the existing campus chilled water network presently meets the acceptable velocity and pressure drop criteria. New or upgraded chilled water lines are only anticipated to be required for new building infrastructure, such as the capital improvement projects listed in the OSU Campus Master Plan 2025. Generally, these upgrades can happen as each building comes online.

The anticipated chilled water upgrades needed for 5-year capital improvement projects are shown in Figure 23, 5-Year Plan Map & Table for Chilled Water below.

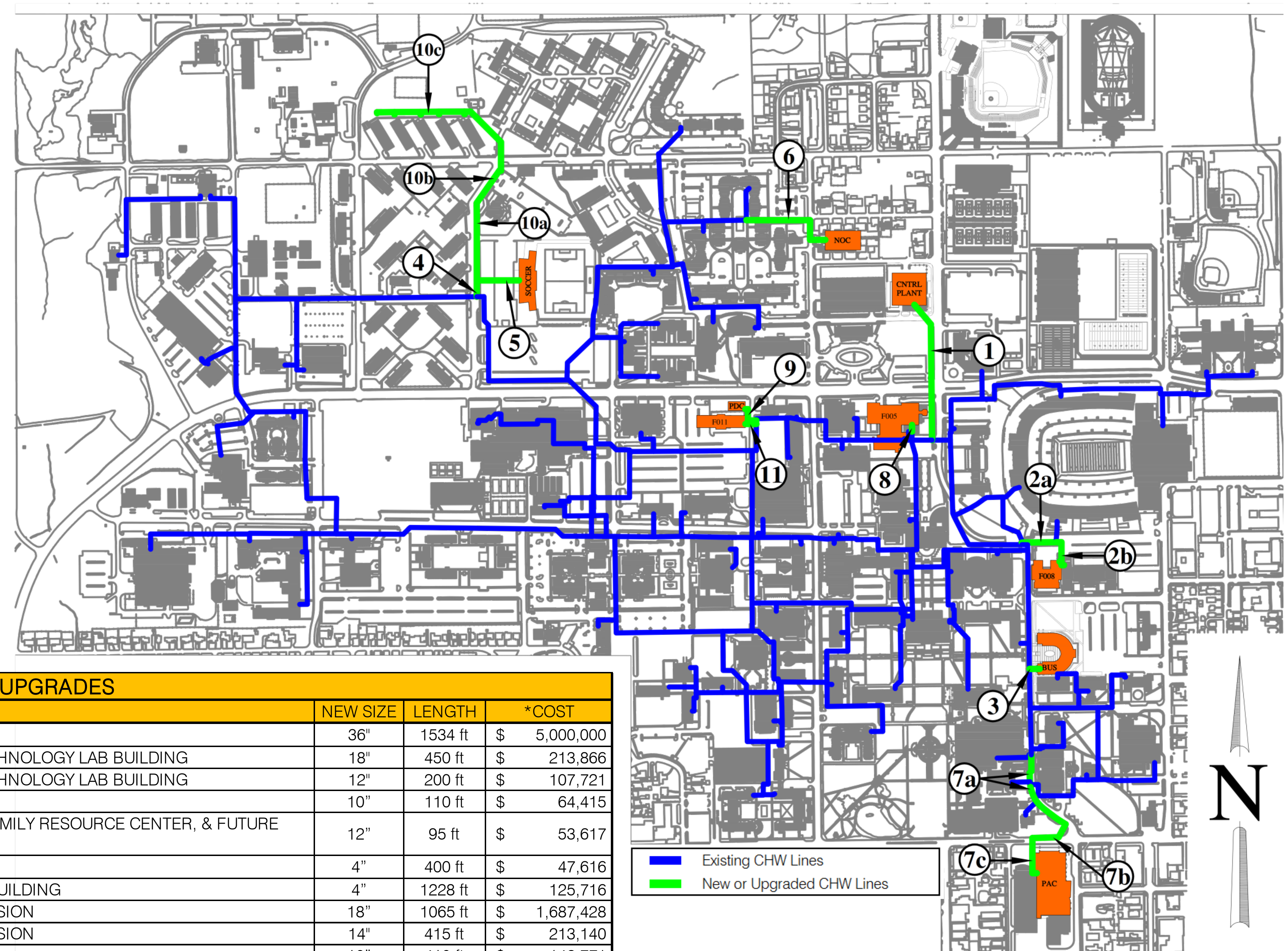


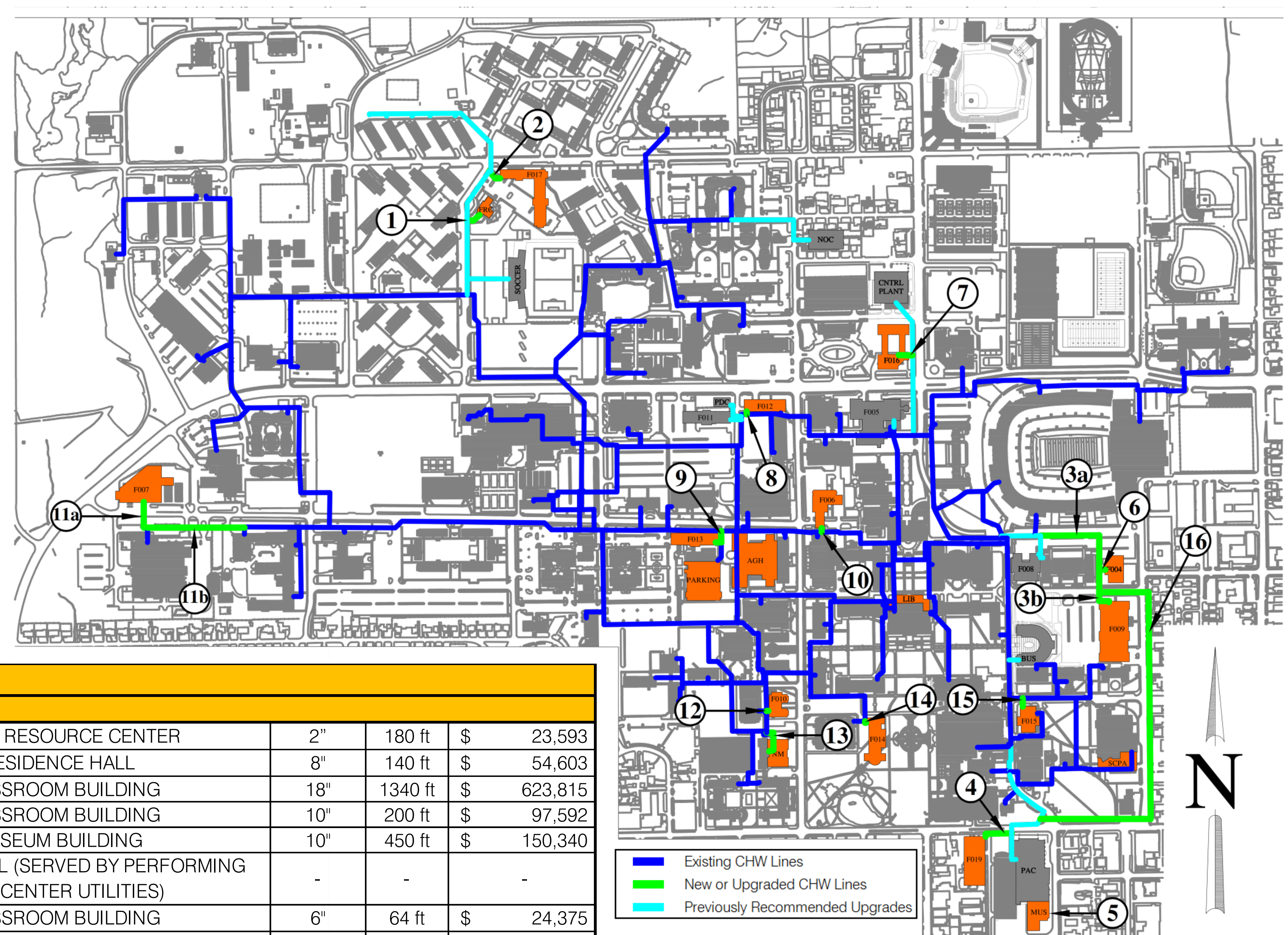
Figure 23, 5-Year Plan Map & Table for Chilled Water

5 YEAR CHILLED WATER UPGRADES						
PIPE	YEAR	EXIST SIZE	UPGRADE	NEW SIZE	LENGTH	*COST
1	FY16	-	CENTRAL PLANT UTILITIES	36"	1534 ft	$ 5,000,000
2a	FY17	10"	COLLEGE OF ENGINEERING, ARCHECTURE AND TECHNOLOGY LAB BUILDING	18"	450 ft	$ 213,866
2b	FY17	-	COLLEGE OF ENGINEERING, ARCHECTURE AND TECHNOLOGY LAB BUILDING	12"	200 ft	$ 107,721
3	FY17	-	BUSINESS BUILDING	10"	110 ft	$ 64,415
4	FY17	-	WILLIAMS APARMENT BUILDINGS, SOCCER STADIUM, FUTURE FAMILY RESOURCE CENTER, & FUTURE RESIDENCE HALL	12"	95 ft	$ 53,617
5	FY17	-	SOCCER STADIUM	4"	400 ft	$ 47,616
6	FY18	-	NORTHERN OKLAHOMA COLLEGE BUILDING	4"	1228 ft	$ 125,716
7a	FY18	10"	NEW SOUTHEAST UTILITY EXTENSION	18"	1065 ft	$ 1,687,428
7b	FY18	-	NEW SOUTHEAST UTILITY EXTENSION	14"	415 ft	$ 213,140
7c	FY18	-	PERFORMING ARTS CENTER	10"	410 ft	$ 142,771
8	FY19	-	FUTURE BUILDING	12"	100 ft	$ 111,740
9	FY19	-	POWER DISTRIBUTION CENTER	8"	260 ft	$ 81,045
10a	FY20	-	WILLIAMS APARMENT BUILDINGS, FUTURE FRC, & FUTURE RESIDENCE HALL	10"	355 ft	$ 97,599
10b	FY20	-	WILLIAMS APARMENT BUILDINGS & FUTURE RESIDENCE HALL	8"	395 ft	$ 96,255
10c	FY20	-	WILLIAMS APARMENT BUILDINGS	4"	865 ft	$ 121,672
11	FY20	-	DASNR BUILDING	8"	130 ft	$ 32,434

*FUNDING DETERMINED ON A CASE BY CASE BASIS

1.3.3 20-Year Capital Improvement Projects, Chilled Water

The anticipated campus 20 year peak demand is 18,992 tons. The campus firm chilled water capacity will be 18,000 tons upon completion of the Central Plant. Therefore, a new chiller or thermal storage system is expected to be needed to the Central Plant in the fiscal year of 2032. Shown in Figure 24, 20-Year Plan Map & Table for Chilled Water are the anticipated piping upgrades with associated sizes, length and cost.



20 YEA							
PIPE	YEAR	EXIST SIZE					
1	FY22-26	-	FAMILY RESOURCE CENTER	2"	180 ft	$	23,593
2		-	RESIDENCE HALL	8"	140 ft	$	54,603
3a		-	CLASSROOM BUILDING	18"	1340 ft	$	623,815
3b		-	CLASSROOM BUILDING	10"	200 ft	$	97,592
4		-	MUSEUM BUILDING	10"	450 ft	$	150,340
5		-	MUSIC SCHOOL (SERVED BY PERFORMING ARTS CENTER UTILITIES)	-	-		-
6		-	CLASSROOM BUILDING	6"	64 ft	$	24,375
7	FY27-31	-	SUPPORT BUILDING	8"	130 ft	$	52,730
8		-	CLASSROOM BUILDING	8"	40 ft	$	27,787
9		-	CLASSROOM BUILDING	10"	160 ft	$	77,051
10		-	RESEARCH BUILDING	8"	50 ft	$	29,660
11a	FY32-36	-	RESEARCH BUILDING	12"	350 ft	$	158,402
11b		8"	RESEARCH BUILDING	12"	1130 ft	$	407,846
12		-	CLASSROOM BUILDING	6"	40 ft	$	27,340
13		6"	NORTH MURRAY ADDITION	8"	330 ft	$	98,274
14		-	CLASSROOM BUILDING	8"	40 ft	$	27,787
15		-	CLASSROOM BUILDING	6"	100 ft	$	35,508
16		-	FUTURE CHILLED WATER LOOP	18"	4500 ft	$	1,996,646

*FUNDING DETERMINED ON A CASE BY CASE BASIS

1.4 Steam System

Existing steam piping on campus has many deficiencies which will be shown in this report. The main cause is undersized piping which creates a high steam velocity in the pipe creating premature wear, reduced efficiency, and results in a lack of adequate heating capacity in some buildings on cold days. The maximum recommended velocity for the transport of steam is 80 feet per second, and much of the campus distribution system exceeds this rate under peak load conditions.

Most heating system upgrades recommended over the next ten years are the result of piping which is currently undersized. The majority of condition related issues are programmed to be remedied in the following ten years. Capital projects will necessitate upgrades as they occur.

1.4.1 Existing Steam System and Load Growth

The existing steam system (Figure 25, Existing Steam Piping System) is fed from one steam plant at the Power Plant. The construction of the new Central Plant is underway as of 2016 and will house three 60,000 lb/hr boilers, one 40,000 lb/hr boiler, as well as room for one future 60,000 lb/hr boiler. Space has also been programmed for heat exchangers and pumps required for a future heating water loop to serve areas North and West of the Central Plant. As part of the Central Plant project, two 18" steam lines and one 8"condensate return line will be extended from the Power Plant location to the Central Plant. Two steam lines were chosen in conjunction with two pressure reducing stations included in the plant for redundancy.

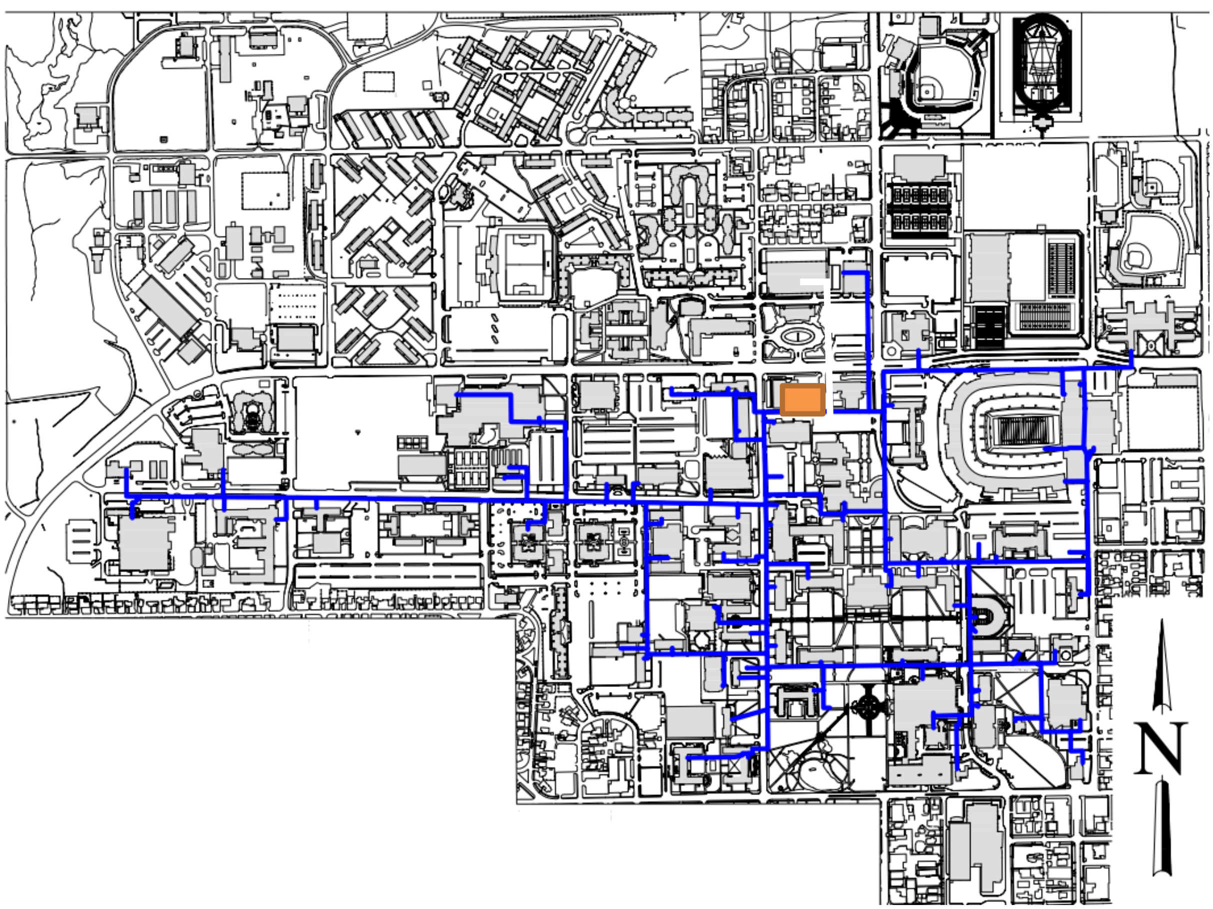


Figure 25, Existing Steam Piping System

As shown in Figure 27 below, the firm capacity of the steam system will be 160,000 LB/HR upon completion of the new Central Plant. Firm capacity is defined as capacity that is guaranteed to be available in the event of losing any single boiler. Therefore if a boiler fails, or just needs routine maintenance and cannot operate, the campus can still be provided with necessary steam capacity.

EXISTING STEAM CAPACITY				
PLANT	ENERGY	YEAR INSTALLED	CAPACITY (LB/HR)	FIRM CAPACITY (LB/HR)
Existing Power Plant (Hall of Fame Ave.)				
BOILER 1	Natural Gas	1947	40,000	40,000
BOILER 2	Natural Gas	1947	40,000	40,000
BOILER 3*	Natural Gas	1947	38,600	-
BOILER 4	Natural Gas	1956	115,000	-
BOILER 5	Natural Gas	1962	90,400	90,400
TOTAL			324,000	170,400

*Boiler 3 has been deemed unreliable and is in dry layup status

Figure 26, Existing Steam Capacity Table

STEAM CAPACITY WITH NEW PLANT (2018)				
PLANT	ENERGY	YEAR INSTALLED	CAPACITY (LB/HR)	FIRM CAPACITY (LB/HR)
Central Plant (Washington & Scott)				
BOILER 6	Natural Gas	2018	60,000	60,000
BOILER 7	Natural Gas	2018	60,000	60,000
BOILER 8	Natural Gas	2018	60,000	-
BOILER 9	Natural Gas	2018	40,000	40,000
BOILER 10	*FUTURE 60,000 LB/HR*			
TOTAL			220,000	160,000

Figure 27, Steam Capacity Table Including New Central Plant

The New Central Plant will have less steam capacity than the existing Power Plant due to steam no longer being required to produce electricity. Additionally, the new boilers will be 21% more efficient than existing boilers.

The historical steam peak demand is 150,000 LB/HR. Steam demand is projected to grow by approximately 27% over the next 20 years as shown in Figure 28.

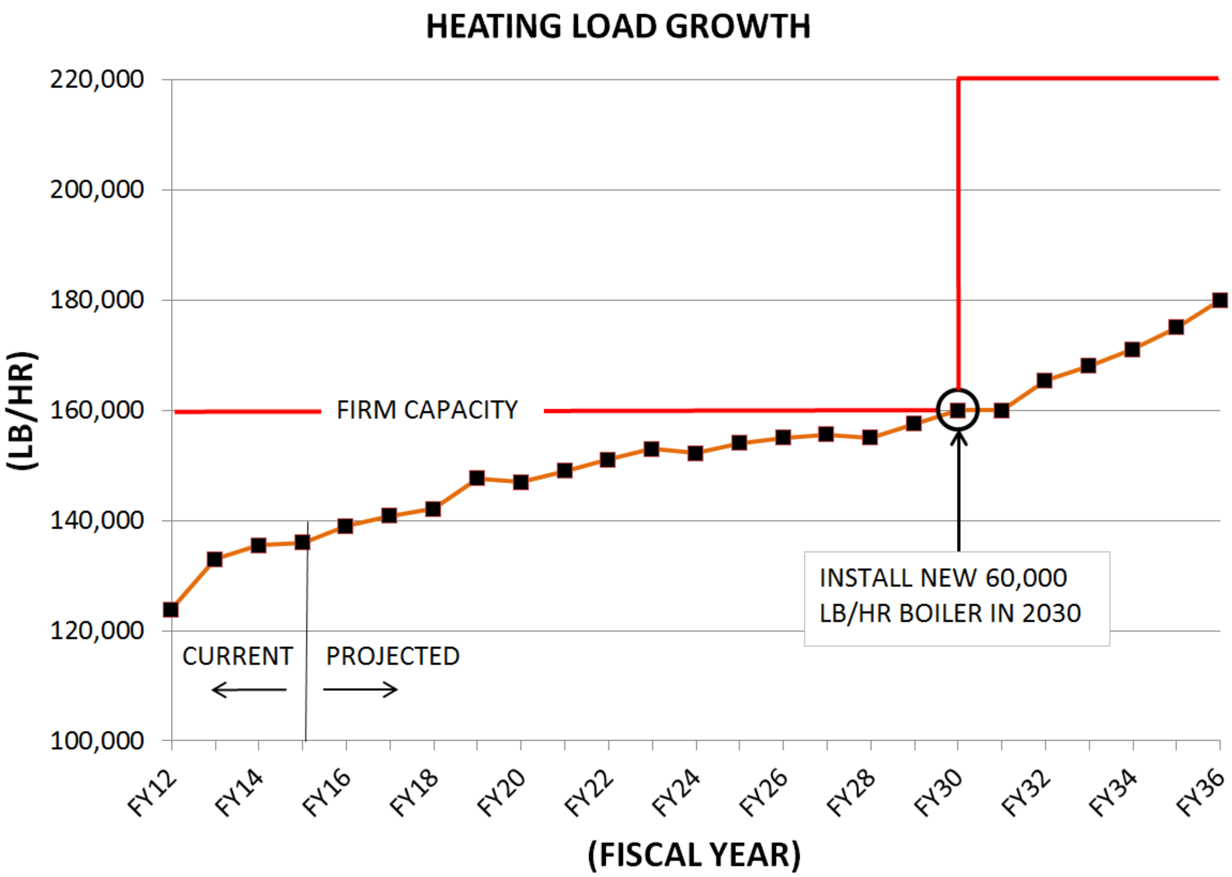


Figure 28, Heating Load Growth

The 160,000 LB/HR of firm capacity provided by the new Central Plant is expected to be exceeded in 2030. When this occurs, an additional 60,000 LB/HR will be needed at the Central Plant. Much of the anticipated capacity is planned to be utilized through a future heating water loop housed at the Central Plant.

1.4.1.1 Heating Hot Water Loop

A central heating water loop is being considered as a future heating source for buildings North and West of the new Central Plant where no existing steam service exists. Additionally, the heating water loop could be utilized to provide in floor radiant heating at the Indoor Practice Facility. The heating water loop would consist of a series of shell and tube heat exchangers, pumps, and hydronic accessories installed in the new Central Plant. The shell and tube heat exchangers would utilize steam from the new boilers as their heat source. Piping will be extended from the plant to new and existing buildings.

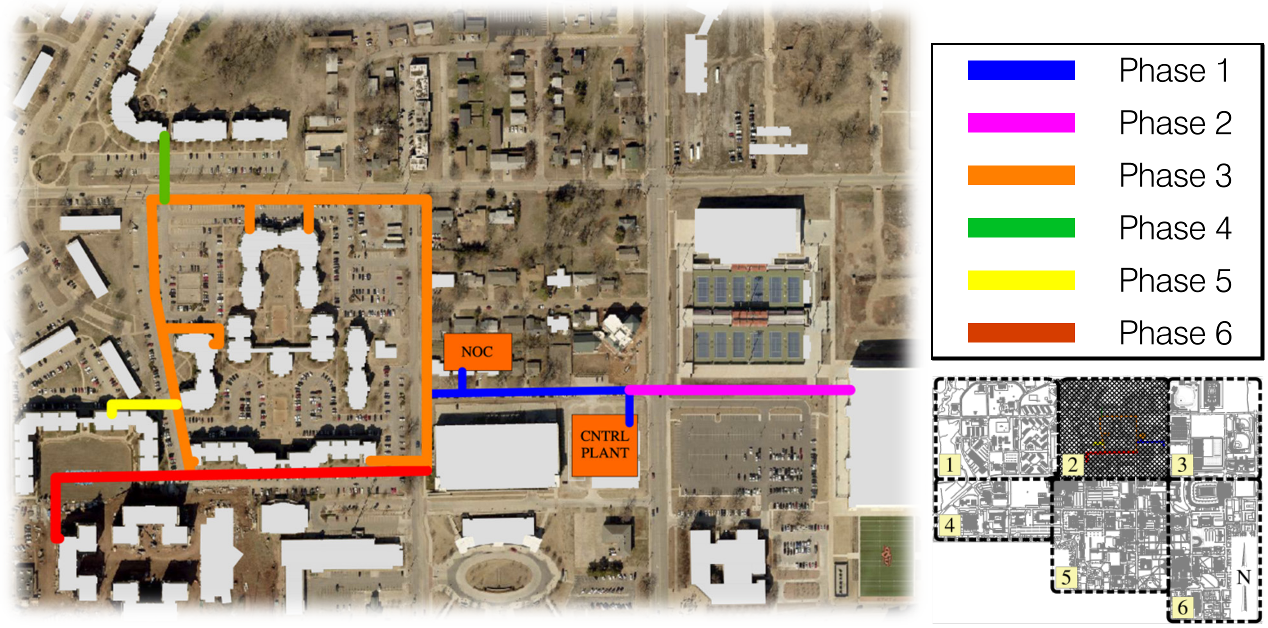


Figure 29, Heating Water Loop Phasing Plan

A heating water loop would reduce maintenance, increase controllability, and reduce energy consumption. Most of the buildings being considered for the heating water loop are heated by packaged boilers today.

The heating water loop would have a life of well over 50 years, while packaged boilers typically have a useful life of approximately 15 years. The total cost for all phases of the heating water loop is estimated to be $8,425,509, of which $6,596,188 is dedicated to replacing existing hot water boilers in Residential Life buildings. By comparison, the cost to replace the boilers at the end of their life with similar packaged boilers at each building is $4,729,850. This is a recurring cost that is expected to repeat every 15 years, therefore utilizing the hot water loop as a future source of heat will result in a savings of $5,764,042 in equipment costs alone over the course of a 50 year life cycle. This savings is in comparison to the total cost of the hot water loop, which includes providing heating to the future NOC Classroom Building and to the Indoor Practice Facility. When compared only to the portion of the hot water loop associated with replacing existing boilers, an equipment cost savings of $7,593,363 is realized over a 50 year period.

In addition, the removal of 34 boilers would reduce the University's yearly maintenance costs and increase redundancy. Figure 29, Heating Water Loop Phasing Plan shows the extent of the heating water loop, and how the project could be phased.

For additional phasing details and cost breakdown, please see section 4.7 of the full Utility Master Plan.

1.4.1.2 Heating System Upgrade Costs

The existing steam system on the OSU Stillwater campus has exceeded its expected life in many areas. Steam piping is undersized as a result of campus growth throughout the years, and large sections of steam piping are in need of replacement due to poor condition. As a result, heating system upgrades are significantly higher than those seen in the chilled water system. If the campus grows as projected, a significant expense will be incurred in the year FY30 when a new 60,000 lb/hr boiler is added.

The cost of steam upgrades needed in the next 5 years is anticipated to be approximately: $20,440,920

Likewise, the cost of the steam upgrades needed for the 20-year plan is: $49,388,826

The cumulative costs for 5-year plan + 20-year plan for steam upgrades is: $69,829,746

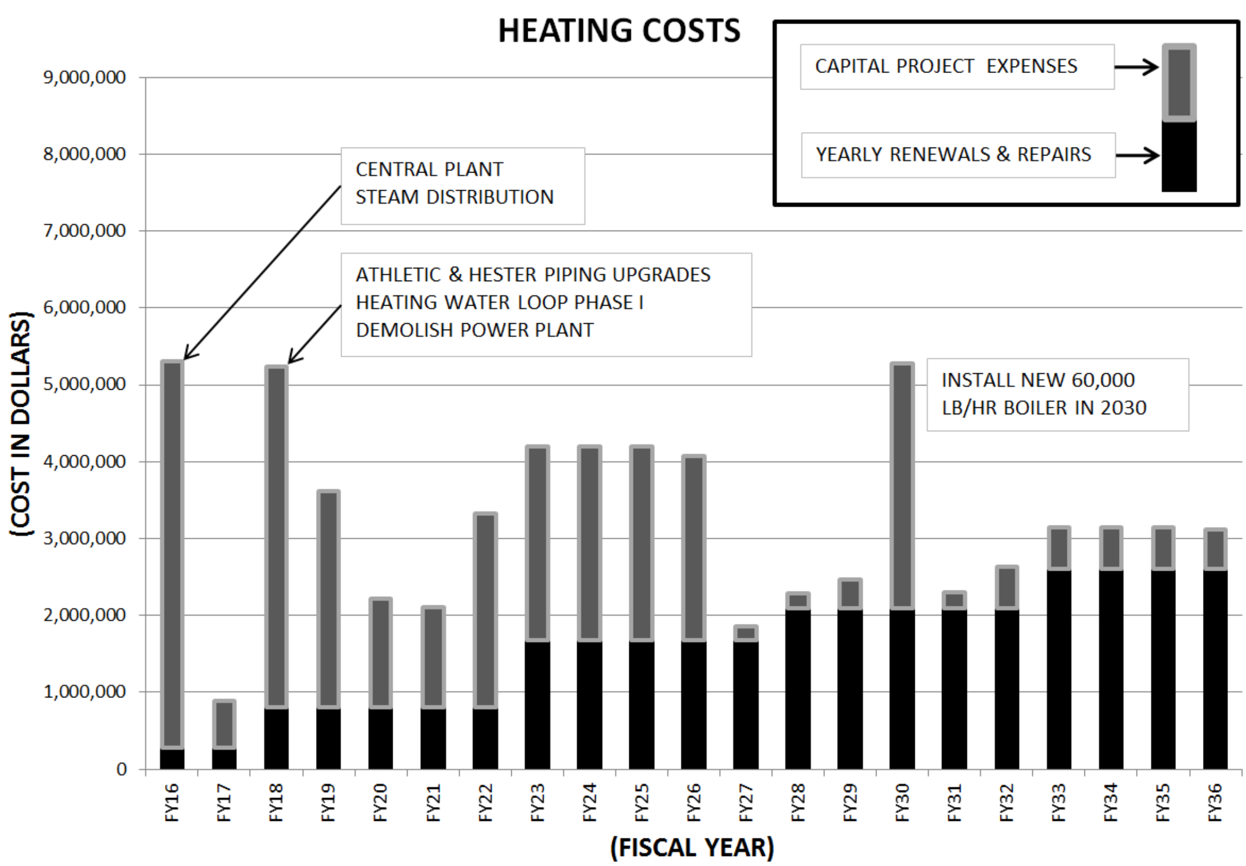


Figure 30, Steam Costs

Figure 30, Steam Costs above shows the yearly estimated cost associated with currently needed upgrades, upkeep and new capital projects. These numbers include the cost of installed steam piping, utility design fees, and yearly renewals and replacements.

1.4.2 Existing Steam Pipe Capacity Deficiencies

Reference Figure 31, Existing Steam Pipe Deficiencies Map and Table, which shows that much of the existing campus steam piping is undersized. The piping deficiencies shown below are based on pipe size only, and not on current pipe condition.

Steam Velocities of 0 – 80 ft/s Acceptable

Steam Velocities of 81 – 130 ft/s High

Steam Velocities of 131 ft/s and above Critical

Recommended Steam Upgrade Priority #1 – Wehr Rd. / Monroe St.

Upgrade the existing steam piping from along Farm Rd, Monroe St and Wehr Rd. This upgrade prevents nearly 29 buildings from being starved of steam heat in the winter. This upgrade is denoted in the adjacent map and corresponding table as items 1a, 3,and 4. A small critical portion along Monroe (item 1b) is also listed.

Recommended Steam Upgrade Priority #2 – Athletic and Hester

Upgrade the existing steam piping from the old Power Plant down Washington to Athletic St. This upgrade prevents nearly 34 buildings from being starved of steam heat in the winter. The upgrade is denoted in the adjacent map and corresponding table as item 2.

EXISTING STEAM PIPE CAPACITY DEFICIENCIES

PIPE	YEAR	EXIST SIZE	STEAM VELOCITY	NEW SIZE	LENGTH	*COST
1a	FY17	10"	238 ft/s	18"	60 ft	$ 114,579
1b	FY17	5"	135-172 ft/s	8"	127 ft	$ 131,899
2	FY18	8"-12"	127-198 ft/s	16"-20"	1509 ft	$ 2,943,421
3	FY19	12"	140-144 ft/s	20"	1174 ft	$ 2,658,626
4	FY20	10"	139-151 ft/s	14"	722 ft	$ 988,620
5a	FY21	8"	95 ft/s	10"	138 ft	$ 113,751
5b	FY21	8"	87 ft/s	10"	212 ft	$ 157,843
5c	FY21	5"	163-208 ft/s	8"	143 ft	$ 153,915
5d	FY21	10"	88 ft/s	12"	190 ft	$ 190,880
6	FY21	6"	156 ft/s	8"	866 ft	$ 550,066
7a	FY22	4"	131 ft/s	6"	160 ft	$ 220,832
7b	FY22	6"	122 ft/s	8"	133 ft	$ 102,993
7c	FY22	3"	194 ft/s	4"	121 ft	$ 55,666
7d	FY22	2 ½"	103 ft/s	3"	385 ft	$ 142,325
8a	FY23	2"	186 ft/s	3"	234 ft	$ 90,377
8b	FY23	2"	163 ft/s	3"	136 ft	$ 50,701
8c	FY23	5"	81 ft/s	6"	464 ft	$ 232,843
8d	FY23	2"	144 ft/s	6"	22 ft	$ 87,546
8e	FY23	2 ½"	91 ft/s	3"	35 ft	$ 19,465
9a	FY24	4"	104 ft/s	8"	562 ft	$ 388,042
9b	FY24	6"	82 ft/s	8"	165 ft	$ 155,205
10	FY25	8"	130 ft/s	14"	409 ft	$ 429,631
11a	FY26	8"	121 ft/s	14"	207 ft	$ 220,832
11b	FY26	8"	82 ft/s	10"	160 ft	$ 141,327
11c	FY26	4"	86 ft/s	6"	25 ft	$ 34,277
11d	FY26	8"	122 ft/s	10"	244 ft	$ 175,775

*FUNDING DETERMINED ON A CASE BY CASE BASIS

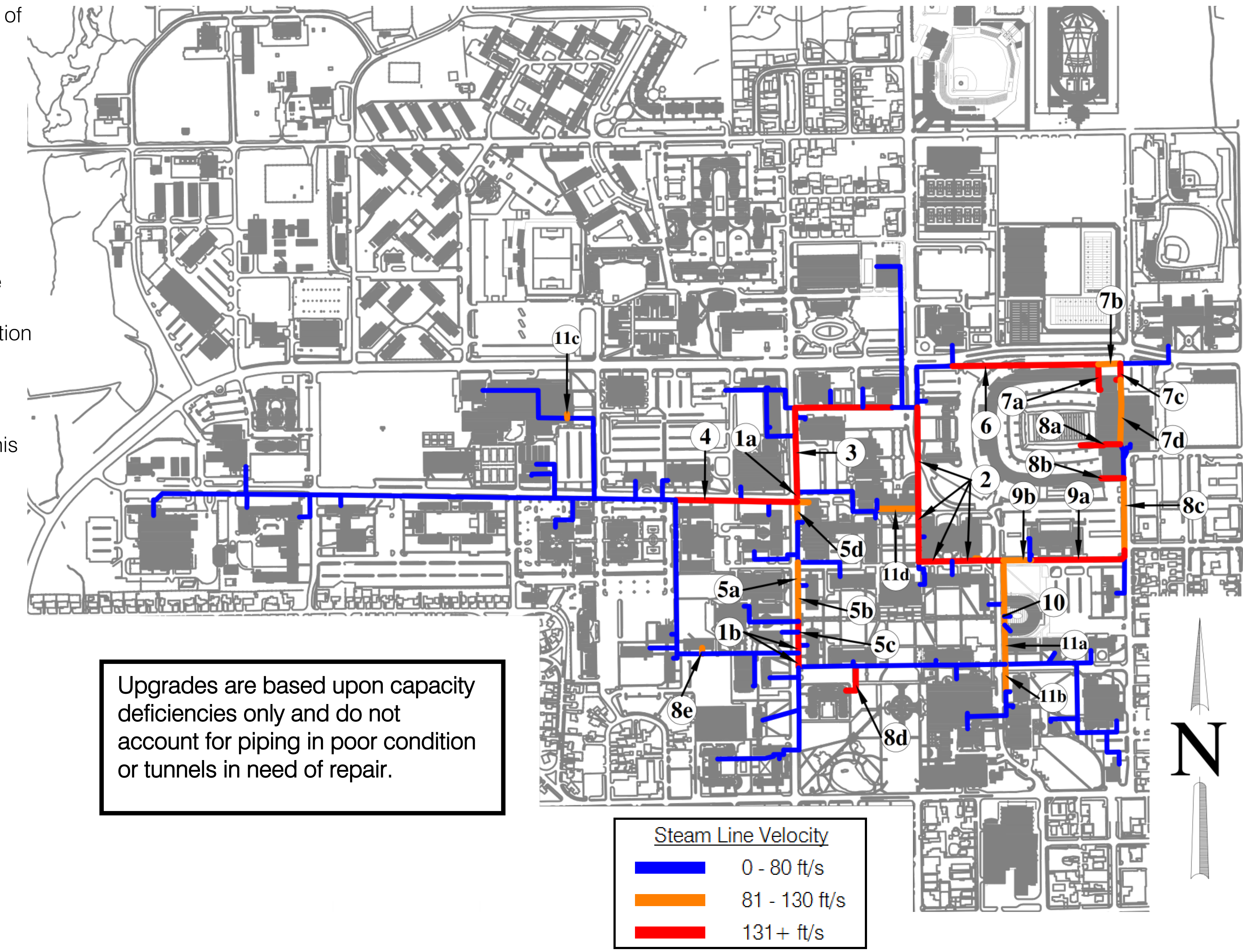
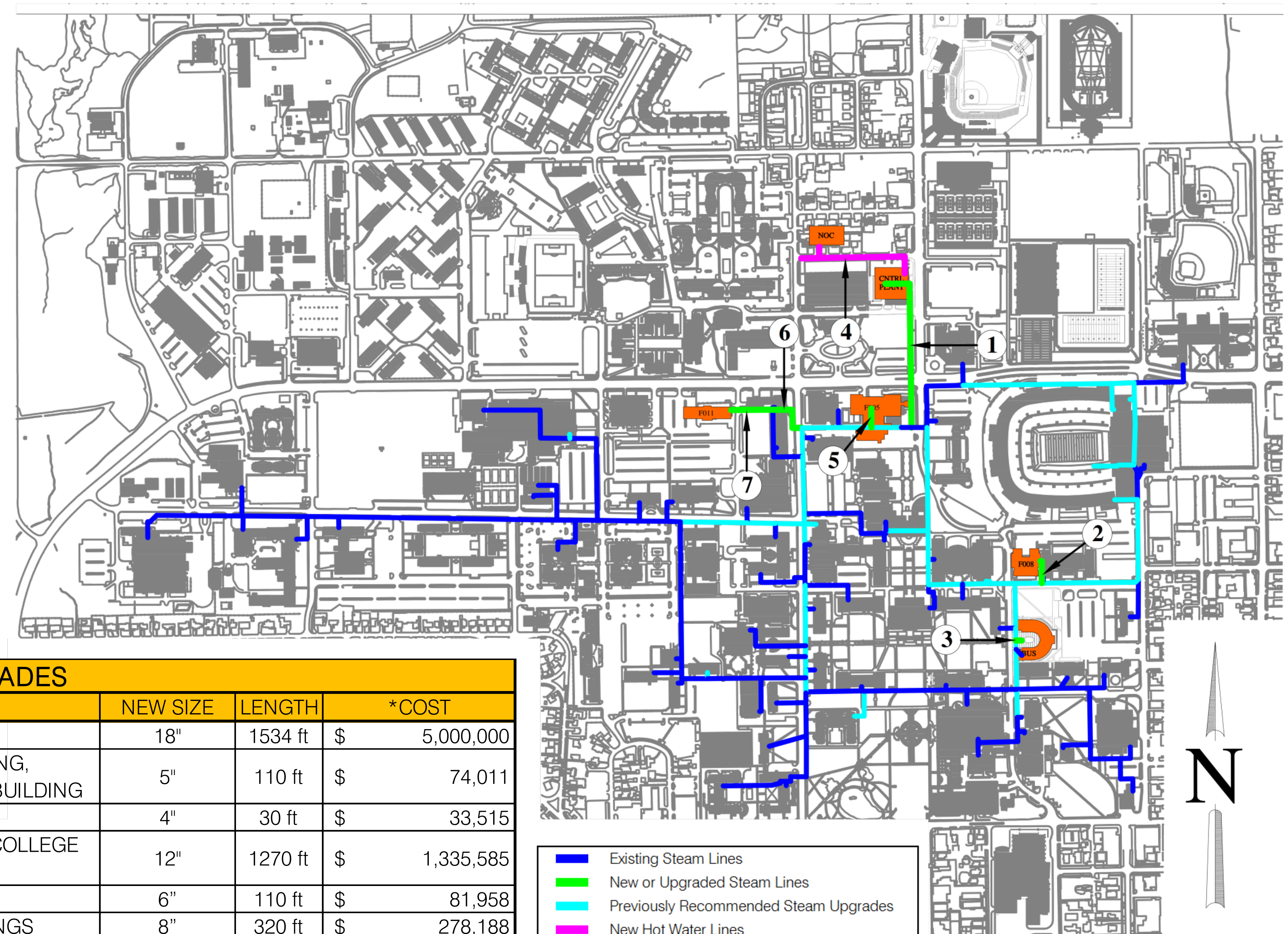


Figure 31, Existing Steam Pipe Deficiencies Map and Table

1.4.3 5-Year Capital Improvement Projects, Heating

New or upgraded steam and hot water lines are anticipated in Figure 32 to be required for new building infrastructure, such as the capital improvement projects listed in the OSU Campus Master Plan 2025. The table and map shown on this page represent new buildings planned for construction within the 5-year plan and associated steam piping upgrades.

Existing deficiencies identified in the previous Section 1.4.2, item 2, must be completed to provide sufficient steam to the Business Building and CEAT lab.



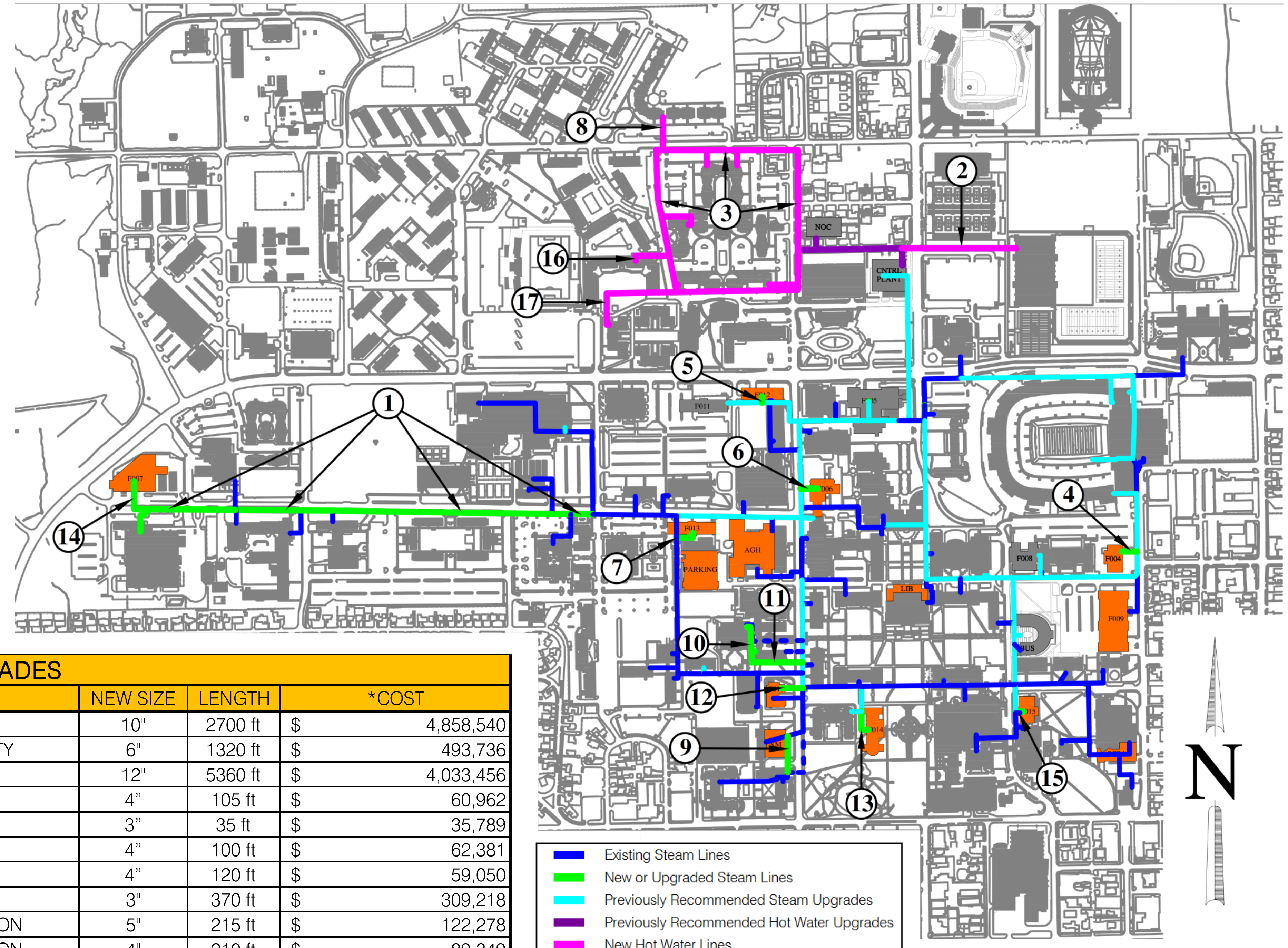
5 YEAR HEATING UPGRADES						
PIPE	YEAR	EXIST SIZE	UPGRADE	NEW SIZE	LENGTH	*COST
1	FY16	-	CENTRAL PLANT UTILITIES	18"	1534 ft	$ 5,000,000
2	FY17	-	STEAM TO COLLEGE OF ENGINEERING, ARCHITECTURE, AND TECHNOLOGY LAB BUILDING	5"	110 ft	$ 74,011
3	FY17	-	STEAM TO BUSINESS BUILDING	4"	30 ft	$ 33,515
4	FY18	-	HOT WATER TO NORTHERN OKLAHOMA COLLEGE BUILDING	12"	1270 ft	$ 1,335,585
5	FY19	-	STEAM TO FUTURE BUILDING	6"	110 ft	$ 81,958
6	FY20	-	STEAM LINE TO CLASSROOM BUILDINGS	8"	320 ft	$ 278,188
7	FY20	-	STEAM TO DASNR BUILDING	3"	200 ft	$ 78,556

*FUNDING DETERMINED ON A CASE BY CASE BASIS

Figure 32, 5-Year Heating Plan Map and Table

1.4.4 20-Year Capital Improvement Projects, Heating

New or upgraded steam and hot water lines are anticipated in Figure 33 to be required for new building infrastructure, such as the capital improvement projects listed in the OSU Campus Master Plan 2025. The table and map shown on this page represent new buildings planned for construction within the 20-year plan and associated steam piping upgrades.



20 YEAR HEATING UPGRADES						
PIPE	YEAR	EXIST SIZE	UPGRADE	NEW SIZE	LENGTH	*COST
1	FY22-26	-	FARM ROAD STEAM UPGRADES	10"	2700 ft	$ 4,858,540
2		-	HOT WATER TO INDOOR PRACTICE FACILITY	6"	1320 ft	$ 493,736
3		-	HOT WATER TO RESIDENCE HALLS	12"	5360 ft	$ 4,033,456
4		-	STEAM TO CLASSROOM BUILDING	4"	105 ft	$ 60,962
5	FY27-31	-	STEAM TO CLASSROOM BUILDING	3"	35 ft	$ 35,789
6		-	STEAM TO RESEARCH BUILDING	4"	100 ft	$ 62,381
7		-	STEAM TO CLASSROOM BUILDING	4"	120 ft	$ 59,050
8		-	HOT WATER TO RESIDENCE HALLS	3"	370 ft	$ 309,218
9		-	UPGRADE DUE TO STEAM TUNNEL CONDITION	5"	215 ft	$ 122,278
10		-	UPGRADE DUE TO STEAM TUNNEL CONDITION	4"	210 ft	$ 89,349
11		-	UPGRADE DUE TO STEAM TUNNEL CONDITION	6"	330 ft	$ 161,491
12	FY32-36	-	STEAM TO CLASSROOM BUILDING	3"	120 ft	$ 50,238
13		-	STEAM TO CLASSROOM BUILDING	4"	145 ft	$ 66,143
14		-	STEAM TO RESEARCH BUILDING	6"	245 ft	$ 134,555
15		-	STEAM TO CLASSROOM BUILDING	3"	40 ft	$ 31,364
16		-	HOT WATER TO RESIDENCE HALLS	6"	425 ft	$ 444,912
17		-	HOT WATER TO UNIVERSITY COMMONS	6"-12"	2740 ft	$ 1,808,602

*FUNDING DETERMINED ON A CASE BY CASE BASIS

Figure 33, 20-Year Heating Plan Map and Table

1.5 Electrical System

The OSU Stillwater campus electrical system consists of a 12.5 kV underground system with an original 2400 volt system running from the Power Plant and the Poultry Substation. Much of the existing ductbank was installed between 1940 through1960 and is in poor condition. The condition of this ductbank often times makes it impossible to feed new conductors through the existing infrastructure.

Upgrade of the 2400 V portions of the distribution system to 12.5 kV must be completed prior to demolition of the Power Plant. Additionally, the construction of the Power Distribution Center (PDC) must be completed prior to demolition of the Poultry Substation.

Because of the condition of existing infrastructure and the desire to demolish the Power Plant and Poultry Substation, most electrical upgrades identified are anticipated to occur within the 5-year plan period.

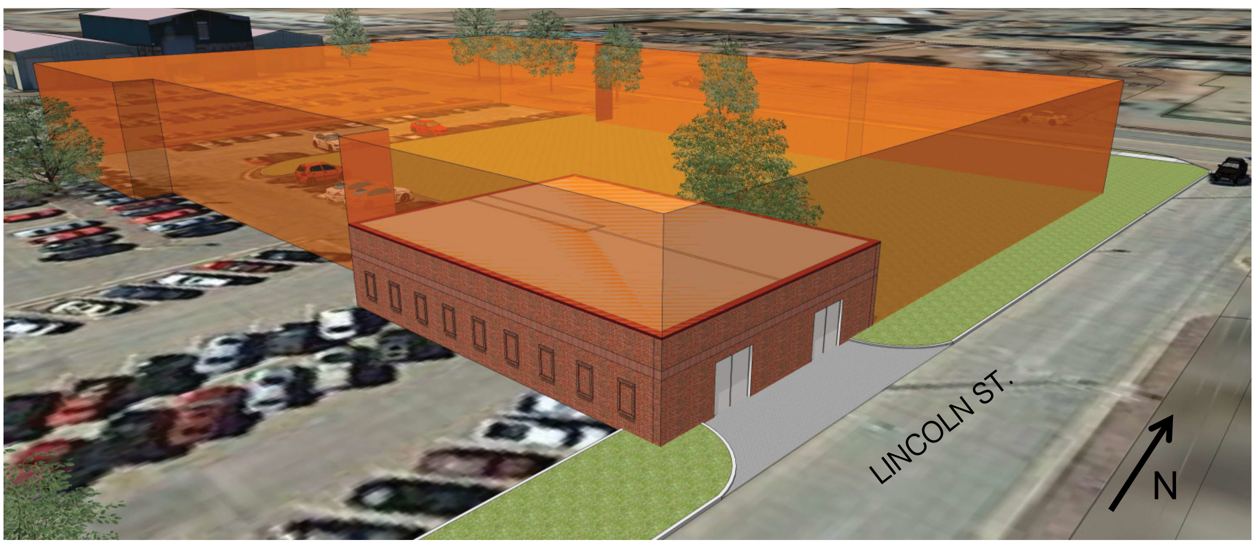


Figure 34, Rendering of Proposed Power Distribution Center (PDC) on Lincoln St with Future Agricultural Building in Orange

1.5.1 Existing System and Load Growth

Figure 35, McElroy Substation

Power is supplied to the OSU campus by three 138-12.5 kV, 20 MVA transformers from McElroy Substation located at McElroy and Willis (Figure 35). This substation in turn supplies power to the OSU/Poultry Substation at Hall of Fame and Lincoln (Figure 36). Starting here, the power distribution system is underground with feeders at two voltages, 2400 V and 12.5kV. Approximately 15% of the campus demand is served from the 2400 V system; with the remaining 85% of the demand load served from the 12.5 kV system. The transformers at the OSU/Poultry Substation are the primary source of 2400 V and 12.5 kV feeders routed throughout the majority of campus. The OSU/Poultry Substation also provides 2400 V to switch gear in the Power Plant, which further distributes the 2400 V feeders. An overhead 2400 V and 12.5 kV distribution system provides power to loads located west of Western Ave.

The majority of 2400 V distribution cabling and equipment was installed between 1940 and 1960. After 1960, the majority of the installed distribution system was rated 12.5 kV. Medium Voltage cables provide reliable service for 25-30 years depending on the installation and operating conditions. Medium Voltage switches and transformers will provide 35-40 years of service. Some of the existing in-service equipment and cabling is 10-20 years beyond its designed operating age.

Figure 36, Poultry Substation

Figure 37, Failed Orangeburg Electrical Conduit

The condition of the 2400 V and 12.5 kV feeders is further adversely affected by the age and condition of the older duct bank raceways in which they are installed. The duct bank raceways were constructed from "Orangeburg" material (bituminized fiber conduit made from layers of wood pulp and pitch pressed together) that was utilized in the early 1900's thru the 1970's, prior to production of modern durable PVC material. Orangeburg conduit has been known to last under ideal conditions as long as fifty years but in many instances they also failed in under a decade due to excessive pressure, type of duct bank construction and the bedding material. Removal of old cables from the failed "Orangeburg" and pulling new cables in many cases is not possible. Refer to Figure 37 for typical failed Orangeburg conduit/pipe. Upgrading the 2400 Volt power system to a 12.47 kV system will greatly modernize and replace the system that was installed in the 1940's thru 1960's.

Figure 38 shows a snapshot of the current electrical distribution system which includes 12.5 kV and 2400V underground and overhead circuits. As shown, the electrical system is much more expansive than the steam or chilled water system and supports a campus-wide demand of 30.4 MW. The existing electrical distribution system extends to the west beyond Sangre Road.

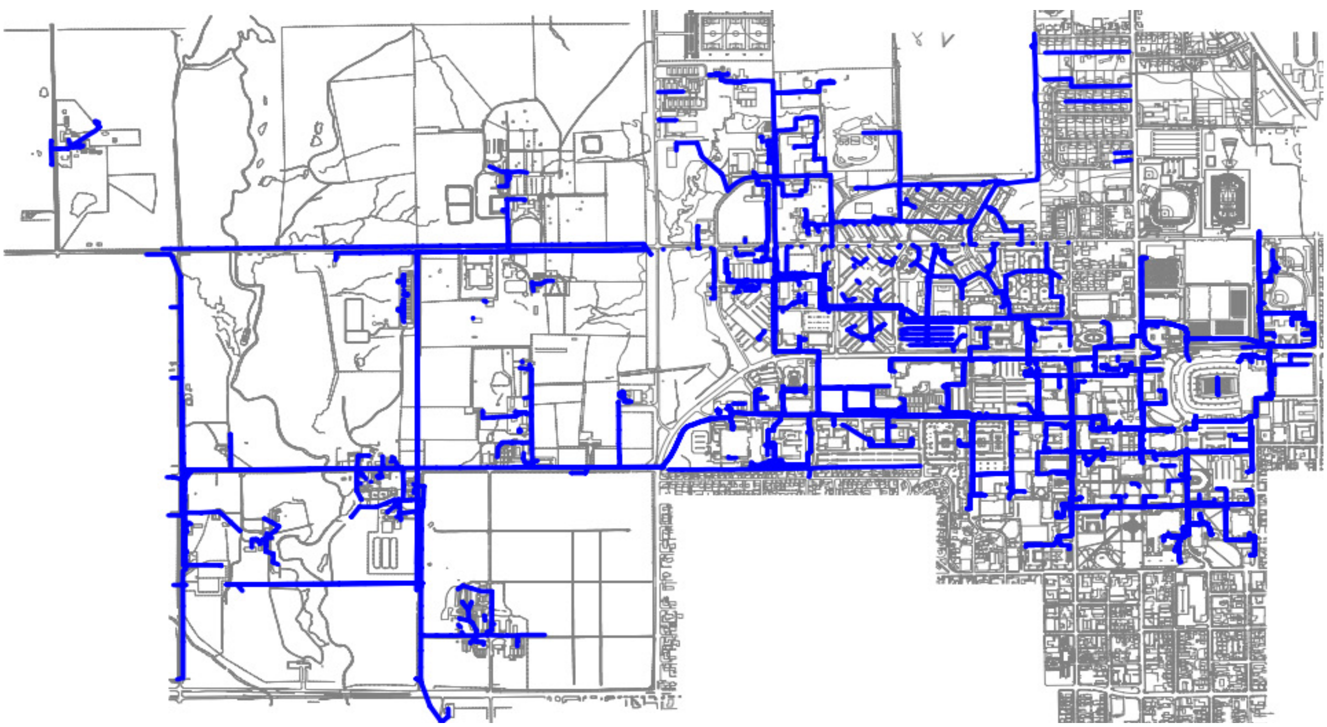


Figure 38, Existing Electrical Distribution

The three, 138-12.5kV, 20 MVA transformers at McElroy Substation provide a total of 60MVA capacity. The campus maximum demand (MD) at a typical power factor of 0.87 is 35MVA. Even with the loss of one OG&E transformer, there is adequate capacity and switching means available to assume the campus load. Figure 39 below shows the MD at each existing meter and the coincident maximum campus demand. The difference between the total of the maximum feeder demand and the coincident peak campus demand reflects the level of diversity that occurs between the campus electrical demand load.

2015 ELECTRICAL DEMAND		
OG&E METER	OSU FEEDER(S)	EXISTING MAX DEMAND (KW)
OSU 1	7, 8, 9, 10	1,236
OSU 2	1, 2, 3, 4, 5, 6, L	4,301
OSU 3 (1&2)	16*	3,594
OSU 3 (3&4)	21	4,454
OSU 4 (1&2)	17, 18*	5,238
OSU 4 (3&4)	13, 14, 15	5,806
OSU 5	26	10,913
OSU 6	24, 25	5,906
OSU 7	30+WCWP	7,526
COINCIDENT MAXIMUM CAMPUS DEMAND**		30,390

*These feeders provide power to the Power Plant.

**A summation of each feeder's MD would give an inncorrect 49.0 MW. The coincident MD is the greatest peak demand in 2015 for the entire campus. These were provided by the OG&E Energy Advisor application.

Figure 39, Existing Electrical Demand Table

The twenty year growth estimate of approximately 26% produces a future MD of 38.3 MW or 44MVA. Figure 40 below shows a projected peak demand for each area of the OSU Stillwater campus after feeder reconfiguration as well as the total projected campus peak. University Substation, a new 12.5 kV substation, is being constructed by OG&E to provide additional power for the campus including supplying a second feed for the Central Plant and the West Chilled Water Plant. The new substation will provide a level of redundancy, thereby increasing reliability. It includes two 20 MVA transformers with provisions for a third. Upon completion of the University Substation, the combination of the McElroy and University Substation will provide the campus with 100 MVA of available capacity with capability to grow to 120 MVA.

FUTURE ELECTRICAL DEMAND	
CAMPUS AREA	PEAK DEMAND (KW)
NORTH	11,897
SOUTH WEST	7,038
SOUTH EAST	17,595
WEST	1,759
TOTAL	**38,290**

Figure 40, Campus Future Electrical Demand

The campus power system will be fully redundant upon completion of the new University Substation, the Low Voltage Upgrade and the construction of a new Power Distribution Center. The entire campus power system will be capable of being served from either substation. The distribution system will have the capability of switching campus power feeders between substation power sources during a planned or unplanned power outage at either substation.

Figure 41, Electrical Load Growth, reflects the anticipated electrical demand on OG&E. Note the firm capacity does not change upon initial completion of the University Substation as this facility will initially only serve as a source of redundancy. Upon addition of a third 20 MVA transformer in FY24, the firm capacity will increase to accommodate future campus growth.

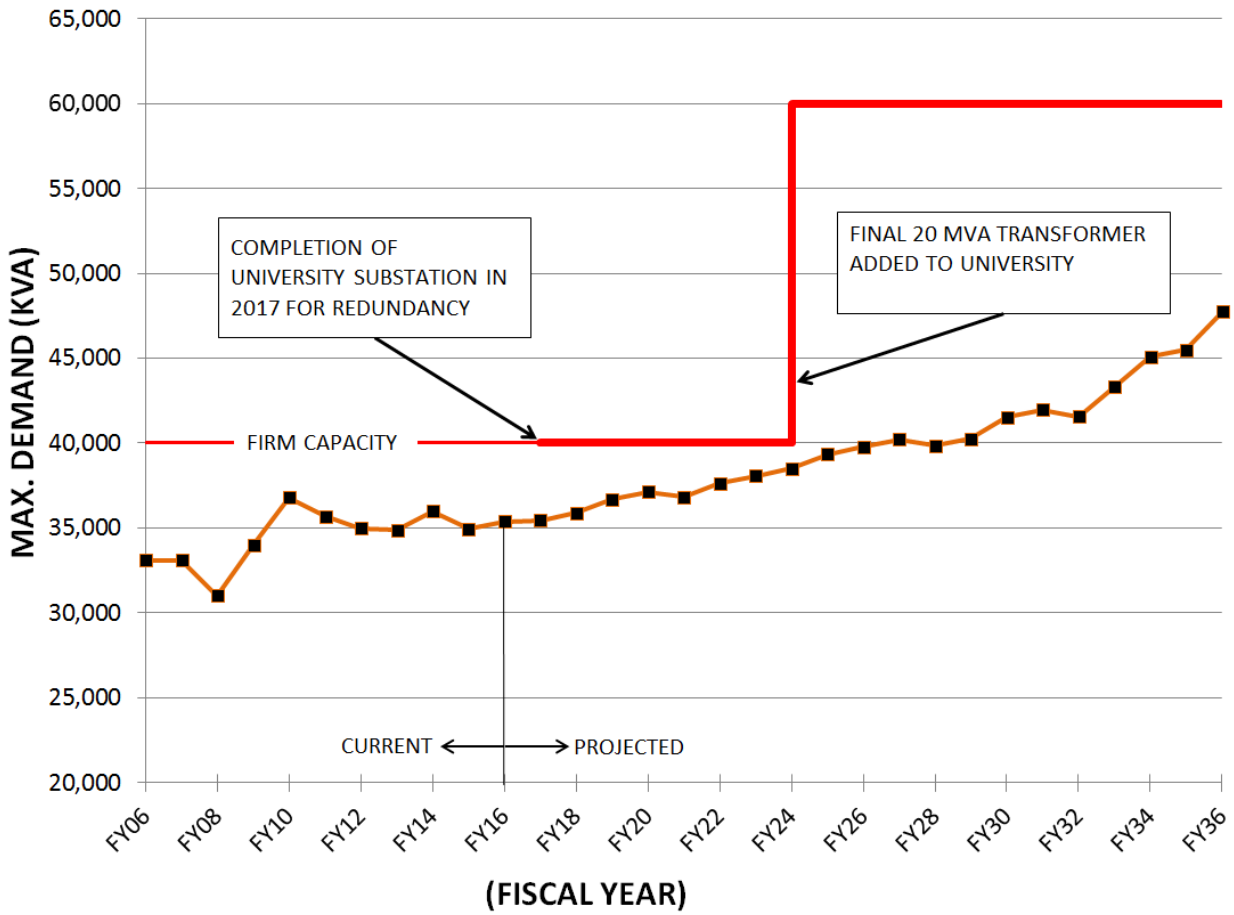


Figure 41, Electrical Load Growth

1.5.2 Potential Gas Turbine Power Generation Plant

As part of the development of the Utilities Master Plan, a conceptual study was performed to include an onsite campus gas turbine power generation system, located in Figure 42 below. It was determined that the addition of a 20 MVA Gas Turbine Power Generation Plant near the new University Substation should be considered as an option in FY33 at the end of the OG&E wind power agreement. The results are summarized below:

- Consideration in 2033 when OG&E Wind contract expires
- 20 MVA gas turbine generator
- Potential site located near the University Substation
- Reduce electricity costs through load demand limiting
- Provide base load power source for campus

Figure 42, Gas Turbine Power Generation Site

An analysis is recommended to be performed in the future that compares the costs and benefits of OSU generating their own power versus purchasing power from a local utility company.

For more information, please refer to Section 5.10 Gas Turbine Power Generation Plant of this report.

1.5.3 Electrical System Upgrade Costs

Many significant electrical upgrades are needed in the coming years. The need for upgrading the electrical distribution system is due to several factors which include, but are not limited to the following:

- The age of existing equipment, raceways, and conductors. The antiquated 2400 V system needs to be upgraded to the modern 12.47 kV distribution system serving the campus.
- The 2400 V power system originating from the Power Plant must be upgraded by connecting to the 12.5 kV system in order to demolish the Power Plant.
- The demolition of the OSU Poultry Substation cannot be accomplished until the remaining 2400 V feeders are connected to the 12.5 kV system and a new Power Distribution Center (PDC) is completed (Figure 34).
- After the new PDC is constructed, the 12.5 kV electrical distribution system can be reworked to redistribute existing loads and provide new feeders from McElroy and the University Substations and the PDC.
- The need for new electrical services to support future capital improvement projects such as the Performing Arts Center, Soccer, NOC, and the CEAT laboratory.

The cost of electrical upgrades needed in the next 5 years is anticipated to be approximately $37,236,429.

The cost of the electrical upgrades needed for the 20-year plan is $19,171,747, and the cumulative cost for 5-year plan + 20-year plan for electrical upgrades is $56,408,176.

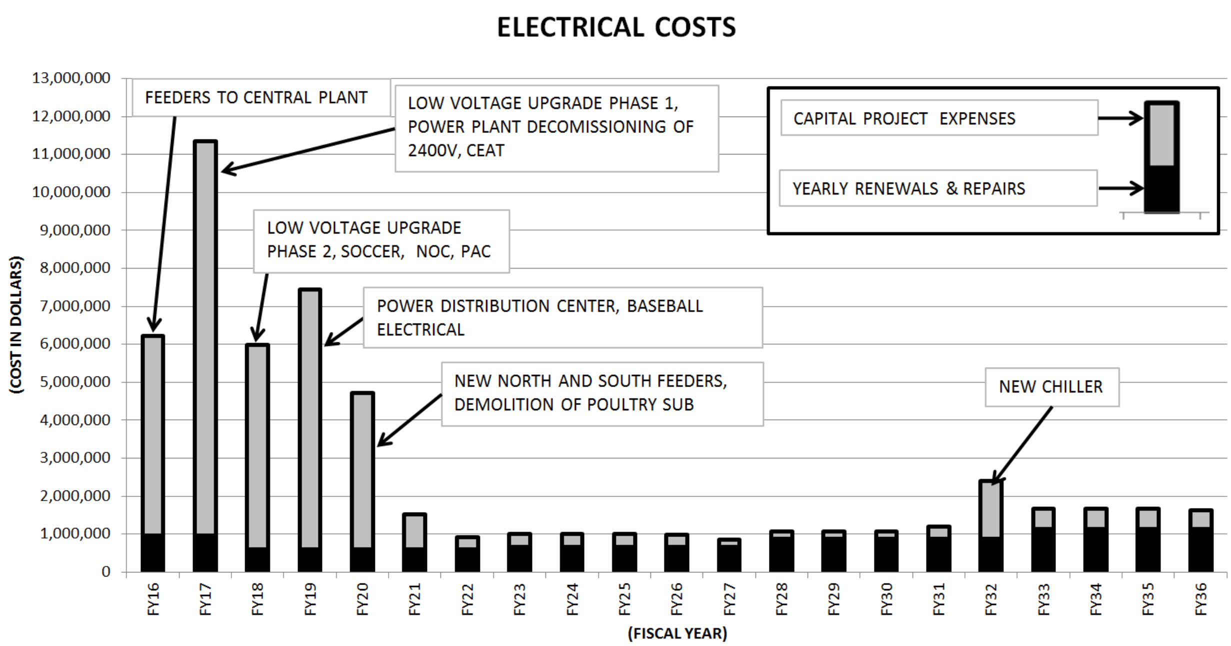


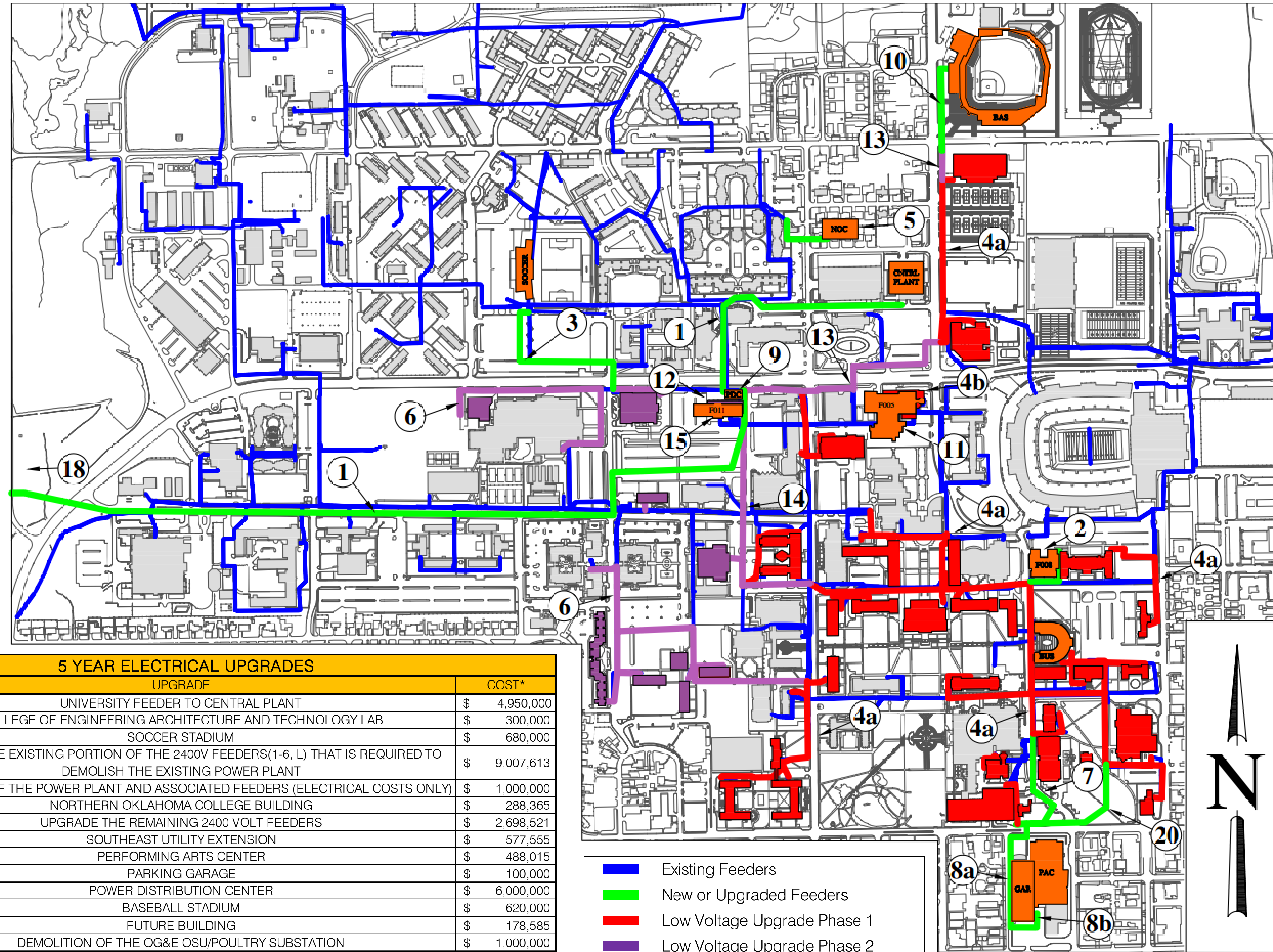
Figure 43, Electrical Costs

Figure 43 above shows the yearly estimated cost associated with currently needed upgrades, system maintenance and future system extensions required to support new capital projects. These values include the cost of installed electrical infrastructure, utility design fees, and annual renewals/replacements.

1.5.4 5 Year Plan, Electrical

The focus of this plan is to modernize the existing power distribution system, demolish the Power Plant, and demolish the Poultry Substation. The new Power Distribution Center (PDC) will replace the outdated Poultry Substation and solely distribute 12.5 kV feeders to campus from the new University Substation and the McElroy Substation. The PDC will ensure the electrical distribution will keep up with campus growth. In order to accomplish this 5 year plan, all 2400 V loads must be transitioned to the existing 12.5 kV system (Upgrades No. 4a and 6). Since the Power Plant provides approximately half of the 2400V feeders, it may only be demolished after all loads have been transitioned (Upgrade No. 4b). At this point, the PDC can be constructed (Upgrade No. 9) and the Poultry Substation can be demolished (Upgrade No.12).

Figure 44 summarizes the major upgrades, as well as, Capital Improvement Projects happening in the next 5 years.



5 YEAR ELECTRICAL UPGRADES			
No.	YEAR	UPGRADE	COST*
1	FY16	UNIVERSITY FEEDER TO CENTRAL PLANT	$ 4,950,000
2	FY17	COLLEGE OF ENGINEERING ARCHITECTURE AND TECHNOLOGY LAB	$ 300,000
3	FY17	SOCCER STADIUM	$ 680,000
4a	FY17	UPGRADE THE EXISTING PORTION OF THE 2400V FEEDERS(1-6, L) THAT IS REQUIRED TO DEMOLISH THE EXISTING POWER PLANT	$ 9,007,613
4b	FY18	DEMOLITION OF THE POWER PLANT AND ASSOCIATED FEEDERS (ELECTRICAL COSTS ONLY)	$ 1,000,000
5	FY18	NORTHERN OKLAHOMA COLLEGE BUILDING	$ 288,365
6	FY18	UPGRADE THE REMAINING 2400 VOLT FEEDERS	$ 2,698,521
7	FY18	SOUTHEAST UTILITY EXTENSION	$ 577,555
8a	FY18	PERFORMING ARTS CENTER	$ 488,015
8b	FY18	PARKING GARAGE	$ 100,000
9	FY19	POWER DISTRIBUTION CENTER	$ 6,000,000
10	FY19	BASEBALL STADIUM	$ 620,000
11	FY19	FUTURE BUILDING	$ 178,585
12	FY20	DEMOLITION OF THE OG&E OSU/POULTRY SUBSTATION	$ 1,000,000
13	FY20	RUN NORTH 12.5 KV FEEDER FROM POWER DISTRIBUTION CENTER	$ 915,701
14	FY20	RUN SOUTH 12.5 KV FEEDER FROM POWER DISTRIBUTION CENTER	$ 1,748,687
15	FY20	DASNR BUILDING	$ 178,585
16	FY20	INSTALL ELECTRIC METERS AT BUILDINGS WITH SIGNIFICANT LOADS (NOT DEPICTED)	$ 105,875
17	FY20	IMPROVE POWER DISTRIBUTION SYSTEM POWER FACTOR (NOT DEPICTED)	$ 165,000
18	FY21	WATER TREATMENT PLANT SUBSTATION CONNECTION TO NEW UNIVERSITY SUBSTATION 12.5 KV FEEDER (NOT DEPICTED)	$ 270,820
19	FY21	CONVERT WEST CAMPUS OVERHEAD 2400V SYSTEM TO 12.5KV (NOT DEPICTED)	$ 216,686
20	FY21	SOUTHEAST UTILITY LOOP FEED	$ 411,796

*Funding to be determined on a case by case basis.

Figure 44, 5-Year Electrical Map and Table

1.5.5 20 Year Plan, Electrical

It is proposed to set in place a replacement program for the remaining aging switchgear, transformers, cabling and duct banks. Funding to replace 5% of the aging system each fiscal year starting in FY 2016 for 20 years (thru FY36) will achieve the goal of 100% replacement of the system.

Capital Improvement projects forecasted in the 20 year plan contains 21 new buildings as shown in Figure 45. Most major duct banks will be installed within the 5-year plan, but extensions from this infrastructure will be required as new buildings are constructed. This includes new duct bank, 12.47KV feeders, switches, and service transformers to the buildings.

20 YEAR ELECTRICAL UPGRADES			
No.	YEAR	UPGRADE	COST*
1		REPLACE THE WEST CAMPUS DIRECT BURIED 12.47 KV FEEDERS WITH CONCRETE ENCASED DUCTBANKS WEST OF WALNUT AND NORTH OF TYLER. (NOT DEPICTED)	$ 96,694
2		UNIVERSITY SUB TO WEST CHILLED WATER	$ 327,085
3		SERETEAN CENTER	$ 219,175
4		FAMILY RESOURCE CENTER	$ 168,575
5	FY22-26	RESIDENCE HALL	$ 184,415
6		CLASSROOM BUILDING	$ 174,735
7		CLASSROOM BUILDING	$ 184,415
8		MUSEUM BUILDING	$ 178,585
9		MUSIC SCHOOL	$ 28,270
10		SUPPORT BUILDING	$ 178,585
11		EDMON LOW LIBRARY	$ 219,175
12	FY27-31	CLASSROOM BUILDING	$ 178,585
13		CLASSROOM BUILDING	$ 178,585
14		RESEARCH BUILDING	$ 174,735
15		RESEARCH BUILDING	$ 184,415
16		ARGICULTURE BUILDING	$ 219,175
17		CLASSROOM BUILDING	$ 168,575
18		CLASSROOM BUILDING	$ 178,585
19		CLASSROOM BUILDING	$ 168,575
20	FY32-36	NORTH MURRAY ADDITION	$ 229,185
21		POTENTIAL 20 MVA GAS TURBINE POWER GENERATION PLANT	TBD
22		POLICE BUILDING	$ 584,595
23		FIRE STATION	$ 399,465
24		INTRAMURAL FIELDS	$ 381,975

*Funding to be determined on a case by case basis.

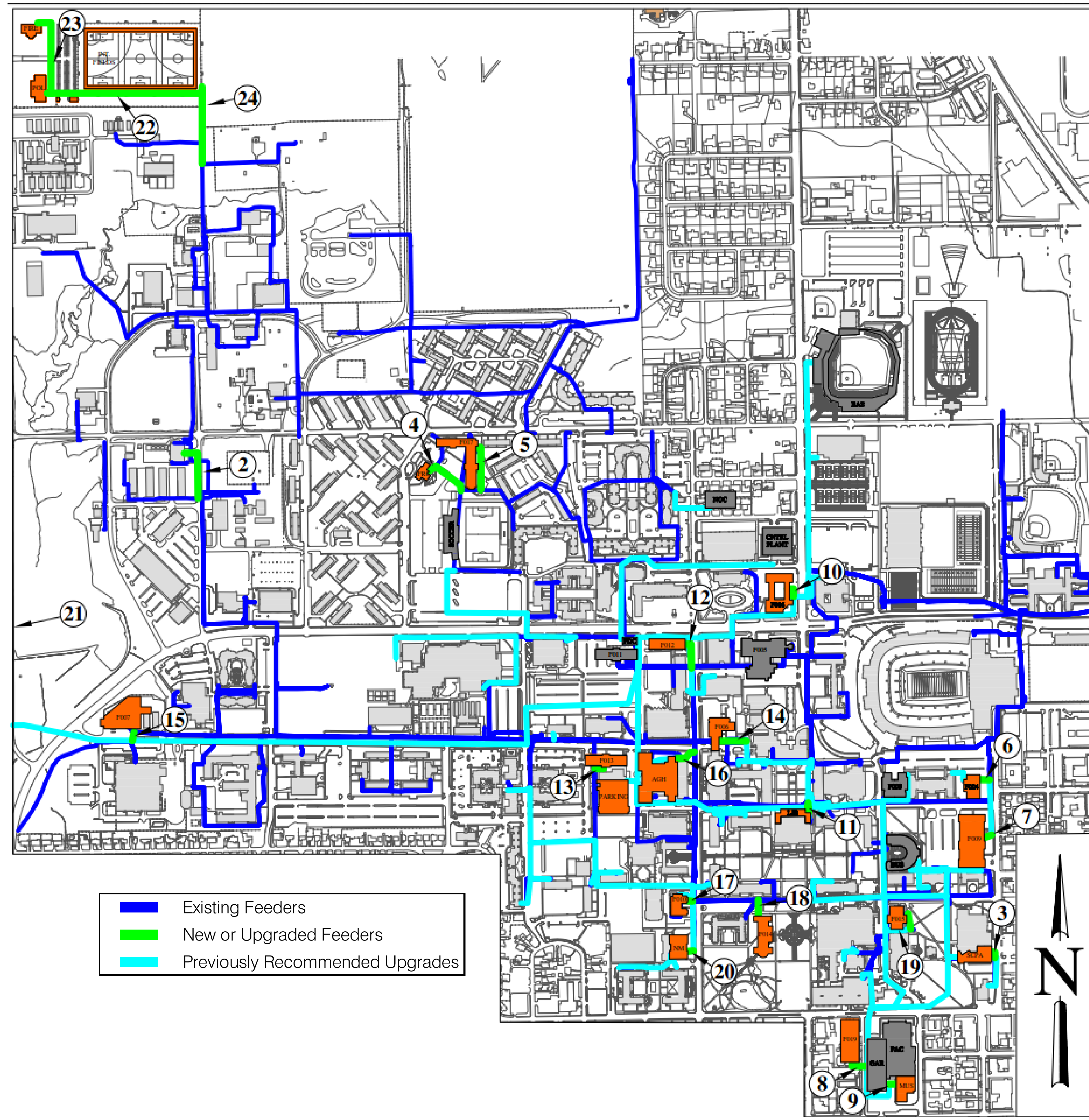


Figure 45, 20-Year Electrical Map and Table

1.6 Domestic Water System

To be developed by Energy Services and included within the 5-year plan period.

1.7 Sanitary Sewer System

To be developed by Energy Services and included within the 5-year plan period.

1.8 Natural Gas System

To be developed by Energy Services and included within the 5-year plan period.

1.9 Geographic Information System (GIS)

As a part of the FSB Utility Master Plan project, Olsson Associates was tasked with building a Geographical Information System (GIS), which included the Chilled Water, Steam, and Electrical Systems currently in place at OSU. Figure 46, Electrical System GIS Data Overlaid on Aerial Photograph shows an example of the Electrical System GIS data.

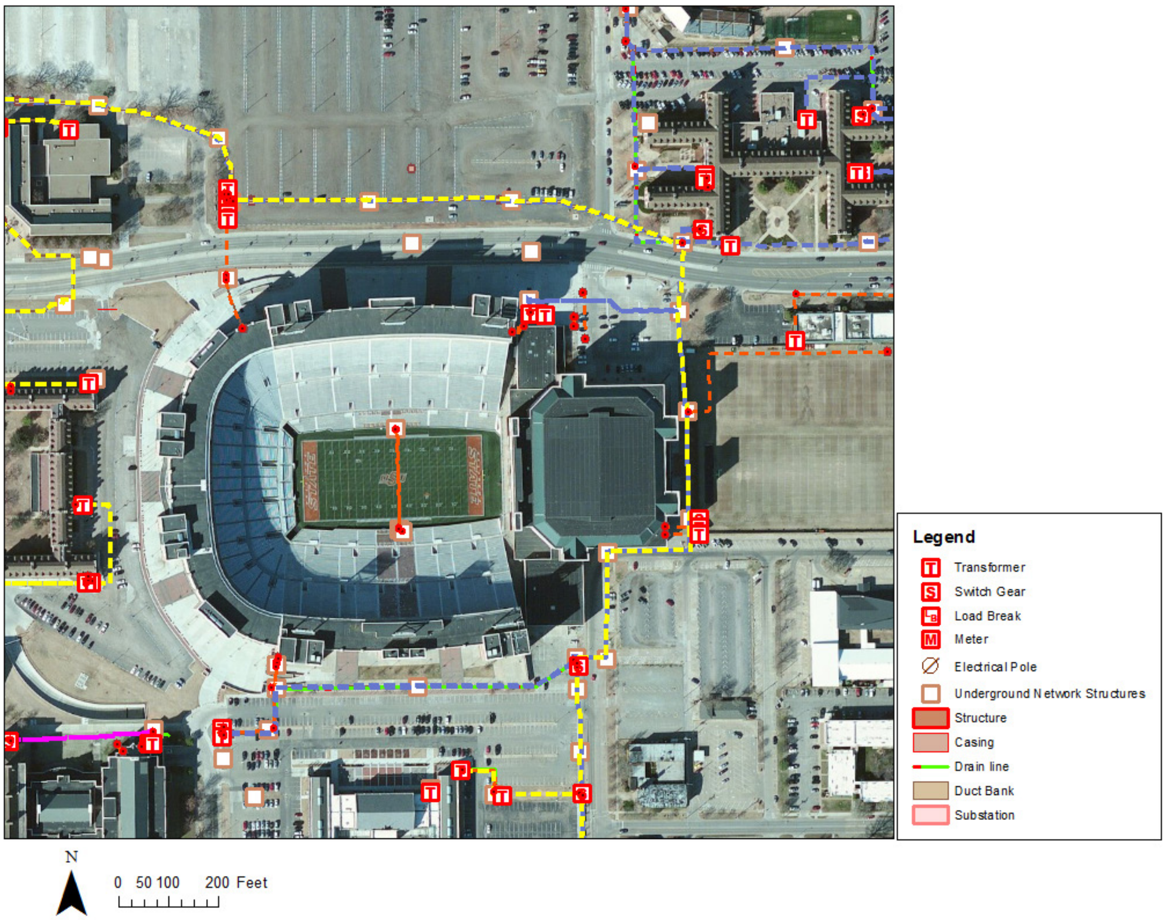


Figure 46, Electrical System GIS Data Overlaid on Aerial Photograph

Information for each of the three systems was stored in the ESRI Geodatabase format, with the database structure for each based on the ArcGIS Local Government Data Model. The database structure was designed by OSU Geospatial Systems and provided to Olsson Associates for their use. The ArcGIS add-in, Attribute Assistant*,* was used to automate population of information within the geodatabase of all three systems.

The GIS data for each of the three systems were developed by,

- Converting existing AutoCAD files into point and line features within the GIS.
- Populating GIS fields with information contained within the AutoCAD layers, (e.g., pipe size), where this information was available. Bringing information that was gleaned from text labels within the CAD files into the GIS using the ArcGIS Spatial Join command.

A Geometric Network was constructed for all three systems mapped in the GIS, which ensures that point features snap to the vertices of line features. The use of a geometric network also allows for further analysis, such as tracing of the network and the isolation of water main breaks. Figure 47, Steam System GIS Data Overlaid on Aerial Photograph provides an example of the Steam System network data.

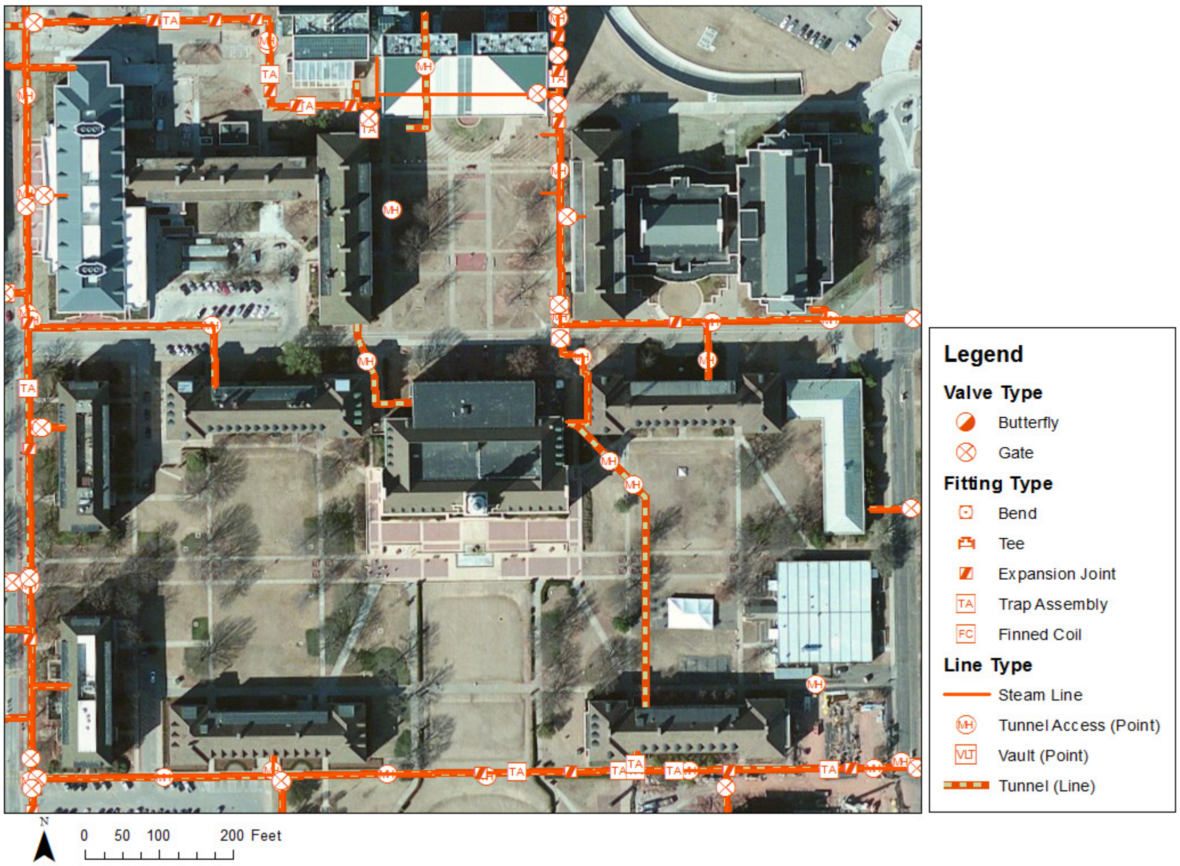


Figure 47, Steam System GIS Data Overlaid on Aerial Photograph

While the majority of the GIS data conversion was a straightforward process, there were some difficulties encountered in migrating some of the CAD data into the GIS. The most prominent issue discovered when converting the data was the existence of AutoCAD blocks drawn in the map with inconsistent insertion points. Such insertions were corrected on a case by case basis by using a Python script and the Field Calculator command within ArcGIS.

Upon completion of the GIS data entry, metadata was developed for each GIS feature class established during the project and delivered to Geospatial Systems for inclusion in OSU's GIS. Metadata provides information about the creation, ownership, history, purpose, and use of the GIS datasets. The metadata was developed using the Federal Geographic Data Committee (FGDC) Content Standard for Digital Geospatial Metadata (CSDGM) standard. The FGDC CSDGM is a widely accepted standard that has been used for many years. A workbook describing the FGDC CSDGM standard has been included in the end of this report. Refer to section 10, Geographic Information System (GIS) and Appendix W Geographic Information Systems (GIS) – Full Report, for further information in the full UMP report.

1.10 Conclusion

Figure 48, Central Plant Construction Progress, as of 6/13/2016

The Utility Master Plan has resulted in many enhancements which allow the University to prepare for future growth. A new Central Plant has been designed and is currently under construction (Figure 48). The Central Plant is being constructed with capacity to meet the heating and cooling needs of the campus for the next 20 years, and space has been allocated to meet needs beyond that time. The energy efficiency of the plant will result in an estimated $350,000 in annual utility savings, and an additional $120,000 per year in Operations & Maintenance savings is anticipated as a result of new equipment and Energy Services consolidation. The Central Plant has been designed to positively impact the architecture of the campus while freeing up a valuable site for a future building. In addition, the Central Plant has been designed to be an educational tool for many future generations of OSU students.

Dynamic steam, chilled water, and electrical models have been created and will be utilized by OSU engineers in the future to evaluate the impact of new buildings on campus utility systems. GIS models have been developed to provide an accurate database and mapping of all campus utilities which will assist with future planning.

Finally, 5-year and 20-year plans have been developed for steam, chilled water, and electrical upgrades necessary to rehabilitate existing systems as well as expand systems to future buildings. These plans provide a road map for future upgrades which has never before been available to the University.

Many factors contribute to the need for a utility upgrade, such as efficiency, undersized infrastructure, new construction, or agreements with local providers. It is recommended to properly plan for these necessary upgrades. As such, this report has quantified the anticipated upgrades. The total cost of upgrades is listed below for FY16-FY20 (Figure 49) and FY21-FY36 (Figure 50). A table that summarizes each upgrade is also provided on the following page in Figure 51.

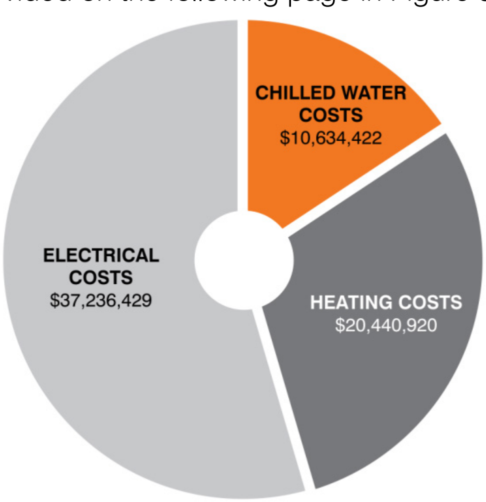


Figure 49, 5-Year Utility Upgrade Costs

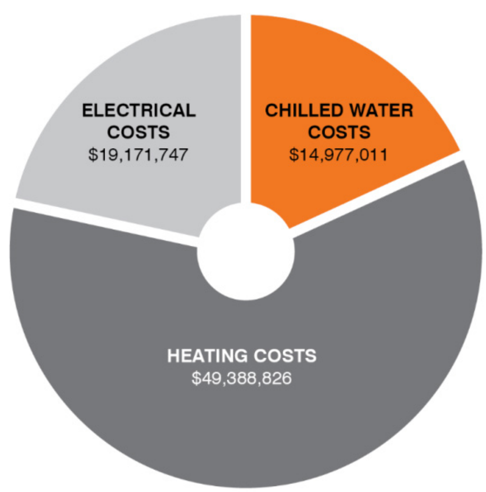


Figure 50, 20-Year Utility Upgrade Costs

UTILITY UPGRADE COSTS PER FISCAL YEAR						
YEAR	UPGRADES	COSTS				
		CHILLED WATER	HEATING	ELECTRICAL	R&R*	TOTAL
FY16	CENTRAL PLANT UTILITY DISTRIBUTION	$ 5,000,000	$ 5,000,000	$ 4,950,000	$ 1,821,309	$ 16,771,309
FY17	COLLEGE OF ENGINEERING ARCHITECTURE AND TECHNOLOGY LAB	$ 321,587	$ 74,011	$ 300,000	$ 2,256,486	$ 13,085,338
	BUSINESS BUILDING	$ 64,415	$ 33,515	-		
	EXISTING STEAM PIPE DEFICIENCIES	-	$ 246,478	-		
	UPGRADE 2400V FEEDERS 1-6, L	-	-	$ 9,007,613		
	WILLIAMS APARTMENT BUILDINGS, SOCCER STADIUM, FUTURE FAMILY RESOURCE CENTER (FRC), & FUTURE RESIDENCE HALL	$ 53,617	-	-		
	SOCCER STADIUM	$ 47,616	-	$ 680,000		
FY18	NORTHERN OKLAHOMA COLLEGE BUILDING (INCLUDES HEATING WATER LOOP INITIAL INFRASTRUCTURE)	$ 125,716	$ 1,335,585	$ 288,365	$ 2,024,965	$ 15,625,482
	UPGRADE REMAINING 2400V FEEDERS	-	-	$ 2,698,521		
	DEMOLISH POWER PLANT	$ 1,000,000	$ 1,000,000	$ 1,000,000		
	SOUTHEAST UTILITY EXTENSION	$ 1,900,568	-	$ 577,555		
	PERFORMING ARTS CENTER (PAC)	$ 142,771	-	$ 488,015		
	PARKING GARAGE	-	-	$ 100,000		
	EXISTING STEAM PIPE DEFICIENCIES	-	$ 2,943,421	-		
FY19	POWER DISTRIBUTION CENTER (PDC)	$ 81,045	-	$ 6,000,000	$ 1,757,690	$ 11,489,644
	FUTURE BUILDING	$ 111,740	$ 81,958	$ 178,585		
	EXISTING STEAM PIPE DEFICIENCIES	-	$ 2,658,626	-		
	BASEBALL ELECTRICAL	-	-	$ 620,000		
FY20	WILLIAMS APARTMENT BUILDINGS, FUTURE FRC, & FUTURE RESIDENCE HALL	$ 97,599	-	-	$ 1,690,863	$ 7,498,034
	WILLIAMS APARTMENT BUILDINGS & FUTURE RESIDENCE HALL	$ 96,255	-	-		
	WILLIAMS APARTMENT BUILDINGS	$ 121,672	-	-		
	DASNR BUILDING	$ 32,434	$ 356,744	$ 178,585		
	EXISTING STEAM PIPE DEFICIENCIES	-	$ 988,620	-		
	DEMOLISH POULTRY SUBSTATION	-	-	$ 1,000,000		
	12.5KV FEEDER NORTH	-	-	$ 915,701		
	12.5KV FEEDER SOUTH	-	-	$ 1,748,687		
	ELECTRIC METERS	-	-	$ 105,875		
	IMPROVE POWER FACTOR	-	-	$ 165,000		
FY21	WATER TREATMENT PLANT SUBSTATION CONNECTION TO NEW UNIVERSITY SUBSTATION	-	-	$ 270,820	$ 1,776,209	$ 3,841,966
	CONVERT WEST CAMPUS OVERHEAD 2400V SYSTEM TO 12.5KV	-	-	$ 216,686		
	EXISTING STEAM PIPE DEFICIENCIES	-	$ 1,166,455	-		
	SOUTHEAST UTILITY LOOP FEED	-	-	$ 411,796		
FY22-26	FAMILY RESOURCE CENTER	$ 23,593	-	$ 168,575	$ 12,775,481	$ 27,306,280
	RESIDENCE HALL	$ 54,603	-	$ 184,415		
	CLASSROOM BUILDING (F004)	$ 24,375	$ 60,962	$ 174,735		
	CLASSROOM BUILDING (F009)	$ 721,407	-	$ 184,415		
	MUSEUM BUILDING (F019)	$ 150,340	-	$ 178,585		
	FARM ROAD STEAM LINE UPGRADES	-	$ 4,858,540	-		
	EXISTING STEAM PIPE DEFICIENCIES	-	$ 2,547,837	-		
	HOT WATER TO RESIDENCE HALLS	-	$ 4,033,456	-		
	HOT WATER TO INDOOR PRACTICE FACILITY	-	$ 493,736	-		
	REPLACE WEST CAMPUS DIRECT BURIED WITH CONCRETE ENCASED DUCTBANK	-	-	$ 96,694		
	UNIVERSITY SUBSTATION FEED TO WEST CHILLED WATER	-	-	$ 327,085		
	SERETEAN CENTER	-	-	$ 219,175		
	MUSIC SCHOOL	-	-	$ 28,270		
FY27-31	SUPPORT BUILDING (F016)	$ 52,730	-	$ 178,585	$ 16,793,530	$ 21,749,979
	CLASSROOM BUILDING (F012)	$ 27,787	$ 35,789	$ 178,585		
	CLASSROOM BUILDING (F013)	$ 77,051	$ 59,050	$ 178,585		
	RESEARCH BUILDING (F006)	$ 29,660	$ 62,381	$ 174,735		
	EDMON LOW LIBRARY	-	-	$ 219,175		
	HOT WATER FOR RESIDENCE HALLS	-	$ 309,218	-		
	UPGRADES DUE TO STEAM TUNNEL CONDITIONS	-	$ 373,118	-		
	5th BOILER TO CENTRAL PLANT	-	$ 3,000,000	-		
FY32-36	RESEARCH BUILDING (F007)	$ 566,248	$ 134,555	$ 184,415	$ 20,679,164	$ 34,481,326
	AGRICULTURE BUILDING	-	-	$ 219,175		
	CLASSROOM BUILDING (F010)	$ 27,340	$ 50,238	$ 168,575		
	NORTH MURRAY ADDITION	$ 98,274	-	$ 229,185		
	CLASSROOM BUILDING (F014)	$ 27,787	$ 66,143	$ 178,585		
	CLASSROOM BUILDING (F015)	$ 35,508	$ 31,364	$ 168,575		
	FUTURE CHILLED WATER LOOP	$ 1,996,646	-	-		
	4th CHILLER TO CENTRAL PLANT	$ 5,000,000	-	$ 1,000,000		
	HOT WATER FOR RESIDENCE HALLS	-	$ 444,912	-		
	HOT WATER FOR UNIVERSITY COMMONS	-	$ 1,808,602	-		
	POLICE BUILDING	-	-	$ 584,595		
	FIRE STATION	-	-	$ 399,465		
	INTRAMURAL FIELDS	-	-	$ 381,975		

*INCLUDES ANNUAL RENEWAL AND REPLACEMENTS AND DESIGN FEE COSTS FOR CAPITAL IMPROVEMENT PROJECTS

Figure 51, Summary of Utility Upgrade Projects and Associated Costs