I. Executive Summary

A. Introduction

Project Description

The University of Wyoming (UW) commissioned Affiliated Engineers, Inc. and their sub-consultants to perform a Utility Master Plan (UMP). The UMP included:

- Identifying existing campus conditions
- Analyzing projected campus building growth, and
- Assisting in options development and recommendations that address system and utility deficiencies for the existing campus conditions and projected campus growth through year 2030.

The campus infrastructure and systems investigated in this utility master plan include:

- Steam and Condensate
- Chilled Water
- Controls Demand Opportunities and Compressed Air
- Electrical
- Domestic Water
- Irrigation
- Sanitary Sewer
- Storm Sewer

The UMP also included field surveying efforts and Geographical Information System (GIS) mapping. The surveyed utilities included storm and sanitary sewer manholes on and around campus and their inverts. The GIS mapping service included sub foot GPS positioning to identify all utilities noted above, and features on a current aerial photograph that would be represented within an updated campus geo-database.

Long Range Development Plan Project and Campus Projections

Concurrent to the UMP, the Long Range Development Plan (LRDP) project was performed by MIG, Inc. The LRDP provided estimates of projected building growth through the year 2050. These estimates were applied to specific opportunity areas shown in Figure I-A-1 below.

The projected load growth and opportunity areas were used in the UMP to determine impact on existing system capacities and campus infrastructure; however, the timeframes of the UMP an LRDP didn't coincide, resulting in excessive growth when applied to the UMP. Therefore the projected growth was adjusted through UW Staff input to suit realistic numbers of load growth through year 2030.

These realistic numbers were based on known projects and timeframes, as well as historic campus growth, resulting in approximate growth of around 500,000 SQFT per five year increment. Total building additions equal approximately 2 million SQFT by year 2030 that may require additional equipment to campus systems and utility corridor infrastructure. Preliminary proposed utility corridors for each utility are shown in Figure I-A-2.

Figure I-A-1- Long Range Development Plan Opportunity Areas

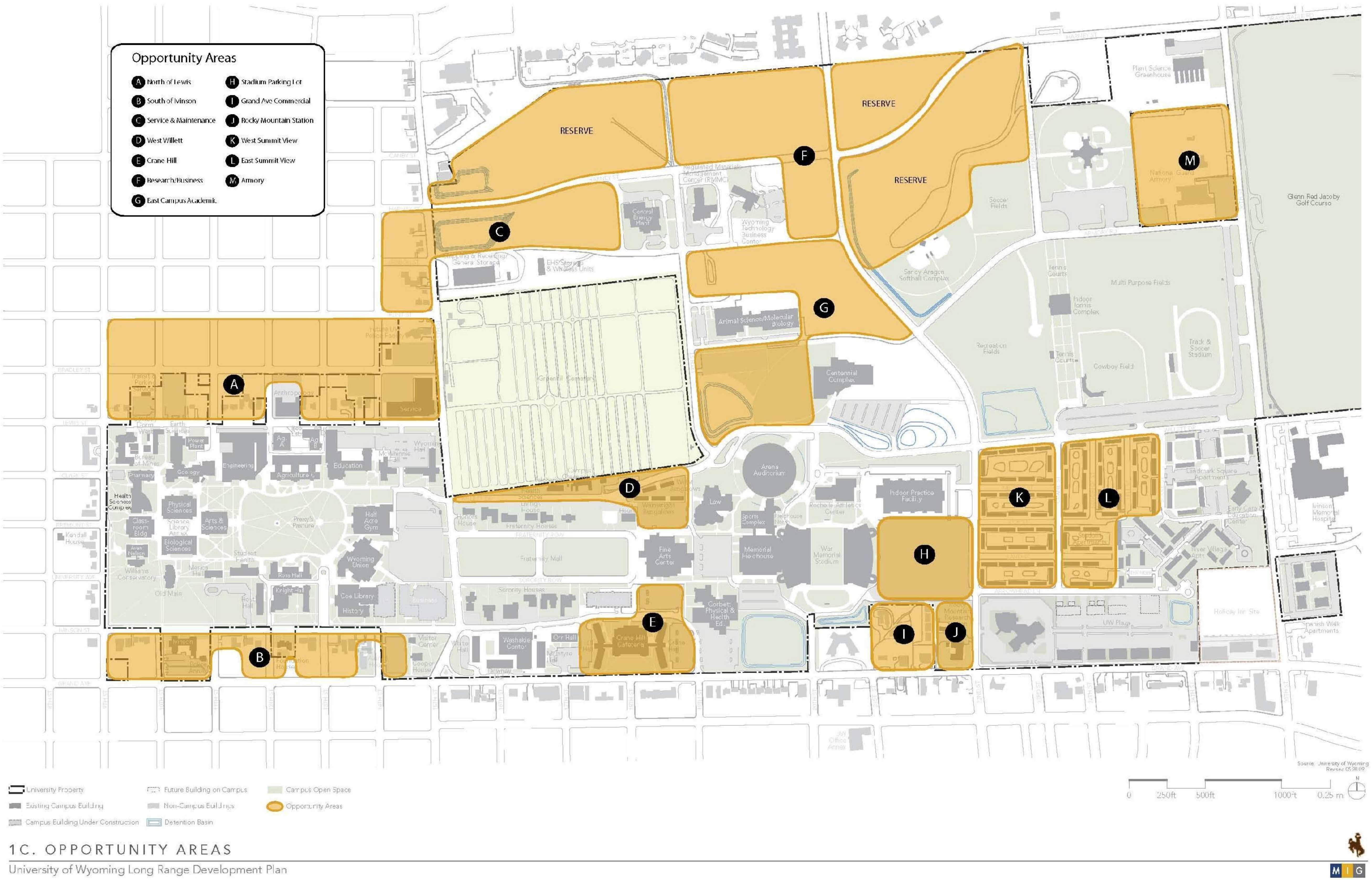
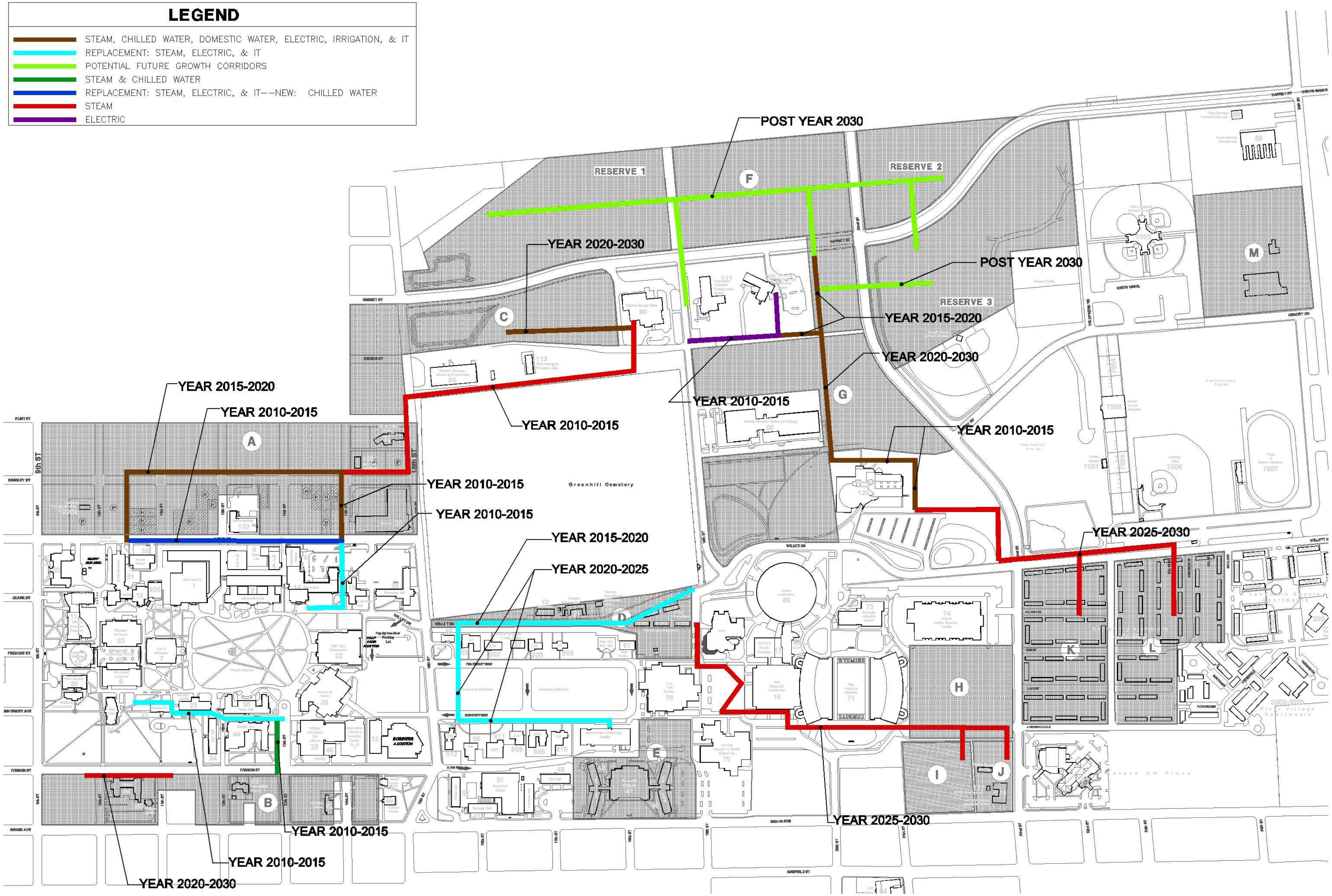


Figure I-A-2 – Proposed Upgrades and Projected Utility Corridors



Campus Green House Gas (GHG) Emissions Reduction

There is growing concern regarding Green House Gas (GHG) emissions; therefore, the UW is investigating options to accommodate load growth, while maintaining their commitment to the American College and University Presidents Climate Commitment (ACUPCC) to reduce GHG emissions produced on campus.

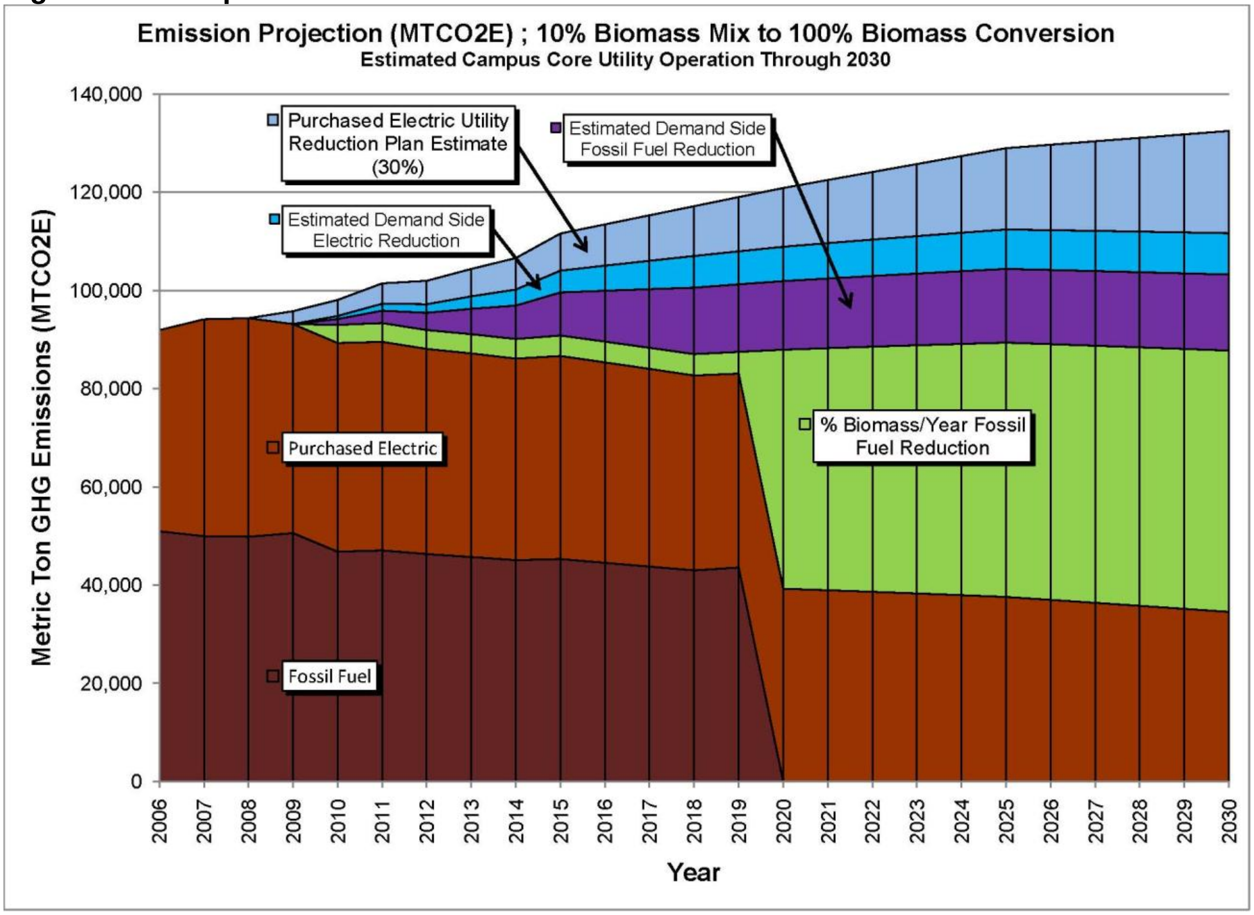
The UW developed a campus Climate Action Plan (CAP) as required by the ACUPCC. In accordance with the CAP, the UW is committed to reducing carbon use emissions (CO2E) 15% by year 2015 and 25% by 2020. The baseline year for emissions is 2005, as estimated from the Green House Gas Inventory performed for the UW in 2007.

The UMP addresses the University's commitment to reduce GHG emissions by presenting preliminary reduction strategies and economic analysis of the options. The reductions have been considered during the evaluations and recommendations have been made to suit the campus projections, preferred operations, and assist in reductions to GHG emissions. These recommendations and estimated GHG reductions include.

- Demand side reductions of thermal and electric use at buildings through upgrades made to building controls and building systems. The upgrades would optimize building operations, improve efficiencies and in turn impact the demand on the system that directly relates to fossil fuel or use of purchased electricity. The estimated GHG reductions are 14% and 23% at years 2015 and 2020 respectively for core campus utilities.
- Using multiple fuel sources at the CEP including coal and woody biomass is an option to effectively reduce emissions. Using woody biomass as the primary GHG reduction could be used starting with 10% biomass by weight eventually increasing to 100% by weight. Coal and other fossil fuels such as natural gas would be utilized as supplement sources if required. The estimated reductions are 5% and 53% at years 2015 and 2020 respectively for core campus utilities.

A graphical representation of the reductions noted above are included in Figure I-A-3 and compares the estimated reductions to net estimated metric ton carbon dioxide emissions (MTCO2E) projected on campus.

Figure I-A-3 – Options Estimated Emissions Reductions



As can be seen above the options primarily address fossil fuel use. To address indirect CO2E from purchased electric reductions the UW could consider wind turbine electric production or purchasing Green E Certified energy credits that would essentially offset the carbon production of this source. Energy credits may be appealing as compared to UW owned wind fields since there are no large capital expenditures for equipment or operation and maintenance cost. Either option will need to be weighed to determine if the cost to offset indirect CO2E is necessary to meet the UW's commitment to the ACUPCC and/or economic conditions brought on by a carbon tax.

<u>Projected Estimates</u>

The estimates defined within the tables herein are projected cost based on each section recommendations as they apply to the conditions and expansions recognized within the Utility Master Plan analysis. The utility expansions and or upgrades that will eventually be required to support building growth on campus are shown in Figure I-A-2 above. The estimates are in 2009 dollars, and include engineering and contingency costs.

When upgrades and new installations are considered to be implemented, detailed survey, design, cost estimates, and potential modeling of the new system and infrastructure will be required.

B. *Steam Heating/Process Load System*

Overview of Existing Campus System

Campus steam is produced at a Central Energy Plant (CEP), located at the corner of Harney and 19th St., and distributed through a steam piping network located in tunnels throughout campus. The combustion equipment and auxiliaries consist of fuel feed and storage silos, one (1) natural gas/distillate oil fired steam boiler, three (3) stoker grade coal/natural gas/distillate oil steam boilers, feed water systems, emissions reduction bag houses, and ash transfer systems for any spent coal fuel. The primary source of fuel is coal, which is currently mined within the state of Wyoming, delivered to the University, and ash hauled back to the mine for disposal. Natural gas and under special circumstances diesel fuel are utilized as backup fuel sources.

The CEP produces 125 psig (lb/in^2) high pressure steam for efficient distribution to pressure reducing valve stations (PRVs) located on campus. Each PRV reduces the pressure to as low as 12 psig for the building heating and generating building hot water. A significant amount of the reduced pressure steam is also transported within the tunnels to building equipment or secondary PRV sets that are part of heating and process steam systems.

Existing System Evaluations:

AEI and Ross Infrastructure (RI) investigated the University of Wyoming steam and condensate system to determine existing conditions of the CEP equipment and campus piping infrastructure. The investigation included a visual review of the system and components, interactive discussions with Physical Plant staff, and flow modeling of the current piping system that would enable the team to determine any deficiencies for the current CEP components and campus infrastructure. Flow modeling was performed through AFT Arrow which provides detailed analysis of compressible fluid flow through piping networks. The deficiencies that were recognized in the system are as follows:

- The fuel handling system requires additions and upgrades for efficient and safe operations for multiple fuel sources.
- The UW recently experienced coal quality issues due to excessive quantity of coal fines and high moisture content that led to operation inefficiencies as well as safety issues.
- The coal boiler stokers and fuel feed systems are nearing the end of their useful life expectancies.
- The steam exhauster utilized for ash removal is nearing its useful life and is a single point of steam system failure.
- Flow model results indicate that the west campus steam piping infrastructure is at or near capacity with little room for campus growth.
- Existing tunnels that house the steam piping are aging and are in need of replacement/major repair for personnel safety. Segments recommended for replacement or repair includes Biological Sciences to Knight Hall, the tunnel segment under the Engineering and Education buildings, and north of the Ag C addition. Approximate areas of these upgrades are shown in Figure I-A-2.
- There are limited access/egress locations within the existing tunnel. For improved personnel safety, shafts are recommended at approximately 250-300 ft intervals.

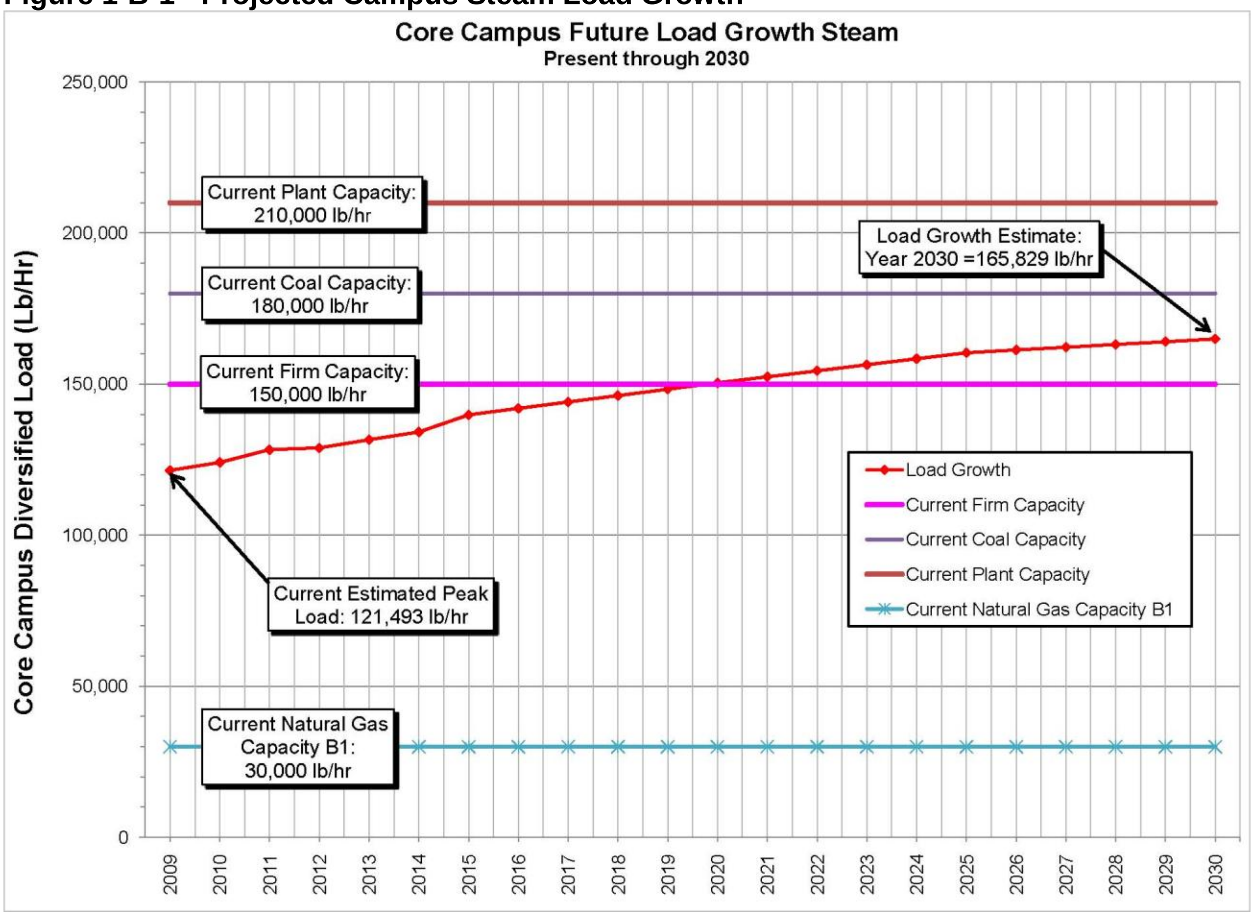
Each of the deficiencies above are recommended to be upgraded or replaced to improve campus system reliability, increase operation and maintenance efficiency, and eliminate potential safety issues. Estimates for these upgrades and timeframes for each are summarized within the conclusions at the end of the steam system section.

Building Load Analysis and Projected Outlook:

The steam system loads were developed through historic peak and diversified building data gathered from past higher education projects. Diversified loads represent swings that occur in individual buildings based on occupancy and building use and are applied to equipment capacities. Each diversified load was considered to be similar to and was applied to the existing UW campus buildings since individual buildings are not metered. These estimated loads were then compared and adjusted to trended CEP peak load data.

Future loading to the steam system was developed by applying the same historic data to the projected building areas and types defined through the LRDP and Physical Plant Staff. The load analysis is represented below in Figure 1-B-1 and compared to the existing equipment capacities. To accommodate campus requirements the firm capacity should be greater to or equal to the anticipated load growth of the campus through all years of operation. Firm capacity is defined as the total installed equipment capacity, minus the largest equipment capacity, assuming an equipment failure or out of service period. This capacity allows a fully functional system that satisfies peak campus loads.

Figure 1-B-1 - Projected Campus Steam Load Growth



As can be seen in the figure above, the current firm capacity is adequate until approximately year 2020 at which time capacity should be added or revised operations should take place to satisfy the campus growth.

The projected loads from the LRDP defined opportunity areas were applied to the existing fluid model and analyzed to determine if the existing infrastructure could support the additions. The following observations were made based on recommended operating parameters for proper function, safety and non-deteriorating operations.

- The campus infrastructure east of 15^{th} St. is adequate to sustain the additional loads in areas C through L defined in the LRDP map above in (Figure I-A-2).
- Area A, north of Lewis St. experiences a large immediate growth in demand load which cannot be supported by portions of the existing piping infrastructure.
- The existing steam infrastructure west of 15^{th} St. cannot sustain the load in area A, north of Lewis St., and Area B without extensive revisions to the existing infrastructure.

To supplement west campus deficiencies and support projected growth, construction of a high pressure steam line along the north edge of the cemetery, south along 15^{th} St. and into area A that connects to the existing west campus infrastructure is recommended. This utility route is indicated in Figure I-A-2. The advantages of this addition over replacement of existing infrastructure include:

- Eliminating extensive system shutdowns.
- The added infrastructure will serve as a redundant loop and support the existing west campus, as well as new buildings or additions in this area.
- The piping will supplement PRV capacity serving the west campus infrastructure.

System Options Analysis and Recommendations:

To address existing campus loads and deficiencies in projected campus loads, and GHG emissions reductions, multiple options were evaluated towards a realistic approach that satisfies campus capacity and operational requirements. Each defined option was based on the UW system size, preference toward staffing operation and maintenance of specific technologies and general knowledge from past studies performed by AEI and RI as to what technology and system would suit the campus. The options include:

- CEP upgrades to improve operation for intended fuel sources (Established from existing conditions noted above).
- Demand side reductions through campus controls and building system upgrades.
- Converting the CEP to a 100% natural gas fuel source.
- Conversion to coal and wood biomass mixture, beginning at 10% biomass.
- Increase to 100% wood biomass.
- Heat and Power: Natural-gas fired turbine generator which produces power and steam from waste heat. (Preliminary Biomass Fuel Evaluation)
- Heat and Power: Backpressure turbine steam electrical generation with waste steam for campus use (Preliminary Biomass Fuel Evaluation)

Each option consists of utilizing different fuel sources and technologies, as well as implementing and upgrading technologies that are well known to the Physical Plant staff. The results of the evaluations indicate that multiple systems and or alterations could be considered based on initial cost analysis, proven technology advances, and available fuel sources. The recommendations best suited for the UW operation include the following:

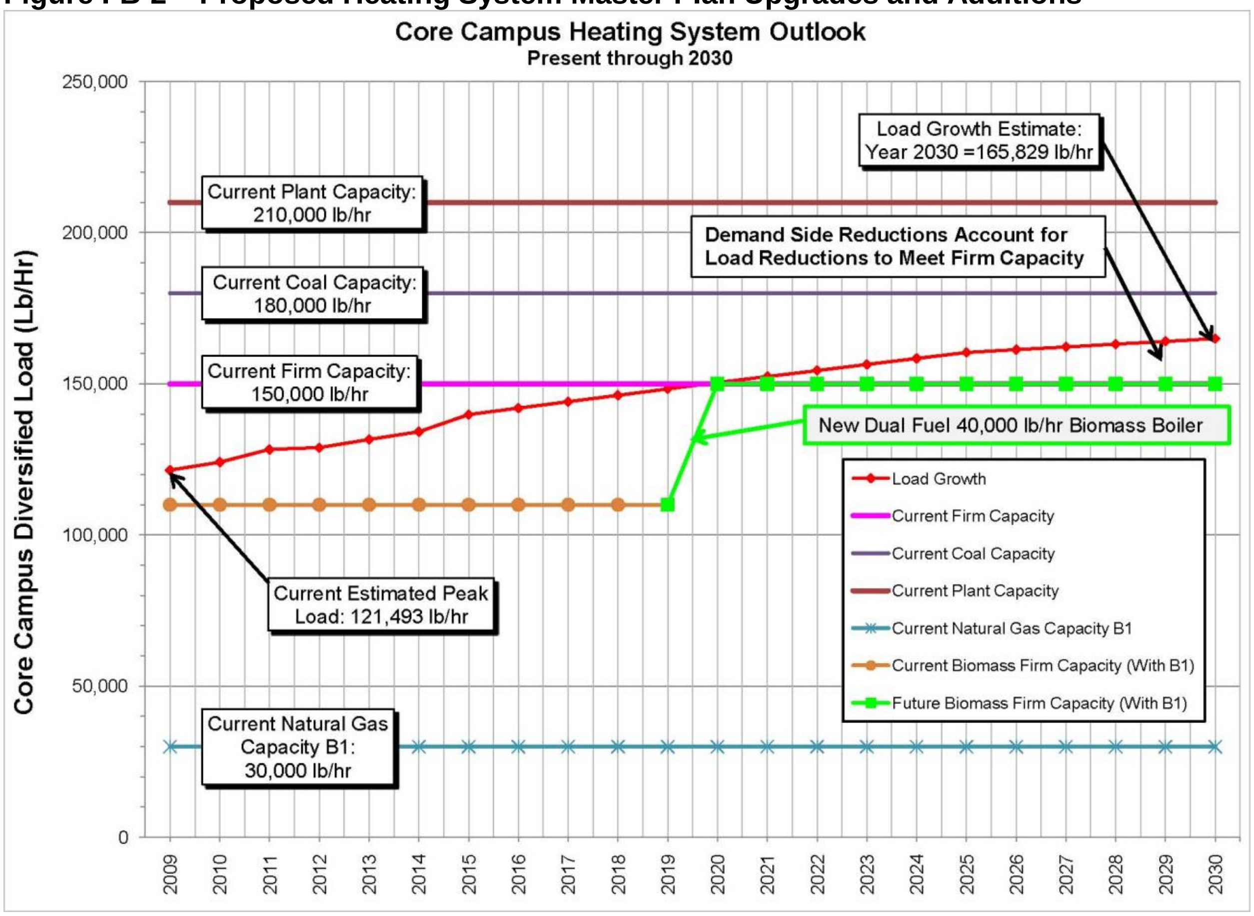
- Implement a schedule of upgrades to campus controls and building systems for demand side reductions. The upgrades will support an increase in building efficiency, reduce energy use, and reduce demand placed on the steam and electrical systems. Comparison of these upgrades to similar model data resulted in an estimated 17%

decrease in steam demand. The reductions can offset future campus steam load growth as well as decrease GHG emissions directly through fossil fuel reductions. Demand side reductions are further discussed in Section D below.

- Immediately implement upgrades to the CEP for coal quality and biomass use (upgrades apply to existing conditions noted above).
- Immediately implement testing of and potentially utilize biomass mixture to reduce GHG emissions.
- Add a boiler, wood chipper and auxiliaries in approximately year 2020 for multiple fuel use (coal/NG/Oil/biomass). The addition will allow options for GHG emissions reductions and add capacity to satisfy an increase in campus steam load.
- Upgrade existing boilers and auxiliaries to burn similar fuel sources to the new boiler noted above in approximately year 2020.

Projected steam demands, equipment revision, and equipment additions throughout the 20-year planning horizon are represented in Figure I-B-2. Note that the firm capacity of the plant in this figure does not meet the anticipated load growth. However, it is represented in this fashion to emphasize the importance of upgrading existing systems and controls as well as implementing efficient building design which will allow heat demand to be reduced closer to the plant's firm capacity. The selected boiler size should be adjusted as necessary at this time frame to meet campus loads as required.

Figure I-B-2 – Proposed Heating System Master Plan Upgrades and Additions



Conclusion

The system recommendations noted above are based on preliminary economics in present value dollars for installed and operating cost when compared to one another. The estimated project capital and approximate timeframe of the installations are summarized in Table I-B-1 and may be used as an initial guide by the UW for prioritizing the options. The estimated cost includes capital for design and engineering, equipment, installation and a 25% contingency.

Table I-B-1 – Projected Capital Cost and Timeframes of Heating System Projects.

CAMPUS UTILITY	ITEM #	DESCRIPTIONS	ESTIMATED CAPITAL COST BUDGET PER TIMEFRAME			
			2010-2015	2015-2020	2020-2025	2025-2030
CENTRAL ENERGY PLANT (CEP) STEAM SYTEM	1	E xisting Steam System and Auxiliary Upgrades	$1,500,000			
	2	Biomass Conversion and Additon of dual fuel biomass boiler with chip yard.		$42,200,000		
		TOTAL	$1,500,000	$42,200,000	$0	$0
EXISTING STEAM UTILITY	1	Replace section of existing utility tunnel with new tunnel between Biological Sciences and Knight Hall.	$3,800,000			
	2	Install new utility tunnel and ductbank underneath Lewis Street to replace the existing utility tunnel underneath Engineering and Agriculture.	$7,200,000			
	3	Install new utility tunnel and ductbank to replace direct buried piping between the Arena and Willet Pit.		$5,360,000		
	4	Install new utility tunnel and ductbank to replace existing tunnel along Sorority Row, north along 15th Street from Sorority Row to Willet Pit.			$8,000,000	
		TOTAL	$11,000,000	$5,360,000	$8,000,000	$0
NEW STEAM UTILITY	1	Install new direct buried piping from CEP to development area A, from existing tunnel to development area B, to Berry Building, and from Centenniel Complex to new Visual Arts.	$2,946,000			
	2	Install new utility tunnel and ductbank in development area A from Lewis Street to Bradley Street.	$1,460,000			
	3	Install new utility tunnel and ductbank in development area A and from Wyoming Business Technology Center into development area B and north to Harney Street.		$8,496,250		
	4	Install new direct buried piping from the CEP to development area C.		$308,000		
	5	Add piping to the existing utility tunnel from Law to Corbett Physical Education for expansion.			$283,500	
	6	Install new direct buried piping from Corbett Physical Education to development areas I and J and from new Visual Arts to development areas K and L.			$3,266,750	
	7	Install new direct buried piping north of Ivinson to serve development area B.			$367,500	
	8	Install new utility tunnel from CEP to area F and from Animal Science to Wyoming Technology Business Center.			$8,420,000	
		TOTAL	$4,406,000	$8,804,250	$12,337,750	$0
TOTAL COST		TOTAL	$16,906,000	$56,364,250	$20,337,750	$0

C. *Cooling Systems*

Overview of Existing Campus System

The current building cooling systems on campus consists of a mixture of systems and include:

- Small local building chillers or Direct Refrigerant Expansion (DX) chillers,
- Direct evaporative cooling, and
- Chilled water, produced at the CEP and fed to buildings via buried piping.

The chilled water system serves the majority of the campus cooling requirements. Several more recent buildings employ evaporative cooling. DX is primarily used as a backup cooling source when chilled water is not available in critical high load areas including data centers.

The chilled water system at the CEP consists of two water cooled electric driven centrifugal chillers, two plate and frame heat exchangers, and three primary chilled water pumps. The chillers are sized for 800 and 1200 tons and are utilized during seasonal peak campus loads. The plate and frame heat exchangers serve as a free cooling system during seasonal low campus loads. The pumps are operated to satisfy campus fluctuating loads.

The condenser water system for the chilled water system rejects heat from the chillers to the atmosphere, and consists of two 1200 ton cooling towers and three condenser water pumps. One cooling tower is a packaged tower and basin system, while the other is a field erected unit.

Existing System Evaluation

AEI investigated the UW's chilled water system to determine existing conditions of the CEP equipment and campus infrastructure. The investigation included a physical review of the system and components, interactive discussions with Physical Plant staff, and flow modeling of the current piping system that enabled the team to determine any existing system deficiencies. Flow modeling was performed through AFT Fathom which provides detailed analysis of non-compressible fluid flow through piping networks

Chilled water equipment was upgraded or replaced in 2008 and 2009. The new equipment is currently being commissioned for proper campus operations. Generally the chilled water system is in good shape with exception to the following deficiencies:

- Equipment firm capacity is short of the peak campus load (further noted below in Building Load Analysis and Projected Outlook).
- Part of the condenser water system does not incorporate a means to prevent icing conditions in a climate that has this potential.
- The condenser pumps do not promote full equipment redundancy.

The existing campus infrastructure was reviewed according to age of the system pipe and fluid modeling. There are no notable deficiencies that resulted from this evaluation beyond piping that was installed in 1968 near Physical Sciences, Biological Sciences, Classroom, and Earth Sciences. The piping installed in this timeframe may be nearing the end of its useful life and should be replaced as required from failures or with new projects.

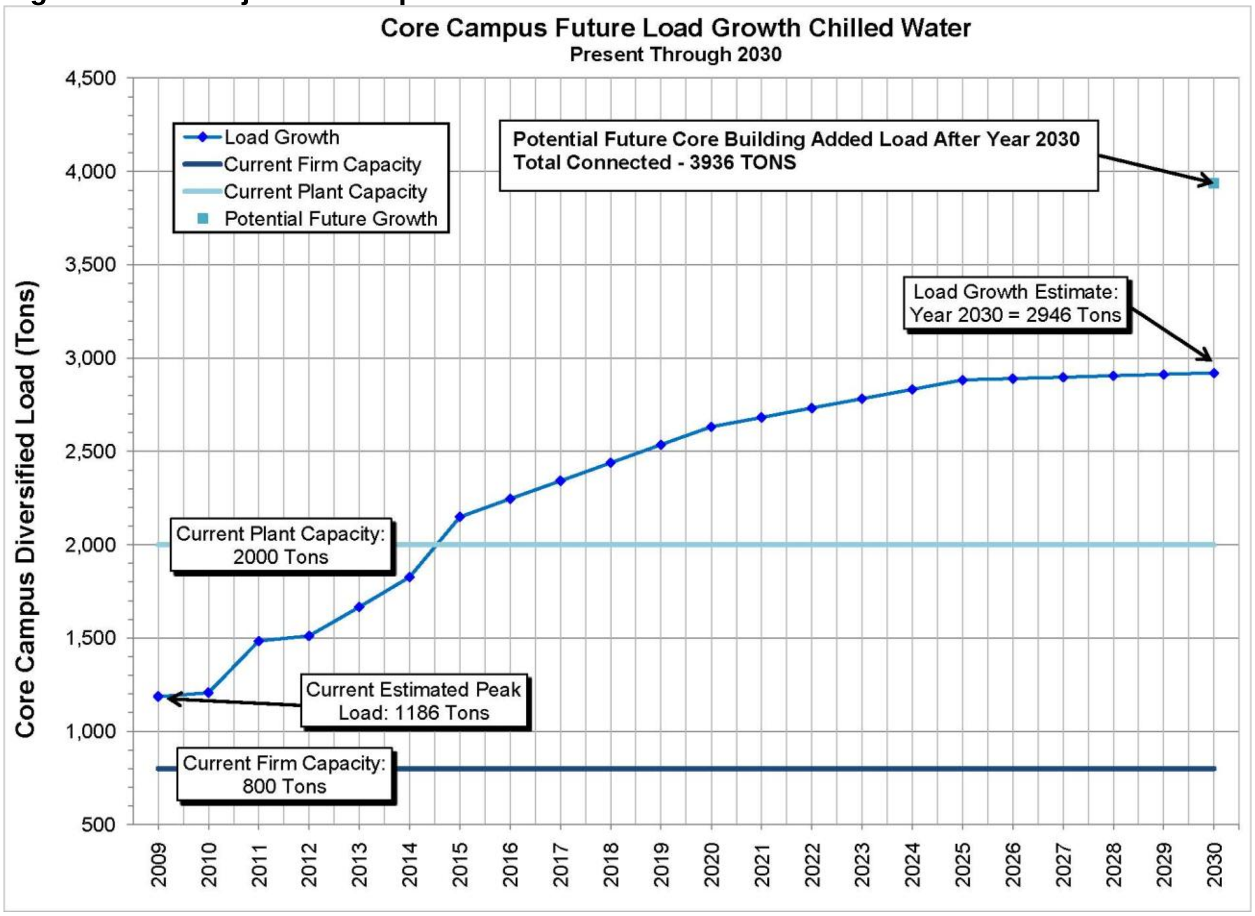
Evaporative cooling systems are suitable due to the consistent low wet bulb temperatures (dry air) throughout the spring, summer and fall seasons. The UW currently utilizes direct evaporative cooling at multiple buildings, and implements a control scheme that has been successful for operations of the units and buildings to control the known issues with evaporative cooling, such as mold from the moist air content.

Building Load Analysis and Projected Outlook:

The chilled water system loads were developed through historic peak and diversified building data gathered from past higher education projects. Diversified loads represent swings that occur in individual buildings based on occupancy and building use and are applied to equipment capacities. Each diversified load was considered to be similar and was applied to the existing UW campus buildings since individual buildings are not metered. These estimated loads were then compared and adjusted to trended CEP peak load data.

Future loading to the chilled water system was developed by applying the same historic data to the projected building areas and types defined through the LRDP and Physical Plant staff. The load analysis is represented below in Figure 1-C-1 and compared to the existing equipment capacities and firm capacities.

Figure I-C-1 - Projected Campus Chilled Water Growth



As can be seen in the figure above the current firm capacity is inadequate and the projected loads exceed equipment capacity at approximately year 2015. Timeframes when capacity is exceeded should consider equipment additions and revised operations to satisfy loads through all operations.

Options Analysis and System Recommendations

The cooling systems on campus are diverse and given campus use and climate are questioned in terms of type of systems that should be utilized. System options were approached to address deficiencies and implement systems that are consistent with the UW Physical Plant staff experience, and preferred direction. The following are recommendations to suit campus operations and capacity deficiencies:

- Implement a schedule of upgrades to campus controls and building systems for demand side reductions. The upgrades will support an increase in building efficiency, reduce energy use, and reduce demand placed on the chilled water produced by electric motor driven centrifugal compressors on the chillers. Comparison of these upgrades to similar model data resulted in an estimated 22% decrease in chilled water production. The reductions can be applied back to future campus growth as well as a decrease in GHG emissions indirectly through electric utility reductions. Demand side reductions are further discussed in Section D below.
- Consider using evaporative cooling for each new building or renovation on campus based on building type, functionality and location of chilled water utility. Implementing this option over use of chilled water will delay the capital necessary to expand the chilled water system as noted in phase 2 of the options noted below
- Add chilled water capacity in phases to satisfy campus firm capacity for the current and estimated projections. The options consider locations and quantity of load added to the system as follows:

  Option 1

  - Phase 1: Add one (1) 1200 ton chiller, cooling tower, and auxiliaries within a small CEP plant expansion
  - Phase 2: Add one (1) 800 ton chiller in a larger plant expansion that can house 1600 tons.
  - Phase 3: Revise existing chiller plant pumping equipment and campus infrastructure to maintain acceptable pressure and velocity conditions.
  - Phase 4: Add an 800 ton chiller to fill the 1600 ton capacity noted in phase 2 of this option.

  Option 2

  - Phase 1: Add one (1) 1200 ton chiller, cooling tower, and auxiliaries within a small CEP plant expansion
  - Phase 2: Add 1600 tons of capacity at a new West Campus plant that can house 2400 tons and a west campus electrical distribution center defined below.
  - Phase 3: Add an 800 ton chiller to fill the 2400 ton capacity noted in phase 2 of this option.

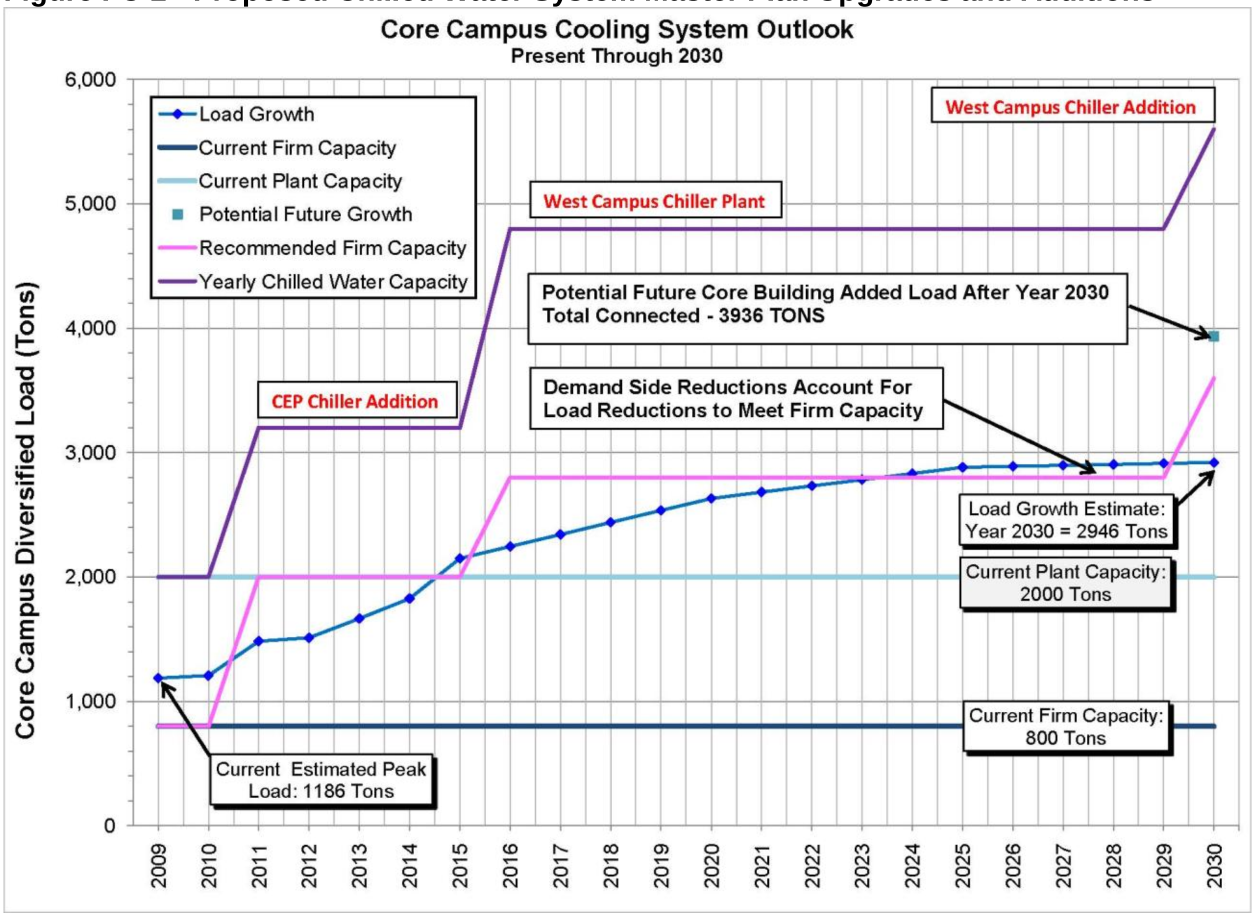
Through cost comparisons and overall campus system operation, addition of a West Campus plant described in ***Option 2*** is recommended over ***Option 1*** due to the following:

- The system provides full redundancy and firm capacity through 2030.
- Infrastructure upgrades are not required which eliminates the need for lengthy system shutdowns from new infrastructure installation.
- Addition of a West Campus plant maintains the remaining useful life of the equipment installed at the CEP in 2008.

- Pumping head and energy use is not increased at the CEP
- Load points shift to serve the campus equally from each plant direction which results in reduced head pressure required by pumps and in the system.

A graphical representation of a timeline for the projected load and capacity upgrades is represented in Figure I-C-2. It should be noted that the firm capacity of the plant in this figure does not meet the anticipated load growth. However, it is represented in this fashion to understand the importance of upgrading existing systems and controls as well as implementing efficient new building design which will allow cooling demand to be reduced closer to the plant firm capacity. The chiller tonnage should be adjusted as necessary at each added capacity time frame to meet campus loads as required.

Figure I-C-2 - Proposed Chilled Water System Master Plan Upgrades and Additions



Conclusion

The system recommendations noted above are based on preliminary economics of installed cost in present value dollars. The existing system configuration and function will not be compromised by the installation of any new equipment. The estimated values and approximate timeframes of the installations are summarized in Table I-C-1 which may be used as an initial guide towards project implementation that the University of Wyoming chooses to pursue.

Table I-C-1 – Projected Capital Cost and Timeframes of Chilled Water System Projects

CAMPUS UTILITY	ITEM #	DESCRIPTIONS	ESTIMATED CAPITAL COST BUDGET PER TIMEFRAME			
			2010-2015	2015-2020	2020-2025	2025-2030
CENTRAL ENERGY PLANT (CEP) CHILLED WATER SYTEM	1	Increase Chiller Firm Capacity at CEP	$2,600,000			
	2	Add new 2400 ton chilled water plant with 1600 tons capacity		$5,850,000		
	3	Add an 800 ton chiller at the West Campus Plant to increase to campus firm capacity.				$2,080,000
		TOTAL	$2,600,000	$5,850,000	$0	$2,080,000
NEW CHILLED WATER UTILITY	1	Install new direct buried chilled water piping in development area A underneath Lewis Street and north to Bradley Street, from Centennial Complex to Visual Arts, and to Crane Hill Hall.	$1,172,150			
	2	Install new direct buried chilled water piping in development area A from Lewis Street Alcove to Bradley Street and underneath Bradley Street, from CEP to development area C, and from Wyoming Technology Business Center to development area F.		$1,318,150		
	3	Install new direct buried chilled water piping to development area B and G.			$391,500	
	4	Install new direct buried chilled water piping from CEP to development area F.			$810,000	
		TOTAL	$1,172,150	$1,318,150	$1,201,500	$0
TOTAL COST		TOTAL	$3,772,150	$7,168,150	$1,201,500	$2,080,000

D. Control Upgrade Demand Side Reductions and Compressed Air System

Overview of Existing Campus System

The campus currently employs a mixture of legacy DDC (Direct Digital Control) and pneumatic building controls. The majority of DDC controls have been provided only for major mechanical systems which provide limited ability to efficiently operate each building and the campus as a whole. Where possible existing building DDC systems are monitored at a central maintenance workstation for troubleshooting purposes. Recently the UW has installed a Johnson Controls ADX server which is utilized for monitoring of controls for new buildings and building upgrades.

The compressed air system is currently utilized for pneumatic building controls and process loads on campus. The system equipment consists of three equally sized air compressors with a capacity of 320 standard cubic feet per minute (SCFM) each. Two compressors are located within the Engineering building and the third at the CEP. The compressed air is transported to campus buildings through infrastructure routed within the campus steam tunnels. The compressors operate through individual pressure sensors to maintain piping pressures that equate to campus compressed air use.

Existing System Evaluation

AEI performed a cursory survey of four buildings on campus to gain an understanding of the current conditions of Mechanical, Electrical, and Plumbing systems and the method of control that is used for each. The buildings evaluated include Fine Arts, Arts and Sciences, Physical Science and the Wyoming Union.

For the buildings surveyed, there is no consistent control system or strategy, within a single building or between buildings that enables the energy efficient operation of individual buildings or campus as a whole.

AEI also investigated the University of Wyoming compressed air system to determine existing conditions of equipment and campus piping infrastructure. The investigation included interactive discussions with Physical Plant staff, flow modeling of the current piping system, and review of infrastructure that would enable the team to determine any deficiencies for the current equipment and campus infrastructure.

From the analysis and fluid modeling there are no notable concerns or deficiencies within the compressed air system. Piping infrastructure should be replaced as required by failures, leakage, or new building projects.

Building Load Analysis and Projected Outlook

The existing system loads were developed from similar building historic loads and applied to the existing campus buildings. The resultant load was compared to existing system trends and compressor operations.

Future loading to the compressed air system was developed by applying the same historic loads to the projected additional building areas and types defined through the LRDP and Physical Plant staff direction. The load was then adjusted to represent the trend of Pneumatic controls being replaced by or installed as Direct Digital Control with electric actuation.

Conclusion and System Recommendations

To gain full benefit of the demand side opportunities it is recommended that campus buildings currently using outdated pneumatic and legacy DDC controls be upgraded to a modern DDC control system implementing energy saving control strategies. These strategies include but are not limited to the following:

- Convert constant volume air/water systems to variable volume.
- Implement occupancy schedules for mechanical systems.
- Implement demand side air reset control.
- Implement automated lighting controls (occupancy sensors, daylight harvesting, automated window shades, etc.)
- Re-commission and rebalance all mechanical systems.
- Interface new and upgraded building controls to the ADX server and evaluate the server for any upgrades required for complete campus monitoring.

These recommendations were then analyzed against similar building modeling efforts recently completed for a separate campus to help understand the energy reductions that are potentially available from the upgrades. The results indicate an approximate demand reduction of 17% steam, 22% chilled water, and 7% electrical which directly relates to campus load reductions, energy savings, and reductions to GHG emissions.

A summary of estimated capital cost towards controls and building systems improvements bulleted above is shown in Table I-D-1. The capital also represents demand side reduction recommendations applied to the heating, cooling, and electrical sections described herein. These values were determined based on particular buildings and applied to the campus as a whole as a preliminary value and historically, control and system adjustments have typically produced results that are economically justified and improve building operations. When upgrades and new installations are considered to be implemented, detailed survey, potential energy modeling, design, and cost estimates of each building and portion of infrastructure will be required

Table I-D-1 – Projected Capital Cost and Timeframes of Building Controls and System Upgrades

CAMPUS UTILITY	ITEM #	DESCRIPTIONS	ESTIMATED CAPITAL COST BUDGET PER TIMEFRAME			
			2010-2015	2015-2020	2020-2025	2025-2030
CONTROLS UPGRADES	1	Controls and Sytem upgrades to support demand side opportunities.	$12,000,000	$12,000,000		
		TOTAL	$12,000,000	$12,000,000	$0	$0
TOTAL COST		TOTAL	$12,000,000	$12,000,000	$0	$0

E. *Electrical System*

Overview of Existing Campus System

The existing main electrical primary service and distribution equipment for the University of Wyoming Laramie Main Campus consists include:

- West Campus Distribution Center (WCDC)
- East Campus Distribution Center (ECDC)
- Miscellaneous feeds to buildings from the Rocky Mountain Power (RMP) system

The two main existing UW campus primary electrical distribution systems are rated at 7,620/13,200 volts (7.62/13.2 KV), 3-phase as delivered to the campus by Rocky Mountain Power (RMP). These two systems (WCDC and ECDC) are serving the great majority of existing loads with minimal loading problems.

Existing System Evaluation

Each of the two main service switchgear units serve several feeders to campus loads through a distribution system that is mostly underground. Service transformers are utilized to serve the facilities at 120/208 volt or 277/480 volt, 3-phase. The service transformers are mostly oil filled type, with the most current developments utilizing pad mounted construction.

The systems have performed effectively with few problems or concerns. The systems of switches, feeders, and transformers have been maintained in a manner consistent with effective practices of the industry. Cable and transformer oil testing procedures have assured a reasonable level of operation and reliability. Problems and potential issues with service reliability and issues improving system development include:

- Outages on individual distribution center main devices have resulted in occasional outages on large portions of campus. Adjustment and modification of equipment has improved overall reliability.
- Most of the existing utilization, switching, and protective equipment is in acceptable condition, with only 25% to 35% of the components subject to replacement on a continuously scheduled basis through 2030 as noted in Table I-E-1 below. Development of prioritized replacement activities can serve to remedy these issues.
- The CEP contains an existing outdated 2400 volt system that is complex, is not reliable, and is becoming more difficult to maintain and find parts for.

The existing infrastructure is operating with an acceptable level of utilization, but as load growth continues the need for system modification will become necessary.

Options Analysis

Programmed campus growth will need to be accompanied by expansion or replacement of the existing primary service configuration. The existing West Campus Distribution Center (WCDC) is operating near system rated capacity and extensive expansion or addition of facility space with related loads will force modification to the WCDC. Other areas of campus will face similar development as campus growth continues.

With the expansion of the west campus system, a second west campus primary system WCDC2, with related distribution equipment, will be required. Part of the development of the WCDC2 component will be extension of a tie feeder to the CEP. The new WCDC2 equipment will serve new loads and facilities, the CEP tie feeder, and other interconnection possibilities to improve reliability and redundancy. Options can be considered in order to facilitate this step as follows:

- Addition of a second 13.2 KV primary service from RMP to new substation equipment that will distribute to feeders. This added service point will allow service to new or expanded loads and will provide load reduction from the existing WCDC equipment.
- Development of new substation facilities that will be supplied at transmission voltages, including a five to ten thousand volt-ampere (5 to 10 MVA) rated substation transformer to allow feeder extension at 13.2 KV to campus loads.

Expansion of the WCDC and addition of a new substation to allow the west campus programmed load growth can be coupled with other measures throughout campus to provide flexibility, remedy deficiencies and allow controlled expansion of the campus electrical systems. Maintenance issues and options with regard to the above approach are as follows:

- The existing outdated and unreliable 2,400 volt system in the CEP needs to be removed and replaced with new pad mount transformer equipment and a new standby engine-generator system. This will allow conversion directly from the 13.2 KV source to 480 volt, 3-phase power without the 2,400 volt portion of the existing system. This work needs to be given top priority as this system provides backup power to the CEP systems and operations required to support campus heating and cooling needs.
- Programmed growth for the campus will place both the East and West campus primary systems into situations where capacities and capabilities are exceeded. This limitation can be resolved by additional service points, added primary service substation(s), and interconnection of distribution systems to remove existing incident loads from the East and West Distribution Systems and permit new loads to be served north and east of the existing campus.
- Development of new substations with all equipment being University-owned will permit campus expansion and allow a reduction in effective electric power rates in the order of $0.018 per KWH through change in power delivery and corresponding billing schedules from the utility distribution company or change to a wholesale power supplier, such as Western Area Power Administration (WAPA). Using the annual electrical energy utilized for the two substations at approximately 58,315,000 KWH (Kilowatt-Hours) and a savings of $0.018 per KWH, the savings potential to utilize a primary service rate and maintain ownership of the primary service substation gear would be approximately $1,049,700.
- Remedial measures to allow campus growth include one added service point to both the East and West systems with interconnection options to improve reliability and interconnection to provide redundancy to selected existing service feeders.
- A portion of the programmed building growth could be served from the existing distribution systems, where allowed by demand diversity and load configuration. Modifying the existing distribution switchgear to allow power monitoring of each feeder would allow real time analysis and establish limits of adding load to the East and West primary service systems.
- Extensions to existing feeders or expansion of the system by added service points along utility corridors could provide the means of facilitating campus growth. Projected utility corridors are represented in Figure I-A-2 above.

<u>Conclusion and System Recommendations</u>

Recommendations for campus development and project implementation are follows:

- Apply both Items #1 and #2 under electrical systems upgrades (A.) in order to maintain system reliability and remove hazardous conditions or code violations

- The CEP modifications in B. involving Items #1 and #2 will improve equipment application and reduce maintenance costs.
- Regarding Utility Upgrades shown under C, the new service points in Item #1 are essential to programmed expansion of the campus facilities. While not absolutely required, the recommended power monitoring system shown as Item #2 will provide baseline information to more accurately track system loading.
- The new ductbank construction items show under D. are shown in a phased manner to follow campus development.
- The substation development listed in E. will allow for improved campus growth and reduction in electrical energy costs. While the 138 KV substation will allow greater future expansion, the 13.8 KV pad mounted equipment (Item #1) with a simple payback of 0.38 years is recommended over the 138 KV facility (Item #3) with a 5.0 year payback.

The system recommendations noted above as relates to the capital cost for Options A, through E are defined in Table I-E-1 below.

Table I-E-1 – Projected Capital Cost and Timeframes of Electrical System Projects

CAMPUS UTILITY	ITEM #	DESCRIPTIONS	ESTIMATED CAPITAL COST BUDGET PER TIMEFRAME			
			2010-2015	2015-2020	2020-2025	2025-2030
A. CAMPUS ELECTRICAL SYSTEM UPGRADES	1	Programmed Equipment replacement	$50,000	$50,000	$50,000	$60,000
	2	Replacement of Outdated Equipment and Correct Safety Isues	$90,000	$40,000	$40,000	$60,000
		TOTAL	$140,000	$90,000	$90,000	$120,000
B. CENTRAL ENERGY PLANT ELECTRICAL SYSTEMS UPGRADES	1	Two (2) New 1000 KW, 480 V Gen Set	$822,000			
	2	Two (2) New 1,500 KVA Pad Mount Transformers	$105,000			
		TOTAL	$927,000	$0	$0	$0
C. EXISTING ELECTRICAL UTILITY UPGRADES	1	New Service Points		$100,000	$100,000	
	2	Power Monitoring on Primary Distribution System	$85,000	$85,000		
		TOTAL	$0	$100,000	$100,000	$0
D. NEW CAMPUS ELECTRICAL UTILITY CORRIDORS	1	Install new Ductbank to development Area A down to exisitng campus in 2010-2015, Install remainder through A	$26,505	$58,125		
	2	Install new Ductbank to Area G and to Wyoming Tech Center in 2010-2015, Install remainder in G	$46,300		$65,100	
	3	Install new Ductbank from Corbet to Memorial Fieldhouse		$9,300		
		TOTAL	$72,805	$67,425	$65,100	$0
E. NEW CAMPUS ELECTRICAL SUBSTATIONS AND RELATED DISTRIBUTION	1	New 13.2KV IN, 13.2KV out pad mounted 600A substations with five distribution sections	$398,000	$30,000		$30,000
	2	Option for new 13.2KV in, 13.2 KV out steel substation with five distribution sections	$2,340,000	$30,000	$65,100	$30,000
	3	Option for new 138KV in, 13.2 KV out steel sub with 10MVA max transf and switchgea		$5,240,000	$30,000	$30,000
		TOTAL	$2,738,000	$5,300,000	$95,100	$90,000
TOTAL COST		TOTAL	$3,877,805	$5,557,425	$350,200	$210,000

In keeping with programmed space expansion and corresponding electrical load growth, the University of Wyoming can utilize the existing distribution configuration to maintain campus electrical needs. Attention to system limitations and application of load expansion with selected equipment replacement can serve to extend the system viability. Planned expansion of the facility will allow for additional service and maintenance of overall system integrity.

F. *Domestic Water System*

Overview of Existing Campus System

The UW domestic water supply system is a portion of the City of Laramie public water supply and distribution system. The campus system consists of water distribution pipes of varying ages, diameters, materials, and contains approximately 12 master flow meters. While older cast iron water pipes in some areas of Laramie have corroded because of aggressive soils, the City considers campus soils to be relatively neutral. As a result, the useful life of existing cast iron pipes on campus may be up to 50 years. The campus is located within the City of Laramie water Pressure Zone 2, which receives water from two above-ground storage tanks that are located in the City of Laramie on a ridge, a short distance east of UW. Both the quantity of water and water pressure that are available to the campus are satisfactory.

Existing System Evaluations

The potable water distribution system portion of this project focused on preparation of campus water distribution system WaterCAD® computer models of the water distribution system on campus and in adjacent areas. WaterCAD® model output provides calculated rates of flow and available pressures at selected points throughout the distribution system. The critical factor applied to modeled evaluation of water distribution system performance is typically the available rate of flow and pressure of fire flow water demand since the rate of fire flow demand is significantly higher than that of average or peak daily water demand. Fire flow demand was assessed at or near each existing fire hydrant location on campus. This assessment indicated a number of problem areas on campus where a standardized 2,000 gallon per minute (gpm) fire flow, at minimum pressure of 20 psig was not available. Inability to achieve adequate modeled fire flows was typically attributable to the existence of 6" or smaller diameter water distribution pipes, particularly in the eastern student housing portion of campus and in the oldest central campus area. Flow velocities through 6" and smaller diameter pipes are high during fire flow demand, resulting in decreased available rates of flow and water pressures. Installation of 6" and smaller diameter water distribution lines is not currently a standard engineering practice. Beyond identifying the piping age, assessment of the condition of existing campus water pipes requires excavating, exposing, and viewing the pipes and was not performed in this analysis.

Future Water Demand Analysis and Projected Outlook

The domestic water supply system was also modeled using WaterCAD® to assess the impacts of future campus growth on the campus potable water distribution system and on an expanded campus system. Modeling considered future campus growth both within currently developed areas adjacent to the campus and within undeveloped areas near campus. Modeling was utilized to generate proposed future water main alignments and pipe diameters on the basis of estimated future fire flow demand. Recommendations and planning-level cost estimates were prepared regarding future water distribution system improvements.

Conclusions and System Recommendations

Recommended water distribution system improvements should provide adequate fire flow demand rates of flow and pressures for the existing and future campus. Campus water distribution system improvement recommendations include:

- Replacing approximately 22,700 linear feet of existing 6" and smaller diameter campus water lines with 10" diameter pipe as shown on report WaterCAD® maps and as described above.

- Installing five new looped 10" diameter water lines east and northeast of the main campus to serve future campus development
- Assessing, as UW staff and equipment are available, the conditions of known sections of older campus water pipes by excavating to, viewing, and possibly removing and replacing short sections of sample pipe.

Descriptions of, and planning-level cost estimates for, recommended campus water distribution system improvements are included in report Section IV and are summarized below in Table I-F-1. Each cost estimate in the table below was prepared based on 2009 dollars and typically included estimated engineering and related professional service costs as well as a 25% contingency amount.

Table I-F-1 – Projected Capital Cost and Timeframes of Domestic Water System Projects

CAMPUS UTILITY	ITEM #	DESCRIPTIONS	ESTIMATED CAPITAL COST BUDGET PER TIMEFRAME			
			2010-2015	2015-2020	2020-2025	2025-2030
EXISTING DOMESTIC COLD WATER	1	Replace existing 6 inch diameter campus water mains with 10 inch diameter water mains	$1,350,000	$1,350,000	$1,350,000	
		TOTAL	$1,350,000	$1,350,000	$1,350,000	$0
NEW DOMESTIC COLD WATER	1	10 inch water line - Flint Street loop - future development Area A	$623,000			
	2	10 inch water line - Ivinson/Grand loop - future development Area B		$205,000	$205,000	
	3	10 inch water line - Gibbon Street extension - future development Area C		$284,800		
	4	10 inch water line - 22nd Street loop - future development Area G	$95,000	$95,000	$95,000	
	5	10 inch water line - student housing loop - future development Areas K and L			$712,000	
		TOTAL	$95,000	$584,800	$1,012,000	$0
TOTAL COST		TOTAL	$1,445,000	$1,934,800	$2,362,000	$0

G. *Irrigation Water System*

Overview of Existing Campus System

The UW turf irrigation water system is complex and not fully understood or fully documented by campus staff. Most components of the system currently receive water from a single UW-owned water well that is located near the campus Fine Arts Building. This well discharges at rates up to approximately 400 gpm and at a relatively constant 80 psig discharge pressure. A second campus irrigation well that is located near the intersection of 15th Street and Willet Drive has provided supplementary discharges in the past, but this well was not operable during the 2009 irrigation season due to sediment in the well. Reliance on one water well to provide water for most of the campus irrigation system results in a lack of redundancy in the irrigation water supply and increases the risk that, should the existing well fail or should well operation be interrupted, campus irrigation operations could be significantly impeded.

Some portions of the campus irrigation system, including the golf course, receive water from the City of Laramie water supply system. Other portions of the campus irrigation system may be operated to utilize City water if required. The campus irrigation system is operated by three separate administrative entities, including staff from Physical Plant, Athletics, and Student Housing, all of whom currently utilize the same irrigation water supply well. This operational situation contributes to the incomplete understanding or standardization of the system and its operation.

Existing System Evaluations

As was the case with the campus potable water distribution system assessment, consideration of the campus irrigation water system was based primarily on preparation of WaterCAD® models of campus irrigation system main distribution pipelines. These models assessed both existing irrigation system distribution lines and discharge points and future proposed irrigation system lines and distribution points. Modeling efforts were aimed at determining available discharge rates at various points in the system at a minimum 60 psig discharge pressure. While significant effort was expended to obtain and organize information regarding the existing campus irrigation system, the project irrigation system model can serve only as a base to be refined and expanded in the future. Information regarding the existing campus irrigation system that is currently available is inadequate to complete appropriately refined irrigation system WaterCAD® models. At the level of detail currently feasible in campus irrigation system WaterCAD® models, existing system water mains appear to function adequately. Reliance on a single water well as the primary source of irrigation water supply is a weakness in the system.

Future Irrigation Water Demand Analysis and Projected Outlook

Modeling of future campus irrigation conditions included the addition of two new campus water supply wells for the irrigation system and additional water distribution pipelines. As the UW campus expands, the area on campus requiring turf irrigation will also increase. The extent of that increase may be mitigated by installation of landscaping requiring less irrigation than existing campus turf. New sprinkler systems will presumably be designed and constructed as part of individual new or remodeled building plans. Existing irrigation system water mains will presumably have to be extended to provide irrigation water for future areas of campus irrigation. Of probably greater importance, at least one additional campus water well is required to provide a redundant water supply for and to meet increasing demand from the campus irrigation system. Campus irrigation system operations would also be significantly enhanced if a centralized, computer-based monitoring and control system were purchased and installed.

Conclusions and System Recommendations

Options for assessing, improving, and expanding the campus irrigation system that are described in Section IV of this report include:

- Completing a more detailed study and documentation of the existing system.
- Constructing at least one new water supply well.
- Extending irrigation mains into areas that will be developed in the future,
- Completing a feasibility study pertaining to use of existing building sump pumping systems and roof drains to provide supplemental supplies of irrigation water,
- Install a centralized irrigation system SCADA (supervisory control and data acquisition) system that will support operating and monitoring the entire campus irrigation system from one location. This will place the management and coordination of irrigation operations into one department rather than three.

Since turf irrigation systems around new and remodeled buildings are typically included as part of the building construction or remodeling designs and costs, cost estimates for this report were prepared only for expansion of campus irrigation water supply mains, not for additional distribution tubing, sprinkler heads, and related items.

Descriptions and cost estimates for each of these items are included in report Section IV and summarized below in Table I-G-1. Each cost estimate was prepared based on 2009 dollars and typically included estimated engineering and related professional service costs as well as a 25% contingency amount.

Table I-G-1 – Projected Capital Cost and Timeframes of Irrigation Water System Projects

CAMPUS UTILITY	ITEM #	DESCRIPTIONS	ESTIMATED CAPITAL COST BUDGET PER TIMEFRAME			
			2010-2015	2015-2020	2020-2025	2025-2030
EXISTING IRRIGATION WATER	1	Study/report/mapping - existing system	$93,000			
	2	New irrigation well (per well)	$762,000			
	3	Study alternative sources of irrigation water (roof drains, building sumps)	$56,500			
	4	SCADA monitoring and control system	$1,337,000			
		TOTAL	$2,248,500	$0	$0	$0
NEW IRRIGATION WATER	1	Extend 3 inch, 4 inch, and 6 inch irrigation mains	$219,000	$219,000	$219,000	
		TOTAL	$219,000	$219,000	$219,000	$0
TOTAL COST		TOTAL	$2,467,500	$219,000	$219,000	$0

H. *Sanitary Sewer System*

Overview of Existing Campus System

The campus sanitary sewer collection system is a component of the City of Laramie sanitary sewer collection and treatment system. The campus sanitary sewer collection system discharges into the City collection system at several points around the periphery of the campus, and campus domestic wastewater is conveyed to and treated at the City wastewater treatment plant. The campus sanitary sewer collection system is a gravity-flow system consisting of piping infrastructure of varying age and that contains no sanitary sewer pump stations. The existing UW sanitary sewer collection system and adjacent components of the City of Laramie sanitary sewer collection system consist of approximately 400 manholes with connecting pipelines of various diameters and materials. The campus is located southeast of the treatment plant. Long reaches of City gravity sanitary sewer lines between the campus and the City wastewater treatment plant could significantly impact UW options for upgrading the conveyance capacities of existing campus sanitary sewer lines.

Existing System Evaluations

Project work pertaining to the campus sanitary sewer collection system focused on collecting, recording, and organizing a large quantity of field survey data. Field survey data was supplemented by information from existing campus site plans. Approximately 400 sanitary sewer manholes were surveyed and a detailed spreadsheet was prepared that included survey point numbers, survey coordinates for manholes, manhole rim elevations, manhole flow line elevations, pipe diameters and flow directions. A series of campus maps were prepared showing existing campus sanitary sewer facilities.

UW staff is currently preparing a campus sanitary sewer collection system model utilizing information that was collected and organized during this study. Sanitary sewer collection system improvement options and cost estimates that are considered in this report should be conveyed through the model. These improvements include:

- Installing manhole flow meters
- Collecting and recording flow data

By doing so the campus may use this data to calibrate the in-progress sanitary sewer model; completing a campus infiltration and inflow (I/I) study used to determine the extent of groundwater seepage into sanitary sewer pipes; installing new manholes where sanitary sewer pipe junctions are located but are inaccessible; and installing larger diameter sanitary sewer lines with higher conveyance capacities than existing sewer lines.

The physical condition of campus sanitary sewer manholes was assessed during this survey by the GIS team and is included in the GIS database. Assessment of the condition of existing campus piping system requires excavating, exposing, and viewing the pipes, of which was not performed in this analysis.

Future Sanitary Sewer Demand Analysis and Projected Outlook

Using future estimated sanitary sewer discharge data that was generated during this study by others, the sanitary sewer spreadsheet flow model was used to assess potential impacts of estimated future sanitary sewer discharges on selected existing campus sanitary sewer lines. This analysis indicated that, for the most part, existing sanitary sewer lines should be capable of safely conveying future campus sanitary sewer discharges. As individual future buildings are designed, more detailed assessments of additional sanitary sewer flows in existing sanitary sewer pipes will be required. These assessments should utilize building design and the campus sanitary sewer distribution system model. Any future expansion of the campus sanitary sewer collection system will have to be coordinated closely with the City of Laramie since existing or enlarged City lines between campus and the City wastewater treatment plant must be capable of conveying increased campus flows.

Conclusions and System Recommendations

Proposed improvements to the campus sanitary sewer collection system include the following:

- Monitoring existing sanitary sewer flows
- Completing an infiltration/inflow (I/I) study
- Installing new manholes at currently inaccessible existing sanitary sewer line junctions
- Installing larger diameter replacement sanitary sewer at known locations where existing lines provide inadequate conveyance capacity or where larger diameter lines discharge into smaller diameter lines.
- Replacing existing piping that is old and nearing the end of its useful life as determined by exploratory pipeline excavation or during new campus infrastructure construction.

A summary of estimates for sanitary sewer system improvements is shown below in Table I-H-1. These cost estimates were prepared based on 2009 dollars and included estimated engineering and related professional service costs as well as 25% contingency amounts.

Table I-H-1 – Projected Capital Cost and Timeframes of Sanitary Sewer System Projects

CAMPUS UTILITY	ITEM #	DESCRIPTIONS	ESTIMATED CAPITAL COST BUDGET PER TIMEFRAME			
			2010-2015	2015-2020	2020-2025	2025-2030
EXISTING SANITARY SEWER	1	Monitor existing sanitary sewer flows	$27,500			
	2	Infiltration/Inflow study	$22,500			
	3	Install new manholes – assume 20 structures	$155,100	$155,100		
		TOTAL	$205,100	$155,100	$0	$0
NEW SANITARY SEWER	1	Install new/larger sanitary sewer lines (1)	$157,300	$157,300	$157,300	$157,300
		TOTAL	$157,300	$157,300	$157,300	$157,300
TOTAL COST		TOTAL	$362,400	$312,400	$157,300	$157,300

(1) Cost estimates based on assumed replacement of 400 linear feet of 12 inch diameter sanitary sewer line, 200 linear feet of 18 inch diameter sanitary sewer line, and 200 linear feet of 24 inch diameter sanitary sewer line during each time period.

I. *Storm Sewer System*

Overview of Existing Campus System

Campus storm sewer facilities; including catch basins, manholes, and other structures; were surveyed concurrently with campus sanitary sewer facilities. Campus storm water management facilities are intended to control and convey campus storm water runoff from various campus drainage basins to the City storm water collection system that is located on the periphery of the campus. Data regarding campus storm sewer facilities were tabulated on a spreadsheet concurrently with and in the same manner as data regarding the campus sanitary sewer collection system. Surveyed storm sewer facilities were also shown on the same maps as were sanitary sewer system facilities.

Existing System Evaluations

In addition to surveying and mapping existing campus storm water management facilities, this project included delineation of a number of campus storm water runoff basins. The basins and appurtenant storm water management facilities that were identified by UW staff as problem areas insofar as storm water runoff is concern were modeled using the Natural Resources Conservation System (NRCS) triangular hydrograph or curve number (CN) storm water modeling method. Model output includes peak calculated rate of storm water discharge and volume of storm water discharge for a specified storm over a defined drainage basin. During this study, storm water runoff from the 10 year, 6 hour storm (a storm having a 10% chance of occurring during any year) and the 100 year, 6 hour storm (a storm having a one percent change of occurring during any year) was typically modeled. Storm water management design is typically based on runoff from the 100 year storm. Upgrade options for the existing campus storm water management system that are discussed in this report and for which planning-level cost estimates were generated included:

- Assessing existing 15th St. catch basins and installing additional basins as required;
- Completing field surveying and more detailed hydrologic and hydraulic analysis of existing storm water management facilities in the vicinity of the Law Building and the Arts and Sciences building;
- Designing and re-grading the east stadium parking lot and installing a new storm sewer line under 22nd St. between the parking lot and the intersection of 22nd St. and Grand Avenue;
- Constructing a new storm water detention pond at the intersection of 20th St. and Grand Avenue;
- Designing and installing an expanded storm sewer collection system along part of Ivinson Avenue and utilizing existing campus depressions as detention facilities; and
- Enlarging the existing detention Pond B21 that is located along the east side of 15th St. at the northern edge of campus.

The physical condition of campus storm sewer manholes were assessed during this survey by the GIS team and is included in the GIS database. Assessment of the condition of existing campus piping system requires excavating, exposing, and viewing the pipes, of which was not performed in this analysis.

Future Storm Water Management Analysis and Projected Outlook

Storm water runoff from areas of anticipated future campus growth was also modeled, and estimated increases in peak storm water runoff rates of flow resulting from future development were generated. Using the same modeling software and the same storms as during hydrologic analysis of existing campus conditions, hydrologic analysis of future campus development focused on the area between Bradley St. and Flint St. and between 9th St. and 15th St., the area between Ivinson Avenue and Grand Avenue and between 9th St. and 15th St., the old student housing area, and six currently undeveloped areas in the eastern and northeastern part of campus.

In areas that are currently developed, future storm water analysis provided estimated peak storm water runoff values during the 100 year storm. These values should not change significantly as a result of demolition of existing structures and construction of new UW facilities. In currently undeveloped areas on campus, storm water analysis provided estimated increases in peak storm water runoff values during the 100 year storm under current, pre-development conditions and under future, post-development conditions. Development typically increases the impermeable portion of a parcel of land due to construction of buildings and parking facilities and, as a result, causes an increase in peak post-development storm water runoff values compared to pre-development values.

Conclusions and System Recommendations

A summary of estimates for the storm sewer system is identified below in Table I-H-1. Each cost estimate was prepared based on 2009 dollars and typically included engineering and related professional service costs as well as a 25% contingency.

Table I-I-1 – Projected Capital Cost and Timeframes of Storm Sewer System Projects

CAMPUS UTILITY	ITEM #	DESCRIPTIONS	ESTIMATED CAPITAL COST BUDGET PER TIMEFRAME			
			2010-2015	2015-2020	2020-2025	2025-2030
EXISTING STORM SEWER	1	15th Street catch basin assessment, design, and construction	$66,000			
	2	Engineering analysis and design - Law Bldg/A&S/Physical Science Bldg	$36,500			
		TOTAL	$102,500	$0	$0	$0
NEW STORM WATER	1	Design and construction - stadium parking lot and 22nd Street storm sewer		$780,000		
	2	Ivinson Avenue storm sewer and campus detention ponds		$275,000		
	3	Pond B21 (intersection of 15th and Harney) enlargement with landscaping		$83,500		
	4	New detention pond - Grand Avenue and 20th Street		$182,000		
		TOTAL	$0	$1,320,500	$0	$0
TOTAL COST		TOTAL	$102,500	$1,320,500	$0	$0

J. Utility Master Plan Project Summary and Conclusions

AEI and sub-consultants investigated campus utilities and the CEP for existing deficiencies and ability to accommodate projected campus growth and GHG emissions reductions.

In our judgment, along with UW Physical Plant staff input, the top ranked list of recommendations includes the following:

Central Energy Plant (CEP) Upgrades:

- Installation of an electric vacuum pump for redundancy of the single point of failure steam injection vacuum system.
- Installation of adequate backup electrical generation at the plant to run the entire plant, which includes replacement of the existing 2400 volt generator system.
- Replace the existing coal conveyor with an auger type that will allow mixing coal with bio-mass at ratios from 10% biomass/90% coal to 100% biomass.
- Install a new 1200 ton chiller to increase campus firm capacity.
- Conversion of CEP to biomass as economics drive the move to reduce GHG emissions.

Steam Distribution Infrastructure Upgrades, Additions

- Install new piping infrastructure from the CEP to Area A to support future growth in this area.
- Install access egress to the steam tunnel as required for personnel safety
- Repair and/or replacement of existing tunnels to meet projected growth and improve safety. Existing tunnels with structural concerns need attention first.

Upgrades for Demand side reductions to reduce energy consumption;

- Adjust existing controls to optimize building efficiencies.
- Re-commission existing buildings to optimize operations
- Conduct a campus wide lighting survey and delamp where illumination levels are too high. If funding is available, install lighting controls and use them.
- Perform a major, campus wide effort where buildings receive control upgrades, mechanical and electrical equipment upgrades, lighting upgrades and building envelope improvements. A "performance contract" may be a means to accomplish this while minimizing capital expenditures.

Electrical System Upgrades:

- Replace the existing 2400 volt system at the CEP.
- Extension of the campus electrical distribution on the east campus with the Visual Arts Facility which would include looping the existing feed that will be used for the project with one by the Stadium.

Domestic Water System Upgrades

- As the campus grows north of Lewis, extend existing feeds to the area and keep redundancy by looping.
- Core campus waterline replacement to improve fire flows (property protection and safety issue).

Irrigation System Upgrades

- Add another well of sufficient capacity to provide redundancy for irrigation well system as it is a single point of failure.
- Place the irrigation system under single management and a single computerized irrigation controller system to reduce demand and overuse of the system based on weather patterns.
- Tie building sump and roof drain discharge into the system as allowed by local regulations.

Sanitary Sewer Upgrades

- Collect and organize sanitary sewer flow data for use in calibrating the campus sanitary system model and for use when designing future campus sanitary sewer lines.
- Install manholes at existing sanitary sewer pipe junctions where manholes do not exist.
- Install larger sanitary sewer lines at places where existing sanitary sewer conveyance capacity is not adequate.

Storm Sewer Upgrades

- Complete field surveys and detailed storm water runoff/conveyance hydraulic analyses of existing problem areas on campus for which inadequate survey data currently does not exist.
- Assess and re-design storm water management facilities for the area east and south of the stadium.
- Modify existing detention Pond B21 at the intersection of 15th Street and Harney Street.

General Recommendations

- Verify and detail improvements to the utility system as the UW moves into future growth areas.
- Establish a committee or charge a campus entity to promote and facilitate these improvements and related long-range planning efforts.

A summary table of projected cost is identified in Table I-J-1 below.

Future Considerations

Existing and maturing alternative energy technologies should be revisited periodically for feasibility in UW's energy and GHG reduction portfolio. For example, wind and solar energy industries are evolving. UW may seek opportunities for partnering with a wind farm developer to provide further GHG reductions. There is great interest in carbon sequestration research and heat and power technologies are also evolving to directly burn biomass to drive turbine generators from the byproducts of the fired fuel. Similarly, existing technologies and options described in this report should be revisited if a carbon tax goes into effect or fuel prices change significantly.

Small-scale options may become more feasible for select building loads. These may include the use of smaller micro, building-mounted wind turbines, solar hot water collectors, photo-voltaic arrays, and geothermal heating.

Table I-J-1 – Projected Capital Cost and Timeframes of Top Ranked Items.

CAMPUS UTILITY	ITEM #	DESCRIPTIONS	ESTIMATED CAPITAL COST BUDGET PER TIMEFRAME			
			2010-2015	2015-2020	2020-2025	2025-2030
CEP UPGRADES	1	E xisting Steam System and Auxiliary Upgrades	$1,500,000			
	2	Increase Chiller Firm Capacity at CEP in a Plant expansion.	$2,600,000			
	3	Two (2) New 1000 KW, 480 V Gen Set in a Plant Expansion	$822,000			
		TOTAL	$4,922,000	$0	$0	$0
STEAM DISTRIBUTION INFRASTRUCTURE	1	Replace section of existing utility tunnel with new tunnel between Biological Sciences and Knight Hall.	$3,800,000			
	2	Install new utility tunnel and ductbank underneath Lewis Street to replace the existing utility tunnel underneath Engineering and Agriculture.	$7,200,000			
	3	Install new utility tunnel and ductbank to replace direct buried piping between the Arena and Willet Pit.		$5,360,000		
	4	Install new utility tunnel and ductbank to replace existing tunnel along Sorority Row, north along 15th Street from Sorority Row to Willet Pit.			$8,000,000	
	5	Install new direct buried piping from CEP to development area A, from existing tunnel to development area B, to Berry Building, and from Centenniel Complex to new Visual Arts.	$2,946,000			
		TOTAL	$13,946,000	$5,360,000	$8,000,000	$0
DEMAND SIDE REDUCTIONS	1	Controls and Sytem upgrades to support demand side opportunities.	$12,000,000	$12,000,000		
		TOTAL	$12,000,000	$12,000,000	$0	$0
ELECTRICAL SYSTEM UPGRADES	1	Removal of 2400 Volt by addition of a New 1,500 KVA Pad Mount Transformer and switches for new Gen Set arrangement.	$105,000			
	2	Programmed Equipment replacement	$50,000	$50,000	$50,000	$60,000
	3	Replacement of Outdated Equipment and Correct Safety Isues	$90,000	$40,000	$40,000	$60,000
	4	Campus Electrical Distribution Extensions	$398,000	$30,000		$30,000
		TOTAL	$643,000	$247,000	$247,000	$247,000
DOMESTIC WATER SYSTEM UPGRADES	1	10 inch water line - Flint Street loop - future development Area A	$623,000			
	2	10 inch water line - Ivinson/Grand loop - future development Area B		$205,000	$205,000	
	3	10 inch water line - Gibbon Street extension - future development Area C		$284,800		
	4	10 inch water line - 22nd Street loop - future development Area G	$95,000	$95,000	$95,000	
	5	10 inch water line - student housing loop - future development Areas K and L			$712,000	
		TOTAL	$718,000	$584,800	$1,012,000	$0
IRRIGATION SYSTEM UPGRADES	1	New irrigation well (per well)	$762,000			
	2	SCADA monitoring and control system	$1,337,000			
		TOTAL	$2,099,000	$0	$0	$0
SANITARY SEWER SYSTEM UPGRADES	1	Monitor existing sanitary sewer flows	$27,500			
	2	Install new manholes – assume 20 structures	$155,100	$155,100		
	3	Install new/larger sanitary sewer lines	$157,300	$157,300	$157,300	$157,300
			$339,900	$312,400	$157,300	$157,300
STORM SEWER SYSTEM UPGRADES	1	Design and construction - stadium parking lot and 22nd Street storm sewer		$780,000		
	2	Pond B21 (intersection of 15th and Harney) enlargement with landscaping		$83,500		
		TOTAL	$0	$863,500	$0	$0
TOTAL COST		TOTAL	$34,667,900	$19,367,700	$9,416,300	$404,300

Consultant Team Members:

Affiliated Engineers, Inc. (AEI): Lead consultant firm and specializes in evaluation, analysis, and modeling of steam and chilled water systems and infrastructure.

Ross Infrastructure, LLC. (RI): Specializes in evaluation and design of heat and power systems.

Coffey Engineering and Surveying (CES): Specializes in and provides evaluation, analysis, and modeling of civil utilities including Domestic Cold Water, Irrigation Water, Sanitary Sewer, and Storm Sewer. CES also performed field surveying of Sanitary and Storm Sewer manholes on and around campus.

Electrical Systems Engineering (ESC): Specializes in and provides evaluation, analysis, and modeling of electrical systems and utilities. ESC also performed the GIS mapping and database entry of information from this service.