WESTERN WASHINGTON UNIVERSITY

UTILITIES MASTER PLAN UPDATE

Bellingham Main Campus

SP045

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Wilson
SURVEY/ENGINEERING

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EXECUTIVE SUMMARY

1. Introduction

This utilities master plan presents a comprehensive evaluation of the capacity and functionality of the existing utilities on the main Western Washington University campus. The study evaluates utility capacity relative to the anticipated 10-year Capital Plan growth and the Institutional Master Plan build-out growth. This study also lists the recommended utility system improvements, along with their approximate costs, needed to meet current and future demands. A preliminary timeline is included at the end of this Executive Summary indicating when the recommended improvements are needed and their sequence relative to planned projects. Project sequencing is also referenced in the discussion of each recommended utility improvement.

The utility systems evaluated in this study include: water distribution (domestic, fire, and irrigation), sanitary sewer, stormwater, district steam heating, district cooling potential, electrical power distribution, and emergency and standby power. Assessment of other campus utilities, performed by WWU staff, is included in the Appendices Chapter 9.

This utilities master plan is a 10-year update of the plan that was completed in 2007. The student population has increased about 8.6 percent since then. However, due to conservation and infrastructure upgrades, the consumption of water, gas, and electricity has actually decreased by about 7 to 12 percent despite the population growth.

The 2017-2027 10-year Capital Plan anticipates an on-campus building growth of 302,000 GSF (gross square feet), which is a 9.5 percent increase. This increase includes these planned facilities: a new 100-200 bed residence hall near Buchanan Towers (100,000 GSF), Support Services Facilities (68,000 GSF) near the Physical Plant, and additional academic buildings (District 14: 80,000 GSF, District 6: 48,000 GSF, District 11: 6,000 GSF).

The 2001 Institutional Master Plan (IMP) anticipated build-out growth in low, medium and high scenarios. The build-out scenario utilized for this study represents a 24.3 percent increase above existing (2017). This approximates the “High” future envisioned in the IMP, which is appropriate to a utility planning effort.

Following is a summary of the discussions and recommendations for each major utility system studied. Approximate order of magnitude total project costs are provided for each recommendation for preliminary planning purposes. See the Appendices in Chapter 10 for recommendations on utility systems analyzed by WWU staff.

2. Water Distribution System

The campus water distribution system has been improved substantially over the past ten years. Water consumption is approximately 7 percent less than in 2007. This indicates that water main replacements and repair projects implemented by WWU over the past 10 years have decreased leakage substantially. Installation of low-flow fixtures and other conservation measures contributed to the consumption reduction as well.

The water distribution system was analyzed using computerized hydraulic modeling. Historical data were used to calibrate the model to reasonable accuracy. Key segments of the water system were field tested to further calibrate the model.

Domestic Water Service. The capacity of the water distribution system is adequate to provide water service (at required minimum 30 PSI pressure) to all building water service connections (at ground level) during normal use now and in the future. However, water pressure may be less than 30 PSI at the highest service point in five buildings (operational issue only, not regulatory). This is because the elevation (or pressure head) in City reservoirs is not high enough relative to the height of these five buildings. This deficiency can be overcome by installing domestic booster pumps in individual buildings.

Fire Flow. The capacity of the existing water distribution system is adequate to supply fire flows (and maintain water main pressure above the 20 PSI minimum per current fire codes) to all but one campus building (Commissary). This is a major improvement over 2007, when 14 buildings had insufficient fire flows. This is due to water main upgrades and installation of building sprinklers. At IMP build-out, Arntzen, Ross Engineering Technology, and SMATE may have marginally inadequate fire flows.

Fire Sprinkler Flow. The calculated/modeled water pressure at the top floor in 9 buildings currently (same for build-out conditions) is less than the 14 PSI criterion for fire sprinklers. Four buildings of these nine buildings already have fire booster pumps to boost pressure. A listing of affected buildings can be found in Section 2.3.5.3.

Operational Recommendations: Continue monitoring system to identify pipe conditions and potential pipe leaking and broken pipes.

Improvements Needed:

The following improvements are recommended due to the age and condition of pipes and for capacity in the case of the East College Way Loop. These improvements are listed in general order of priority based primarily on life expectancy of existing facilities.

- Replace domestic water piping serving all Ridgeway Buildings with 4-inch or 6-inch piping. Replace segments over time or all at once. Replace due to age and probable condition. Approximate Costs are $525,000 to $650,000 total.
- Complete the Ridgeway Complex fire loop improvements replacing the remaining 6-inch diameter cast iron piping at the south end with ductile iron piping. Replace due to age and condition. Approximate Costs are $200,000 to $250,000.
- Replace the East College Way Loop 10-inch cast iron piping with 12-inch ductile iron piping. Replace to increase capacity and due to age and condition. Approximate Costs are $1,200,000 to $1,600,000 (or $800,000 to $1,100,000 for just over half the loop).
- Replace the Fairhaven Complex old cast iron piping with ductile iron piping. Replace due to age and condition. Approximate Costs are $175,000 to $225,000.
- Install fire sprinkler pumps as desired (or as required during building retrofits) to provide adequate pressure to meet building fire sprinkler system design criteria.

Build-Out Improvements Needed:

- None anticipated.

3. Sanitary Sewer

The on-campus sanitary sewer system has a large capacity for absorbing increased flows, with the exception of the South College Drive sewer. As such, the capacity of the sanitary sewer system does not need to be increased to accommodate the planned future growth on campus, with the sole exception of the South College Drive sewer.

The primary concern for the sanitary sewer system is maintaining the sewer pipe and manholes in good condition, replacing aging pipe before it deteriorates, preventing large increases in infiltration and inflow (I&I), and preventing failures that could back up sewers into buildings. One sewer main upgrade is needed to increase capacity (see 10-year Improvements).

There are three segments of sewer trunk lines or sewer lines that need repair or replacement and one longer segment of sewer trunk line (SS600) that needs replacement and size upgrade as described below. The repair or replacement projects are needed due to age related conditions or localized defects.

IMP District 14 will see the highest increase in sewer flows in the future. These future sewer flows are most easily routed to the South College Drive sewer (SS600 in Fig 3-2). Sewer flows from District 14 (i.e., Academic Instruction Center) were rerouted to this sewer line to accommodate Harrington Field construction in 2015. See Figure 3-2 for a map of sanitary sewers in this part of campus.

Operational Recommendations: Continue monitoring system (with visual and camera inspections) to identify pipe conditions and potential flow capacity or leaks into or from piping. Ensure that all sewer manholes are labeled SEWER and not DRAIN or STORM. Install new frames and lids as needed.

10-Year Improvements Needed:

- Replace and upgrade the 1034-foot, 8-inch Trunk line SS600-602 on South College Drive to 12-inch sewer. Approximate Costs are $350,000 to $450,000.
- Rehabilitate 240 feet of 12-inch corrugated metal pipe adjacent to NE side of Carver Gym. Approximate Costs are $100,000 to $150,000.
- Replace or repair sewer line between Humanities and Bond Hall (in Red Square). Approximate Costs are $30,000 to $70,000.
- Replace Highland 2 Sewer Line Running Downhill to Trunk Line 200. Approximate Costs are $70,000 to $110,000.
- Add MH frame/lid replacements to correct mislabeled lids.

Build-Out Improvements Needed:

- None anticipated.

4. Stormwater

North Campus. For the north campus, capacity is just adequate. Any significant increase in runoff generation for the north campus will need flow mitigation such as providing stormwater detention facility(s) or equivalent expansion of the downstream conveyance by the City (Cedar Street). The purpose of detention is primarily to prevent overwhelming of the downstream City-owned storm sewer system. A detailed analysis (and detention facilities most likely) will be required for any projects that increase impervious area, in order to demonstrate whether the flow increases are significant enough to impact the City system.

The City-owned main off-campus downstream conveyance system for the north campus on Cedar Street should have enough capacity to convey the required 25-year storm flow (existing conditions). The system is likely to overflow onto Cedar Street during a 100-year storm according model estimates. The overflow may be greater if the condition of the infrastructure is poorer than estimated.

On campus, flooding in the area between the track and SMATE is possible if the main storm sewer becomes partially blocked by roots or debris (continued maintenance is key to maintaining system capacity and preventing backups).

South Campus IMP Districts 15, 17, 18, and 22/23. Any new developments (or redevelopments) in the south campus IMP Districts 15, 17, 18 (near Buchanan Towers), and 22/23 (near Physical Plant) will require preparation of a full stormwater site report and installation of full flow control (e.g., detention) and water quality treatment facilities per current regulations.

South Campus IMP Districts 11, 12, 13, 14, and 16. Any new developments (or redevelopments) in south campus IMP Districts 11, 12, 13, 14, and 16 will require stormwater treatment.

Operational Recommendations: Continue monitoring system (with visual and camera inspections) to identify pipe conditions and potential flow capacity problems. Ensure that all storm manholes are labeled DRAIN or STORM and not SEWER.

Current Improvements Needed:

- Improvement 9 addresses fueling area spill containment at the Physical Plant (protection of Taylor Creek). Approximate Costs are $35,000 to $50,000.
- Localized Stormwater Problems: Recommended improvements 10 - 15 are intended to improve reliability of conveyance at certain locations where localized flooding of buildings has occurred or is likely to occur. Approximate Costs are $15,000 to $50,000 each project.
- Localized Stormwater Problems: Recommended improvements 16a-16g are intended to correct bad joints (allowing root intrusion) and damaged pipe sections of the north campus storm sewer main as detected by video inspection.

10-Year Improvements Needed:

- **North Basin.**
  - Project-specific stormwater mitigations (or regional detention) will be required as part of the proposed building renovations in the north campus drainage basin if runoff rates are increased as part of the District 6 projects. Note that detention would not be required if the downstream City conveyance piping systems are upgraded and the City allows increased flow rates.
- **South Basin.**
  - Project specific stormwater <u>treatment</u> facilities will be needed for the Support Services Project, New Student Housing Project, and District 14 Academic Building Projects. No non-project related upgrades are anticipated. See Section 4.4.2 for a detailed discussion of the south campus drainage basin.
  - Project specific stormwater <u>detention</u> facilities will be needed for the Support Services Project and New Student Housing Project. No non-project related upgrades are anticipated. See Section 4.4.2 for a detailed discussion of the south campus drainage basin.

Unit Quantity Detention and Water Quality Facilities Costs:

- Detention – Underground $40/cubic foot ($12/square foot of impervious area for north campus; $25/square foot of impervious area for south campus)
- Water Quality Treatment $50/square foot ($2.50/square foot of impervious area)

Build-Out Improvements Needed:

- North basin stormwater improvements are required to accommodate proposed build-out in the north campus.
  - North Storm Sewer Alternative A
    (15,000 cubic feet of detention): Approximately $600,000
    OR
  - North Storm Sewer Alternative B
    (replace all downstream pipe): Approximately $700,000*
    (replace 18-inch downstream pipe only): Approximately $450,000
    * Does not include potentially high cost of replacing pipe through contaminated soils on Cornwall Beach Park site.
    OR
  - Project specific stormwater treatment facilities will be needed for IMP Districts 4, 5, 9, and 10. Detention may be needed also. See Section 4.4.1.
- South basin stormwater improvements are required to accommodate proposed build-out in the south campus.
  - Project specific stormwater treatment facilities will be needed for IMP Districts 11, 12, 13, 14, and 16. No non-project related upgrades are anticipated. See Section 4.4.2.

5. District Heating System

Western Washington University owns and maintains a significant district heating system that provides heat to the majority of the buildings on the WWU campus. This district heating system is comprised of a steam production plant located central to campus and a distribution system primarily located in an extensive walkable tunnel. Most of the campus buildings convert steam to hot water which is then circulated throughout the facility for heating needs; however there are a select number of buildings that utilize steam directly for heating and or use with kitchen facilities. The following items are highlights from the main document:

- Most of the existing steam boilers are past their useful life which will make operating and maintain them more of a challenge in the years to come. The current age span of the boilers is 22-71 years with an average age of 50 years across all five boilers.

- The overall annualized operating efficiency of the district heating system is 56%. This low efficiency is due to the inherit nature of steam distribution being a high temperature and near constant pressure system.
- Given the current boiler capacity, piping configuration, and distribution pipe capacity, it is estimated that the existing district heating system can accommodate up to 380,000 GSF of additional of new building space (at a nominal heating intensity of 40 btu/hr/sq.ft.).

Current Improvements Needed:

WWU should begin to make long term renewal and energy efficient investments in the existing district heating system; making sure to do so in a planned, flexible approach that provides short term improvements while setting the stage for long term expansion and conversion to new, more efficient production and distribution systems.

- Complete a long term life cycle cost analysis of different district heating production and distribution possibilities to determine the most economical and environmentally sound path forward for the University.
- Transition the existing buildings to low temperature heating hot water systems; while simultaneously implementing similar requirements for new construction and expansion of facilities. This will require the following measure be taken (as well as additional longer term improvements shown below in "10-Year Improvements Needed").
    - Update campus mechanical specifications to ensure all new and remodeled buildings utilize a low temperature hot water distribution system that is connected to the existing district energy heating system.
- Implement a short and long term plan for renewal and/or replacement of the heating production plant. A long-term plan concerning whether the distribution system remains steam or is converted to hot water will allow for more cost effective decisions as to how limited funds are spent to repair & upgrade existing boilers or replace them with newer boiler technology.

10-Year Improvements Needed:

- Transition the existing buildings to low temperature heating hot water systems; while simultaneously implementing similar requirements for new construction and expansion of facilities. This will require the following measures be taken.

    - Phase in a process to upgrade and replace existing energy transfer stations with better technology, staged systems that make more efficient use of the heat at each building, sending lower temperature condensate back to the plant.
    - Phase in a conversion to hot water of all existing systems that currently utilize steam directly for heating.
    - Review opportunities to utilize additional heat from the collected condensate to serve select heating requirements on campus.
- If a decision is made to remain in steam the following long-term costs should be budgeted for ongoing renewal of the aging production plant and distribution system. The costs shown below are based on an assumed 15 year renewal period.
    - Steam Plant Production Equipment: $750,000 - $1,100,000 per year
    - District Steam Piping: $700,000 - $1,000,000 per year
    - District Condensate Piping: $450,000 - $750,000 per year

Long-Term Improvements Needed:

- Convert existing steam production and distribution system to a lower temperature hot water system. Consider new technologies for primary heating equipment such as condensing boilers, heat pumps, or cogeneration. Converting the district heating system to hot water production and distribution has the greatest ability to reduce energy usage, carbon emissions, operating expenses, and increase efficiency and reliability. A hot water production system also has the most flexibility for incorporating renewables and renewable technologies as they become economically viable. While it may not be feasible to convert the campus in a single large scale project, actions can be taken to steer the campus in that direction today. As noted above, it is recommended that WWU begin converting buildings to hot water use and stipulate any new buildings and remodels must use low temperature hot water and be connected to the district steam system (when viable). This will provide benefits whether the campus remains in steam or is converted to hot water.

6. Chilled Water Systems

Western Washington University operates and maintains ten (10) distributed chilled water cooling systems on the WWU campus with each system dedicated to a specific building. The cooling plants range in age, size and usage with some systems providing full building cooling while other systems provide cooling for electrical equipment rooms and/ or high occupancy spaces. The following are highlights from the main document, meant to give a brief overview of important aspects of the chilled water system(s):

- Three of the Ten chilled water systems on campus have exceeded their expected useful life; Bond Hall, Morse Hall and Ross Engineering Tech.
- Haggard Hall chilled water system requires frequent monitoring beyond what is planned as preventative maintenance. This can likely be attributed to a large chilled water system operating at low load conditions which is resulting in multiple starts and stops per day; approximately every 2-hours of operation. Frequent starts will reduce the operable life of the chiller as well as an operating efficiency ~2x greater than the design efficiency of 0.6 KW per ton.
- Seven of the ten chilled water systems use an HCFC refrigerant which will be completely phased out by January 1, 2020. While no new R-22 and R-123 refrigerant will be manufactured or imported to the US, it's likely some refrigerant will be available (refrigerant recyclers) at an expected premium price. New equipment selections will largely be unaffected as the current typical refrigerant selection is R-134a (although R-134a, an HFC type refrigerant, will also experience a phase out plan similar to HCFC's in the future as the industry shifts to HFO's and natural refrigerants).

Current Improvements Needed:

- Update mechanical specifications to ensure all new and remodeled buildings utilize similar pumping logic, coil performance and energy metering to allow for connection to a future district chilled water loop.
- Implement a short and long term plan for replacement of existing aging chilled water systems. Bond Hall is the highest priority as the system has extensive run-time hours, suspect condition and has reached the end of its useful life.
- Develop a refrigerant equipment utilization and phase out plan for all equipment using HCFC ozone depleting chemicals.

10-Year Improvements Needed:

- Extension of the Haggard Hall chilled water system to cool Wilson Library. Additional cooling will likely decrease the number of starts and stops as well as increase the operational efficiency of the Haggard Hall chiller. This implementation should be part of the planned Wilson Library Major Renovation project.
  - Please note: the existing Haggard Hall chiller uses R-123 refrigerant. This should not have an impact on the expansion of the chilled water system as no modifications should be needed to the chiller itself. However, in the event that the existing refrigerant charge was to become unusable, an analysis would need to be made on re-charging the existing chiller or purchasing a new one. This potential issue may be avoided depending on the timing of the Wilson Library Major Renovation project (as the project date may be past the useful life of the chiller necessitating the purchase of new equipment).
- Complete a long term life cycle cost analysis for different chilled water loop options and distribution options at the north and south ends of campus. Include expansion of the Haggard Hall and Communications Facility chilled water plants in the life cycle cost study for any building or chiller renewal project(s) in their vicinity. Potential projects include replacement of Bond Hall chillers, major renovation of Environmental Studies, cooling for the Performing Arts, Arntzen Hall, Biology and potential new buildings in the south academic quad.

Long-Term Improvements Needed:

- Install cooling in future buildings where necessary. Estimated cost for a new high efficiency chilled water plant is approximately $3,000 - $4,000 per ton; this includes mechanical room equipment, plant piping infrastructure, accessories and labor. Typical air conditioning infrastructure at the floor level is between $8.00/ SF to $25.00/ SF depending on building type and mechanical system type. Administrative buildings would be toward the lower end of this unit cost estimate (typically utilizing VAV type systems) while lab buildings would be toward the higher end (typically utilizing chilled beams or other type equipment).

7. Electrical Power Distribution System

In the mid-1990's, WWU began a program through various projects to upgrade the existing service and power distribution system on the campus. The primary goals of that program were to replace the old cables, loop the system so a failure could be bypassed easily, restore power within hours instead of days, and to replace the old 4160 volt system which was a serious bottleneck in the system. The upgrade program has recently been implemented with great success. Old cables were replaced, loop systems have been installed, switches have been installed to switch around failure points in order to restore power to buildings within hours and the 4160 volt system has been completely removed. The removal of the 4160 volt system included the removal of a large inefficient transformer located at the Steam Plant which was the bottleneck and potential main failure point in the system.

Current Improvements Needed:

- Begin implementation of replacing aging medium voltage system as described below in the 10-Year Improvements.

10-Year Improvements Needed:

- Great accomplishments were made with the last ten year plan, however, as newer systems age, maintenance and planning for replacement are still necessary to retain a healthy system. The next ten year improvements that are needed are as follows:
- Arntzen Hall – Replace aging medium voltage switchgear. Approximate cost $198,000.
- Buchanan Towers – Replace aging medium voltage transformer. Approximate cost $99,000.
- Commissary – Replace aging medium voltage switchgear and transformer. Approximate cost $286,000.
- Engineering Technology - Replace aging medium voltage switchgear and transformer and provide loop circuit from Arntzen Hall. Approximate cost $313,000.
- Environmental Studies – Replace aging medium voltage transformer. Approximate cost $100,000.

- Fairhaven Residence Dorm Building Complex – Convert supply circuit from a radial feed configuration to a loop feed system. This will allow power to be supplied to each building from two directions, allowing any failure point on the system to be isolated and building power restored within hours. Approximate cost $143,000.
- Fairhaven Residence Dorm Building Complex – The existing exterior padmount transformers are approximately 21 years old. They are nearing the end of their lifecycle. It is anticipated that they will be okay for the next ten years, however, oil testing and monitoring are recommended. Approximate cost $138,000.
- Fairhaven Academic – Replace aging medium voltage switchgear and transformer. Approximate cost $286,000.
- Fine Arts - Replace aging medium voltage switchgear and transformer, remove supply from tap in the tunnel and resupply with its own circuit from the Steam Plant Switchgear. Approximate cost $319,000.
- Outback Area – Provide a medium voltage feeder from tunnel Node T7 and provide power service for Outback Area and Amphitheater (this item possibly could be considered a long term improvement that could be achieved beyond the next 10 years). Approximate cost $138,000.
- Parks Hall – Replace aging medium voltage transformer. Approximate cost $55,000.
- Physical Plant – Provide a medium voltage feeder and transformer to Physical Plant yard to create a service for battery vehicle charging stations (vans and cars). Approximate cost $138,000.
- Steam Plant – Replace aging medium voltage transformer supplying the Steam Plant building. Approximate cost $114,000.

8. Emergency and Standby Power System

Individual diesel fueled engine-generator sets for each building has been the method of choice for providing backup power for emergency systems, fire pumps, legally required and optional standby power. This study evaluated alternatives to individual building generators including battery inverter systems, generators that serve multiple nearby buildings, and campus wide centralized systems. Individual engine-generator sets that either serve one building directly or nearby multiple buildings remains the best choice from initial cost, maintenance costs, and reliability standpoints. The challenge is to find suitable locations either inside or outside of the buildings where the engine-generator sets could be located and meet the various codes, standards, regulations, aesthetics, and operational/maintenance/testing requirements.

With the last Master Plan, WWU began a program through various projects to upgrade existing emergency generators, legally required standby and optional standby power supplies and power systems. They have had several successful projects with this program. The generator systems have either been upgraded when a facility goes through a major renovation or as other work similar work is being performed in the same area or building.

The upgrade program needs to be continued. As difficult and expensive as it may be, it is critical that emergency and legally required standby power supplies and system equipment be installed, maintained, tested and records kept in accordance with current codes, regulations and standards. If this is not done, by definition, what was thought to be an emergency power system becomes an optional standby system and that facility does not have a reliable emergency system. See map MP-E3 at the end of chapter 8 for a graphic depiction of the condition of emergency power systems across campus.

Current Improvements Needed:

- Replace generators and upgrade standby power segregation at buildings with questionable reliability and/or location deficiencies. Prioritize facilities with existing generator issues and buildings with high occupant loads first. Buildings in close proximity with similar loads may benefit from a shared generator.
- Biology Building – Remove and relocate from Steam Plant location. It does not start reliably and is difficult to refuel. Approximate cost $405,000.
- Chemistry Building – Remove and relocate from Steam Plant location. It does not start reliably and is difficult to refuel. Approximate cost $405,000.
- Fine Arts – Add new generator to this building. It currently has no generator. It only has battery backed up devices only. Recommend to connect to a shared Steam Plant Generator. Approximate cost $116,000.
- Higginson Hall – Replace existing battery backup inverter system with new generator. Approximate cost $296,000.

- Steam Plant – Remove and relocate from Steam Plant Tower Roof. Generator has reliability issues and is difficult to refuel. Locate new generator in Steam Plant Utility yard and size large enough to share with Fine Arts building. Approximate cost $132,000.
- Viking Complex – Generator is at its max capacity. Its capacity is so close it may experience overloading depending on building use during an outage. It is a high priority to keep the kitchen on generator power and have the ability to add new or replaced kitchen equipment on the generator system. Approximate cost $405,000.
- Typical building generator set costs range between $116,000 to $405,000 depending on size required, architectural requirements, and complexity of the installation. An approximate total improvement cost would range from $1.5 million to $2 million. (See Timeline)

10-Year Improvements Needed:

- Replace generators in buildings planned for major renovation. Generator replacement at residence halls should be planned to be concurrent with fire sprinkler upgrades in case those projects trigger additional emergency or standby power needs.
- Bond Hall – Evaluation of generator size will be required if Campus Telecommunications Systems are removed from 32nd Street and consolidated in Bond Hall. Approximate cost $370,000.
- College Hall – Replace aging generator or tie into Carver generator system. Approximate cost $296,000.
- Communications Facility – It has a potential of leaking indoors. Replace aging generator and relocate outdoors or tie into Academic Instructional Center (AI) generator system. Approximate cost $296,000.
- Edens Hall– Replace aging indoor generator and tie into a shared generator with Edens North. Approximate cost $150,000 (combine with EN).
- Edens North – Replace aging indoor generator and tie into a shared generator with Edens Hall. Approximate cost $150,000 (combine with ES).
- Wilson Library – Currently supplied generator power from Haggard Hall directly. Add automatic transfer switches in Wilson Library so they can start Haggard Hall Generator. Approximate cost $97,000.

- Ridgeway Alpha, Beta, Commons, Delta, Gamma, Kappa – Replace aging generators, add generators to Beta and Gamma that currently don't have generators, and consolidate/share new generator installations between buildings that are close together where possible. Ridgeway Commons dining hall would be the logical place to begin replacement project phasing due to the priority of providing kitchen/dining hall power. Ridgeway Complex also lends itself to a Central Generator for the entire Ridge, however, this would require extensive trenching. This could be performed with a repaving project or other waterline project so that trenching and patching costs can be shared between projects. Approximate cost $888,000.
- Separate emergency and standby loads at existing engine generator systems. Costs vary significantly depending on the building. (See Timeline)
- Typical building generator set costs range between $116,000 to $405,000 depending on size required, architectural requirements, and complexity of the installation. An approximate total improvement cost would range from $2 million to $3 million. (See also Timeline)

Build-Out Improvements Needed:

- Provide additional engine-generator sets as needed on a project-by-project basis.

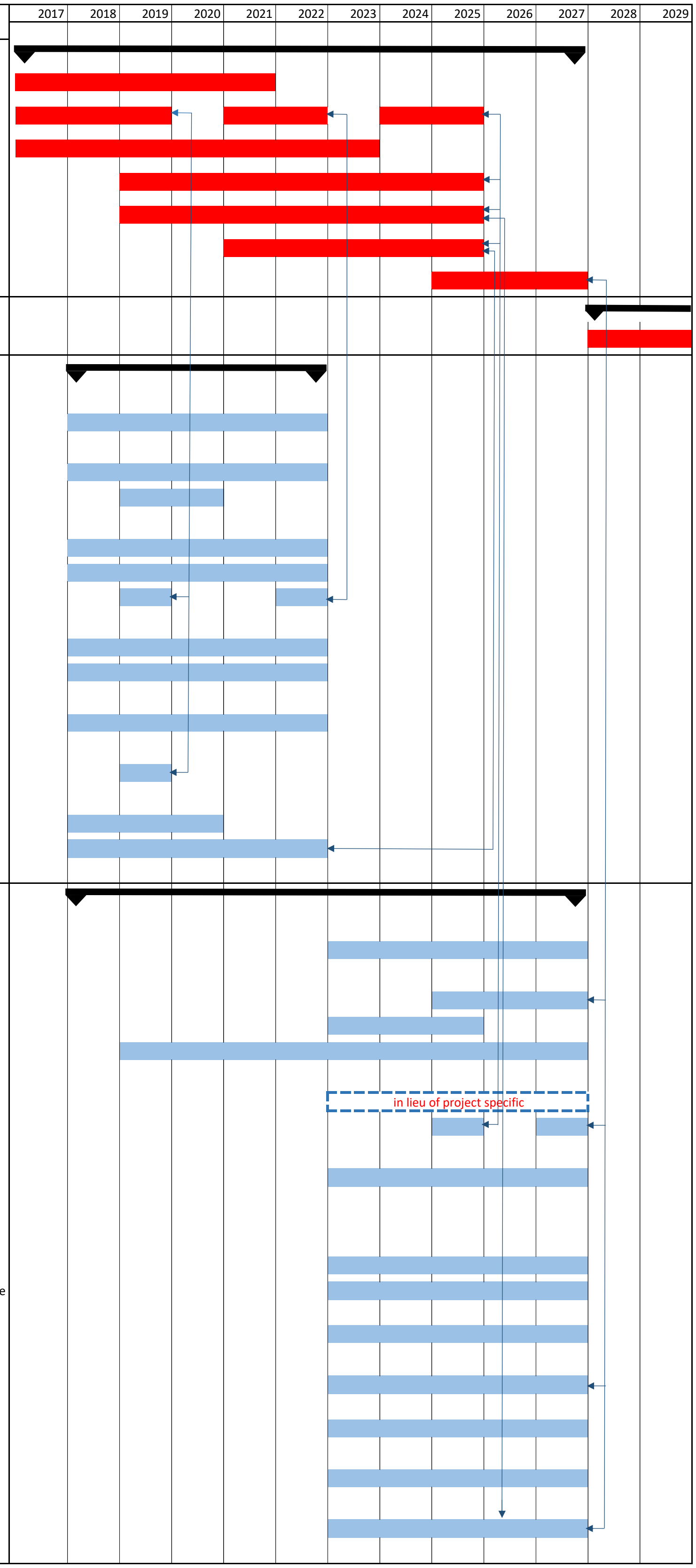
9. Preliminary Timeline

The attached timeline provides a graphic display of the links between projects and a possible phasing scenario. The top of the chart plots timing of major capital improvement projects as red bars based on the funding requested in the 2017-2027 Capital Plan. The lower part of the chart plots the potential timing of the various utility improvement projects in blue bars. If a particular utility improvement is required to service a capital project, the link arrow starts at the end of utility improvement (blue bar) and goes to the beginning of the capital project (red bar). If the utility improvement is planned to be completed as part of, or concurrent with, the major capital improvement, then the end of the improvement (blue bar) is linked at the end of the project (red bar).

All bars are representative of the construction duration for the project or utility improvement. The starts of new major improvements are deferred to at least the midpoint of the next biennium, 2020. If a particular utility improvement is not linked to another project is has “float” and is generally adjusted to level off the peaks and valleys of the funding stream.

WESTERN WASHINGTON UNIVERSITY
UTILITIES MASTER PLAN
10-YEAR PRELIMINARY TIMELINE
BELLINGHAM MAIN CAMPUS

Task ID	Task Name
	2017-2027 Capital Plan Highlights
1	Sciences Building Addition & Renovation
2	Support Services Facility (I,II,II)
3	Heating System Carbon Reduction & Energy Eff. Improvements
4	CFPA Renovation and Addition
5	Wilson Academic Renovation
6	Fine Arts/Arts Annex Renovation
7	New 100-200 Bed Residence Hall
	Planned Growth after 2027
8	Campus Buildout per IMP
	Current Improvements Needed
	Water
9	Leak Testing, Condition Investigations
	Sanitary Sewer
10	Monitoring condition of sewer pipes
11	Replace Sewer Traversing Downhill from Highland 2
	Stormwater
12	Monitoring condition of storm sewer pipes
13	Localized Stormwater Improvements 9-16
14	Detention/Water Quality Improvements
	Heating
15	Update Heating System Specifications
16	Further Evaluate New Heating Technologies
	Cooling
17	Further Evaluate New Cooling Technologies
	Electrical Power
18	Re-feed Fine Arts from the Steam Plant switchgear
	Generators
19	Reconfigure to Meet Ventilation Requirements (RK, SL)
20	Replace or Recertify 6 Generator Systems (BI,CB,FA,HG,SP,VU)
	10-Year Improvements Needed
	Water
21	Complete Replacement of Ridgeway Fire Loop
	Sanitary Sewer
22	Replace Trunk Line 600-602
23	Rehabilitate Sewer Line NE of Carver Gym
24	Monitor/Repair Sewer Between Humanities and Bond Hall
	Stormwater
25	North Campus Detention System
26	Detention/Water Quality Improvements
	Heating
27	Upgrade Existing Steam Boilers to Efficient, Modular Heating Water Boilers With Stack Condensing Economizers
	Replace / modify the Current Direct Steam Coils and Systems Within Each Building as Required:
28	- Decrease building steam pressure from > 30 to <5 psig
29	- Reconfigure Existing Domestic Hot Water Production to Use Steam Condensate and Water Storage
30	- Install Additional Building-Side Metering
	Cooling
31	Centralized North Loop - Chilled Water Expansion from Haggard Hall to Wilson Library
32	Heat Recovery Chillers/ Heat Pumps
	Electrical Power
	Selected projects from Section 7.4
	Generators
33	Replace or Recertify 13 Generator Systems (BH,CH,CF,EH,EN,ES,RA,RB,RC,RD,RG,RK,WL)



WESTERN WASHINGTON UNIVERSITY
UTILITIES MASTER PLAN
10-YEAR PRELIMINARY TIMELINE
BELLINGHAM MAIN CAMPUS

Task ID	Task Name	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029
	Build-Out Improvements (2028- buildout)													
	Water													
34	Replace domestic water - Ridgeway Buildings													
35	Replace 10-Inch Main Loop in the Central Campus													
36	Replace Fairhaven College Water Main													
37	Fire Sprinkler Additions													
	Sanitary Sewer													
	None identified													
	Stormwater													
38	North Campus Detention System (in lieu of project specific)													
39	Detention/Water Quality Improvements (project specific)													
	Heating													
40	Utilize Combustion Air Preheating Heat Exchanger Installed in the Boiler Stack Exhaust Stream													
41	Replace the Existing Steam & Condensate Distribution to New Hot Water													
	Cooling													
42	Centralized South Loop - Chilled Water Expansion from Communications Building to South Campus													
	Electrical Power													
	Selected projects from Section 7.4													
	Emergency Generators													
43	Generators plan remaining to be completed for 10-year plan													

1. INTRODUCTION

1.1. *Purpose*

The purpose of this plan is to provide a comprehensive evaluation of the existing utilities on the main Western Washington University campus. This plan evaluates capacity of utilities relative to the 10-year Capital Plan forecasted growth and the Institutional Master Plan build-out growth. This study also provides recommended utility system improvements that are needed to meet current and future demands. Reasonable order of magnitude (ROM) cost estimates are provided, where appropriate, for recommended improvements. All ROM costs are project costs, which include consultant services and administrative costs as well as construction costs.

The utility systems evaluated in this study include: Water distribution (including domestic, fire and irrigation), sanitary sewer, stormwater, steam distribution, steam condensate return, chilled water, electrical power distribution, and emergency & standby power. Information on other campus utilities not included as part of the study are summarized by the WWU managers and provided in the Appendices in Chapter 9.

1.2. *Background*

A comprehensive assessment of the entire on-campus utility systems was completed in 2007. Much of the south campus utilities (water, sanitary sewer, stormwater and electrical distribution) were previously evaluated in detail in the 1998 *Campus Infrastructure Predevelopment – Predesign Study* (David Evans and Associates et al, 1998).

The Institutional Master Plan (IMP), October 5, 2001, provides a framework for future development of Western Washington University to accommodate the projected growth (some growth will be accommodated by off campus facilities). All projected future growth and future utility needs are based on the IMP growth projections. The IMP divides the main campus into 23 districts according to land use. These districts are shown in Figure 1-1 and their characteristics are listed in Table 1-1. The IMP Districts shown reflect a revision to boundaries made in 2016/2017.

Geotechnical Issues: Variable and problematic subsurface conditions ranging from deep peat deposits to shallow sandstone bedrock have created problems in design and maintenance of infrastructure, particularly gravity dependent piping systems such as stormwater collection. These issues should be considered in all designs and cost estimates, and in fact can prohibit an otherwise best solution from being implemented.

1.3. *Study Area*

This Utilities Master Plan Study is limited to the main campus area as shown in Figure 1-1. The study includes the Physical Plant (IMP 22 and 23) and the south campus stormwater treatment facilities (IMP 20) but does not include Birnam Wood residential area (IMP 21).

1.4. *Recent Growth*

Substantial building and grounds improvements since 2007 include:

- PW465 - Miller Hall Renovation
- PW528 - Buchanan Towers Addition
- PW540 - Chemistry Building Addition (renamed Morse Hall)
- PW574 - New Greenhouse
- PW645 - Carver Renovation/Addition
- SP004 - Softball Complex Renovation
- PW660 - Multi-Purpose Field (Harrington Field)
- PW700 - PL C Lot Upgrade Paving Phase 1
- PW713 - PL C Lot Upgrade Paving Phase 2

1.5. *Future Growth*

The WWU Institutional Master Plan (IMP) provides predictions for the future growth on campus. Figure 1-1 shows the growth in gross square feet (GSF) of new building space projected for the 2017-2027 10-year Capital Plan and the Institutional Master Plan Median Build-Out. Table 1-1 shows this information in tabulated form, sorted by IMP districts.

The anticipated 10-year Capital Plan predicts an expected on-campus growth of 302,000 GSF (9.5 percent increase) with the following approximate breakdown of growth per IMP district:

- District 6 – 16 percent (48,000 GSF)
- District 11 – 2 percent (6,000 GSF)
- District 14 – 26 percent (80,000 GSF)
- District 18 – 33 percent (100,000 GSF)
- District 22/23 – 23 percent (68,000 GSF)

The anticipated IMP build-out includes an additional 597,000 GSF (added after 2027) (24.3 percent cumulative increase over 2017) with the following breakdown per IMP district:

- District 4 – 5 percent (30,000 GSF)
- District 9 – 17 percent (101,000 GSF)
- District 10 – 17 percent (102,000 GSF)
- District 11 – 3 percent (15,000 GSF)
- District 13 – 1 percent (7,000 GSF)
- District 14 – 52 percent (309,000 GSF)
- District 15 – 5 percent (27,000 GSF)
- District 16 – 1 percent (6,000 GSF)

The total anticipated build-out increase is 899,000 GSF.

The majority of growth is expected to be in the southern half of campus. District 14, surrounding Communication and the Stadium Sculpture Steps, is expected to have the largest growth on campus (over 50 percent of total).

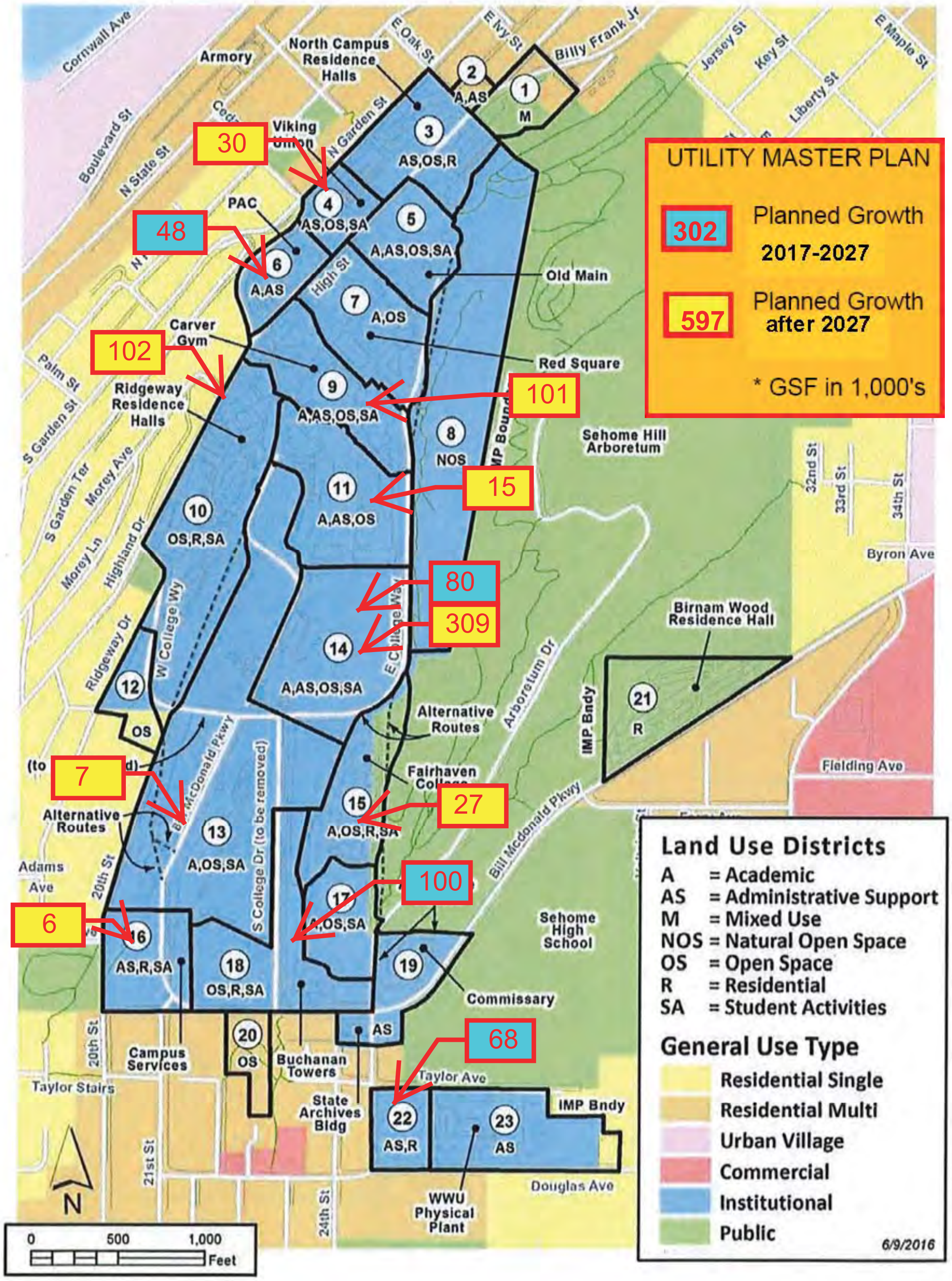
In this study, the capacities of existing utilities were evaluated for both the anticipated 10-year Capital Plan growth and IMP Median Build-Out growth.

Future parking structures or parking lots are not addressed specifically in this study. The possible increased demand to utilities is relatively insignificant for parking improvements, with the exception of stormwater management facilities.

1.6. *Sustainability*

WWU is committed to sustainability in all aspects of campus development, energy consumption, and environmental stewardship. This is reflected in the design of each project as it is developed. This study is focused on the capacities of the various utilities to meet current and future demands. Energy and resource conservation measures such as water efficient plumbing fixtures and energy efficient buildings will extend the service life of existing limited capacity systems, thereby reducing the need for capital intensive upgrades. Low impact site development techniques will reduce the need for additional capital intensive stormwater control facilities.

Figure 1-1. IMP Land Use District Map with Projected Growth in Gross Square Feet (7/20/16).



[Amended by Ord. 2010-12-073; Ord. 2016-07-020 § 1 (Exh. A)]

Western Washington University Institutional Master Plan II-15

Table 1-1. Existing and Future Gross Square Footage of On Campus Buildings. The Projected Increase is shown as the Difference between Existing and Future.

Districts	Existing July 2017 GSF	Proposed 2027 GSF	IMP Medium Buildout GSF	10-year Increase 2017 to 2027 GSF	Increase 2017 to Buildout GSF	Increase 2027 to Buildout GSF
1	--	--	--	--	--	--
2	3,000	3,000	3,000	0	0	0
3	320,000	320,000	320,000	0	0	0
4	83,000	83,000	113,000	0	30,000	30,000
5	145,000	145,000	145,000	0	0	0
6[1]	144,000	192,000	192,000	48,000	48,000	0
7	519,000	519,000	519,000	0	0	0
8	--	--	--	--	--	--
9	232,000	232,000	333,000	0	101,000	101,000
10	262,000	262,000	364,000	0	102,000	102,000
11	542,000	548,000	563,000	6,000	21,000	15,000
12	--	--	--	--	--	--
13	103,000	103,000	110,000	0	7,000	7,000
14	257,000	337,000	646,000	80,000	389,000	309,000
15	174,000	174,000	201,000	0	27,000	27,000
16	35,000	35,000	41,000	0	6,000	6,000
17	--	--	--	--	--	--
18[2]	151,000	251,000	251,000	100,000	100,000	0
19	56,000	56,000	56,000	0	0	0
20	--	--	--	--	--	--
21	121,000	121,000	121,000	0	0	0
22/23[3]	36,000	104,000	104,000	68,000	68,000	0
TOTAL	**3,183,000**	**3,485,000**	**4,082,000**	**302,000**	**899,000**	**597,000**
			PERCENT INCREASE	**9.5%**	**28.2%**	**17.1%**

Notes:

1. District 6 buildout increased by 3,000 GSF since 2007.
2. District 18 buildout increased by 100,000 GSF since 2007.
3. District 22/23 buildout increased by 23,000 GSF since 2007.

Table 1-2. Key to IMP District Building Locations in the Study Area

SORTED BY BUILDING ID		
Building ID	Building Name	IMP Area
AA	ARTS ANNEX	9
AB	ARCHIVE BUILDING	19
AH	ARNTZEN HALL	11
AI/AW	ACADEMIC INSTRUCTION CENTER	14
BH	BOND HALL	7
BI	BIOLOGY BUILDING	11
BK	BOOKSTORE	4
BT	BUCHANAN TOWERS	18
BQ	BUCHANAN TOWERS EAST	18
CA	CANADA HOUSE	6
CB	CHEMISTRY BUILDING (Morse Hall)	11
CF	COMMUNICATION FACILITY	14
CH	COLLEGE HALL	9
CM	COMMISSARY	19
CS	CAMPUS SERVICES FACILITY	16
CV	CARVER GYMNASIUM	9
EH	EDENS HALL	3
EN	EDENS NORTH	3
ES	ENVIRONMENTAL STUDIES CENTER	11
ET	ROSS ENGINEERING TECHNOLOGY	11
FA	FAIRHAVEN COLLEGE ACADEMIC	15
FX01-12	FAIRHAVEN TOWERS	15
FI	FINE ARTS BUILDING	9
FR	FRASER HALL	7
HG	HIGGINSON HALL	3
HH	HAGGARD HALL	7
HI	HIGHLAND	10
HL	HIGHLAND LOUNGE	10
HS	HIGH STREET HALL	6
HU	HUMANITIES BLDG	7
MA	MATHES HALL	3
MH	MILLER HALL	7
NA	NASH HALL	3
OM	OLD MAIN	5
PA	PERFORMING ARTS CENTER	6
PH	PARKS HALL	11
PP	PHYSICAL PLANT	23
RA	RIDGEWAY ALPHA	10
RB	RIDGEWAY BETA	10
RC	RIDGEWAY COMMONS	10
RD	RIDGEWAY DELTA	10
RG	RIDGEWAY GAMMA	10
RK	RIDGEWAY KAPPA	10
RO	RIDGEWAY OMEGA	10
RS	RIDGEWAY SIGMA	10
SL	SMATE (SCIENCE LECTURE HALLS)	11
SP	STEAM PLANT	9
SV	STUDENT RECREATION CENTER	13
VC	VIKING COMMONS	3
VU	VIKING UNION	4
WL	WILSON LIBRARY	7

SORTED BY IMP DISTRICT		
IMP Area	Building ID	Building Name
3	EH	EDENS HALL
3	EN	EDENS NORTH
3	HG	HIGGINSON HALL
3	MA	MATHES HALL
3	NA	NASH HALL
3	VC	VIKING COMMONS
4	BK	BOOKSTORE
4	VU	VIKING UNION
5	OM	OLD MAIN
6	CA	CANADA HOUSE
6	HS	HIGH STREET HALL
6	PA	PERFORMING ARTS CENTER
7	BH	BOND HALL
7	FR	FRASER HALL
7	HH	HAGGARD HALL
7	HU	HUMANITIES BLDG
7	MH	MILLER HALL
7	WL	WILSON LIBRARY
9	AA	ARTS ANNEX
9	CH	COLLEGE HALL
9	CV	CARVER GYMNASIUM
9	FI	FINE ARTS BUILDING
9	SP	STEAM PLANT
10	HI	HIGHLAND
10	HL	HIGHLAND LOUNGE
10	RA	RIDGEWAY ALPHA
10	RB	RIDGEWAY BETA
10	RC	RIDGEWAY COMMONS
10	RD	RIDGEWAY DELTA
10	RG	RIDGEWAY GAMMA
10	RK	RIDGEWAY KAPPA
10	RO	RIDGEWAY OMEGA
10	RS	RIDGEWAY SIGMA
11	AH	ARNTZEN HALL
11	BI	BIOLOGY BUILDING
11	CB	CHEMISTRY BUILDING (Morse Hall)
11	ES	ENVIRONMENTAL STUDIES CENTER
11	ET	ROSS ENGINEERING TECHNOLOGY
11	PH	PARKS HALL
11	SL	SMATE (SCIENCE LECTURE HALLS)
13	SV	STUDENT RECREATION CENTER
14	AI/AW	ACADEMIC INSTRUCTION CENTER
14	CF	COMMUNICATION FACILITY
15	FA	FAIRHAVEN COLLEGE ACADEMIC
15	FX01-12	FAIRHAVEN TOWERS
16	CS	CAMPUS SERVICES FACILITY
18	BT	BUCHANAN TOWERS
18	BQ	BUCHANAN TOWERS EAST
19	AB	ARCHIVE BUILDING
19	CM	COMMISSARY
23	PP	PHYSICAL PLANT

Table 1-3. Residence Hall Capacities

Building ID	Year Constructed	Year of Major Renovation	Gross Square Feet (historical)	Total Operating Capacity
BT	1971	2011	101,095	424
BQ	2011		50,000	105
BW[1]	1970		121,448	520
EH	1994	2005	51,420	158
EN	1956		26,432	114
FX	1970		138,012	650
HG	1961	2008	47,241	221
HI	1960	2003	16,071	137
MA	1966		75,381	300
NA	1967		76,891	348
RA	1962		21,109	107
RB	1964		35,857	207
RD	1962		22,513	115
RG	1964	2016/17	38,529	226
RK	1963	2015	48,577	235
RO	1962		20,693	108
RS	1962		20,471	108
SYSTEM TOTALS	**average 1967**		**977,018**	**4,083**

1. BW is not included in this study

2. WATER DISTRIBUTION SYSTEM

2.1. Existing System

2.1.1. Description

The water distribution system has been improved substantially over the past ten years. Water consumption is approximately 7 percent less than in 2007. This indicates that water main replacements and repair projects completed by WWU have decreased leakage substantially. Installation of low-flow fixtures and other conservation measures have contributed to the reduction as well.

The majority of the water distribution system for the campus exists within the City's South 457 Pressure Zone. The exception is the Ridgeway Complex area, for which the domestic water and fire protection water are supplied by the City's Sunset Heights 541 Pressure Zone. Figure 2-1 shows the University vicinity and the surrounding City of Bellingham water distribution system pressure zones.

The static pressure or head (in feet) at any particular location in the 457 pressure zone is equal to the static head (i.e. water tank elevation of nominally 457 feet) minus the elevation at that location. Pressure (in PSI, pounds per square inch) is equal to the head in feet multiplied by 0.433 (e.g., 100 feet = 43.3 PSI).

<u>457 Pressure Zone</u>

The 457 Pressure Zone is supplied by the Otis Street Pump Station and includes three storage reservoirs; Sehome (0.7 million gallons), Sunset (0.5 million gallons), and Padden (0.5 million gallons), all with maximum water surface elevation of 457 feet. The Otis Street Pump Station consists of four pumps:

- Pump 1 – 2,200 gallons per minute (GPM) at 200 feet total pressure head
- Pump 2 – 3,775 GPM at 200 feet total pressure head
- Pump 3 – 3,775 GPM at 200 feet total pressure head
- Pump 4 – 1,400 GPM at 200 feet total pressure head

541 Pressure Zone

The static pressure (in feet) at any particular location in the 541 Pressure Zone is equal to the total head supplied by the pump station (i.e., water tank elevation of nominally 457 feet plus the pump boost of 94 feet) minus the elevation at that location. The City demolished the Sunset Heights water tower in 2005 (0.07 million gallons, maximum water surface elevation 541 feet) and installed the Sunset Heights Pump Station to supply the zone from Sunset Reservoir. The Sunset Heights Pump Station consists of three sets of parallel pumps with the listed capacities:

- Two (2) domestic pumps: 88 GPM at 133 feet total pressure head
- Two (2) peak domestic pumps: 576 GPM at 142 feet total pressure head
- Two (2) fire/booster pumps: 1,750 GPM at 89 feet total pressure head

Total dynamic head supplied during a 1,750 GPM fire flow would be approximately the equivalent of the pressure head supplied by the old water tower.

Campus Water System

The City distribution mains supply the University system with direct service connections and with connections to University-owned mains. The University mains are isolated from the City distribution mains with meters and backflow preventers. With the exception of two dead end service extensions (near Commissary and Miller Hall), City water lines supplying the University system are looped. University water supplies are also looped in most instances, but several dead end lines do exist. The City is responsible for supplying water and pressure as well as maintaining and upgrading reservoirs, pump stations, distribution mains, and any components such as fire hydrants, valves, etc. The University is responsible for maintaining and upgrading its service lines and respective components connected to City mains.

The existing water distribution system, including approximate locations of reservoirs, pipes, hydrants, and meters is shown in Figure 2-2 and in detail in Figure 2-2A. Also shown in the figure are University area buildings, streets, parking lots, and topography. Figure 2-3 shows additional identification and location information for the nodes (junctions) used in the system hydraulic model analysis. Model information including junction pressure zone, demand type, and elevation and pipe diameter, length, installation year, owner, and start and end node are all contained on compact disc provided under separate cover. Information on the existing water system was obtained from University Facilities Management, record drawings, past studies and reports conducted for the University, and the City of Bellingham Public Works Department.

Improvements 2007 - 2017

- WWU upgraded the campus water system and buildings such that all buildings are now served by hydrants capable of meeting minimum flow and pressure requirements (with the exception of Commissary).

- WWU replaced the University-owned 6-inch cast iron line (circa 1968), from Oak Street to Carver Gym with 12-inch ductile iron. The City now has ownership of this water main. This improved the flow capacity of the campus water system and in particular fire flow to six buildings (Edens Hall, Humanities, Old Main, Wilson Library, Haggard Hall, and Fraser Hall).

- WWU replaced the aging 6-inch cast iron fire loop piping with new 6-inch and 8-inch piping (except for the very southern portion). Connected Ridgeway fire hydrants and sprinklers to the City Sunset Heights 541 Pressure Zone, which brought fire flow capacity to greater than the required minimum of 1,500 GPM.

- Replaced existing City 8-inch cast iron dead-end line serving Miller Hall to the south with new 10-inch ductile iron pipe. This increased the available flow to approximately 4,200 GPM for Miller Hall.

- WWU added sprinkler systems in the following residence halls: Buchanan Towers, Mathes Hall, Nash Hall, Ridgeway Halls, and Fairhaven Towers. The new Buchanan East has sprinklers as well. Edens North is the only residence hall without sprinklers.

- WWU added sprinkler systems in the following academic halls: Carver, Miller.

- The gate valve to the north of Fairhaven College now remains open (versus being closed as before). This allows the buildings to be supplied by looped piping rather than dead-end piping. This improvement increases the available flow at the hydrant nearest Fairhaven Academic to approximately 4,300 GPM. The lowest available flow is approximately 2,500 GPM at the south “dead-end” hydrant. Therefore, all Fairhaven residence towers now have sufficient fire flow.

- City of Bellingham made no known significant improvements.

2.2. Existing Conditions Demand Evaluation

2.2.1. Basis of Analysis

The campus potable water system supplies flow for two consumptive uses: (1) domestic (indoor) use and (2) irrigation use, which is usually metered separately. The water system also supplies water to fire hydrants, building sprinkler systems and building fire hose systems. These fire flow uses are non-consumptive except for limited water used in testing systems. Domestic consumption and irrigation consumption are considered separately. These two uses do not generally overlap in their peak consumption periods. Irrigation is the third consumptive demand which herein is considered separately, as feasible, from domestic water demand.

The three measures of domestic water demand (consumption) used herein are Average Day Demand (ADD), Maximum Day Demand (MDD) and Peak Hour Demand (PHD). The Average Day Demand is calculated from the monthly or bimonthly water meter records during in-session periods. The maximum day is equivalent to the highest expected 24-hour demand, expressed in gallons per day (GPD). The PHD is equal to the highest expected 1-hour demand, expressed in gallons per minute (GPM).

In determining the distribution system capacity to meet domestic water requirements, the system must be able to supply the PHD and maintain a minimum pressure at the highest point of service for each building (per University standards). For this study, the desired minimum pressure is 30 PSI (based on pressure needed for toilet flush valves) and 25-30 PSI is defined as marginal. Any pressure less than 25 PSI at the highest point of service for a particular building is considered inadequate.

In determining the distribution system capacity to meet fire flow requirements, the system must be able to provide the fire flow together with the maximum day flow. The water main pressure may be below 30 PSI but must be at least 20 PSI throughout its length during fire flows (City of Bellingham Fire Protection Development Standards 5-01.3 and WAC 246-290-230[6]). Note that available fire flows for all new buildings must meet the requirements of the City's Fire Protections Development Standards;

however, these requirements do not strictly apply to existing older buildings. Please note that the term "required" is used throughout this section in either case.

In determining the distribution system capacity to meet automatic fire sprinkler flow requirements, the system must be able to supply the pressure needed at the top floor sprinkler heads. The design minimum sprinkler head pressure criterion used in this study is 14 PSI.

2.2.2. Domestic Flow Demand

Water demands for the University were evaluated using water meter data for the time period 2013 through 2016. Only full in-session months of water use data were used (i.e. NOT winter break, spring break, or summer months). Meter data generally is from mid-month to mid-month, thus full in-session periods of data evaluated typically included mid-January to mid-March, mid-April to mid-June, and mid-October to mid-December. Some meters serve individual buildings and some serve more than one building. For meters corresponding to more than one particular building, the total water consumption data was assigned proportionately to each building weighted by the buildings gross square footage.

Average Day Demand

The average day for each building was calculated by dividing the total consumption for the full in-session months over the three-year period by the total days for the corresponding months of data used. The University's current average day demand for the South 457 and Sunset Heights 541 Pressure Zones are approximately 101 GPM and 24 GPM, respectively (125 GPM total). This is a 7 percent reduction since 2007. Irrigation meters were not included in the calculation of ADD.

Maximum Day Demand

The maximum day for this analysis was assumed to be equal to the average day multiplied by a factor of 2 for both residential and academic/auxiliary building types. The Washington State Department of Health (DOH) Water System Design Manual suggests that historical data and experience supports maximum day to average day ratios in the 1.5 to 3.0 range (2.0 being typical). The factor is considered appropriate since the average day calculations already consider higher demand when all students are present. Based on the meter data and these assumptions, the University's current MDDs for the

South 457 and Sunset Heights 541 Pressure Zones, respectively, are estimated to be 202 GPM and 48 GPM (250 GPM total).

Peak Hour Demand

PHD for the University was calculated assuming a ratio of PHD:ADD of 3:1 for residential type buildings and 6:1 for academic/auxiliary type buildings. Sanitary sewer flow monitoring data collected in 1998 and in 2007 appears to support these factors for PHD. The PHDs for the South 457 and Sunset Heights 541 Pressure Zones, respectively, are 425 GPM and 72 GPM (497 GPM total). Domestic water meter data and subsequent calculations for the demand evaluation are presented in Table 2-1.

2.2.3. Irrigation Flow Demand

Most of the irrigation water demands for the University are metered separately from domestic water demands and were evaluated using water meter data for the time period 2013 through 2016. Only the peak irrigation season months (July and August) of water use data were used. Peaking factors for maximum day/ average day ratio of 2 were used in calculating irrigation demands. The total University irrigation average day and maximum day demands were approximately 63 GPM and 125 GPM, respectively. The irrigation water meter data are presented in Table 2-1. The University uses irrigation management practices such as rotating water schedules and nighttime watering to reduce the impact of irrigation on the domestic water demand. Irrigation demands were not included in the hydraulic modeling analyses for this study because peak irrigation use and peak in-session periods have different timing.

2.2.4. Fire Flow Demand

Fire flow demands for the University were calculated based on the City of Bellingham Fire Protection Development Standards, which reference the latest Edition of the International Fire Code. The fire protection standards require a minimum residual pressure of at least 20 pounds per square inch (PSI) in the mains for fire flow, whether it is temporary or permanent, and the required demand duration is two (2) hours. The fire flow requirement for each building was calculated by identifying the flow requirement based on square feet of fire area and building construction type and then making modifications depending on sprinkler system installations, hazard classification, proximity to other buildings, and fire/smoke detection system installations.

Base Fire Flow

The "base" fire flow requirement (i.e., not including flow reductions for sprinklers, etc.) for each University building was determined based on gross square feet and the construction type from either City or University records.

Fire Flow Adjustments

Each building's base fire flow requirement was determined using a combination of sources and assumptions. Building sprinkler system and fire detection system information was obtained from University Facilities Management to assess any qualifying deductions in the fire flow requirement. Few building hazard classifications were compiled from old project reports or University records, thus, most classifications were assumed based on typical building activity and applied to the calculations for hose stream allowances. GIS mapping was used to compile distances to nearby buildings, which are used to adjust (increase) flow requirement due to close proximity. Table 2-2 shows the calculated required fire flows for the University buildings and relevant information used including gross fire area, IBC construction type, sprinkler system description, hazard classification, hose stream allowance, and distance to nearest building(s). The table also shows building height.

2.2.5. System Capacity

2.2.5.1 Hydraulic Model

The University water distribution system was modeled using Innovyze InfoWater for ArcGIS computer program. This is the same software that the City of Bellingham uses to model the City's water distribution system.

Data Sources

Data for constructing the model was obtained from a number of sources. The City's GIS database for the City water distribution system was used as the primary source of data and provided information for pipe age, material, and diameter on the City mains that supply the University services and mains. Pipe age, material, and diameter information on service lines, such as the University-owned supply lines, was not available from City GIS data. The primary sources for the University-owned lines were University Facilities Management shop drawings, the 1998 *WWU Campus Infrastructure Development Pre-Design* (CID) study, and various archived record drawings. Information for updates to the model infrastructure reflecting improvements since the last UMP update (2007) were obtained from record drawings provided by Facilities Management staff.

<u>Pipe Characteristics</u>

The roughness of a pipe's interior affects the flow capacity of the pipe. Flow capacity is proportional to the roughness factor (i.e. a pipe with a Hazen-Williams C value (roughness factor) of 130 has twice the flow capacity of a pipe with a C value of 65). Pipe roughness values modeled were based on values reported in the CID study, which was based on the results of previous City field calibration tests. For all pipes for which the roughness has not been determined by testing, the Hazen-Williams C factor is assumed to be C=130 for new pipes and C=100 for 60 year old pipes or the appropriate interpolated value In between (assuming an annual decrease of 0.5 units/year). City GIS data, CID study data, and record drawings were used to approximate node junction elevations used in the model. Model nodes are shown in Figure 2-3 and additional information concerning model nodes and pipes is available on a separate compact disc as stated previously.

<u>Model Boundary Conditions</u>

The University water distribution system is contained within and supplied by the City's South 457 Pressure Zone. The following assumptions were made for the University computer model boundary conditions:

- The City's South 457 Pressure Zone is essentially an unlimited source and that the University vicinity water pressure provided by the Otis Street Pump Station is a constant 457 feet (elevation).
- City water supply demands outside the campus were conservatively estimated and applied to the computer model based on the size of the pipe supplying those demands or the population density.

<u>Model Calibration Data</u>

Available system pressure tests and hydrant flow tests were used as a source of calibration for the model. Hydrant flow test data was used as appropriate. Residual pressure data at non-flowing hydrants was used to calibrate or verify the computer model. Residual pressure data from flowing hydrants was not used because the pressure drop in a flowing hydrant can be substantially higher than pressure drop in the water main. The computer model evaluates the residual pressure in the water main not in hydrant service lines. Flow testing was conducted in March 2017 in the Fairhaven Towers complex and the College Way Loop. Calculated C values based on the flow testing results were incorporated into the updated model.

2.2.5.2 Peak Hour Demand Capacity

The existing University system was analyzed at each building to determine its ability to provide the desired pressure of 30 PSI at the highest point of service for each building. The existing university system is fully capable of providing at least 30 PSI to all building water service connections at ground level (required per WAC 246-290-230[5]) under estimated peak hour demands. Building water pressure at the highest point of service was calculated by applying static head loss (vertical distance to top floor service at 4 feet above the floor) and dynamic head losses through the building piping system (calculated as 5 PSI). All University buildings, with the exception of those listed below, are estimated to be capable of supplying pressures above 30 PSI at the top level:

- Environmental Studies 20.8 PSI (inadequate)
- Old Main 26.1 PSI (marginal)
- Arntzen Hall 26.8 PSI (marginal)
- Edens Hall 26.8 PSI (marginal)
- Parks Hall 27.6 PSI (marginal)
- *Edens North 30.1 PSI (marginally adequate)*
- *Wilson Library 30.4 PSI (marginally adequate)*
- *Biology Building 30.6 PSI (marginally adequate)*
- *Chemistry Building (Morse) 30.8 PSI (marginally adequate)*
- *Communications Facility 31.0 PSI (marginally adequate)*

2.2.5.3 Fire Flow Capacity

The existing system was analyzed in two different ways to determine the fire flow capacity. In the first analysis, available fire flows were determined for each fire hydrant in the system, at the design conditions of: maximum day flows and a minimum 20 PSI residual pressure in the water main throughout the system (per WAC 246-290-230[6]). The available flows were determined assuming, conservatively, that the hydrant of interest is the only hydrant flowing. In the second analysis, sprinkler system residual pressure at the top of each building was determined for the condition: sprinklers activated during system wide maximum day flows. The sprinkler plus hose allowance flows are 310 GPM for residence halls and 650 GPM for all other buildings. This analysis was conducted in order to determine (1) the water pressure available for charging sprinkler systems and (2) if fire flow booster pumps or other system upgrades might be needed to meet sprinkler system design criteria. Both analyses were conducted with Sehome and Sunset Reservoirs modeled as half full.

Available Fire Flows

Figure 2-4 shows each fire hydrant in the existing system and its available flow while maintaining 20 PSI residual pressure throughout the system. In assessing which buildings can be served by which fire hydrants, it was assumed for simplicity that each fire hydrant has a 150-foot radius reach. The following is a summary list of buildings or zones with existing inadequate fire flows as estimated by the hydraulic model simulations:

- Commissary building supplied by the City 1968 6-inch cast iron (dead-end branch).

It is important to note that a few buildings have marginal (+/- 500 GPM) capacity relative to calculated required fire flows, including Ridgeway Beta, Ridgeway Kappa, and SMATE (Science Lecture Halls). However, these buildings have other hydrants nearby that can supply adequate fire flows.

Note that the above fire flow adequacy was assessed assuming conservatively that one critical nearby hydrant was flowing. In reality, some locations may be effectively supplied adequate fire flow if pumping from two or more hydrants that are not on directly interconnected branch lines.

Sprinkler System Residual Pressure

The available residual pressures at the highest sprinkler elevation of each building during design sprinkler fire flow conditions are displayed in Table 2-3. The nominal design requirement is 310 GPM for residence halls (light hazard: 210 GPM for sprinklers, 100 GPM for combined inside and outside fire hose) and 650 GPM for all other buildings (ordinary hazard: 400 GPM for sprinklers, 100 GPM for inside fire hose, and 150 GPM for outside fire hose). The criteria for the water pressure at the top of the building (at the sprinkler head) is 14 PSI for all buildings. The water pressure at the top of the building is calculated from the pressure at the street level water main connection (computer model result at either 310 GPM or 650 GPM, plus maximum day flows) minus pressure losses. The assumed pressure loss through the sprinkler system includes: a safety factor pressure reduction of 10% at the water main connection, 6 or 8 PSI head loss (for light or ordinary hazard, respectively) through the backflow preventer and building piping, and the difference in elevation between the top sprinklers and the service main connection.

As shown in Table 2-3, several academic/auxiliary type buildings (ordinary hazard) do not currently have enough pressure at the service main connection to achieve the desired design sprinkler flow pressure (14 PSI) under assumed conditions, including Environmental Studies Center, Old Main, Arntzen Hall, Parks Hall, Chemistry Building (Morse Hall), Biology Building, Wilson Library, Communications Facility, and Bond Hall (marginal). Note: Bond Hall is adequate according to a more detailed independent analysis by BCE. The following buildings (only of those listed) have pumps to overcome the pressure deficit: Environmental Studies Center, Old Main, Biology Building, and Communications Facility. All residential type buildings (light hazard) currently are estimated to have enough pressure at the service main connection to achieve the desired design sprinkler flow pressure under the assumed conditions. **As a rule of thumb, buildings in the 457 pressure zone with sprinkler elevations of 383 feet and higher may not have adequate pressure. However, each building should be designed and tested individually to precisely determine pressure adequacy.**

2.3. Future Conditions Demand Evaluation

2.3.1. Description

The capacity of the existing water distribution system was evaluated for the 10-year Capital Plan growth scenario and the IMP Median Build-Out growth scenario. For these future scenarios, the analysis assumes that NO infrastructure improvements in the existing system pertaining to hydraulic modeling will have already occurred. It is assumed that all residence halls will have full wet fire protection sprinkler systems. It is important to note that the infrastructure for any new buildings needs to support automatic fire sprinklers in case they are required by the building use or design.

2.3.2. Domestic Flow Demand

The University water meter data records for the existing system analysis were used to estimate planned growth demands by determining an ADD/area average separately for academic and residential buildings. The ADD/area averages were then applied to estimate future demand increases based on the planned growth building gross square footage area and land use category (academic or residential) for each District. Details on the projected University demands by land use District are presented in Table 2-4. Note that water usage went down significantly over the last ten years (inversely with growth), so this may be an overly conservative assumption.

The University 10-year Capital Plan growth will increase the domestic water demand to approximately:

- MDD: 290 GPM (currently 250 GPM) (40 GPM or 16% increase)
- PHD: 569 GPM (currently 497 GPM) (72 GPM or 14.5% increase)

The estimated domestic water demand totals for the University IMP Median Build-Out are estimated to be approximately:

- MDD: 346 GPM (currently 250 GPM) (96 GPM or 38% increase)
- PHD: 690 GPM (currently 497 GPM) (193 GPM or 39% increase)

The estimated future demands were applied to the model for each of the 2027 10-year Capital Plan and IMP Median Build-Out scenarios. The City growth (demands external to the University system model) around the University will be negligible for both future scenarios. Based on City of Bellingham projected growth for 2017 - 2027, the largest area of growth around the University would be 200 residents in the Happy Valley neighborhood (southeast of main campus near Birnam Wood residences). This is a 10% growth from the 2010 population and most is expected to be in areas relatively insignificant to University water supply from the City. Hydraulic model sensitivity analyses performed in 2007 showed less than 1 PSI decrease in water pressures in the worst case scenario.

2.3.3. Irrigation Flow Demand

University irrigation demands for the 10-year Capital Plan and IMP Median Build-Out were assumed to remain approximately the same as existing irrigation demands. It is believed that a balance of additional building area and parking lot removal may be achieved in the long term plans of the University. Any changes that may occur in future irrigation demands are expected to have a no effect on the overall capacity of the water distribution system. Current irrigation demands are approximately 13% of the total domestic and irrigation water demands.

2.3.4. Fire Flow Demand

University fire flow demands for the 10-year Capital Plan and IMP Median Build-Out are the same as presented in the existing conditions fire flow demands Table 2-2, with the exception of buildings that are planned to have full sprinkler systems installed. The University's near term plan is to install full sprinkler systems in all residence halls, except Highland Hall (only Edens North remains to be equipped with sprinklers). The installation of full sprinkler systems for the following buildings would reduce the fire flow requirement to the 1,500 GPM minimum:

- Arntzen Hall
- Bond Hall
- Commissary (currently inadequate fire flow capacity)
- Edens North (only residence hall remaining to be equipped with sprinklers)
- Fine Arts (after 2027)
- Performing Arts (both new and rebuilt)
- Ross Engineering Technology
- Wilson Library (after 2027)

2.3.5. System Capacity

2.3.5.1 Peak Hour Demand

Estimated PHD increases for future growth of the University will have negligible effect on the pressure supplied at each building. All buildings will have the minimum required 30 PSI <u>at the water service connection</u> for peak hour demand (PHD). However, the tap water pressures in the upper floors of some buildings are marginal to inadequate and will be somewhat more so with full build-out in the future. Water pressures will decrease by approximately 0.5 PSI between 2017 and 2027 and by approximately 1 PSI between 2017 and IMP Median Build-Out conditions in some locations near where future growth is concentrated (i.e. District 14). These buildings and their existing top level water pressures at PHD flow are listed in Section 2.2.5.2 Peak Hour Demand Capacity. The identified buildings that are clearly inadequate need domestic booster pumps to achieve satisfactory pressure and flow at the upper floor taps and toilet flush valves.

2.3.5.2 Available Fire Flows

Figure 2-5 shows model estimated available fire flows while maintaining 20 PSI residual pressure at hydrants for the 10-year Capital Plan (2027) future scenario. The 2027 modeled scenario reflects estimated 2027 demands, additional pipe aging of 10 years (pipe friction C-value decrease of 5 from existing approximations) applied to all system pipes. Figure 2-6 shows model estimated available fire flows while maintaining 20 PSI residual pressure at hydrants for the IMP Median Build-Out future scenario. The build-out scenario reflects estimated build-out demands, additional pipe aging of 20 years (C-value decrease of 10 from existing approximations) applied to all system pipes. Estimated maximum day increases for future growth of the University have relatively little effect on the overall fire flow capacity of the system in relation to increased pipe age and roughness. In areas very near where the additional future demands are assumed to be applied to the system, it is estimated that available flows generally decrease approximately 25 GPM due to demand increases (additional flow decrease is due to pipe aging effects).

As expected, campus buildings and areas that currently have inadequate fire flows will continue as such into the future (Commissary). Other buildings that are currently adequate will become marginally adequate or inadequate in future scenarios (Arntzen, Ross Engineering technology, SMATE). However, if sprinkled then available fire flows may be adequate. Some fire loop piping in the Ridgeway Complex is still old cast iron piping (south end near Ridgeway Gamma) that may cause certain areas of limited available fire flow in future conditions. This area should continue to be monitored.

2.3.5.3 Sprinkler System Residual Pressure

The IMP Median Build-Out growth future scenario available residual pressures at the highest sprinkler elevation of each building during design sprinkler fire flow conditions (310 GPM for residence halls and 650 GPM for all other buildings) are displayed in Table 2-5. Anticipated pressure decreases over time generally range from 0.5-1.5 PSI from existing conditions to IMP Median Build-Out growth conditions (less for the 10-year Capital Plan growth conditions). **As a rule of thumb, buildings in the 457 pressure zone with sprinkler elevations of 383 feet and higher may not have adequate pressure.** Buildings that do not appear to have adequate water pressure to meet the sprinkler flow design criteria of 14 PSI are (in order of increasing water pressure):

- Environmental Studies Center (currently has fire pump)
- Old Main (currently has fire pump)
- Chemistry Building
- Biology Building (currently has fire pump)
- Wilson Library
- Communications Facility
- Bond Hall (adequate according to BCE's independent analysis)

2.4. Recommended Improvements

The following recommended improvements are planning level improvements. Therefore, the sizing and extent of the improvements should be further refined if selected for implementation. Table 2-6 provides a summary of fire flow status and sprinkler improvement recommendations for selected critical areas in the University water distribution system. It is also recommended to implement investigation efforts, particularly at Ridgeway and Fairhaven complexes. Investigation recommendations include, but are not limited to the following:

- Conduct leak testing during inter-session periods to identify major leaks and areas to prioritize, or establish priority of major projects,
- Expose and investigate actual conditions of piping,
- Conduct flow testing and/or excavation to confirm infrastructure network and connectivity (particularly at Fairhaven complex).

2.4.1. Minimum Recommended Improvements

Figure 2-7 shows the location of the following minimum recommended improvements. These are not capacity issues yet and do not have to be implemented within the next 10 years. Replacement of Ridgeway Fire Loop is recommended as a 10-year capital project.

1. **Replace domestic water piping serving all the Ridgeway Buildings**
   The entire domestic 3-inch and 4-inch diameter cast iron piping loop through the area should be replaced, including all building branches off of the main through loop piping. The pipe was installed circa 1962 and is past its useful life. At least 4-inch diameter ductile iron piping should be installed (6-inch recommended). This does not include replacing the fire service lines which are a separate system. Pipe

replacements can be made in one large project or separate smaller projects. Approximate length of main pipe replacement is 1,800 LF.

2. **Complete Replacement of Ridgeway Fire Loop**
   Replace existing 6-inch diameter cast iron fire loop piping south of Ridgeway Kappa and Gamma buildings. This segment of piping limits available fire flows under future conditions primarily due to continued aging and degradation of pipe capacity. The piping should be replaced with 8-inch HDPE (plastic) to match recent adjacent upgrades. Approximately length of main pipe replacement is 600 feet.

3. **Replace University 10-Inch Water Main Loop in the Central Campus (College Way Loop)**
   Replace existing University 10-inch cast iron line circa 1965, also known as the College Way Loop from south of Academic Instruction Center to the north end between Fine Arts and Ross Engineering Technology buildings. This line, particularly on the east side of the loop, has been repaired several times in recent years. The piping should be replaced with 12-inch ductile iron pipe. The southern part of this area is expected to have the most growth. The piping should be upgraded prior to or concurrent with additional development of this area. Approximately length of main pipe replacement is 3,500 feet.

   3 (Alternative): A less expensive alternative would be to leave in place the west half of the loop (from the Academic Instruction Center to Fine Arts). This would provide most of the desired improvement in fire flows. Service connections to the buildings could be rerouted to the new 12-inch piping. Additional improvements could be made during development projects in IMP District 14. The remaining 1965 pipe from Environmental Studies to the Fine Arts could possibly be rehabilitated in place with cured-in-place liner or pipe bursting (with pipe bursting the service lines would have to be relocated or reinstalled using excavation). Approximate length of main pipe replacement is 2,000 feet.

4. **Replace Fairhaven College Water Main**
   Replace water main from near South College Drive to the Fairhaven Towers with 8-inch HDPE. A less-disruptive method such as direction drilling is preferred in order to preserve most of the hardscaping. Approximately length of main pipe replacement is 350 feet from the edge of the parking lot to Stack 5.

2.4.2. Capacity with Minimum Recommended Improvements

Improvement 1 - Ridgeway Domestic Water Main Replacement

There are no existing water pressure issues to be resolved by installing this improvement. However, this project will prevent future pressure loss problems and improve the level of service to the area by greatly reducing the likelihood of service line breaks, service interruptions, and potential flood damage. The improvement will also reduce leakage in the area.

Improvement 2 - Ridgeway Fire Loop Main Replacement

With the fire loop upgrade completion, the available fire flows well into the future will be adequate and will meet requirements for the Ridgeway buildings (Kappa, Gamma, Beta). If this improvement is not completed these buildings will eventually have inadequate fire flow. Until these improvements are made there are hydrants nearby that may provide adequate fire flow. Minimum available fire flows in the southern portion of the fire loop will improve from approximately 1,600 GPM to 3,900 GPM (for build out conditions).

Improvement 3 - College Way Loop Water Main Replacement

With the College Way Loop piping upgraded, the available fire flows in the area will increase by 400 GPM to 1,100 GPM in the area (for build-out conditions). This will be a big improvement for buildings with marginal fire flow. Sprinkler pressures will increase nominally, but generally not enough to overcome inadequate sprinkler system pressure issues (due to the small differential between building height and City water reservoir elevations.

3 (alternative) – Replacing only the east half of the loop would provide most of the overall benefit and fire flows are expected to increase a bit less than the full loop replacement.

Improvement 4 - Fairhaven Towers Water Main Replacement

Replacing the old cast iron piping at the west entrance to Fairhaven Towers will increase available fire flows to the area by 200 to 1,000 GPM in the area (for build-out conditions). Although available fire flows are expected to be adequate under build out conditions without the improvement (due to the incoming water east of the Fairhaven Towers), replacing this pipeline will ensure a higher level of service to the area, reduce leakage, and reduce chances of pipe failure and the ensuing damage.

2.4.3. Cost Estimates

Reasonable order of magnitude cost estimates (2017 dollars) for water system upgrades including design and installation are (actual costs will be more or less depending on the simplicity of design and installation):

IMPROVEMENT	ESTIMATED COST		
Improvement 1	$525,000	to	$650,000
Improvement 2	$200,000	to	$250,000
Improvement 3	$1,200,000	to	$1,600,000
Improvement 3(Alternative)	$800,000	to	$1,100,000
Improvement 4	$175,000	to	$225,000

2.5. Conclusions

The capacity of the existing University water distribution system is:

- Adequate to provide at least 30 PSI to all building water service connections (at the water main) during peak hour demands. (Section 2.2.5.2 Peak Hour Demand Capacity).

- Inadequate to supply 30 PSI to the highest service point in five buildings during peak hour demands. Water pressure ranges from 20 to 28 PSI. (Section 2.2.5.2 Peak Hour Demand Capacity).

- Adequate to supply desired fire flows while maintaining 20 PSI residual pressure to all but one building (Commissary). (Section 2.2.5.3 Fire Flow Capacity).

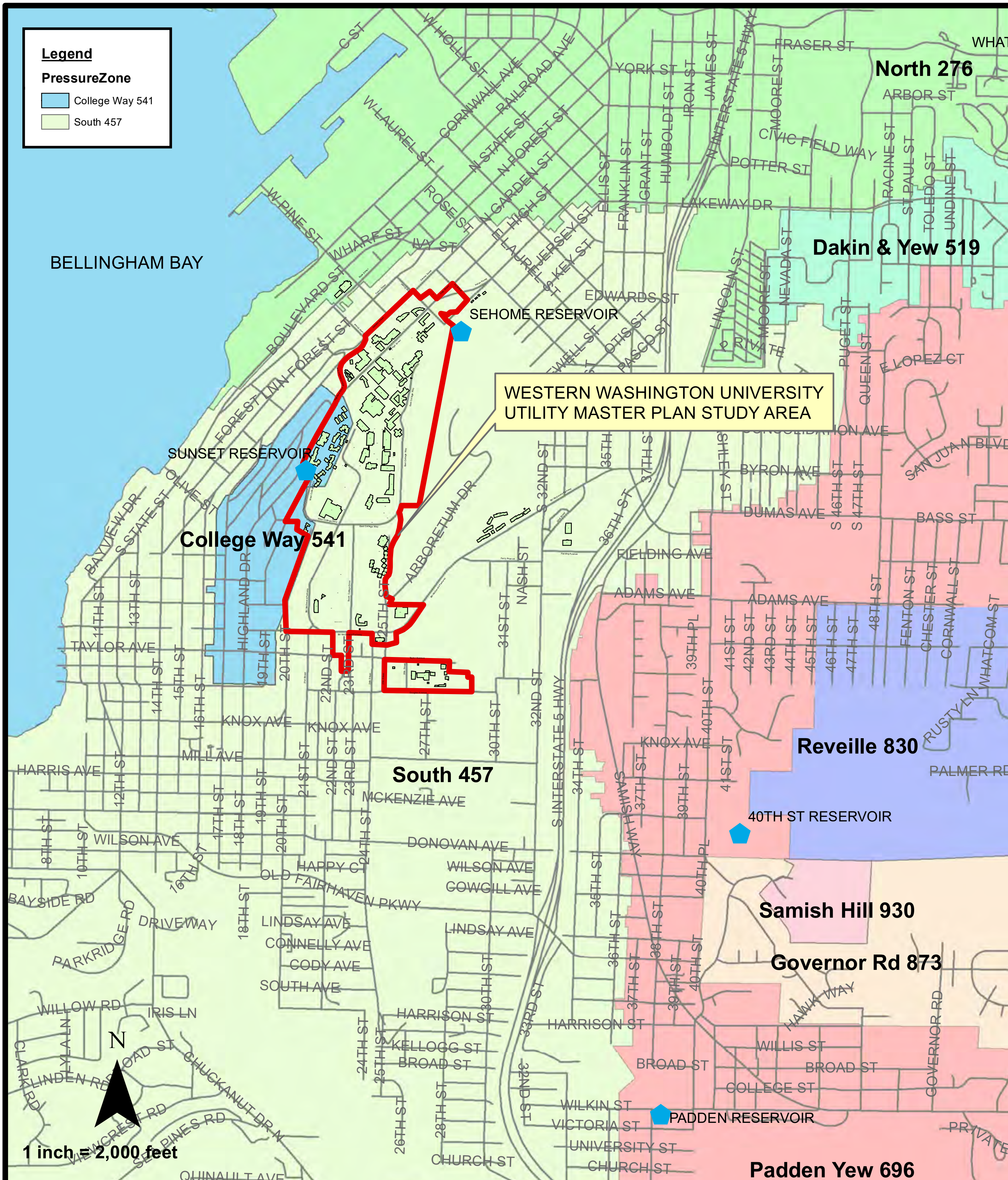
- For future conditions, one more building (SMATE) will have inadequate fire flow at 20 PSI. However, this building can be served by other nearby hydrants. (Section 2.3.5.2 Available Fire Flows).

- Inadequate to supply the design fire sprinkler head pressure of 14 PSI at the highest level in nine buildings for existing and future conditions. Four of these nine buildings already have fire sprinkler system pumps. (Sections 2.2.5.3 - 2.3.5.3 Sprinkler System Residual Pressures).

The capacity of the existing campus water distribution system can be improved by:

- Completing the Ridgeway Complex fire loop upgrades with 6-inch diameter ductile iron piping at the south end.
- Replacing the College Way Loop 10-inch cast iron piping with 12-inch ductile iron piping. Alternative phasing: prioritize east half of loop.
- Replacing the Fairhaven Complex old 8-inch cast iron piping with 8-inch HDPE piping.
- Installing several fire sprinkler pumps where necessary to provide adequate pressure to meet building fire sprinkler system design criteria.

2.6. Appendices (Figures and Tables)



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DATE	SHEET	WWU Utility Master Planning
JUNE 2017	1	WHATCOM COUNTY WASHINGTON
SCALE	OF	FIGURE 2-1
JOB NUMBER 2016-139	1	WWU VICINITY PRESSURE ZONES

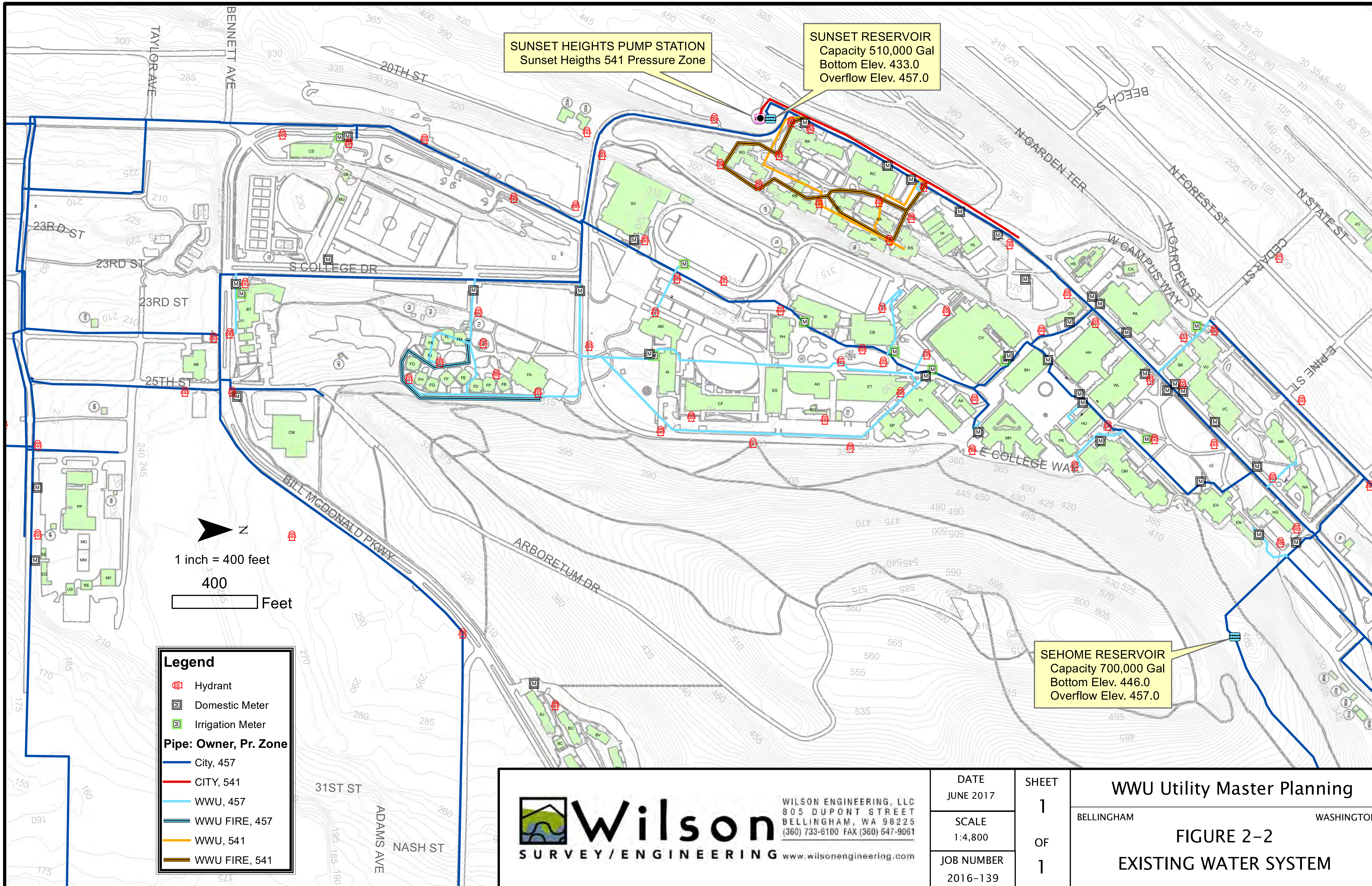
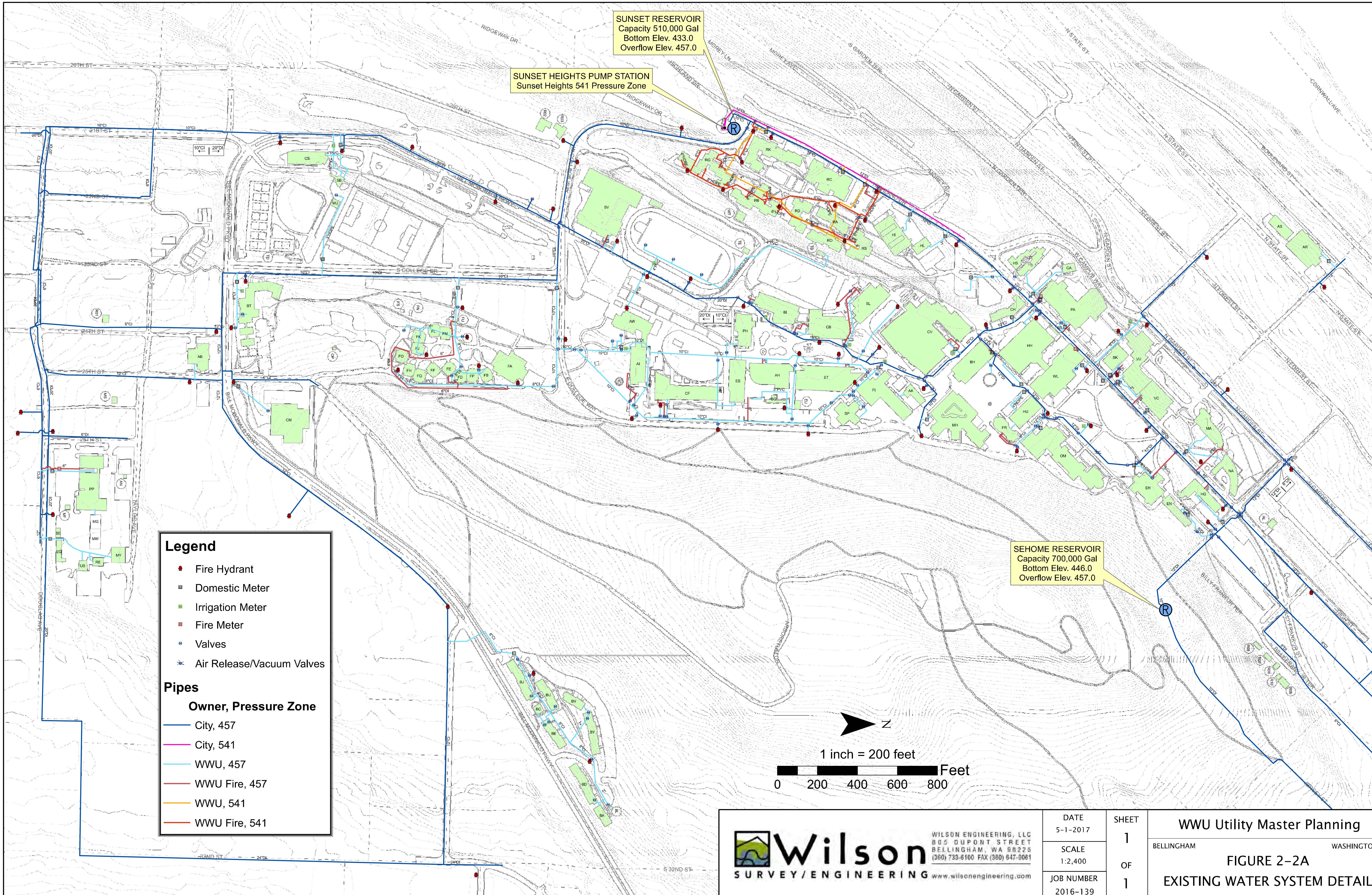


FIGURE 2-2
EXISTING WATER SYSTEM


SUNSET RESERVOIR
Capacity 510,000 Gal
Bottom Elev. 433.0
Overflow Elev. 457.0
SUNSET HEIGHTS PUMP STATION
Sunset Heights 541 Pressure Zone
SEHOME RESERVOIR
Capacity 700,000 Gal
Bottom Elev. 446.0
Overflow Elev. 457.0
Legend
Fire Hydrant
Domestic Meter
Irrigation Meter
Fire Meter
Valves
Air Release/Vacuum Valves
Pipes
Owner, Pressure Zone
City, 457
City, 541
WWU, 457
WWU Fire, 457
WWU, 541
WWU Fire, 541
N
1 inch = 200 feet
Feet
0 200 400 600 800
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JOB NUMBER
2016-139
SHEET
1
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1
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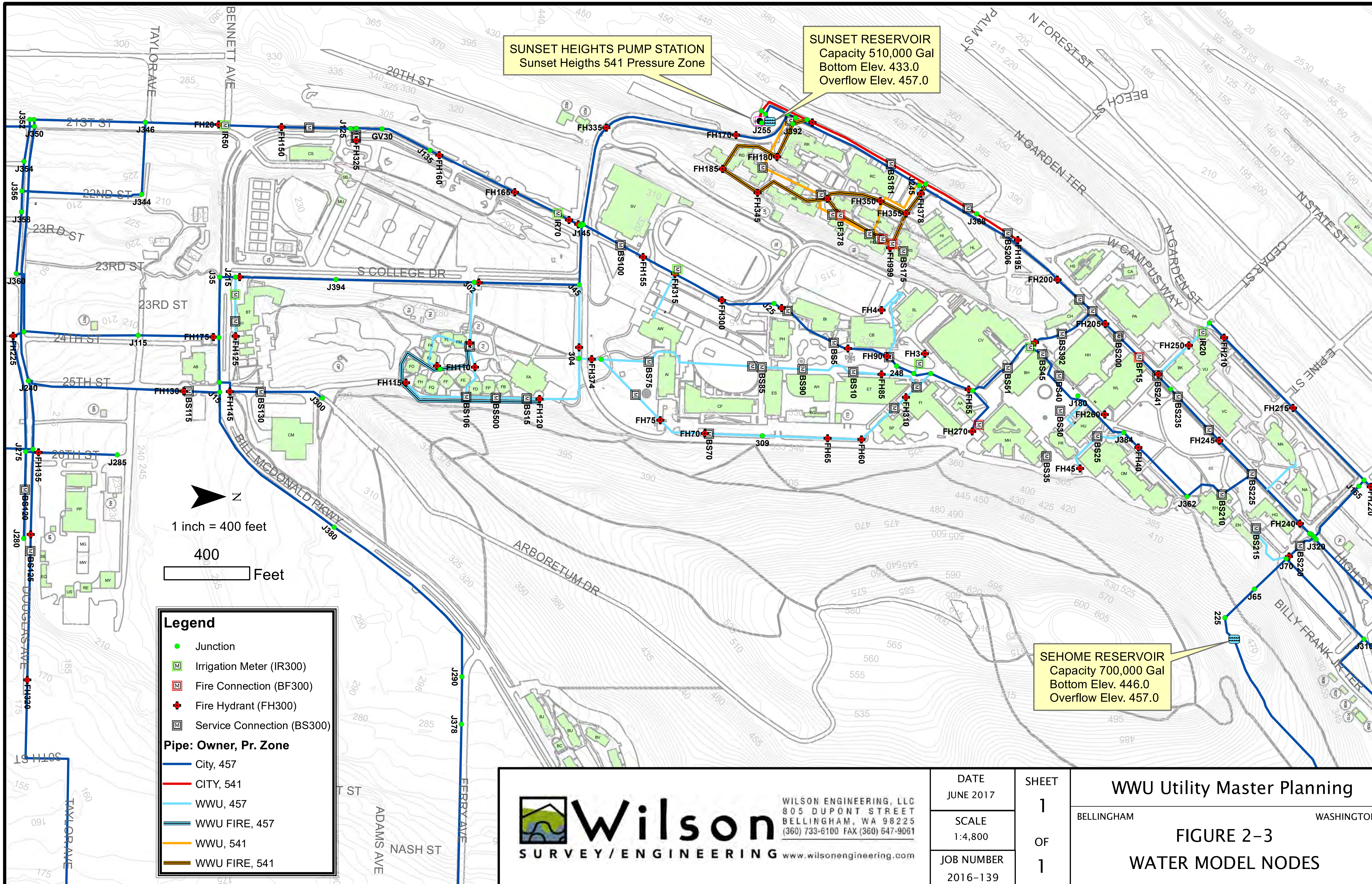
BELLINGHAM
WASHINGTON
FIGURE 2-2A
EXISTING WATER SYSTEM DETAIL



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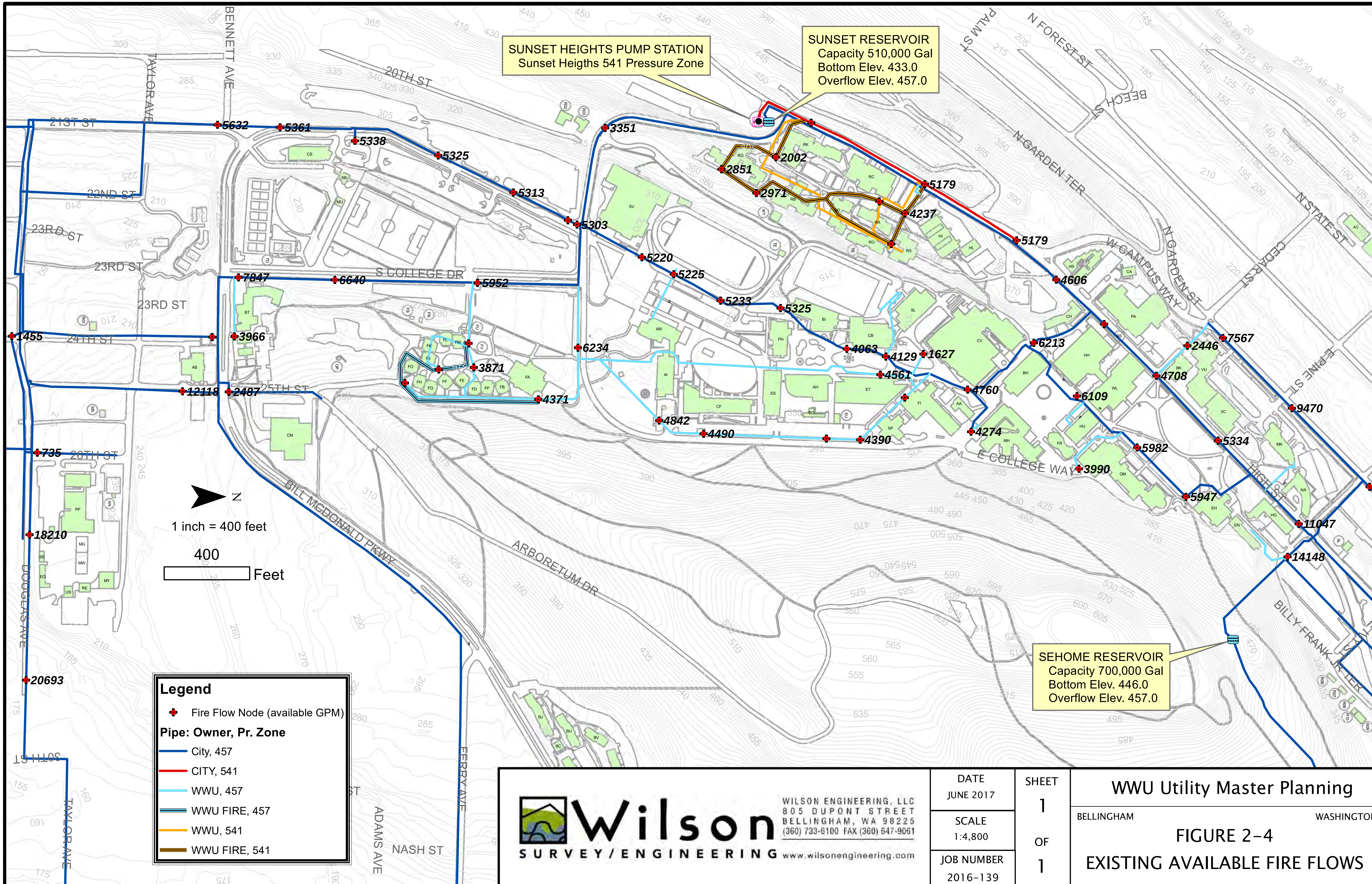
JUNE 2017	1	BELLINGHAM WASHINGTON
SCALE 1:4,800	OF	FIGURE 2-3
JOB NUMBER 2016-139	1	WATER MODEL NODES



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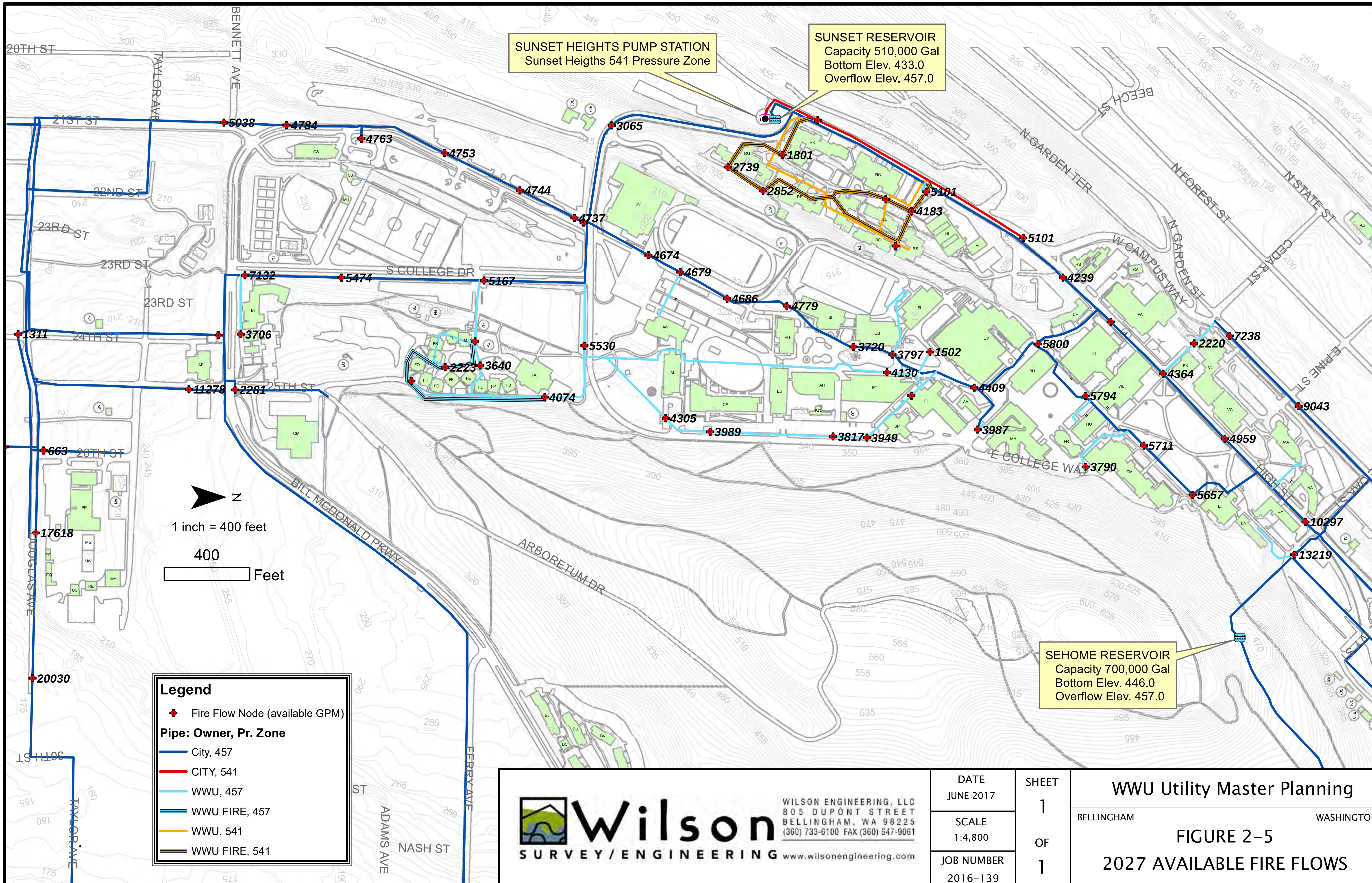
JOB NUMBER		
2016-139		

WWU Utility Master Planning

BELLINGHAM WASHINGTON

FIGURE 2-4

EXISTING AVAILABLE FIRE FLOWS



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DATE	SHEET	WWU Utility Master Planning
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SCALE 1:4,800	OF	FIGURE 2-5
JOB NUMBER 2016-139	1	2027 AVAILABLE FIRE FLOWS

FIGURE 2-5
2027 AVAILABLE FIRE FLOWS

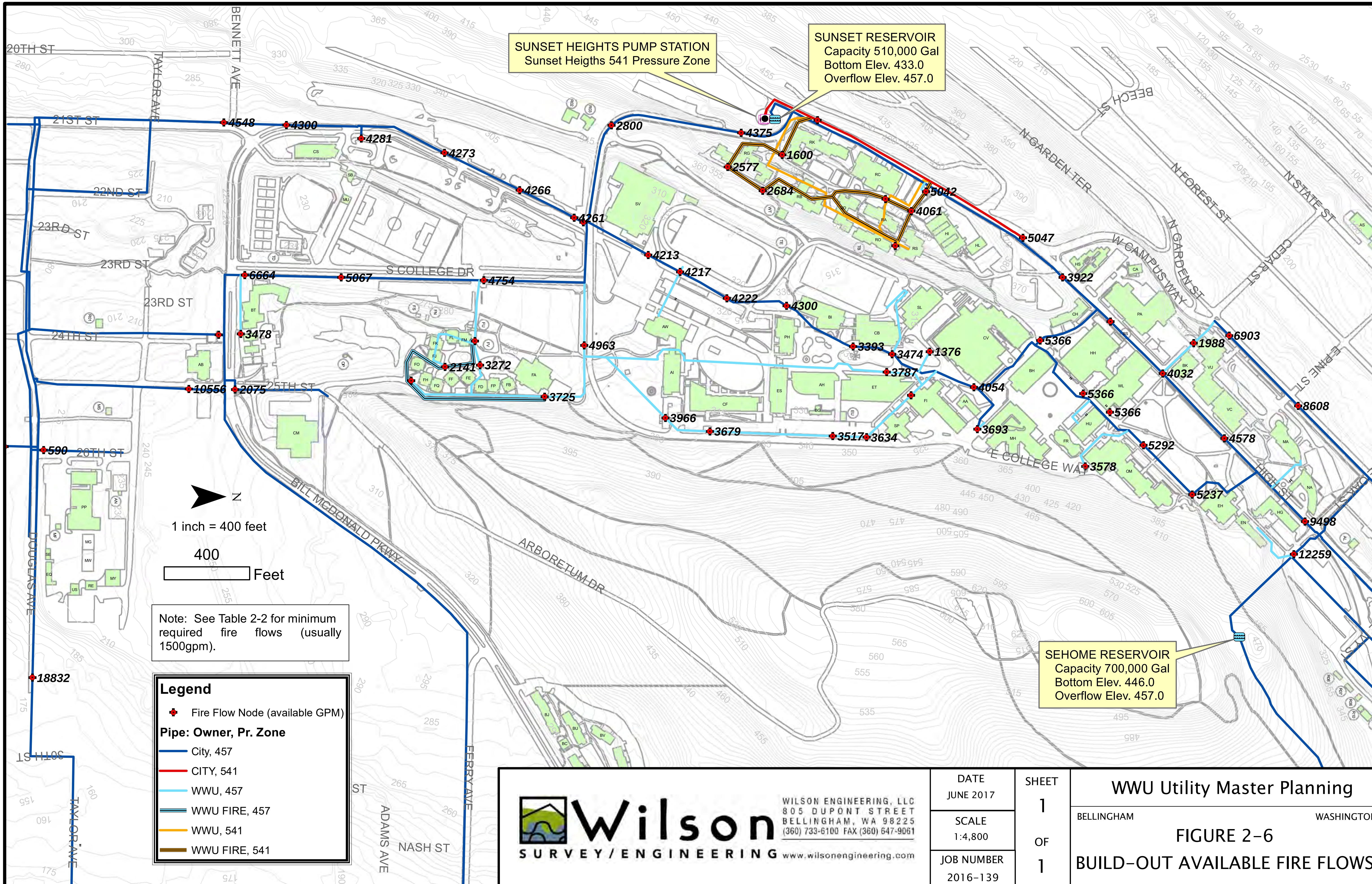
SUNSET HEIGHTS PUMP STATION
Sunset Heigths 541 Pressure Zone
SUNSET RESERVOIR
Capacity 510,000 Gal
Bottom Elev. 433.0
Overflow Elev. 457.0
SEHOME RESERVOIR
Capacity 700,000 Gal
Bottom Elev. 446.0
Overflow Elev. 457.0
20TH ST
21ST ST
22ND ST
23RD ST
24TH ST
25TH ST
30TH ST
TAYLOR AVE
BENNETT AVE
DOUGLAS AVE
S COLLEGE DR
BILL MCDONALD PKWY
ARBORETUM DR
E COLLEGE WAY
FERRY AVE
ADAMS AVE
NASH ST
N GARDEN TER
N FOREST ST
N STATE ST
BEECH ST
W CAMPUS WAY
N GARDEN ST
CEDAR ST
E PINE ST
HIGH ST
4548
4300
4281
4273
4266
4261
2800
4375
1600
2577
2684
5042
4061
5047
4213
4217
4222
4300
3922
6664
5067
4754
3478
4963
3393
3474
1376
5366
1988
6903
2141
3272
3787
4032
10556
2075
3725
4054
5366
5366
8608
3966
3679
3517
3634
3693
4578
5292
3578
5237
9498
12259
590
18832
N
1 inch = 400 feet
400
Feet
Note: See Table 2-2 for minimum required fire flows (usually 1500gpm).
Legend
Fire Flow Node (available GPM)
Pipe: Owner, Pr. Zone
City, 457
CITY, 541
WWU, 457
WWU FIRE, 457
WWU, 541
WWU FIRE, 541
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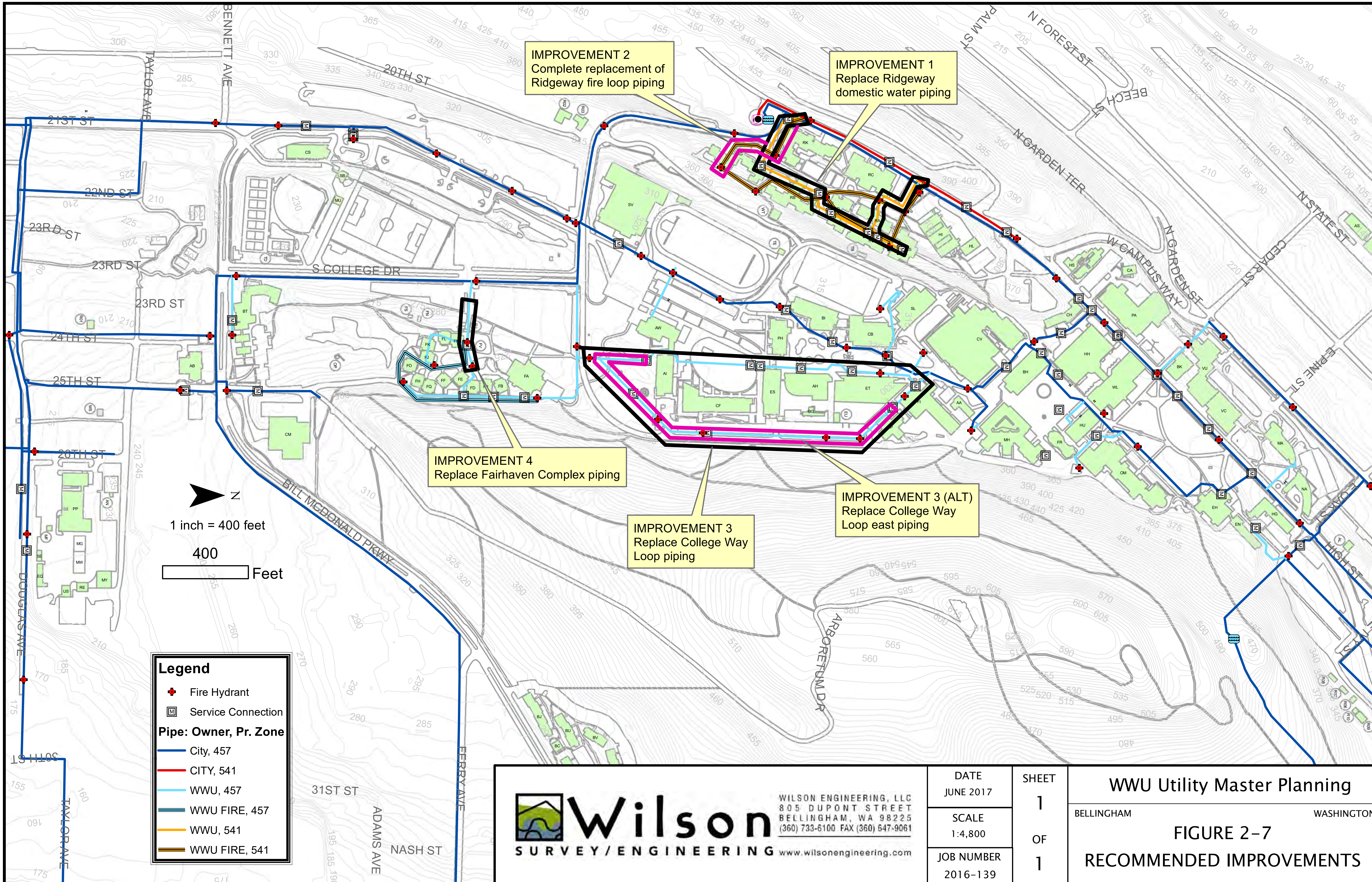
FIGURE 2-6
BUILD-OUT AVAILABLE FIRE FLOWS



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SCALE 1:4,800	OF	FIGURE 2-7
JOB NUMBER 2016-139	1	RECOMMENDED IMPROVEMENTS

Table 2-1. University Meter Data Summary and Demand Calculations

DOMESTIC WATER

NAME	ID	TYPE	ADD (ft^3/day)	ADD (gpd)	MDD (gpm)	PHD (gpm)
21st HUNTOON LOOP			1180	8,826	12.3	36.8
ACADEMIC INSTRUCTION CENTER	AI	ACAD	448	3,351	4.7	14.0
ADMINISTRATIVE SERVICES	AC	ACAD	83	622	0.9	2.6
ALUMNI HOUSE	AL	ACAD	10	79	0.1	0.3
ARCHIVES	AB	ACAD	14	108	0.1	0.4
ARNTZEN HALL	AH	ACAD	377	2,820	3.9	11.7
BIOLOGY BUILDING	BI	ACAD	159	1,189	1.7	5.0
BOND HALL	BH	ACAD	447	3,344	4.6	13.9
BOOKSTORE	BK	RES	108	808	1.1	1.7
BUCHANAN TOWERS	BT	RES	1,925	14,399	20.0	30.0
CANADA HOUSE	CA	ACAD	44	329	0.5	1.4
CAMPUS SERVICES	CS	ACAD	48	359	0.5	1.5
CARVER GYMNASIUM	CV	ACAD	492	3,680	5.1	15.3
CHEMISTRY BUILDING	CB	ACAD	334	2,498	3.5	10.4
COLLEGE HALL	CH	ACAD	85	636	0.9	2.6
COMMISSARY	CM	ACAD	71	531	0.7	2.2
COMMUNICATIONS FACILITY	CF	ACAD	498	3,725	5.2	15.5
EDENS HALL	EH	RES	788	5,894	8.2	12.3
EDENS HALL NORTH	EN	RES	171	1,279	1.8	2.7
ENVIRONMENTAL STUDIES CENTER	ES	ACAD	422	3,157	4.4	13.2
FAIRHAVEN COLLEGE/Academic	FA	ACAD	280	2,094	2.9	8.7
FAIRHAVEN TOWERS 1-12	FB	RES	2,357	17,630	24.5	36.7
FINE ARTS BUILDING (Arts Tech)	FI	ACAD	284	2,124	3.0	8.9
FRASER HALL	FR	ACAD	68	509	0.7	2.1
HAGGARD HALL	HH	ACAD	310	2,319	3.2	9.7
HIGGINSON HALL	HG	RES	765	5,722	7.9	11.9
HIGH ST HALL	HS	ACAD	11	82	0.1	0.3
HIGHLAND HALL 1	HI	RES	315	2,356	3.3	4.9
HIGHLAND HALL 2	HI	RES	105	785	1.1	1.6
HUMANITIES BLDG	HU	ACAD	68	509	0.7	2.1
MATHES HALL	MA	RES	1,276	9,544	13.3	19.9
MILLER HALL	MH	ACAD	271	2,027	2.8	8.4
NASH HALL	NA	RES	1,301	9,731	13.5	20.3
OLD MAIN	OM	ACAD	604	4,518	6.3	18.8
PARKS HALL	PH	ACAD	213	1,593	2.2	6.6
PERFORMING ARTS CENTER	PA	ACAD	145	1,085	1.5	4.5
PHYSICAL PLANT	PP	ACAD	120	898	1.2	3.7
RECYCLE CENTER	RE	ACAD	28	207	0.3	0.9
RIDGEWAY COMMONS	RC	RES	1,362	10,188	14.1	21.2
RIDGEWAY-ALPHA	RA	RES	284	2,124	3.0	4.4
RIDGEWAY-BETA	RB	RES	482	3,605	5.0	7.5
RIDGEWAY-DELTA	RD	RES	302	2,259	3.1	4.7
RIDGEWAY-GAMMA	RG	RES	518	3,875	5.4	8.1
RIDGEWAY-KAPPA	RK	RES	653	4,884	6.8	10.2
RIDGEWAY-OMEGA	RO	RES	278	2,079	2.9	4.3
RIDGEWAY-SIGMA	RS	RES	275	2,057	2.9	4.3
ROSS ENGINEERING TECHNOLOGY	ET	ACAD	294	2,199	3.1	9.2
SMATE (SCIENCE LECTURE HALLS)	SL	ACAD	63	471	0.7	2.0
SOFTBALL BUNKER, TICKET OFFICE & RESTRO	MU	ACAD	23	172	0.2	0.7
STEAM PLANT	SP	ACAD	50	374	0.5	1.6
VIKING COMMONS	VC	ACAD	1,527	11,422	15.9	23.8
VIKING UNION	VU	RES	581	4,346	6.0	9.1
WADE KING STUDENT RECREATION CENTER	SV	RES	655	4,899	6.8	10.2
WILSON LIBRARY	WL	ACAD	371	2,775	3.9	11.6

IRRIGATION

NAME			ADD (ft^3/day)	ADD (gpd)	ADD (gpm)	MDD (gpm)
CAMPUS SERVICES/FIELDS			1,326	9,918	6.9	13.8
COLLEGE HALL			117	875	0.6	1.2
BUCHANAN TOWERS			1,390	10,397	7.2	14.4
ARCHIVES BUILDING			98	732	0.5	1.0
SFII-BIOLOGY			7	50	0.0	0.1
SMATE			430	3,216	2.2	4.5
CHEMISTRY BUILDING			1,469	10,988	7.6	15.3
MILLER HALL			76	568	0.4	0.8
OLD MAIN			1,071	8,011	5.6	11.1
VIKING COMMONS			213	1,593	1.1	2.2
ALL WEATHER FIELD			954	7,135	5.0	9.9
PUBLIC SAFETY			576	4,309	3.0	6.0
STUDENT REC CENTER			4,068	30,429	21.1	42.3
ARCHIVES BUILDING			171	1,278	0.9	1.8

NOTES:
DOMESTIC:
1. ADD data based on available meter records for in-session full months (i.e. October, November, February, April, May) from December 2013 through December 2016. EXCEPT: CM, PP, MU have peak off-session thus annual average shown.
2. Single meter records for multiple buildings were distributed to buildings based on gross square footage.
3. A PHD:ADD ratio of 6:1 is assumed for domestic Academic (ACAD) type building demands.
4. A PHD:ADD ratio of 3:1 was assumed for domestic Residential (RES) type building demands.
5. A MDD:ADD ratio of 2:1 was assumed for all domestic demands.
6. Buildings AC, AL, AB, and RE no new data available, ADD shown is 2007 data plus 28% increase for in-session only use based on campus wide average increase for in-session use only analysis.
IRRIGATION:
7. Data represents highest 2 months of irrigation season use; typically July and August.
8. Irrigation meters Archives Building, SFII-Biology, All Weater Field, Public Safety, and Archives Building had no new data available, ADD is 2007 data plus 273% increase for irrigation season use based on campus wide irrigation meter average increase for irrigation season use only analysis.
9. A MDD:ADD ration of 2:1 was assumed for all irrigation demands.

Table 2-2. Fire Flow Requirements Compared to 2017 Available Fire Flows

NAME	ID	GROSS AREA (SQ.FT.)	FIRE AREA [1] (SQ. FT.)	BUILDING HEIGHT [7] (FT)	IBC CONSTRUCT. TYPE [3]	BUILDING SPRINKLER SYSTEM	HOSE STREAM ALLOWANCE FOR SPRINKLED	DISTANCE TO NEAREST BLDG (GIS) (FT)	FINAL REQUIRED FIRE FLOW (GPM)	AVAILABLE FIRE FLOW (GPM) [8]
ARTS ANNEX	AA	15,586	15,586	358.7	3A [4]	NONE	0	30	1,750	4,274
ACADEMIC INSTRUCTION CENTER	AI	118,000	118,000	352.0	2B	ALL	100	>20	2,250	4,842
ALUMNI HOUSE	AL	2,623	2,623		5B	NONE	0	10 ONE SIDE	1,750	11,047
ARCHIVES	AB	18,765	18,765	261.5	5B	ALL	100	40	1,500	10,683
ARNTZEN HALL	AH	99,337	59,602	400.0	1A	NO, BASEMENT 1 HALL	100	10 TWO SIDES	3,350	4,440
BIOLOGY BUILDING	BI	81,120	60,840	395.0	1B	ALL	100	40	1,500	4,440
BOND HALL	BH	89,591	89,591	383.6	2A	NO, 1-3 HALLWAYS, BASEMENT	100	20 ONE CORNER	4,600	6,213
BOOKSTORE	BK	17,896	17,896	336.2	1A	ALL	100	10 ONE CORNER	1,500	2,446
BUCHANAN TOWERS	BT	101,095	37,911	322.6	1B	ALL	100	150	1,500	7,847
BUCHANAN TOWERS EAST	BTE	50,000	na	na	na	ALL	na	na	1,500	3,966
CANADA HOUSE	CA	5,866	5,866	346.0	5B [4]	NONE	0	30	2,000	4,606
CAMPUS SERVICES	CS	26,946	26,946	316.5	5A	ALL	100	50	1,500	5,338
CARVER GYMNASIUM	CV	126,700	61,233 [5]	371.8	3A	ALL	100	55	1,500	4,760
CHEMISTRY BUILDING	CB	72,574	43,544	396.0	1A	ALL	250	20 ONE CORNER	1,500	4,063
COLLEGE HALL	CH	32,917	32,917	370.0	3A	NONE	0	80	2,500	4,606
COMMISSARY (Housing Owned)	CM	37,121	37,121	298.5	3A	NO, RM 4	100	350	2,850	***2,487***
COMMUNICATIONS	CF	131,365	78,819	390.0	1B	ALL	100	40	1,500	4,490
EDENS HALL SOUTH	EH	63,662	63,662	377.0	3A	ALL	100	20 ONE SIDE	1,500	5,947
EDENS-NORTH	EN	26,432	19,824	370.5	1B [4]	NONE	0	20 ONE SIDE	1,750	14,148
ENVIRONMENTAL STUDIES CENTER	ES	111,145	41,679	416.0	1A	ALL	100	15 ONE SIDE	1,500	4,267
FAIRHAVEN COLLEGE/Academic	FA	15,396	15,396	326.0	5A	NO, BASEMENT	100	10 ONE CORNER	2,600	4,371
FAIRHAVEN TOWERS 1-12 [2]	FB	21,636	21,636	331.0	2A	ALL	100	10 ONE SD/CRNR	1,500	2,544
FINE ARTS BUILDING (Arts Tech)	FI	74,886	74,886	360.6	3A	NONE	0	30	4,000	5,219
FRASER HALL	FR	33,342	33,342	348.8	1B [4]	NONE	0	20 TWO SIDES	2,500	3,990
HAGGARD HALL	HH	107,971	107,971	371.0	2A	ALL	100	20 ONE CORNER	1,688	5,523
HIGGINSON HALL	HG	47,241	28,345	335.1	1B	ALL	100	55	1,500	11,047
HIGH ST HALL	HS	9,918	9,918	342.7	5B [4]	NONE	0	90	2,750	4,606
HIGHLAND HALL 1	HI	21,984	21,984	409.5	5A	NONE	0	10 ONE CORNER	3,000	5,179
HIGHLAND HALL 2	HI	7,328	7,328	409.5	5A	NONE	0	10 ONE SIDE	1,750	4,237
HUMANITIES BLDG	HU	33,342	33,342	355.8	5A	NONE	0	20 ONE SIDE	3,500	6,109
MATHES HALL	MA	75,381	25,127	360.5	1B	ALL	100	30	1,500	9,470
MILLER HALL	MH	133,117	63,590 [6]	361.5	2B	ALL	100	30	1,650	4,274
NASH HALL	NA	76,891	76,891	347.0	2A [4]	ALL	100	30	1,500	11,047
OLD MAIN	OM	145,474	145,474	410.4	3A	ALL	100	15 ONE SIDE	1,913	3,990
PARKS HALL	PH	56,109	33,665	397.0	1A [4]	ALL	100	45	1,500	5,325
PERFORMING ARTS CENTER	PA	128,649	77,189	369.8	1A	NO, ALL BUT SEATING	100	35	3,100	5,523
PHYSICAL PLANT	PP	29,421	29,421	239.0	5A	NO, PAINT SHOP, BASEMENT	250	20 TWO SIDES	3,750	18,210
RECYCLE CENTER	RE	2,080	2,080	240.0	5B [4]	NONE	0	25	1,500	18,210
RIDGEWAY COMMONS	RC	32,853	32,853	446.1	3A	NO, KITCHEN	100	40	2,600	5,179
RIDGEWAY-ALPHA	RA	21,109	21,109	438.8	3A	ALL	100	20 ONE SIDE	1,500	2,440
RIDGEWAY-BETA	RB	35,857	35,857	426.0	3A	ALL	100	10 ONE SIDE	1,500	2,002
RIDGEWAY-DELTA	RD	22,513	22,513	427.9	3A	ALL	100	20 ONE SIDE	1,500	2,440
RIDGEWAY-GAMMA	RG	38,529	38,529	438.9	3A	ALL	100	30	1,500	2,851
RIDGEWAY-KAPPA	RK	48,577	48,577	466.2	3A	ALL	100	40	1,500	2,002
RIDGEWAY-OMEGA	RO	20,693	20,693	399.5	3A	ALL	100	20 TWO SIDES	1,500	3,541
RIDGEWAY-SIGMA	RS	20,471	20,471	429.7	3A	ALL	100	30	1,500	3,541
ROSS ENGINEERING TECHNOLOGY	ET	77,592	77,592	365.3	1B	NO ,LOFT & CLSRMS	100	10 ONE SIDE	3,350	4,561
SMATE (SCIENCE LECTURE HALLS)	SL	40,144	40,144	357.5	5A	ALL	100	20 ONE SIDE	1,575	1,627
STEAM PLANT	SP	13,071	13,071	359.0	5B	NONE	0	40	3,000	4,390
VIKING COMMONS	VC	29,923	29,923	334.0	3A [4]	NO, KITCHEN	100	10 ONE CORNER	2,850	4,708
VIKING UNION	VU	96,081	36,030	358.0	1A	ALL	100	10 ONE CORNER	1,500	4,708
WADE KING STD REC CENTER	SV	98,300	98,300	361.0	3A	ALL	100	210	1,500	3,351
WILSON LIBRARY	WL	141,027	70,514	387.4	1B	NO, BASEMENT	250	30	3,000	4,708

NOTES:
1. Fire areas are based on gross square footage from meter data records. Shading indicates three largest successive floor areas were used because of construction type 1A/1B fire flow reduction.
2. The gross area for Fairhaven Towers is based on a cluster of two buildings.
3. City provided construction types were used with higher priority in assigning base fire flow requirements.
4. City construction type records were unavailable, University records used.
5. Carver Gym has area separation walls dividing the building into effectively three buildings, the worst-case building was used.
6. Miller Hall has area separation walls dividing the building into effectively two buildings, the worst-case building was used.
7. Based on University provided highest sprinkler elevations.
8. Bold italics underline text indicates inadequate fire flow. Where multiple hydrants could cover a building, the lowest meeting requirements is reported.

Table 2-3. Existing Sprinkler System Residual Pressures (sorted by increasing pressures)

NAME	ID	TYPE	SPRINKLER HIGH ELEV (FT)	RESIDUAL PRESSURE MDD & SPRINKLER (PSI) [2]	PRESSURE WITH SAFETY FACTOR (PSI) [3]	PIPE AND BACKFLOW PREVENTER HEAD LOSS (PSI)	STATIC HEAD LOSS (PSI)	PRESSURE AT SPRINKLER HEAD (PSI) [5]
ENVIRONMENTAL STUDIES CENTER	ES	ACAD	416.0	54.0	48.6	8.0	41.6	-1.0
OLD MAIN	OM	ACAD	410.4	55.0	49.5	8.0	40.0	1.5
ARNTZEN HALL	AH	ACAD	400.0	52.0	46.8	8.0	31.6	7.2
PARKS HALL	PH	ACAD	397.0	57.0	51.3	8.0	34.6	8.7
CHEMISTRY BUILDING	CB	ACAD	396.0	49.0	44.1	8.0	26.8	9.3
BIOLOGY BUILDING	BI	ACAD	395.0	52.0	46.8	8.0	29.0	9.8
WILSON LIBRARY	WL	ACAD	387.4	57.0	51.3	8.0	32.6	10.7
COMMUNICATIONS FACILITY	CF	ACAD	390.0	56.0	50.4	8.0	31.6	10.8
BOND HALL	BH	ACAD	383.6	56.0	50.4	8.0	28.8	13.6
MINIMUM REQUIRED PRESSURE AT SPRINKLER HEAD - 14 PSI								
CARVER GYMNASIUM	CV	ACAD	371.8	56.0	50.4	8.0	23.7	18.7
EDENS HALL SOUTH	EH	RES	377.0	68.0	61.2	6.0	36.4	18.8
PERFORMING ARTS CENTER	PA	ACAD	369.8	58.0	52.2	8.0	24.6	19.6
COLLEGE HALL	CH	ACAD	370.0	54.0	48.6	8.0	20.8	19.8
HAGGARD HALL	HH	ACAD	371.0	57.0	51.3	8.0	23.4	19.9
EDENS-NORTH	EN	RES	370.5	68.0	61.2	6.0	33.1	22.1
ROSS ENGINEERING TECHNOLOGY	ET	ACAD	365.3	50.0	45.0	8.0	14.4	22.6
WADE KING STD REC CENTER	SV	RES [1]	361.0	57.0	51.3	8.0	19.9	23.4
MILLER HALL	MH	ACAD	361.5	56.0	50.4	8.0	18.8	23.6
FINE ARTS BUILDING (Arts Tech)	FI	ACAD	360.6	54.0	48.6	8.0	16.7	23.9
ARTS ANNEX	AA	ACAD	358.7	54.0	48.6	8.0	15.9	24.7
VIKING UNION	VU	RES [1]	358.0	58.0	52.2	8.0	19.1	25.1
STEAM PLANT	SP	ACAD	359.0	55.0	49.5	8.0	16.0	25.5
SMATE (SCIENCE LECTURE HALLS)	SL	ACAD	357.5	50.0	45.0	8.0	11.5	25.5
MATHES HALL	MA	RES	360.5	68.0	61.2	6.0	29.2	26.0
ACADEMIC INSTRUCTION CENTER	AI	ACAD	352.0	60.0	54.0	8.0	19.9	26.1
HUMANITIES BLDG	HU	ACAD	355.8	57.0	51.3	8.0	16.8	26.5
RIDGEWAY-KAPPA [4]	RK	RES	466.2	62.0	55.8	6.0	21.3	28.5
FRASER HALL	FR	ACAD	348.8	56.0	50.4	8.0	13.8	28.6
NASH HALL	NA	RES	347.0	68.0	61.2	6.0	23.4	31.8
CANADA HOUSE	CA	ACAD	346.0	54.0	48.6	6.0	10.4	32.2
HIGH ST HALL	HS	ACAD	342.7	54.0	48.6	6.0	9.0	33.6
BOOKSTORE	BK	RES [1]	336.2	58.0	52.2	8.0	10.0	34.2
VIKING COMMONS	VC	ACAD	334.0	58.0	52.2	8.0	8.7	35.5
HIGGINSON HALL	HG	RES	335.1	76.0	68.4	6.0	26.5	35.9
RIDGEWAY COMMONS	RC	RES [1]	446.1	66.0	59.4	6.0	16.9	36.5
FAIRHAVEN TOWERS 1-12	FB	RES	331.0	71.0	63.9	6.0	19.5	38.4
RIDGEWAY-ALPHA [4]	RA	RES	438.8	68.0	61.2	6.0	15.5	39.7
RIDGEWAY-GAMMA [4]	RG	RES	438.9	62.0	55.8	6.0	9.5	40.3
BUCHANNAN TOWERS	BT	RES	322.6	97.0	87.3	6.0	41.0	40.3
CAMPUS SERVICES	CS	ACAD	316.5	75.0	67.5	8.0	18.0	41.5
FAIRHAVEN COLLEGE/Academic	FA	ACAD	326.0	69.0	62.1	6.0	13.4	42.7
RIDGEWAY-SIGMA	RS	RES	429.7	81.0	72.9	6.0	23.7	43.2
RIDGEWAY-DELTA	RD	RES	427.9	79.0	71.1	6.0	21.6	43.5
RIDGEWAY-BETA [4]	RB	RES	426.0	85.0	76.5	6.0	26.8	43.7
COMMISSARY (Housing Owned)	CM	ACAD	298.5	85.0	76.5	8.0	18.4	50.1
HIGHLAND HALL 1	HI	RES	409.5	91.0	81.9	6.0	24.5	51.4
HIGHLAND HALL 2	HI	RES	409.5	82.0	73.8	6.0	14.9	52.9
RIDGEWAY-OMEGA	RO	RES	399.5	81.0	72.9	6.0	10.6	56.3
RECYCLE CENTER	RE	ACAD	240.0	91.0	81.9	8.0	10.4	63.5
PHYSICAL PLANT	PP	ACAD	239.0	91.0	81.9	8.0	10.0	63.9
ARCHIVES	AB	ACAD	261.5	92.0	82.8	8.0	8.4	66.4

NOTES:
1. Type is based on meter records, sprinkler flows assigned as ACAD rather than RES.
2. Sprinkler design flows for RES type buildings = 310 GPM, all other building types = 650 GPM. Residual pressure at water main near building connection point.
3. Safety factor of 10% per BCE.
4. Ridgeway buildings sprinkler systems are connected to dedicated fire loop on City 541 Pressure Zone.
5. Negative pressure indicates the required flow cannot reach the top of the building.

Table 2-4. Projected Growth Demand Increases by Land Use District

10-YEAR CAPITAL PLAN (2027)

WWU DISTRICT	2027 GROWTH GSF (1000s)	GROWTH TYPE PER WWU/IMP	IMP LAND USE CATEGORY	DEMAND INCREASE ADD (GPM)	DEMAND INCREASE MDD (GPM)	DEMAND INCREASE PHD (GPM)
1						
2						
3						
4						
5						
6	48	NEW/EXPAND ACAD	ACAD	1.37	2.73	8.20
7						
8						
9						
10						
11	6	CB INFILL	ACAD	0.17	0.34	1.02
12						
13						
14	80	NEW ACAD	ACAD	2.28	4.56	13.67
15						
16						
17						
18	100	NEW RES HALL(S)	RES	9.70	19.40	29.10
19						
20						
21						
22/23	68		RES	6.60	13.19	19.79
			TOTAL =	20.1	40.2	71.8

IMP MEDIAN BUILD-OUT

WWU DISTRICT	BUILD-OUT GROWTH GSF (1000s)	GROWTH TYPE PER WWU/IMP	IMP LAND USE CATEGORY	DEMAND INCREASE ADD (GPM)	DEMAND INCREASE MDD (GPM)	DEMAND INCREASE PHD (GPM)
1						
2						
3						
4	30	VU EXPANSION	RES	2.91	5.82	8.73
5						
6						
7						
8						
9	101	NEW ACAD(S)	ACAD	2.88	5.75	17.25
10	102	NEW RES HALL(S)	RES	9.89	19.79	29.68
11	15	ET EXPANSION	ACAD	0.43	0.85	2.56
12						
13	7	PARKING	ACAD	0.20	0.40	1.20
14	309	NEW ACAD(S)	ACAD	8.80	17.59	52.78
15	27	NEW RES HALL(S)	RES	2.62	5.24	7.86
16	6	CS EXPANSION	ACAD	0.17	0.34	1.02
17						
18						
19						
20						
21						
22/23						
			TOTAL =	27.9	55.8	121.1

Notes:
1) Average ADD growth for ACAD land use category = 41.0 gpd/1000gsf, RES land use category = 139.7 gpd/1000gsf.
2) MDD:ADD = 2:1 for all categories.
3) PHD:ADD = 6:1 for ACAD land use category, 3:1 for RES land use category.

Table 2-5. Build-Out Sprinkler System Residual Pressures.

NAME	ID	TYPE	SPRINKLER HIGH ELEV (FT)	RESIDUAL PRESSURE MDD & SPRINKLER (PSI) [2]	PRESSURE WITH SAFETY FACTOR (PSI) [3]	PIPE AND BACKFLOW PREVENTER HEAD LOSS (PSI)	STATIC HEAD LOSS (PSI)	PRESSURE AT SPRINKLER HEAD (PSI) [5]
ENVIRONMENTAL STUDIES CENTER	ES	ACAD	416.0	53.0	47.7	8.0	41.6	-1.9
OLD MAIN	OM	ACAD	410.4	54.0	48.6	8.0	40.0	0.6
ARNTZEN HALL	AH	ACAD	400.0	51.0	45.9	8.0	31.6	6.3
PARKS HALL	PH	ACAD	397.0	56.0	50.4	8.0	34.6	7.8
CHEMISTRY BUILDING	CB	ACAD	396.0	48.0	43.2	8.0	26.8	8.4
BIOLOGY BUILDING	BI	ACAD	395.0	51.0	45.9	8.0	29.0	8.9
WILSON LIBRARY	WL	ACAD	387.4	56.0	50.4	8.0	32.6	9.8
COMMUNICATIONS	CF	ACAD	390.0	55.0	49.5	8.0	31.6	9.9
BOND HALL	BH	ACAD	383.6	55.0	49.5	8.0	28.8	12.7
MINIMUM REQUIRED PRESSURE AT SPRINKLER HEAD - 14 PSI								
EDENS HALL SOUTH	EH	RES	377.0	67.0	60.3	6.0	36.4	17.9
CARVER GYMNASIUM	CV	ACAD	371.8	56.0	50.4	8.0	23.7	18.7
PERFORMING ARTS CENTER	PA	ACAD	369.8	57.0	51.3	8.0	24.6	18.7
HAGGARD HALL	HH	ACAD	371.0	56.0	50.4	8.0	23.4	19.0
COLLEGE HALL	CH	ACAD	370.0	54.0	48.6	8.0	20.8	19.8
ROSS ENGINEERING TECHNOLOGY	ET	ACAD	365.3	49.0	44.1	8.0	14.4	21.7
EDENS-NORTH	EN	RES	370.5	68.0	61.2	6.0	33.1	22.1
MILLER HALL	MH	ACAD	361.5	55.0	49.5	8.0	18.8	22.7
FINE ARTS BUILDING (Arts Tech)	FI	ACAD	360.6	53.0	47.7	8.0	16.7	23.0
WADE KING STD REC CENTER	SV	RES [1]	361.0	57.0	51.3	8.0	19.9	23.4
STEAM PLANT	SP	ACAD	359.0	53.0	47.7	8.0	16.0	23.7
ARTS ANNEX	AA	ACAD	358.7	53.0	47.7	8.0	15.9	23.8
VIKING UNION	VU	RES [1]	358.0	57.0	51.3	8.0	19.1	24.2
SMATE (SCIENCE LECTURE HALLS)	SL	ACAD	357.5	49.0	44.1	8.0	11.5	24.6
MATHES HALL	MA	RES	360.5	67.0	60.3	6.0	29.2	25.1
ACADEMIC INSTRUCTION CENTER	AI	ACAD	352.0	59.0	53.1	8.0	19.9	25.2
HUMANITIES BLDG	HU	ACAD	355.8	56.0	50.4	8.0	16.8	25.6
RIDGEWAY-KAPPA [4]	RK	RES	466.2	62.0	55.8	6.0	21.3	28.5
FRASER HALL	FR	ACAD	348.8	56.0	50.4	8.0	13.8	28.6
NASH HALL	NA	RES	347.0	67.0	60.3	6.0	23.4	30.9
CANADA HOUSE	CA	ACAD	346.0	54.0	48.6	6.0	10.4	32.2
BOOKSTORE	BK	RES [1]	336.2	57.0	51.3	8.0	10.0	33.3
HIGH ST HALL	HS	ACAD	342.7	54.0	48.6	6.0	9.0	33.6
VIKING COMMONS	VC	ACAD	334.0	57.0	51.3	8.0	8.7	34.6
HIGGINSON HALL	HG	RES	335.1	76.0	68.4	6.0	26.5	35.9
RIDGEWAY COMMONS	RC	RES [1]	446.1	66.0	59.4	6.0	16.9	36.5
FAIRHAVEN TOWERS 1-12	FB	RES	331.0	70.0	63.0	6.0	19.5	37.5
BUCHANNAN TOWERS	BT	RES	322.6	94.0	84.6	6.0	41.0	37.6
RIDGEWAY-ALPHA [4]	RA	RES	438.8	68.0	61.2	6.0	15.5	39.7
RIDGEWAY-GAMMA [4]	RG	RES	438.9	62.0	55.8	6.0	9.5	40.3
CAMPUS SERVICES	CS	ACAD	316.5	74.0	66.6	8.0	18.0	40.6
FAIRHAVEN COLLEGE/Academic	FA	ACAD	326.0	68.0	61.2	6.0	13.4	41.8
RIDGEWAY-SIGMA	RS	RES	429.7	81.0	72.9	6.0	23.7	43.2
RIDGEWAY-DELTA	RD	RES	427.9	79.0	71.1	6.0	21.6	43.5
RIDGEWAY-BETA [4]	RB	RES	426.0	85.0	76.5	6.0	26.8	43.7
COMMISSARY (Housing Owned)	CM	ACAD	298.5	82.0	73.8	8.0	18.4	47.4
HIGHLAND HALL 1	HI	RES	409.5	91.0	81.9	6.0	24.5	51.4
HIGHLAND HALL 2	HI	RES	409.5	82.0	73.8	6.0	14.9	52.9
RIDGEWAY-OMEGA	RO	RES	399.5	81.0	72.9	6.0	10.6	56.3
RECYCLE CENTER	RE	ACAD	240.0	90.0	81.0	8.0	10.4	62.6
PHYSICAL PLANT	PP	ACAD	239.0	90.0	81.0	8.0	10.0	63.0
ARCHIVES	AB	ACAD	261.5	92.0	82.8	8.0	8.4	66.4

NOTES:
1. Type is based on meter records, sprinkler flows assigned as ACAD rather than RES.
2. Sprinkler design flows for RES type buildings = 310 GPM, all other building types = 650 GPM. Residual pressure at water main near building connection point.
3. Safety factor of 10% per BCE.
4. Ridgeway buildings sprinkler systems are connected to dedicated fire loop on City 541 Pressure Zone.
5. Negative pressure indicates the required flow cannot reach the top of the building.

Table 2-6. Fire Flow Status and Recommended Sprinkler Improvements

BUILDING	ID	HYDRANT FIRE FLOW STATUS [1]	SPRINKLER SYSTEM?	SPRINKLER HIGH ELEV (FT)	SPRINKLER INFRASTRUCTURE NEEDS [3,4]
ARNTZEN HALL	AH	ADEQUATE	PART	400	Pumps needed Upgrade supply line
BOND HALL	BH	ADEQUATE	PART	384	Pumps needed
CARVER GYMNASIUM	CV	ADEQUATE	ALL	372	Verify functional sprinklers
CHEMISTRY BLDG (MORSE HALL)	CB	ADEQUATE	ALL	396	Pumps needed
COLLEGE HALL	CH	ADEQUATE	NONE	370	Verify functional sprinklers
COMMISSARY (Housing Owned)	CM	POOR	NONE	299	No pumps needed
COMMUNICATIONS	CF	ADEQUATE	ALL	390	HAS FIRE PUMPS Upgrade supply line
ENVIRONMENTAL STUDIES CENTER	ES	ADEQUATE	ALL	416	HAS FIRE PUMPS Upgrade supply line
HAGGARD HALL	HH	ADEQUATE	ALL	371	Verify functional sprinklers
PARKS HALL	PH	ADEQUATE	ALL	397	Pumps needed Upgrade supply line
PERFORMING ARTS CENTER	PA	ADEQUATE	PART	370	Verify functional sprinklers
ROSS ENGINEERING TECHNOLOGY	ET	ADEQUATE	PART	365	HAS FIRE PUMPS Upgrade supply line
WILSON LIBRARY	WL	ADEQUATE	PART	387	Pumps needed

Notes:

1. Evaluated at the most limited critical nearby hydrant likely to serve the building, existing 2017 modeled conditions.
2. vacant
3. This column indicates whether pumps are likely to be needed or whether a more detailed evaluation is needed. Also stated is where water supply piping upgrades are needed. Upgrades may also be needed at other buildings in order to avoid the need for fire pumps (note that this is a conservative analysis; for example, it shows that pumps may be needed at buildings even though their full sprinkler system was designed without the need for pumps).
4. The following buildings already have fire booster pumps:
   - Biology Building (BI)
   - Environmental Studies Center (ES)
   - Ross Engineering Technology (ET)
   - Miller Hall (MH)
   - Old Main (OM)
   - Communications Facility (CF)

3. SANITARY SEWER

3.1. Existing System

3.1.1. Description

The existing sanitary sewer system is shown in Figure 3-1 for the north campus and Figure 3-2 for the south campus. The campus sanitary sewer system consists of a series of gravity flow pipes, many of which are very deep. Some sewer mains are owned by the City and some are owned by the University. Sewer laterals and small sewer branches are shown in the figures but are not otherwise addressed in this study. Some buildings have sewer lift stations, which are also not addressed in this study. The dining facilities are equipped with grease traps or grease interceptor vaults to prevent discharge of excessive grease to the sewer system.

<u>North Campus</u>

The north campus sanitary sewer system consists of three separate mains (see Figure 3-1 for locations and identification labels). Most of the north campus is served by a sewer main (**Trunk line SS200**) that begins at the Steam Plant, then traverses across campus to High Street, then north down High Street, then downhill to Garden Street at Cedar Street, and then north down Garden Street. A second sanitary sewer main collects service piping from half of Old Main, Edens Hall, and Higginson Hall. This main flows north down High Street, then down Oak Street, then north down an Alley to Ivy Street, and then to Garden Street. The third sanitary sewer system serves Edens North and flows north down Billy Frank Jr Street.

Many of sewer system pipes are very old, except where piece-meal replacements have been made as part of building improvements. The WWU-owned portion of the main sewer line (**Trunk line SS200**) was inspected with a video camera March 2017. It is in reasonable condition for the most part (mostly concrete pipe or cast iron installed within the last 40-50 years). However, one 230 LF segment (SS216) on the NE side of Carver Gym, is a corroded corrugated metal pipe that needs to be replaced or rehabilitated.

The Garden Street sewer main adjacent to campus is 12-inch PVC (plastic); however, the City-owned downstream system is still only 8-inch pipe.

The 10-inch sewer service pipe for Humanities and part of Old Main traverses under Humanities. The under-building portion is cast iron pipe which is mostly intact; there is one sizable break on the crown of the pipe about 80 feet south of the Rose Garden manhole, but the pipe remains functional. There is a source of gravel coming into the pipe (the source – probably an open joint – was not detected by video inspection, maybe from the aforementioned break. This cast iron segment may be a candidate for cured-in-place-pipe (CIPP) lining rehabilitation. Between Humanities and Bond Hall (through Red Square, the sewer is relatively newer 10-inch PVC sewer pipe. However, it may have been poorly installed or the subgrade may be poor. There is a bulge protruding 5-inches into in the pipe at one location about 30 feet south of Humanities. There is a 30-foot segment being compressed (i.e., squashed to a 7-inch or 8-inch tall by 14-inch or 15-inch wide cross-section) by weight from above (location 105 feet to 135 feet north of the Bond Hall manhole); this segment is also bellied (meaning the bottom few inches of the pipe has standing water). These problems with the PVC pipe should be corrected before the pipe becomes unusable and should be monitored until then.

South Campus

The south campus sanitary sewer system consists of two separate mains (see Figure 3-2 for locations and identification labels). Most of the south campus is served by Sewer **Trunk line 400**, which begins at Carver Gym and flows south to 21st Street and Bill McDonald Parkway. The Academic Instruction Center and the Fairhaven Complex are served by Sewer **Trunk line 600** (Figure 3-2), which is a combination of 12-inch and 8-inch concrete sewer main that flows west to South College Drive, then south, and across Bill McDonald Parkway to the City's sewer main along Taylor Creek. Another sanitary sewer system serves the Commissary and Buchanan Towers and the Archives Building; it flows across Bill McDonald Parkway and south down 24th Street. The Physical Plant sewer discharges to the Douglas Street sewer main, which flows west.

The south campus sanitary sewer system has been revised substantially in recent years. The entire main line, **Trunk Line 400**, was replaced in 2002 with 18-inch PVC pipe from Parks Hall to 21st Street and with 12-inch PVC pipe from SMATE to the northeast corner of the All Weather Track.

Trunk Line 600 receives flow from the Academic Instruction Center (and will receive flow from other future buildings in IMP District 14). This sewer main used to traverse through what is now Harrington Field, but was rerouted to the 8-inch **Trunk Line 600** on

South College Drive via new segment SS603. The 8-inch Trunk Line 600 along South College Drive is one of the oldest (1958) and poorest condition sewer mains on campus. It has numerous leaking joints which allow water and gravel into the pipeline and sewage to leak out.

3.2. Existing Conditions Evaluation

3.2.1. Flow Evaluation

The existing sanitary sewer flow rates were estimated for each building on campus. Sewer flows are expected to be roughly equivalent to the domestic water demand plus infiltration and inflow (I&I) from groundwater and stormwater. Although domestic water demand does include some irrigation use, this is relatively insignificant - especially given that most of the irrigation flows are metered separately.

Mean Daily Flows

The mean daily flows (MDF) for each building were calculated by dividing the total consumption for the full in-session months over the three-year period by the total days for the corresponding months of data used. Table 3-1 shows the existing mean daily flows for each cluster of buildings on a sanitary sewer branch. The total mean daily sewer flows are:

Area	MDF
North Campus	112,000 GPD
South Campus	170,000 GPD
Physical Plant	2,600 GPD
Total	284,600 GPD

Peak Flows

The peak flows for the “in session” season were estimated by multiplying the MDF by a factor 3.0 for residential buildings and a factor of 6.0 for Academic Buildings. Table 3-1 shows the existing peak daily flows for each cluster of buildings on a sanitary sewer branch. The total peak daily sewer flows are (not including infiltration and inflow):

Area	Peak Flows
North Campus	301 GPM
South Campus	446 GPM
Physical Plant	11 GPM
Total	758 GPM

A design safety factor should be included in any design using these flow estimates because these are not necessarily conservative estimates.

3.2.2. Sanitary Sewer Capacity

The flows and flow capacity of the main sewer system pipes are shown in Table 3-2 and flows only in Figures 3-1 and 3-2. The estimated sewer flows are substantially lower than the capacity of the sewer system. The typical peak sewer flow is about 6 percent of the total pipe flow capacity (with no surcharging). Table 3-2 shows the basic pipe data: diameter, length, age, invert elevations, and slope. The estimated flow is simply the sum of all upstream sources, which is conservative since this assumes no storage in the pipes. No backflow analyses were performed because no surcharging occurs at any of the manholes.

Approximately 20% of sewer mains may not see velocities high enough to scour pipes regularly. Pipe segments SS210 (175 LF), SS213-SS217 (703 LF) all have peak flow velocities of between 1.0 fps and 1.8 fps, which is less than the recommended 2 feet per second. Sewer laterals with non-scouring flows include the pipe from Old Main to Bond Hall (under Humanities) and the sewer serving Campus Services.

3.3. Future Conditions Evaluation

The sanitary sewer system has a very large capacity for absorbing increased flows. As such, the sanitary sewer system does not need to be upgraded nor does the capacity need to be increased to accommodate the modest future growth on campus. IMP District 14 will see the highest increase in sewer flows in the future. Sewer flows may be routed to Trunk Lines 400 or 600. Trunk Line 400 has the highest capacity but is also the highest in elevation making it less available for connection. Trunk Line 600 has the least capacity and has condition issues and should be upgraded to 12-inch pipe prior to addition of more flows.

The primary concern for the sewer system is maintaining the sewer pipe and manholes in good condition, providing regular maintenance, replacing aging pipe before it deteriorates, and preventing large increases in infiltration and inflow (I&I).

3.4. Recommended Improvements

3.4.1. Recommended Improvements and Operations

Recommendations are primarily for operations and maintenance or for replacement of aging pipe:

Monitoring and Maintenance

1. **Monitor the sanitary sewer system for infiltration and inflow**
   Monitor the sanitary sewer system for infiltration and inflow (I&I, aka leaks) problems during wet weather (e.g., during January). This could be as simple as placing peak level recording devices in manholes (such as a vertical plastic pipe with cork dust) to record manhole surcharging during wet weather.

2. **Monitoring Sewer Condition**
   Monitor the conditions of the sewer pipe and manholes to identify potential failures, blockages or leak problems. WWU has contracted outside contractors to provide sewer video inspection. These inspections should continue to be performed every two to six years depending on the age and condition of piping.

3. **Flush the sewer systems on an as-needed basis**
   Flush or jet clean the sewer systems on an as-needed basis. The necessity and frequency should be as determined by operations staff observations. If standing water is observed in manhole outlet pipes, then flushing should be performed.

10-year Capital Improvements

4. **Replace Trunk Line 600-602**
   This 8-inch trunk line along South College Drive is one of the oldest and in poorest condition on campus. All pipe and manholes should be replaced in their current configuration using 12-inch sewer pipe to accommodate future development.

5. **Rehabilitate the sewer line adjacent to the east-north side of Carver Gym.** This 240-foot segment of 12-inch corrugated metal pipe should be rehabilitated by sliplining or cured-in-place lining due to its deteriorating condition. Sliplining is the preferred method due to the condition of the corrugated pipe. The reduction in pipe diameter will be acceptable if limited to this 240-foot length. This segment is encased in concrete and is very deep, on piles and is below the water main. In the meantime, this segment should be monitored to identify impending failures.

6. **Repair sewer line between Humanities and Bond Hall (in Red Square).** This segment of pipe should be repaired due to its deteriorating condition. The 30-40 foot long compressed PVC pipe section should be excavated and replaced and the subgrade improved. The PVC pipe section with the large bulge should be excavated and replaced. In the meantime, this segment should be monitored to identify impending failures (pipe collapse or severe compression vertically).

7. **Replace Sewer Line Traversing Downhill from Highland 2 to Trunk Line 200** This segment of pipe should be replaced with new HDPE pipe of equal size. This can be accomplished using pipe bursting as was done with the adjacent steep downslope pipe (thereby avoiding excavation on the steep wooded slope).

3.4.2. Cost Estimates

Reasonable order of magnitude cost estimates (2017 dollars) for upgrades including design and installation are (actual costs will be more or less depending on the simplicity of design and installation):

IMPROVEMENT	ESTIMATED COST		
Improvement 4	$350,000	to	$450,000
Improvement 5	$100,000	to	$150,000
Improvement 6	$30,000	to	$70,000
Improvement 7	$70,000	to	$110,000

3.5. Conclusions

The on-campus sanitary sewer system has a large capacity for absorbing increased flows, with the exception of the South College Drive sewer. As such, the capacity of the sanitary sewer system does not need to be increased to accommodate the planned future growth on campus, with the sole exception of the South College Drive sewer.

The primary concern for the sanitary sewer system is maintaining the sewer pipe and manholes in good condition, replacing aging pipe before it deteriorates, preventing large increases in infiltration and inflow (I&I), and preventing failures that could back up sewers into buildings. One sewer main upgrade is needed to increase capacity (see 10-year Improvements).

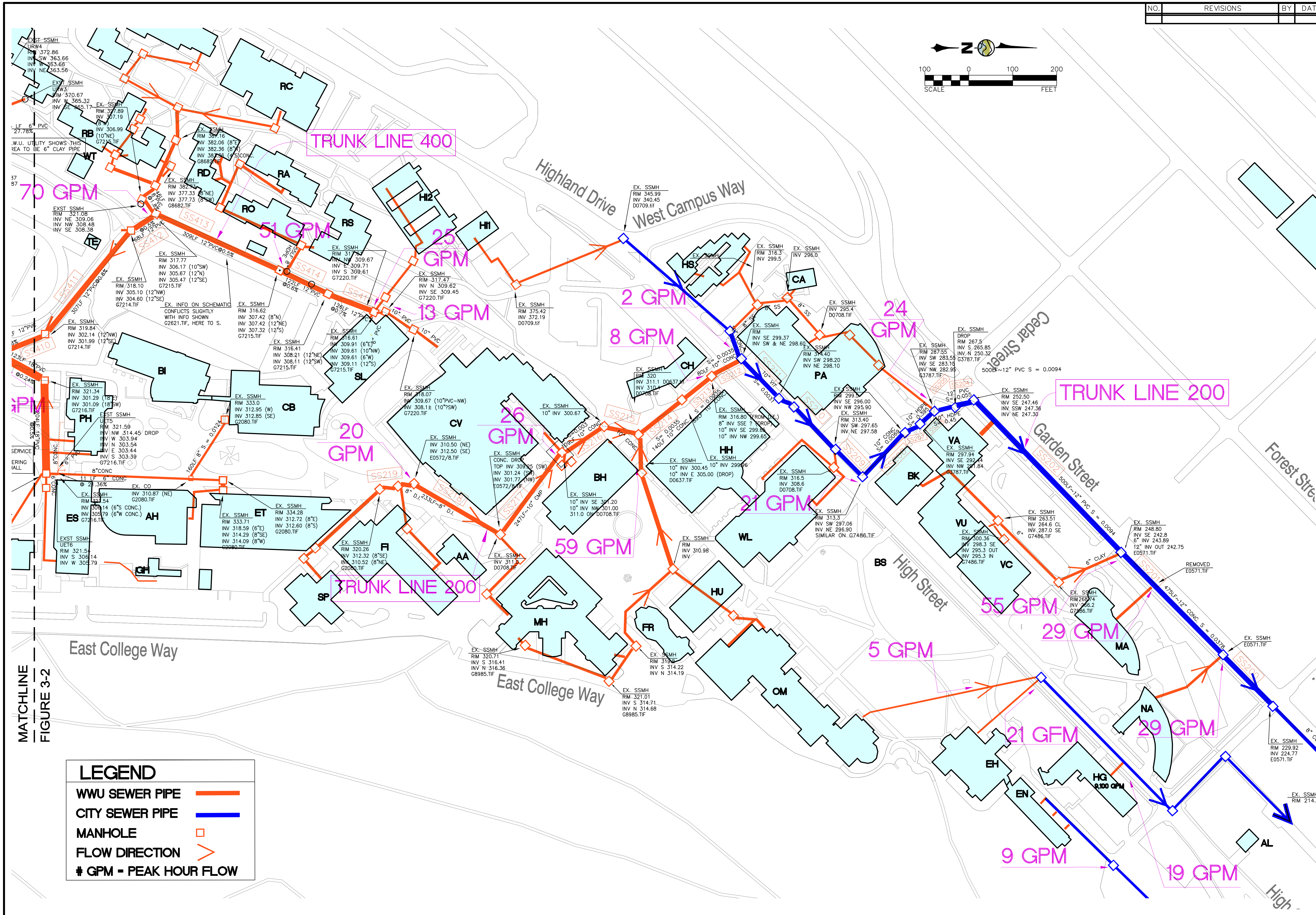
There are three segments of sewer trunk lines or sewer lines that need repair or replacement and one longer segment of sewer trunk line (SS600) that needs replacement and size upgrade as described below. The repair or replacement projects are needed due to age related conditions or localized defects.

IMP District 14 will see the highest increase in sewer flows in the future. These future sewer flows are most easily routed to the South College Drive sewer (SS600 in Fig 3-2). Sewer flows from District 14 (i.e., Academic Instruction Center) were rerouted to this sewer line to accommodate Harrington Field construction in 2015. See Figure 3-2 for a map of sanitary sewers in this part of campus.

- The on-campus sanitary sewer system has a large capacity for absorbing increased flows, with the exception of the South College Drive sewer. As such, the capacity of the sanitary sewer system does not need to be increased to accommodate the planned future growth on campus, with the sole exception of the South College Drive sewer.
- The primary concern for the sanitary sewer system is maintaining the sewer pipe and manholes in good condition, replacing aging pipe before it deteriorates, preventing large increases in infiltration and inflow (I&I), and preventing failures that could back up sewers into buildings. One sewer main upgrade is needed to increase capacity (see 10-year Improvements).

- IMP District 14 will see the highest increase in sewer flows in the future. These future sewer flows are most easily routed to the South College Drive sewer (SS600 in Fig 3-2). Sewer flows from District 14 (i.e., Academic Instruction Center) were rerouted to this sewer line to accommodate Harrington Field construction in 2015. See Figure 3-2 for a map of sanitary sewers in this part of campus.
- Implement repairs or rehabilitation of sewers as needed to prevent problems with sewer flows (e.g., blocked pipes and backups), including the above recommended improvements.

3.6. Appendices (Figures and Tables)



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BELLINGHAM WASHINGTON

FIGURE 3-1

NORTH CAMPUS SANITARY SEWER

DATE: JUNE 2017

SCALE: AS SHOWN

JOB NUMBER: 2016-139

SHEET 1 OF 4

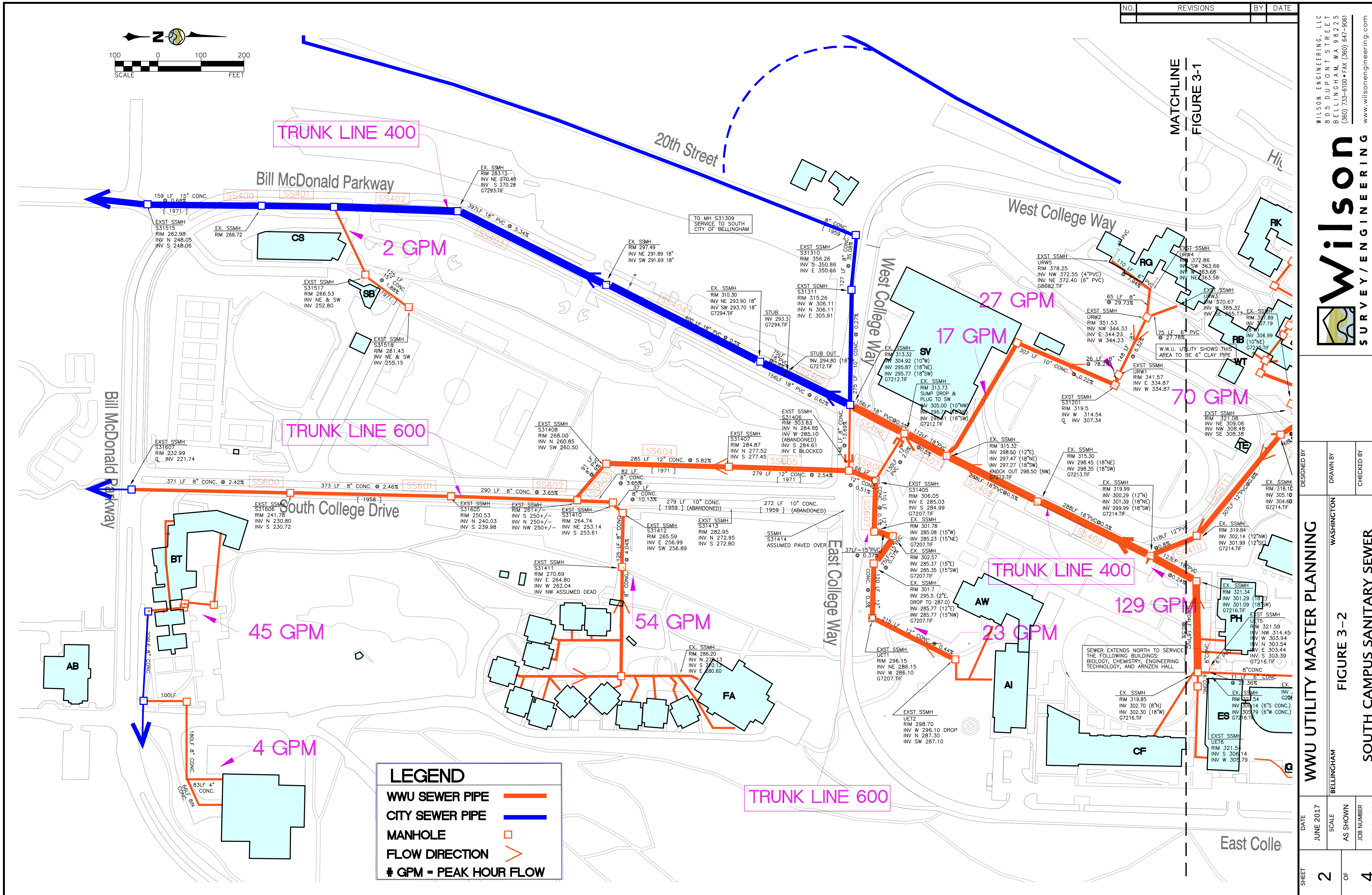
TRUNK LINE 400
TRUNK LINE 600
Bill McDonald Parkway
20th Street
West College Way
South College Drive
East College Way
MATCHLINE FIGURE 3-1
2 GPM
27 GPM
17 GPM
70 GPM
54 GPM
45 GPM
23 GPM
129 GPM
4 GPM
CS
SB
SV
RG
RK
RB
WT
TE
BT
AB
AW
AI
FA
CF
PH
ES
LEGEND
WWU SEWER PIPE
CITY SEWER PIPE
MANHOLE
FLOW DIRECTION
GPM = PEAK HOUR FLOW
SCALE 100 0 100 200 FEET
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FIGURE 3-2
SOUTH CAMPUS SANITARY SEWER
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DATE JUNE 2017
SCALE AS SHOWN
JOB NUMBER 2016-139
SHEET 2 OF 4

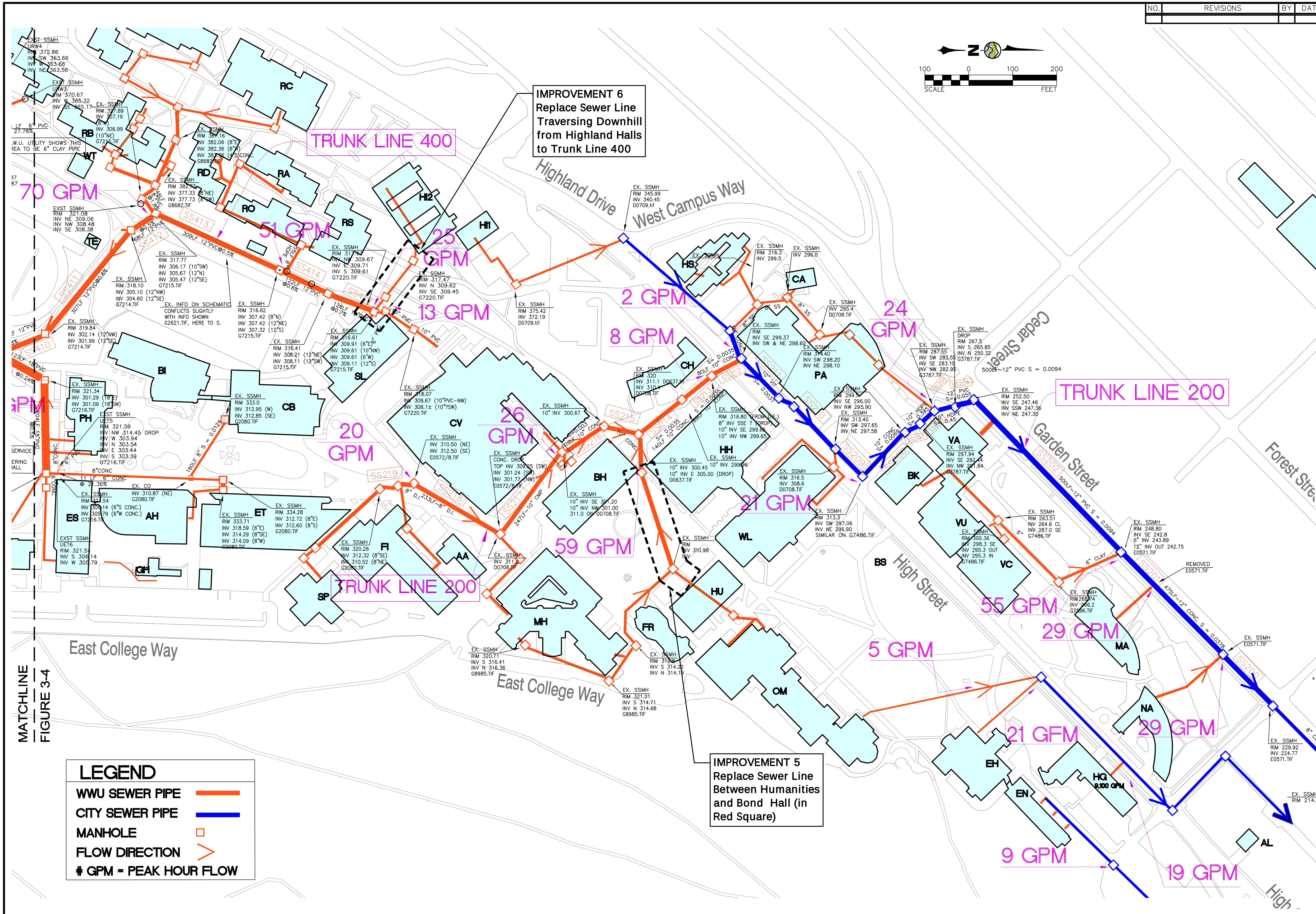

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FIGURE 3-3
RECOMMENDED IMPROVEMENTS NORTH

DATE JUNE 2017
SCALE AS SHOWN
JOB NUMBER 2016-139

SHEET 3 OF 4

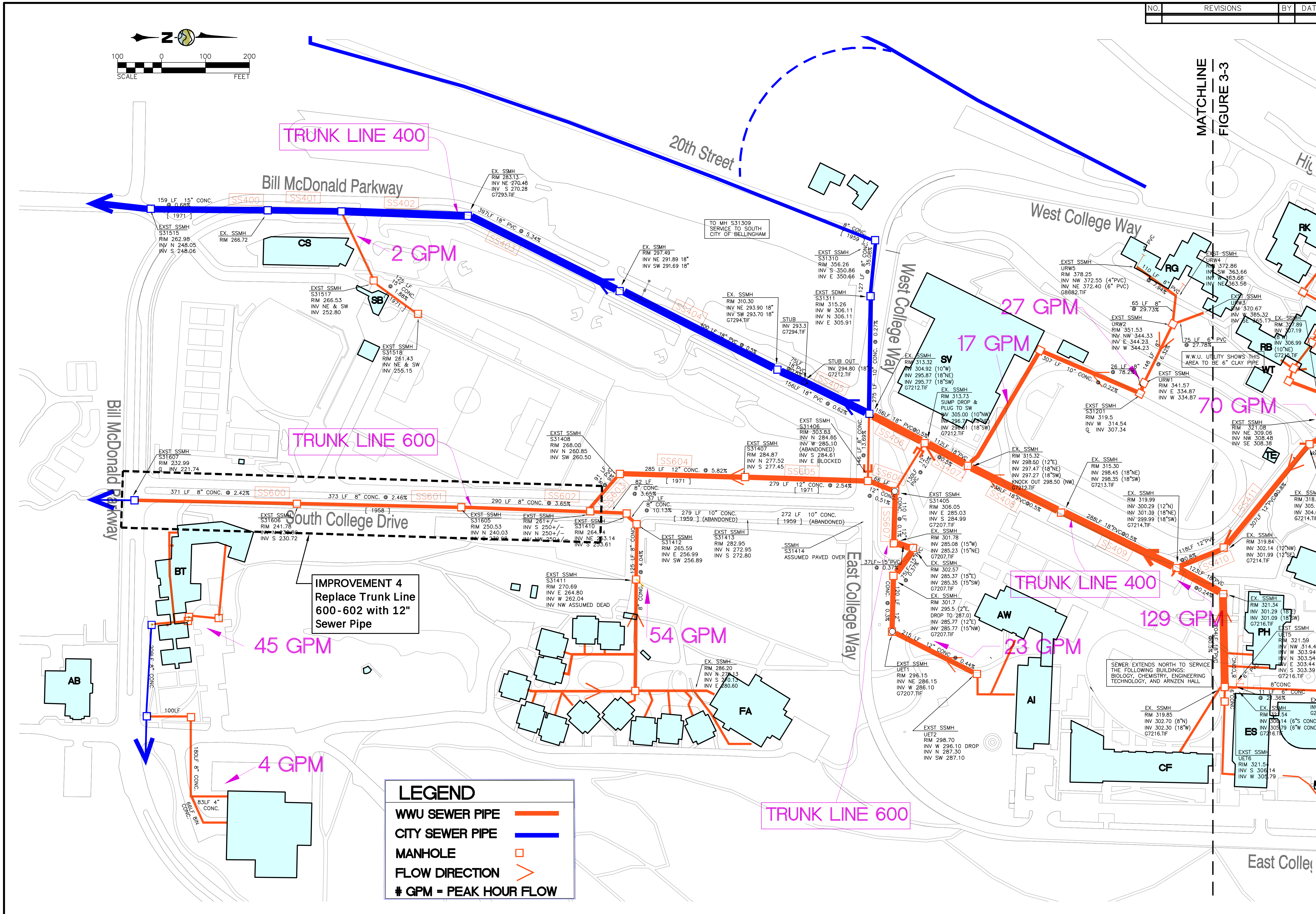

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FIGURE 3-4

RECOMMENDED IMPROVEMENTS SOUTH

DATE JUNE 2017
SCALE AS SHOWN
JOB NUMBER 2016-139
SHEET 4 OF 4

Table 3-1. Existing Sanitary Sewer Flows

Building ID	Building Name	IMP District	MDF (gpd)	MDF (gpm)	MDF (cfs)	Peak Flow[1] (gpm)	Peak Flow[1] (cfs)
EN	EDENS HALL NORTH	3	4,253	3	0.0066	9	0.020
OM	OLD MAIN	5	2,310	2	0.0036	5	0.011
EH	EDENS HALL (SOUTH)	3	10,243	7	0.0158	21	0.048
HG	HIGGINSON HALL	3	9,134	6	0.0141	19	0.042
NA	NASH HALL	3	14,018	10	0.0217	29	0.065
MA	MATHES HALL	3	13,743	10	0.0213	29	0.064
VC	VIKING COMMONS	3	26,273	18	0.0406	55	0.122
VU	VIKING UNION	4					
BK	BOOKSTORE	4					
PA	PERFORMING ARTS CENTER	6	5,878	4	0.0091	24	0.055
CA	CANADA HOUSE	6					
HS	HIGH STREET HALL	6	478	0	0.0007	2	0.004
HL	HIGHLAND LOUNGE	10					
BH	BOND HALL	7	14,139	10	0.0219	59	0.131
MH	MILLER HALL	7					
HH	HAGGARD HALL	7					
HU	HUMANITIES BLDG	7					
FR	FRASER HALL	7					
WL	WILSON LIBRARY	7	5,018	3	0.0078	21	0.047
CH	COLLEGE HALL	9	1,835	1	0.0028	8	0.017
AA	ARTS ANNEX	9	4,863	3	0.0075	20	0.045
SP	STEAM PLANT	9					
FI	FINE ARTS BUILDING	9					
CV	CARVER GYMNASIUM	9	6,200	4	0.0096	26	0.058
RS	RIDGEWAY SIGMA	10	24,503	17	0.0379	51	0.114
RO	RIDGEWAY OMEGA	10					
RD	RIDGEWAY DELTA	10					
RA	RIDGEWAY ALPHA	10					
HI	HIGHLAND	10	6,001	4	0.0093	25	0.056
SL	SMATE (SCIENCE LECTURE HALLS)	11					
RK	RIDGEWAY KAPPA	10	33,561	23	0.0519	70	0.156
RC	RIDGEWAY COMMONS	10					
RB	RIDGEWAY BETA	10					
RG	RIDGEWAY GAMMA	10	12,892	9	0.0199	27	0.060
AH	ARNTZEN HALL	11	30,936	21	0.0479	129	0.287
BI	BIOLOGY BUILDING	11					
CB	CHEMISTRY BUILDING (Morse Hall)	11					
ES	ENVIRONMENTAL STUDIES CENTER	11					
PH	PARKS HALL	11					
ET	ROSS ENGINEERING TECHNOLOGY	11					
CF	COMMUNICATION FACILITY	14					
AI/AW	ACADEMIC INSTRUCTION CENTER	14	5,544	4	0.0086	23	0.051
SV	STUDENT RECREATION CENTER	13	8,218	6	0.0127	17	0.038
FA	FAIRHAVEN COLLEGE - ACADEMIC	15	25,822	18	0.0400	54	0.120
FB	FAIRHAVEN TOWERS	15					
CS	CAMPUS SERVICES FACILITY	16	566	0	0.0009	1.2	0.003
BT	BUCHANAN TOWERS	18	21,399	15	0.0331	45	0.099
BQ	BUCHANAN TOWERS EAST	18					
AB	ARCHIVE BUILDING	19	126	0	0.0002	0.5	0.001
CM	COMMISSARY	19	999	1	0.0015	4	0.009
PP	PHYSICAL PLANT	23	2,604	2	0.0040	11	0.024

Notes:

MDF Mean Daily Flow

1. Peak Flow = MDF x 3.0 (Residential) or MDF x 6.0 (Academic)

Table 3-2. Existing Sanitary Sewer System Pipe Flows and Capacities

	Pipe ID	Owner	Pipe Diameter[1] (in)	Roughness Coeff. n	Condition	Pipe Length (ft)	Year Installed	Invert Elev. Out ft	Invert Elev. In ft	Slope[2] (%)	Estimated Mean Daily Flow[3] (cfs)	Estimated Peak Flow[6] (cfs)	Estimated Total I & I[5] (cfs)	Estimated Tot. Peak Flow[6] (cfs)	Capacity[7] (Pipe Full) (cfs)	Velocity[8] (Pipe Full) (ft/sec)
TRUNK LINE 200	200	City	8	0.013			?	--	224.77	5.00	0.148	0.612	0.155	0.77	2.71	7.76
	201	City	12	0.011		475	1972	224.77	242.75	3.79	0.126	0.547	0.155	0.70	8.214	10.458
	202	City	12	0.011		500	1972	242.80	247.30	0.90	0.064	0.362	0.127	0.49	4.005	5.100
	204	City	10	0.013		50	?	247.36	250.38	6.04	0.064	0.362	0.098	0.46	5.399	9.899
	205	City	10	0.013		50	?	265.85	282.95	34.20	0.064	0.362	0.095	0.46	12.848	23.556
	206	City	10	0.013		42	?	283.23	291.90	20.64	0.055	0.307	0.092	0.40	9.981	18.301
	207	City	10	0.013		45	?	291.90	295.90	8.89	0.055	0.307	0.090	0.40	6.550	12.009
	208	City	10	0.013		140	?	296.00	296.90	0.64	0.055	0.307	0.087	0.39	1.761	3.230
	209	City	10	0.013		87	?	297.06	297.58	0.60	0.055	0.307	0.079	0.39	1.698	3.114
	210	City	10	0.013		175	?	297.65	298.10	0.26	0.048	0.260	0.074	0.33	1.114	2.043
	211	City	10	0.013		120	?	298.20	298.60	0.33	0.048	0.260	0.064	0.32	1.268	2.326
	212	WWU	10	0.013	Grade B	80	1971	299.37	299.65	0.35	0.047	0.256	0.057	0.31	1.300	2.383
	213	WWU	10	0.013	Grade B	89	1971	299.65	299.96	0.35	0.044	0.239	0.052	0.29	1.297	2.377
	214	WWU	10	0.013	Grade B	140	1971	299.96	300.45	0.35	0.044	0.239	0.047	0.29	1.300	2.383
	215	WWU	10	0.013	Grade B	68	1971	300.45	300.67	0.32	0.022	0.108	0.038	0.15	1.250	2.291
	216	WWU	10	0.013	Grade B	109	1971	300.67	301.10	0.39	0.022	0.108	0.034	0.14	1.380	2.530
	217	WWU	10	0.013	Grade D/F	247	1972	301.20	301.77	0.23	0.013	0.050	0.028	0.08	1.055	1.935
	218	WWU	8	0.013	Grade C	233	1972	309.25	310.50	0.54	0.008	0.045	0.014	0.06	0.887	2.542
TRUNK LINE 400	400	City	18	0.013	Grade A	108	?	248.05	255.46	6.86	0.172	0.700	0.201	0.90	27.59	15.61
	401	City	18	0.011	Grade A	166	?	255.46	262.87	4.46	0.172	0.700	0.195	0.90	26.30	14.88
	402	City	18	0.011	Grade A	286	?	262.87	270.28	2.59	0.171	0.698	0.185	0.88	20.04	11.34
	403	City	18	0.011	Grade A	397	2002	270.48	291.69	5.34	0.171	0.698	0.169	0.87	28.77	16.28
	404	City	18	0.011	Grade A	400	2002	291.89	293.70	0.45	0.171	0.698	0.145	0.84	8.37	4.74
	405	City	18	0.011	Grade A	231	2002	293.90	295.77	0.81	0.171	0.698	0.122	0.82	2.34	4.28
	406	WWU	18	0.011	Grade A	156	2002	295.87	296.51	0.41	0.171	0.698	0.108	0.81	7.97	4.51
	407	WWU	18	0.011	Grade A	112	2002	296.71	297.27	0.50	0.171	0.698	0.099	0.80	8.80	4.98
	408	WWU	18	0.011	Grade A	238	2002	297.47	298.35	0.37	0.138	0.600	0.093	0.69	7.57	4.28
	409	WWU	18	0.011	Grade A	288	2002	298.45	299.99	0.53	0.138	0.600	0.079	0.68	9.10	5.15
	410	WWU	12	0.011	Grade A	118	2002	300.29	301.99	1.44	0.090	0.313	0.062	0.37	5.07	6.45
	411	WWU	12	0.011	Grade A	317	2002	302.14	304.60	0.78	0.090	0.313	0.055	0.37	3.72	4.74
	412	WWU	12	0.011	Grade A	68	2002	305.11	306.17	1.56	0.090	0.313	0.037	0.35	5.27	6.71
	413	WWU	12	0.011	Grade A	309	2002	305.67	307.32	0.53	0.046	0.180	0.033	0.21	3.09	3.93
	414	WWU	12	0.011	Grade A	122	2002	307.42	308.11	0.57	0.014	0.084	0.015	0.10	3.18	4.04
	415	WWU	12	0.011	Grade A	126	2002	308.21	309.11	0.71	0.014	0.084	0.007	0.09	3.57	4.54
TRUNK LINE 600	600	WWU	8	0.013	Poor	371	?	221.74	230.72	2.42	0.049	0.171	0.109	0.28	1.89	5.40
	601	WWU	8	0.013	Poor	373	1958	230.80	239.98	2.46	0.049	0.171	0.087	0.26	1.90	5.45
	602	WWU	8	0.013	Poor	290	?	240.03	253.61	4.68	0.049	0.171	0.066	0.24	2.62	7.51
	603	WWU	8	0.011	Grade A	91	2016	253.14	260.50	8.09	0.009	0.051	0.049	0.10	4.07	11.67
	604	WWU	12	0.013		285	1971	260.85	277.45	5.82	0.009	0.051	0.043	0.09	8.62	10.98
	605	WWU	12	0.013		279	1971	277.52	284.61	2.54	0.009	0.051	0.027	0.08	5.69	7.25
	606	WWU	12	0.013		66	1971	277.52	285.00	11.33	0.009	0.051	0.010	0.06	12.03	15.31
	607	WWU	12	0.013		110	1971	277.52	285.08	6.87	0.009	0.051	0.006	0.06	9.37	11.92

Notes

[1] Pipe roughness coefficient: Manning's n = 0.012

[2] Slope = (Upstream IE In - Downstream IE In) ÷ Pipe Length (ncludes drop connection height)

[3] Flow based on estimated flow per gross square foot

[4] Peak Flow = Mean Daily * Peak Factor [Peak Factor equals 3 (Residentail) and 6 (Academic)]

[5] Total Inflow & Infiltration = (40.000 gallons/mile/day = 1.17*10 -5cfs/ft)(length of pipe)(peak factor = 5)

[6] Total Peak Flow = Peak Flow + Total I&I

[7] Capacity based on pipes flowing full (Mannings Equation)

[8] Velocity based on Pipes flowing full

4. STORMWATER

4.1. Regulatory Requirements

WWU has a NPDES Phase II Municipal Stormwater Permit. WWU is a secondary permittee. The City of Bellingham is the primary permittee. WWU has a Stormwater Management Program and provides regular reports on stormwater to the City and Washington State Department of Ecology. The permit requirement of most relevance to the UTMP is that WWU comply with all stormwater requirements for development and redevelopment.

All campus development and redevelopment projects must address all of the 9 Minimum Requirements of the Department of Ecology 2014 version Stormwater Management Manual for Western Washington (Ecology Manual) and Bellingham's stormwater ordinance and Stormwater Handbook. Two Minimum Requirements: #6 (Runoff Treatment aka water quality) and #7 (Flow Control, aka detention) are the two requirements of primary interest for this Utilities Master Plan.

Flow Control (Detention)

South campus development projects must provide detention per the more rigorous requirements of the 2014 version of the Ecology Manual. Stormwater detention requirements, per Ecology, are determined with the use of a continuous simulation time series model. Flow control (detention) must provide stormwater release at flow rates equal to or lower than those for forested conditions for any developed or redeveloped area. The main south campus stormwater system has detention facilities that were designed to accommodate future growth (excluding Districts 15, 17, part of 18, 19, and 22/23

North campus stormwater flow control is only necessary to keep flows below the 25-year storm flow capacity of the downstream pipe and catch basin system. This is because the ultimate point of discharge is to Bellingham Bay which is exempt from flow control requirements. (i.e., there is no need for streambank erosion control). The capacity can be maintained as needed either by improving the capacity of the conveyance system (and the City's off-campus conveyance system in particular) or by providing on-campus detention of stormwater to reduce peak flow rates or a combination thereof. For example, the 2016/2017 Carver Gym Capital Project added two stormwater detention tanks to mitigate for the additional impervious area created by this project.

Water Quality Treatment Requirements

All development and redevelopment projects must provide water quality treatment facilities per the Basic Treatment Menu of the Ecology Manual. Clean rooftop runoff and natural areas need not be treated (pedestrian areas and service roads used infrequently are also normally exempted from treatment requirements). However, treatment facilities must be sized to account for all runoff that commingles with other runoff requiring treatment. Runoff from playing fields and landscape areas requires treatment (note that Ecology determined in 2015 that treatment is required for synthetic turf fields).

4.2. Existing System

4.2.1. Description

There are two major sections of the University campus that collect and convey stormwater runoff. The north campus watershed consists of approximately 105 acres (Figure 4-1) and the south campus watershed consists of approximately 140 acres (Figure 4-2). These watersheds contain off-campus areas including a large area of the forested Sehome Arboretum Hill to the east and a smaller area west of the Ridgeway complex.

The north campus stormwater system flows to Bellingham Bay via the City's storm sewers. Most of the north campus stormwater is collected in a large diameter main that discharges to the City's Cedar Street storm sewer. Two smaller areas flow to the Garden Street storm sewer (one southwest and one northeast from the intersection of North Garden and Cedar Streets).

The south campus stormwater system flows to Taylor Creek via three storm sewers that flow south across Bill McDonald Parkway. Most of the south campus stormwater is collected in a large main that discharges to a large detention vault (at the tennis courts) and a constructed wetland treatment system (south side of Bill McDonald Parkway). Stormwater from Fairhaven Complex and Buchanan Towers area is discharged directly to Taylor Creek. Stormwater from the Commissary area is also discharged directly to Taylor Creek.

The Physical Plant complex discharges runoff to Douglas Street ditch which flows either west to Taylor Creek or east to Connelly Creek depending on location.

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4.2.2. Runoff and Conveyance

4.2.2.1 North Campus

Basin Characteristics

The north campus system consists of nine (9) primary sub-basins (N-01 through N-09) that contribute stormwater runoff to the conveyance system that leaves the campus to the northwest at the North Garden Street and Cedar Street intersection. North campus also has two (2) sub-basins (NE-01 and NE-02) that discharge stormwater runoff into the City stormwater system to the northeast of Cedar Street and one (1) sub-basin (NW-01) that discharges into the City system to the southwest from Cedar Street. The following is a summary of the north campus sub-basin information:

Basin ID	Total Area (AC)	Impervious Building Area (AC)	Impervious Road/Parking Area (AC)	Percent Impervious (%)
N-01	7.66	1.96	1.61	46.7%
N-02	7.51	2.75	2.49	69.7%
N-03	1.25	0.52	0.33	68.7%
N-04	6.39	1.94	3.06	78.2%
N-05	10.92	1.56	3.75	48.7%
N-06	11.13	2.95	2.23	46.6%
N-07	3.04	1.04	1.20	73.7%
N-08	23.34	0.00	0.00	0.0%
N-09	12.23	0.84	1.20	16.6%
NE-01	10.97	1.58	4.19	52.6%
NE-02	5.84	0.00	0.00	0.0%
NW-01	4.21	1.22	1.86	73.3%

Existing north campus sub-basins were delineated based on drainage path information evaluated from a combination of aerial photography, AutoCAD maps, and GIS topography data of the area.

Conveyance System Description

The existing north campus stormwater system consists of a system of pipes, ditches, culverts, catch basins, trench drains, and manholes that collect and convey stormwater from campus to the City stormwater system.

Stormwater treatment consists of sediment capture by catch basins and various bioretention systems installed since 2004 (e.g., behind Miller Hall). These are shown on the map in Figure 4-1.

Detention (or flow control) is limited to incidental detention and some relatively small volume detention vaults/pipes installed since 2004. These are shown on the map in Figure 4-1. These include:

- Large Vault between Ridgeway Beta and the north end of the track
- Large diameter detention pipes at the north and south sides of Carver Gym
- Large diameter detention pipe at metered parking 7G and 3R

Figure 4-1 shows all of the north campus conveyance pipes, catch basins, manholes; the 12 delineated sub-basins; and the north campus treatment and detention facilities. Also shown are campus buildings, roads, and topography.

The north campus drainage system flows generally north beginning at West College Way where surface water runoff is collected from a small portion on the east side of West College Way and is routed to the underground piping system along the new service road on the west side of the Student Recreation Center and the All Weather Track. This 12-inch storm sewer discharges its water into upper and lower bioretention cells and a detention vault (constructed in 2004) at the northwest corner of the track. The stormwater flows from the detention vault into a junction manhole at the downstream (north) end of sub-basin N-09. This manhole also receives runoff piped from the southeastern portion of the Ridgeway Complex and the All Weather Track area. Downstream from here, the main storm sewer increases to 18-inch pipe, then 21-inch pipe, then 24-inch pipe as additional collection pipes feed in the from the west and east from sub-basins N-05, N-06, N-07 & N-08. These flows converge at the manhole junction between Carver Gym and Miller Hall. This manhole junction also receives the surface water runoff from a portion of the western slope of Arboretum Hill to the east. Downstream from here the remainder of the main on-campus storm sewer is 30-inch pipe until the pipe begins descending steeply downhill at High Street adjacent to the

Bookstore. Here, the conveyance pipe size changes to 24-inch and then alternates between 18-inch corrugated metal pipe on steep segments and 21-inch concrete pipe on flatter segments of the off-campus downstream system on Cedar Street. The stormwater discharges into Bellingham Bay approximately 1,500 feet northwest of the campus. This downstream system receives relatively little flow from other sources.

The on campus portion of this storm sewer main was video inspected for this plan. The video showed that the older parts of the system are still functional, but do need some spot repairs to prevent root intrusion and gravel intrusion as well as preventive repairs to prevent pipe failure in certain locations. The specific repairs are listed under improvements.

4.2.2.2 South Campus

Basin Characteristics

Existing south campus sub-basins contributing runoff to the collection and conveyance system were delineated based on drainage path information evaluated from a combination of aerial photography, AutoCAD maps, and GIS topography data of the area. Figure 4-2 shows the south campus stormwater system conveyance pipes, catch basins, manholes, and nine (9) delineated sub-basins. Also shown are campus buildings, roads, and topography. The south campus system has six (6) sub-basins (S-01 through S-06) that flow to the large detention and treatment facilities and three (3) sub-basins (SE-01, SE-02, and SE-03) that flow directly across Bill McDonald Parkway to Taylor Creek. The following is a summary of the existing sub-basin information for the south campus:

Basin ID	Total Area (acres)	Impervious Building (acres)	Impervious Parking (acres)	Impervious Road (acres)	Impervious Pedestrian Paving (acres)	Percent Impervious (%)
S-01	24.25	3.16	0.32	3.20	0.70	30.4%
S-02	22.38	1.46	4.86	2.50	0.50	41.7%
S-03	8.56	0.33	1.57	0.97	1.53	51.5%
S-04	18.94	0.03	10.27	1.17	0.53	63.4%
S-05	20.86	4.08	2.26	1.15	7.62	72.4%
S-06	15.80	0.00	0.00	0.00	0.00	0.0%
SE-01	15.40	1.39	1.31	0.00	1.38	26.5%
SE-02	8.38	0.44	1.45	0.00	0.41	27.5%
SE-03	4.12	0.71	0.96	0.00	0.09	42.8%

Conveyance System Description

The existing University south campus stormwater system consists of a system of pipes, ditches, culverts, catch basins, trench drains, and manholes that collect and convey stormwater from campus to the City stormwater system. The majority of the main stormwater conveyance pipes are either 12-inch or 18-inch pipe. Much of the piping is relatively new PVC or HDPE pipe (compared with older concrete or metal piping in the north campus). Stormwater treatment consists of sediment removal using catch basins, a large constructed multi-celled wetland system that serves most of the south campus area, and numerous bioretention facilities. Detention (or flow control) is provided by a large underground vault (located beneath the tennis courts constructed in 2006) that serves most of the south campus area. Buildings and infrastructure installed since 2008 have included onsite stormwater treatment facilities. The stormwater detention vault constructed with the Buchanan Towers (East) addition in 2011, provides detention and treatment to meet all current stormwater requirements (note Buchanan Towers stormwater discharges directly to Taylor creek and not to the South Campus detention and treatment facilities).

The western branch of the main conveyance system starts at a ditch system along the west side of West College Way collects surface runoff from the hill to the west and discharges into underground piping system along Bill McDonald Parkway. The stormwater is then conveyed along Bill McDonald Parkway to 21st Street and then east to the stormwater detention vault. The system's eastern branch starts with a series of ditches on the east side of East College Way and the parking lot east of South College Drive that collect surface water runoff from the Arboretum Hill to the east where it is then discharged into the underground piping system. The conveyance pipes continue south along South College Drive and are discharged into the stormwater detention vaults beneath the tennis courts north of Bill McDonald Parkway. The stormwater flows from the vault at a controlled rate into a 30-inch culvert under Bill McDonald Parkway to the south. This culvert discharges into the south campus water quality treatment facility. From the treatment facility the stormwater discharges into Taylor Creek which is a tributary of Padden Creek.

4.2.3. Flow Control (Detention)

North Campus

Flow control structures in the north campus stormwater system (Figure 4-1) are: (1) the facility near the northwest corner of the All Weather Track, which is a combination of upper and lower bioretention cells and a reinforced concrete stormwater detention vault constructed in 2004, (2) the Carver Gym detention tanks (installed in 2016/2017), and (3) the Parking Lot 7G detention tank (installed in 2016).

(1) Runoff from 0.75 acres along the new service road between West College Way and the all-weather track is treated and detained. The detention vault is approximately 48 feet long, 25 feet wide, and 5.3 feet deep. The detention facility was designed to control flows from 0.75 acres (approximately 6% of the area of sub-basin N-09). The following is a summary of the flow control parameters used in the design of the vault (from WWU Campus Infrastructure Design [CID] Phase 2 study PW395 record drawings [2004]):

West College Vault Characteristics

Contributing Area:	0.75 ac	Detained	Vault
		Release	Water
Design Storm	Inflow Rate	Rate	Elevation
	cfs	cfs	feet
6-month	0.19	NA	NA
2-Year	0.30	NA	NA
10-Year	0.47	0.08	314.21
25-Year	0.54	0.11	314.59
100-Year	0.67	0.17	315.32
		Vault Inside Bottom Elevation	307.38
		Vault Inside Top Elevation	316.30

(2) The detention pipes installed in 2016 for the Carver renovation are relatively small, but are sufficient to mitigate the increased impervious area of the Carver expansion.

(3) The detention pipe installed in 2016 in Parking Lot 7G is sufficient to fully mitigate the impervious area of Parking Lot 7G.

South Campus

Sub-basins S-01 through S-06: A large reinforced concrete detention vault is located underneath the tennis courts on the north side of Bill McDonald Parkway (Figure 4-2). This vault provides flow control for discharge from the main collection and conveyance system of the south campus area including all of sub-basins S-01 through S-06. A flow control structure at the south end of the vault regulates discharge to meet the design flows. The vault is 75 feet wide and contains eight compartments each 24 feet wide and 12.5 feet deep. The flow control structure of vault was modified in 2017 by decreasing the diameter of the third orifice from 21 inches to 18 inches.

The design discharge rates for the vaults were calculated by Cascade Group Engineering as part of the South Campus Parking Lot Upgrade Projects (2017). This model is for the current developed condition as of 2017, including Parking Lot Phase II paving improvements. The detained release rate is less than the predeveloped release rate. The vault has capacity to accommodate increased flow rates and volumes into the future and still maintain the required release rates.

Below are three tables showing the hydrological characteristics of the S01-S06 basin, the detention vault characteristics, and detention performance:

Hydrologic Model Data Input:

Basin ID	Pervious Area (acres)			Impervious Area (acres)		Total Area (acres)
	Forest A B Soils Steep Slope	Forest C Soils Steep Slope	Lawn A B Soils Moderate Slope	Roads Moderate Slope	Parking Moderate Slope	
Pre-Developed	33.4	14.35	40.38	16.45	9.11	113.7
Post-Developed	24.4	14.35	38.05	38.38	0	115.2

Detention Vault Characteristics:

Characteristic	Diameter (inches)	Elevation (feet)	Height (feet)	Volume (ac-ft)
Vault Dimensions:				
Live Storage Height			12.5	
Vault Inside Height			13.5	
Bottom of Live Storage		212.0		
Top of Live Storage		224.5		
Live Detention Volume				4.12
Control Structure:				
First Orifice	0.50	212.0	0.0	
Second Orifice	7.75	215.0	3.0	
Third Orifice*	18.00*	220.6	8.6	
Riser	36.00	224.2	12.2	

* Revised in Year 2017

Detention System Performance:

Storm Frequency	Pre-Dev Flow Rate	Post-Dev Undetained Flow Rate	Detained Release Rate	Water Elevation (Depth)	Detention Volume
	cfs	cfs	cfs	feet	ac-ft
2-Year Storm	11.93	17.37	6.57	220.7 (8.7)	2.8
10-Year Storm	19.26	27.80	13.87	221.8 (9.8)	3.2
25-Year Storm	23.06	33.18	18.37	223.0 (11.0)	3.6
100-Year Storm	28.88	41.39	26.10	224.7 (12.7)	4.2

Sub-basin SE-02: A detention vault was recently installed with the Buchanan Towers East project. This detention vault provides flow control for discharge directly to Taylor Creek to mitigate new and replaced impervious surfaces.

4.2.4. Water Quality

North Campus

Stormwater treatment consists of sediment removal in catch basins and bioretention systems. The mechanisms for treatment are retention, settling, filtration, and biological uptake of pollutants through a series of layers including vegetation, planting soil, pea gravel, and washed rock all separated by non-woven geotextile fabric. See Figure 4-1 for the locations of all of these water quality treatment facilities.

The bioretention cells are designed to treat approximately 91% of the annual runoff from a particular drainage per Ecology Minimum Requirement #6.

South Campus

S-01 through S-05: The South Campus Water Quality Facility on the south side of Bill McDonald Parkway receives flow from the majority of the south campus system via a 30-inch culvert from the detention vault. Treatment is provided by a series of treatment facilities including a stilling well/flow splitter, bioinfiltration swales, and rock/plant filters. The system has been sized to treat the stormwater at the controlled flow release rates from the vault upstream. A bypass system directs flows in excess of treatment capacity (i.e., during large runoff events) to bypass the treatment system. This facility was completely refurbished in 2016. For more details concerning the design of the facility refer to the *South Campus Water Quality System Stormwater Site Plan* (DEA, 2001).

S-04: The south campus parking lots have recently been converted from gravel to asphalt. This has vastly reduced the quantity of sediment washing into the stormwater conveyance system and reduced the amount of turbidity discharged to Taylor Creek. The south campus parking lots have 14 bioretention facilities to treat runoff from the asphalt surfaces. This treated runoff is routed through the downstream south campus detention vault. The *FA Entry Road Improvements Project (PW662)* improved drainage so that there is no longer a continuous waterlogged area at the entrance (replacement of a 100 LF section of water main probably helped also). List below is a summary of the water quality facilities installed in 2016-2017 in support of the south campus parking lot paving projects.

South Campus Parking Lot Water Quality Facilities Installed in 2016 and 2017

Sub-Basin Name	Contributing Area (acres)	Name and Type of Facility	Minimum Size of Facility
Lots 1, 2 & 3			
Cell 2 North	1.04	Lot 2N Bioretention Cell	805 sf
Cell 2 South B	0.58	Lot 2SB Bioretention Cell	446 sf
Cell 2 South A	2.23	Lot 2SA Bioretention Cell	1,721 sf
Cell 3 South	1.66	Lot 3S Bioretention Cell	1,280 sf
Cell 3 North	0.188	Filterra (“tree box”)	4' x 6' vault
Lot C/CR			
Sub-Basin 1	0.84	Lot C/CR Bioretention Cell	675 sf
Sub-Basin 2	0.310	Filterra (“tree box”)	6' x 6' vault
Sub-Basin 3	0.409	Filterra (“tree box”)	6' x 8' vault
Sub-Basin 4	0.360	Filterra (“tree box”)	6' x 8' vault
Lot 26CP			
Sub-Basins 2a, 2b, &	0.67	Lot 18R B Bioretention Cell	515 sf
Sub-Basin 4	0.79	Lot 26CP A Bioretention Cell	610 sf
Sub-Basin 5	0.77	Lot 26CP B Bioretention Cell	591 sf
Lot 18R			
Sub-Basin 1	2.09	Lot 18R A Bioretention Cell	98 sf

SE-01: The Fairhaven Towers had many localized drainage problems, which were largely fixed with the improvements provided by *PW694 FX Stormwater Drainage Improvements* in 2016. No specific water quality treatment facilities were installed for this project.

SE-02: Buchanan Towers East (2011) has bioretention facilities to treat all runoff before it discharges to the storm conveyance system and then to Taylor Creek.

4.3. Existing Conditions Evaluation

4.3.1. North Campus

4.3.1.1 North Campus Stormwater Model

A computer model of the existing University north campus system was developed using the Environmental Protection Agency's Stormwater Management Model Version 5.0 (SWMM) to quantify stormwater runoff peak discharges and evaluate the hydraulic capacity the conveyance system. SWMM is designed for analyzing stormwater runoff and routing in urban watersheds. The City of Bellingham Stormwater Management Handbook (COB Handbook) requires the use of the 25-year design storm in assessing the conveyance capacity of a system. The Santa Barbara Urban Hydrograph (SBUH) method with a Type 1A rainfall distribution was used to simulate the 25-year, 24-hour design storm of 3.1 inches.

Curve Numbers

Runoff rates are calculated from Curve Numbers that reflect the soil type and land use. Associated runoff Curve Numbers were assigned to each sub-basin based on *Table III 2.3 – Runoff Curve Numbers for Selected Agricultural, Suburban, and Urban Areas* in the 2001 Ecology Manual (not included in the current Manual). The following is a summary of the soil types and runoff Curve Numbers assigned in the stormwater runoff evaluation for the north campus system:

SCS Soil Class. #	Soil Name	Hydrologic Group	Basin Number	Pervious Description	Pervious Curve Number	Impervious Curve Number
29	Chuckanut-Urban Land	B	N-01 - N-07, N-09, NE-01, NW-01	Good Grass Cover	80	98
3	Andic Xerochrepts	C	N-08, NW-02	Good Forested Condition	70	98
110	Nati	C	N-08, NW-02	Good Forested Condition	70	98

Computer Model Description

Figure 4-3 presents a model schematic showing the sub-basins contributing to the northwest outlet at North Garden and Cedar Streets (N-01 – N-09), sub-basins contributing to the northeast outlet along North Garden Street (NE-01 and NE-02), the sub-basin contributing to the southwest outlet (NW-01), and major conveyance system pipes and manhole nodes simulated in the model. Table 4-1 shows detailed information used for the model inputs.

For NE-01 and NE-02, the 10-inch storm sewer on Garden Street downstream of Oak Street has a capacity of 5 cfs to 6 cfs compared to the 25-year storm of about 7 cfs.

4.3.1.2 North Campus Runoff

The estimated runoff for the 25-year, 24-hour storm from each modeled sub-basin in the north campus is as follows:

Sub-Basin ID	Total Precipitation	Total Infiltration	Total Runoff	Peak Runoff
	(inches)	(inches)	(inches)	(cfs)
N-01	3.10	0.81	2.24	3.90
N-02	3.10	0.46	2.59	3.86
N-03	3.10	0.48	2.57	0.49
N-04	3.10	0.33	2.71	2.52
N-05	3.10	0.78	2.27	6.12
N-06	3.10	0.85	2.20	4.07
N-07	3.10	0.40	2.65	1.44
N-08	3.10	2.22	0.83	1.51
N-09	3.10	1.39	1.66	3.41
			System Total:	27.32
NE-01	3.10	0.72	2.34	6.73
NE-02	3.10	2.20	0.86	0.41
			System Total:	7.14
NW-01	3.10	0.41	2.65	2.63

4.3.1.3 North Campus System Capacity

Main North Campus Storm Sewer

Table 4-2 shows the predicted flow depth and velocity, and the depth below the manhole rim at each manhole junction (catch basin) for the 25-year design storm flow and for each pipe segment and upstream node for the main conveyance storm sewer through north campus. The conveyance appears to be adequate for the 25-year storm. However, there is always a level of uncertainty in the model without calibration data. Also, the conveyance system would be likely to overflow during an unusually intense storm event. A previous investigation by Reid-Middleton (2003) predicted that the downstream off-campus system would overflow during the 25-year storm. However, that evaluation used the Rational Method for predicting runoff. That is a more conservative method likely to overestimate runoff. On the other hand, the method used in this study may underestimate peak runoff if the assumptions about peak storm intensity over short durations (say 10 minutes) are incorrect.

Based on the results of the modeling, the nodes where overflows would be most likely to occur during very large or very intense storms include (see Figure 4-3):

- Off Campus Node 762 — Manhole at Cornwall Beach Park (storm sewer slope flattens and increases from 24-inch to 30-inch)
- Off Campus Node 455 — Manhole downhill side of Forest and Cedar Streets (transition from 21-inch concrete to 18-inch CMP)
- Off Campus Node 457 — Manhole downhill side of Garden and Cedar Streets (transition from 21-inch concrete to 18-inch CMP)
- On Campus Node 461 — Manhole adjacent to the Bookstore, near where flows from sub-basin N-02 and N-01 merge with the main 24-inch storm sewer
- On Campus Node 432 — Catch basin between AA, CV, and MH
- On Campus Node 253 — Service road manhole between soccer field and SL
- On Campus Node 250 — Manhole in west edge, middle of soccer field

The main storm sewer line though campus and its downstream off campus storm sewer line are essentially near capacity during the 25-year storm. The model manhole junctions 461, 457, and 455 (see Figure 4-3) are the most likely to overflow during larger storms. The 21-inch concrete pipes and 18-inch corrugated metal pipes are just big enough to handle the predicted flow. The 18-inch corrugated metal pipes have very rough interior surfaces, which significantly impedes flow where the pipe slope is less than about 15%-20%.

The main storm sewer on campus near the soccer field (Node 250) and SMATE (Node 253) is marginal in terms of capacity due to flat slopes and relatively shallow manhole junction depths. The performance of the detention vault near the track is crucial in preventing water depths from exceeding the manhole rim elevations. Without the peak flow attenuation maintained by the detention facility, it is estimated that overflows would occur in this area. Any future development in the Ridgeway Complex vicinity should provide detention to prevent overflows in this vicinity.

The north campus SWMM model input and output report summary is available on compact disc provided under separate cover.

Garden Street Storm Sewer Sub-basins

For NE-01 and NE-02, the City-owned 10-inch storm sewer on Garden Street downstream of Oak Street has a capacity of approximately 5 cfs to 6 cfs compared to the estimated 25-year storm runoff of about 7 cfs. For NW-01, the City-owned 8-inch storm sewer on Garden Street downstream of Cedar Street has a capacity of approximately 2 cfs to 4 cfs compared to the estimated 25-year storm runoff of about 2.6 cfs.

4.3.1.4 North Campus System Physical Conditions

Main North Campus Storm Sewer

The main storm sewer is in functional condition. There are a few specific location where pipe joints need to be repaired or where sections of pipe need to be replaced.

4.3.2. South Campus

4.3.2.1 Description

The south campus stormwater basins and conveyance systems are shown in Figure 4-2 and described in Section 4.2. The flow control (detention) facilities and water quality treatment facilities are shown in Figure 4-2 and described in Section 4.2

4.3.2.2 South Campus System Capacity

S-01 through S-05: The detention and treatment facilities were originally designed for future build-out conditions. The stormwater system upgrade was completed in 2004 to provide the future condition detained discharge rates shown above for the total runoff flows predicted for build-out conditions. **Flow control** capacity is currently sufficient for basin S-01 through S-05 in the large detention vault (and additional capacity for future flow control is available in this vault as shown in Section 4.2.3 subsection Detention Performance). The **Water quality treatment** facilities have no capacity for additional flow. All future projects will require site specific stormwater treatment.

SE-01 through SE-03: The Flow control and water quality treatment facilities have no capacity for additional flow. All future projects will require site specific stormwater detention and treatment.

4.4. Future Conditions Evaluation

4.4.1. North Campus Future Conditions Evaluation

Figure 1-1 shows the University gross footage expansion by Land Use Districts relative to the 10-year Capital Plan and IMP Median Build-Out. Most of the area contributing to stormwater runoff to the north campus system is substantially developed; however there is some expected growth in the area that may increase stormwater runoff. Significant North campus expansion plans for the 10-year Capital Plan are limited to the CFPA Renovation & Addition in District 6. District 9 and District 10 is where most of the IMP median build-out expansion in the north campus stormwater system is expected (Districts 4 and 11 will also see some expansion).

The runoff and flows for future conditions were not calculated because the north campus stormwater system is essentially already at capacity and any increase in runoff will require flow control of some sort. Future increases in undetained runoff would further surcharge the main storm sewer causing some manholes and some stormwater laterals to back up and overflow. Any new development or redevelopment projects will need to provide stormwater detention and/or implement *Low Impact Development* (LID) practices as appropriate, to prevent increases in the 25-year, 24-hour storm peak flow rates (for more on LID practices refer to <u>Low Impact Development Technical Guidance Manual for Puget Sound,</u> Puget Sound Action Team, January, 2005). Alternatively, the downstream conveyance systems (WWU's or City's) could be upgraded to provide adequate conveyance of increased flows. Because the north campus stormwater discharges to Bellingham Bay, no flow control is required (unlike south campus) except as needed due to conveyance system capacity limitations.

The City-owned Garden Street storm sewers, both the 10-inch storm sewer flowing north from NE-01 and the 8-inch storm sewer flowing south from NW-01, are also at capacity and may overflow during the 25-year storm. More detailed analysis is needed to more precisely determine the downstream conveyance capacity.

IMP District 4

Expansions may include enlarging the Viking Union and possibly a new parking facility. This would likely increase impervious area and runoff in **sub-basin NE-01** but would have no effect on sub-basin N-01 runoff. **Future Study:** A detailed downstream hydraulic analysis of the Garden Street storm sewer will be required for development in IMP District 4.

IMP District 6

The CFPA Renovation & Addition is the major project to be implemented in District 6. This project is unlikely to change runoff quantity from **sub-basin NW-01** very much. Basic stormwater treatment systems will be installed as required for this project for parking, driveways, and landscaped areas. Some detention or low impact development methods should be considered to alleviate or at least not increase peak flows downstream of sub-basin NW-01.

IMP District 9

Anticipated build-out may include academic expansion and possibly parking structure(s). The exact footprint of the expansion is unknown, but the expansion may increase stormwater runoff in **sub-basin N-02**, which will likely be collected and routed directly into the 30-inch main storm sewer pipe. Detention may be needed either at the project site or on the main storm sewer system in the vicinity of VU, BK and PA.

IMP District 10

Possible expansion may include housing to the north and/or south of the existing Ridgeway dormitories. This would increase impervious area and runoff in **sub-basins N-05 and/or N-09**. Additional detention volume will be needed to keep the 25-year flow rate from increasing. Detention will be needed either at the runoff source or at least prior to discharge to the 30-inch main storm sewer. Stormwater from north Ridgeway area expansion could be conveyed via the existing City-owned 8-inch and 10-inch storm sewer on Highland Drive, which flows into the 30-inch arterial pipe near College and Haggard Halls. However, this storm sewer is at capacity and would have to be upgraded unless detention is provided at the runoff source.

IMP District 11

Planned expansion projects are for an increase in gross square footage by adding a floor(s) to an existing building A floor addition would have no effect on the existing footprint area and no effect on stormwater in **sub-basin N-06**.

4.4.2. South Campus Future Conditions Evaluation

4.4.2.1 Sub-basins S-01 through S-05

The main south campus stormwater detention and treatment system was designed and constructed to accommodate build-out conditions in sub-basins S-01 through S-05. **Flow control** capacity is currently sufficient for basin S-01 through S-05 in the large detention vault (and additional capacity for future flow control is available in this vault as shown in Section 4.2.3 subsection Detention Performance). **Water quality treatment** facilities have no capacity for additional flow. All future projects will require site specific stormwater treatment.

Future improvements assumed in the CID study that have not yet been constructed (as of June 2017) include:

- Widening of Bill McDonald Parkway to a divided four-lane road.
- Realignment of 21st Street to West College Way eliminating the existing three-way intersection just south of the Student Recreation Center.
- Replacement of South College Drive with a new service road between Bill McDonald Parkway and West College Way.
- Three more academic buildings in addition to the two-wing Academic Instruction Center building.

4.4.2.2 Sub-basins SE-01, SE-02, and SE-03

The only future growth expected in the southeastern sub-basin area (SE-01, SE-02, and SE-03; Figure 4-2) is for the 10-year Capital Plan expansion in District 18. A new residence hall approximately of 100,000 GSF is planned for District 18. If the footprint is approximately the same size as Buchanan Towers (approximately 0.4 acres) and no additional parking is constructed, the expansion will increase sub-basin SE-02 percent impervious from 22% to 27%. Detention for just the additional 0.4 acres would require on the order of 15,000 cubic feet of detention volume. Approximately 1,000 square feet of area may be needed for above-ground water quality treatment (e.g., bioretention).

4.4.2.3 Impacts of South Campus IMP District Growth

IMP District 11

Planned expansion includes an increase in gross square footage. However, this is planned as a floor addition and will have minimal effect on the existing footprint area or on stormwater in **sub-basin S-05**.

IMP District 13 (and 16)

IMP District 13 area is a large fraction of **sub-basins S-02 through S-05**. Non-substantive expansions or changes are planned for District 13. Improvements, if any, will require re-evaluation of the flow control (detention) requirements and very likely additional detention and treatment facilities as explained in Section 4.4.2.1.

IMP District 14

This district includes most of **sub-basin S-05.** Planned expansion includes a substantial increase in impervious area and redeveloped area with the addition of new academic buildings (390,000 GSF) and associated access and landscaping improvements. These improvements will require re-evaluation of the flow control (detention) requirements and very likely additional detention and treatment facilities as explained in Section 4.4.2.1.

IMP District 16

IMP District 16 has substantial space for new buildings. However, plans for expansion in District 16 are as yet limited. Improvements will require re-evaluation of the flow control (detention) requirements and very likely additional detention and treatment facilities as explained in Section 4.4.2.1.

IMP Districts 15 and 18

Some development is planned in **sub-basin SE-01** (IMP 15 - Fairhaven Complex) and **sub-basin SE-02** (IMP 18 – New Student Housing). A full stormwater design report and full flow control and water quality treatment will be required for these developments. However, development in District 15 may consist of improvements with no impact to the stormwater system. Detention facilities or (LID practices) would be modeled and sized per the 2014 Ecology Manual (or current) and the COB Stormwater Handbook. Water quality treatment facilities would be “enhanced treatment” per the 2014 Ecology Manual and would be sized based on the runoff from new paved area and new landscaped area. Above ground water quality treatment facilities would require approximately 500 square feet per 10,000 square feet of impervious area (not including roofs). The capacity of the immediate downstream conveyance system (including part of the Connelly Creek headwaters) would have to be evaluated.

IMP Districts 22/ 23

The vacant lot to the west of 26th Street is planned to be fully developed (Support Services Facility) during the 10-year capital planning period. A full stormwater design report and full flow control and water quality treatment will be required for this development. Detention facilities would be modeled and sized per the 2014 Ecology Manual (or current) and the COB Stormwater Handbook. Water quality treatment facilities would be "enhanced treatment" per the 2014 Ecology Manual and would be sized based on the runoff from new paved area and new landscaped area.

4.5. Recommended Improvements

4.5.1. Recommended or Needed Improvements

Campus Wide

1. Catch Basins and Settlement

Replace catch basins that are too high to accept runoff (due to adjacent settling). This may require replacement (lowering) of pipe laterals to the main storm sewer. In all areas where settlement occurs, catch basins should be installed such that the invert elevations are deeper than initially necessary. Inverts should be at least 1 foot and preferable 2 feet deeper than the minimum. The grate should be installed at least 2 inches below grade. The catch basins should be installed with extra risers between the catch basin and the frame and grate/solid cover. One 2-inch riser and at least three and preferably up to five 4-inch risers should be installed. A riser can be removed and the frame re-grouted in place as each 2-inch or 4-inch increment of settlement occurs.

2. Pipes and Settlement

Pipes should be installed to avoid settlement if possible (e.g., with pilings or other support as necessary in incompetent soils). Where pipe settlement cannot be avoided, major reconstruction of catch basin and pipe may be necessary if significant pipe settlement occurs.

North Campus

3. Flow Control

Install additional underground detention storage volume or upgrade the downstream City storm sewer system.

a. Storm Sewer Main – Detention

Install a detention system in the vicinity of Viking Union to relieve pressure on the aging downstream system. A 15,000 cubic foot underground detention system could be installed (underground) in Parking Lot 6V west of the Viking Union or possibly in conjunction with the CFPA project. High flows from the main storm sewer would be diverted to this vault from Node 461 (Figure 4-3) for flow control. The controlled discharge flow would be flow back to the main storm sewer at Node 459 or 457. However, this may not need to be implemented if detention or conveyance needs are met elsewhere.

3b. Storm Sewer Main – Upgrade Downstream Pipe

The downstream storm sewer system, consisting of alternating 18-inch CMP and 21-inch concrete pipes is aging and barely adequate and should be replaced with higher capacity pipes. The upgrade should include, at a minimum, replacing all the 18-inch CMP pipe segments with smooth-walled 21-inch pipe. Replacing the 21-inch pipe segments with a larger size and/or with a steeper slope would also be beneficial. A more detailed engineering analysis is needed. However, this is not necessarily a cost-effective solution (i.e., compared to detention vaults) for the University to undertake on its own. The 180 LF of 30-inch storm sewer on the Cornwall Beach Park property and BNSF Railroad property may also need to be upgraded (or need detention). Further investigations and discussions with the City will be needed to resolve this issue, particularly because hazardous soils would likely be encountered if replacing this segment of pipe.

4. Detention

Additional detention facilities will likely be needed for expansions in Districts 9 and 10 and probably Districts 4, 5 and 6, unless downstream conveyance is improved or re-evaluated and found to be sufficient without detention.

5. Water Quality Facilities

Additional water quality facilities will be required for all new developments or redevelopments (Districts 4, 5, 9, and 10). Above-ground water quality facilities typically require about 500 square feet per 10,000 square feet of impervious area (roof runoff and some hardscape areas need not be included in the treatment requirement; however, this “untreated runoff” must bypass the treatment facility). Water quality facilities should be located near the source of runoff, where possible, and integrated in with the landscaping. Treatment at the source is more effective because treatment occurs prior to dilution by cleaner runoff from roofs and pedestrian areas.

South Campus

6. Detention

Detention facilities will be needed for IMP Districts 22/23 (Support Services projects). District 15 and 18 will also need detention if construction projects increase runoff rates.

7. Water Quality Facilities

Additional “enhanced treatment” water quality facilities will be required for all new developments or redevelopments in all south campus IMP Districts.

Localized Stormwater Problems

8. Storm Manhole Rim/Lid Replacement

A number of storm manholes have “SEWER” lids and some sanitary sewers have “STORM” or “DRAIN” lids. Investigate and map out mislabeled lids. Replace the frame and lid must be replaced at the same time. Lids generally cannot be just switched between manholes. Approximate cost per replacement is about $500-$1,000 each.

9. Physical Plant Fueling Area Oil/Water Separator

The fueling area does not have an in-place spill control system. A three compartment system (underground) should be installed adjacent to the fuel tanks. Both structures would hold a permanent pool of water in the vault. The first compartment would capture most of the fuel in the event of a spill (fuel would float on top of the water, displacing the water to a coalescing plate separator compartment). The oil water separator would retain most of the remaining fuel. The third and final compartment would be equipped with fuel absorbent material to further remove fuel from the stormwater on a routine basis and in the event of a substantial spill. Spilled fuel captured in the vault would need to be pumped out and disposed offsite by a certified service provider.

Conceptual Design: The area draining to the vault is about 0.12 acres. The water quality design flow is 0.03 cfs (13 gallons per minute). A suitable system for containing spills would include: (1) at the low point, a 48-inch diameter, 6-feet deep catch basin equipped with oil retaining tee outlet, followed by (2) a coalescing plate separator vault (5 feet x 2.5 feet x 4 feet deep), followed by (3) a small catch basin (2 feet x 2 feet) with oil absorbent material (e.g., Smart Sponge) suspended from the grate. Discharge would be south to the Douglas Avenue ditch.
Approximate Project Cost: $35,000-$50,000.

10. Fairhaven College FA Parking Area Drainage Improvements

This parking lot is graded such that all drainage flows into the loading dock vents and back door of the building in the event of drainage system failure. The stormwater conveyance piping needs to be enlarged and deepened to prevent water backing up. All catch basins appear to connect to the building perimeter drain pipe (size and depth unknown). The storm system up-gradient from the parking lot needs to be improved to prevent overflow into the parking lot (there are two truncated dome style drain grates that could easily be bypassed during large runoff events.

Conceptual Design: (1) The first step is to determine the best route for new piping. Survey the location, invert elevation, and diameter of all the main drainage pipes running to the southwest side of the building (which is the likely best route) and to the southeast side of the building. (2) Connect the existing catch basin (located in the middle of the parking lot) to the lowest elevation downstream pipe using at least 8-inch diameter pipe. (3) Install a new catch basin at the end of the trench drain in front of the back door. (4) The shallow swale/ditch on the north side of the parking lot needs to be deepened to prevent overflow. Either (a) excavate the swale to deeper elevation and dig a deeper outlet pipe trench through the parking lot and reinstall the existing outlet pipe at a deeper elevation or (b) install watertight concrete or asphalt berms/curbs around the swale in order to allow the water to better flow into the truncated dome grates. The tops of the truncated dome grates should be at least 4 inches below the maximum ponded water level. If not, then inclined, slotted grates, 2-foot to 4-foot long will work better than the truncated dome grate. Install/improve the check dam just downstream of the upper grate inlet so that flow won't so easily bypass it.

Approximate Project Cost: $30,000-$50,000.

11. Communications (CF) Parking Area Drainage Improvements

This parking lot and the entry ways into the building are graded such that all drainage flows into the building in the event of drainage system failure. The stormwater conveyance piping needs to be improved and the grate inlets need to be improved or expanded to decrease the chances of clogging by debris and subsequent overflow.

Conceptual Design: (1) Replace the frame and grate of existing catch basin with a through curb inlet and grate. This is the catch basin adjacent to the main entry at the driveway curb. (2) Replace the two catch basin grates in East College Drive with through curb inlets and grates (this will prevent runoff for the road flowing down the driveways (3) To insure better drainage flow out from the trench drains in front of the entry doors, insert a new catch basin into the trench drain in front of each of the entry doors. Connect these catch basins to the 18-inch storm main with 8-inch diameter pipe. Before installing this new catch basins ensure that the 18-inch storm main invert is at least 18 inches lower that the catch basin rim. (4) Install a new catch basin with a through curb inlet and grate at the west end of the existing trench drain that spans the width of the paved drive lane.
Approximate Project Cost: $20,000-$30,000.

12. Environmental Studies (ES) Parking Area Drainage Improvements

Stormwater backup and flooding into east doorways. Improve Drainage by installing catch basins, less clog prone grates; thru-curb inlets, redundant inlets. The surface of the main driveway is sloped to the middle of the driveway, but there is no catch basin to collect the runoff. This runoff could flow down the ramp to the Environmental Studies basement.

Conceptual Design: (1) Install a new catch basin with a vaned grate at the northeast corner of the driveway ramp down to Environmental Studies basement. Connect to the existing 18-inch storm main (installing Type 2 storm manhole in storm main is the preferred connection method but costs more). (2) Install a new catch basin with a vaned grate in the center of the paved drive lane, adjacent to the northeast corner of Environmental Studies. Connect to the to the new batch basin in (1) above.
Approximate Project Cost: $20,000-$30,000.

13. Fine Arts (FI) Parking Area Drainage Improvements

This parking lot and the entry ways into the building are graded such that drainage could flow into the building in the event of drainage system failure. The stormwater conveyance piping needs to be improved and the three existing grate inlets need to be improved or expanded to decrease the chances of blockage by debris and overflow.

Conceptual Design: (1) install 115 feet of 12-inch pipe (or 8-inch if necessary) to connect the existing catch basin (located adjacent to the stairs near the east end loading ramp) to the 24-inch storm main manhole near Miller Hall. Alternatively, connect to the 10-inch storm main, which is only 30-50 feet away, but which itself flows into the 24-inch main, (2) Install a new catch basin with a herringbone grate 8 feet to the northwest of the existing catch located near the low point of the parking lot (as indicated by mud stains). Connect this new catch basin with 8-inch pipe to other two existing catch basins in the middle of the parking lot, abandon the existing old 4-inch diameter piping. (3) Replace the grates of the three existing catch basins with herringbone style grates. (4) Install trench drain at the top of the loading ramp.
Approximate Project Cost: $30,000-$40,000.
LOW COST ALTERNATIVES (to eliminate annoying parking lot puddle): (a) Install one new catch basin at low spot, (b) lower the grate of the existing catch basin below the lowest grade of the parking lot (about 2 or 3 inches), (c) or repave the parking lot such that the two existing catch basin become the lowest points.
Approximate Project Cost: $1,500-$5,000.

14. Old Main (OM) East Side Drainage Improvements

At the mid-building back door, at the bottom of ramp, flooding through the door can occur due to improper drainage. The small drain grate in front of the door and connecting pipe are inadequate. Grate and pipe needs to be upgraded or additional drainage system installed to intercept runoff.

Conceptual Design: The first step is to determine the exact configuration of the drainage piping (does it drain to the building perimeter drain the north or south?). Check the elevations of the grate, connecting piping and the storm main. If the relative elevations seem acceptable, investigate the piping with a robotic camera to see if there are damaged components. Replace damaged components, and install a larger catch basin at the bottom of the ramp. A better drain pipe outlet may also be needed, which may require boring/tunneling under the wall and ramp. If the relative elevations are not

acceptable for good drainage flow, then consider a sump pump or installation of a trench drain located on the ramp at elevation high enough to drain back to the storm main with a connecting pipe.
Approximate Project Cost: $15,000-$25,000.

15. Edens Hall (EH) East Side Drainage Improvements

Large flows of runoff can come off the hillside especially at the east corner of Edens Hall. Drainage is fairly flat. Evaluate conveyance capacity of the piping. Add two additional catch basins with grate inlets for capturing runoff. Modify piping per conveyance evaluation.
Approximate Project Cost: $15,000-$25,000.

16a-g. Main North Campus Storm Sewer Improvements

These improvements consist of repairs at seven specific locations along the storm sewer main to address issues detected by video inspection, such as bad joints allowing root intrusion or damaged pipe sections. These repairs are shown and described on Figure 4-4.
Approximate Project Cost: $100,000-$180,000.

Monitoring

It would be beneficial for both planning and future design projects to implement a stormwater flow monitoring program on campus.

17. Inspection of Storm Sewer Pipe

Main storm sewer pipes should be regularly inspected as needed either visually or by video camera service contractor.

4.5.2. System Capacity with Improvements

North Campus

Improvement 3a:

Detention of stormwater runoff may also be used to minimize the peak discharges into the downstream conveyance system to maintain or improve its adequacy. The computer model (SWMM) simulation was used in order to estimate the detention volume needed to reduce the 25-year peak flow by 10 cfs. A detention vault of approximately 15,000 cubic feet would accomplish this reduction. The most beneficial location would be in the area of Performing Arts and Viking Union. An underground vault or series of pipes is likely the only feasible option for this area.

Improvement 3b:

Computer model (SWMM) simulations were run evaluating the capacity of the existing system assuming the conveyance system being improved downstream of Viking Union area of campus. All the existing CMP pipe segments between Georgia Pacific and High Street were modeled as smooth-walled (i.e. concrete, PVC, or HDPE pipe). Changing the pipe to smooth-walled decreases the Manning's n roughness coefficient from approximately 0.024 for CMP to approximately 0.013 for concrete or plastic pipes. Pipe smoothness was the only parameter changed in the model simulation (all pipe diameters, slopes, and manhole configurations were modeled as is). The model results indicate a flow capacity increase of approximately 10 cfs. The pipe size should be increased to add a safety factor. The 18-inch should be upsized to at least 21-inch inside diameter and the 21-inch pipe should be upsized to at least 24-inches inside diameter. When installing catch-basin outlet pipes, the pipes should always be grouted in place with a rounded corner (e.g., 1-inch radius) or a large bevel to maximize the storm sewer capacity (at very little extra cost).

4.5.3. Cost Estimates

Reasonable order of magnitude (ROM) total project cost estimates for stormwater upgrades including design and installation are:

IMPROVEMENT	ESTIMATED COST
Improvement 3a (15,000 cubic feet of detention)	$450,000
Improvement 3b (replace all downstream pipe)	$450,000 (Alternative)
(replace only the 18-inch corrugated pipe)	$300,000 (Alternative)

Improvements 4 through 7 – unit costs for these and other similar projects:

Detention and Water Quality Unit Costs:

Detention – Underground	$25/cubic foot
	$15/square foot of impervious area
Water Quality Treatment	$40/square foot (bioretention)
	$2.00/ square foot of impervious area

Storm Sewer Unit Costs:

Storm Sewer – 12-inch	$95/linear foot (including catch basins, surface restoration, etc.)
Storm Sewer – 18-inch	$130/linear foot (including catch basins, etc.)
Storm Sewer – 24-inch	$180/linear foot (including catch basins, etc.)
Storm Sewer – 30-inch	$230/linear foot (including catch basins, etc.)
Storm Sewer – 36-inch	$320/linear foot (including catch basins, etc.)

Improvements 9 through 15:

Improvement 9	$35,000	to	$50,000
Improvement 10	$30,000	to	$50,000
Improvement 11	$20,000	to	$30,000
Improvement 12	$20,000	to	$30,000
Improvement 13	$30,000	to	$40,000
Improvement 14	$15,000	to	$25,000
Improvement 15	$15,000	to	$25,000
Improvement 16	$100,000	to	$180,000
Total (9 – 16)	$265,000	to	$430,000

4.6. Conclusions

- The main on-campus stormwater systems currently have enough capacity. However, for the north campus, capacity is just adequate. Any increase in runoff generation in the north campus should be mitigated by providing a stormwater detention facility or equivalent mitigation or a detailed analysis demonstrating that mitigation is unnecessary. Detention should be designed to limit peak flows, not flow durations.

- The main City-owned off campus downstream conveyance system for the north campus on Cedar Street probably has enough capacity to handle the 25-year storm flow (as required). The system may see some overflow during the 100-year storm or more overflow if the condition of the infrastructure is poorer than estimated.

- Development in the south campus IMP Districts 15, 18, and 22/23 will require preparation of a full stormwater site report and installation of full flow control (e.g., detention) and “enhanced” water quality treatment facilities.

- Redevelopment in the south campus IMP Districts 11, 12, 13, 14, and 16 may require preparation of a full stormwater site report and installation of full flow control (e.g., detention) and “enhanced” water quality treatment facilities.

- Implement solutions to local area drainage problems to prevent flooding and damage to buildings due to large storms or broken water mains.

4.7. Appendices (Figures and Tables)

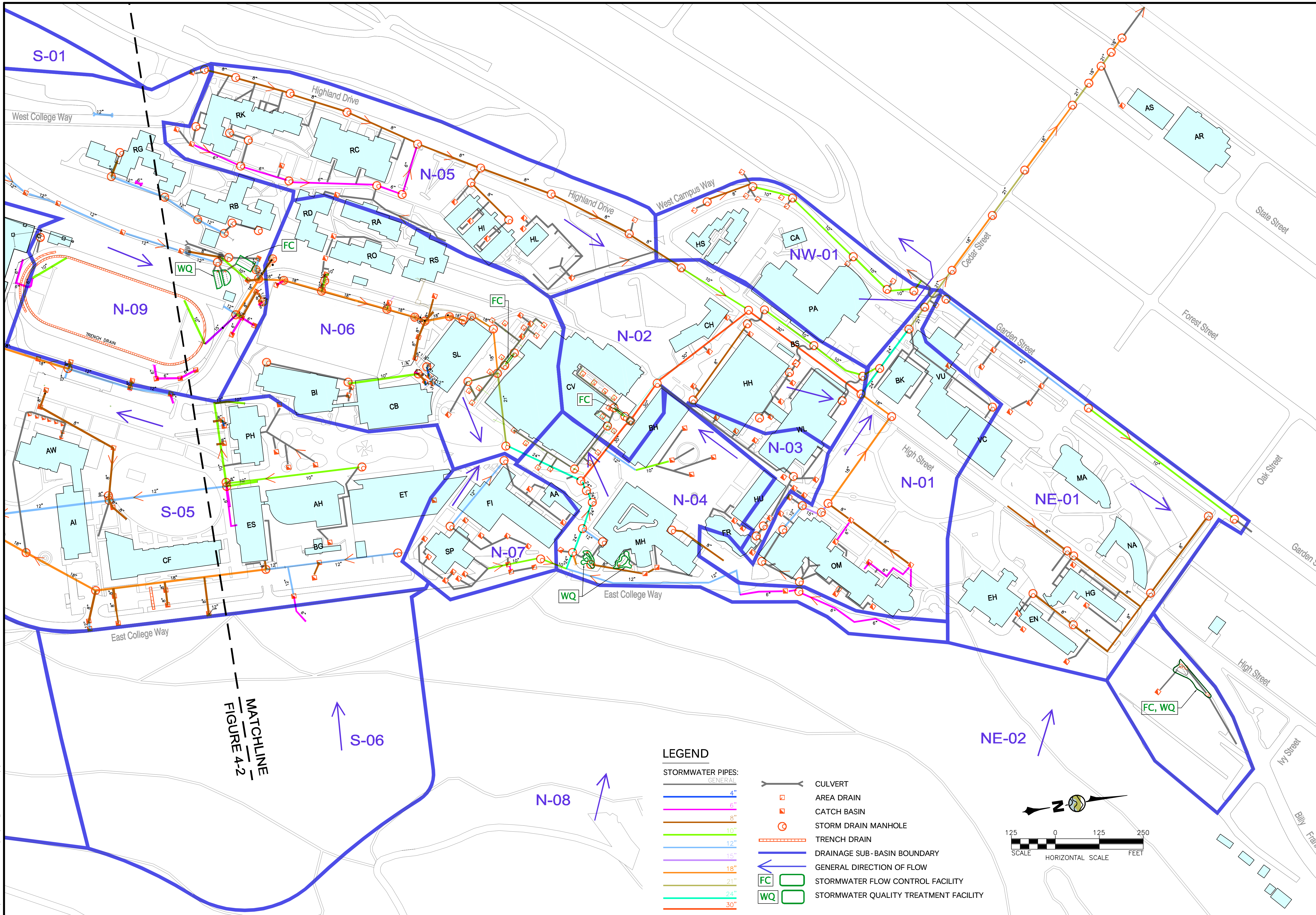

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FIGURE 4-1
NORTH CAMPUS STORMWATER

DATE JUNE 2017
SCALE AS SHOWN
JOB NUMBER 2016-039
SHEET 1 OF 1

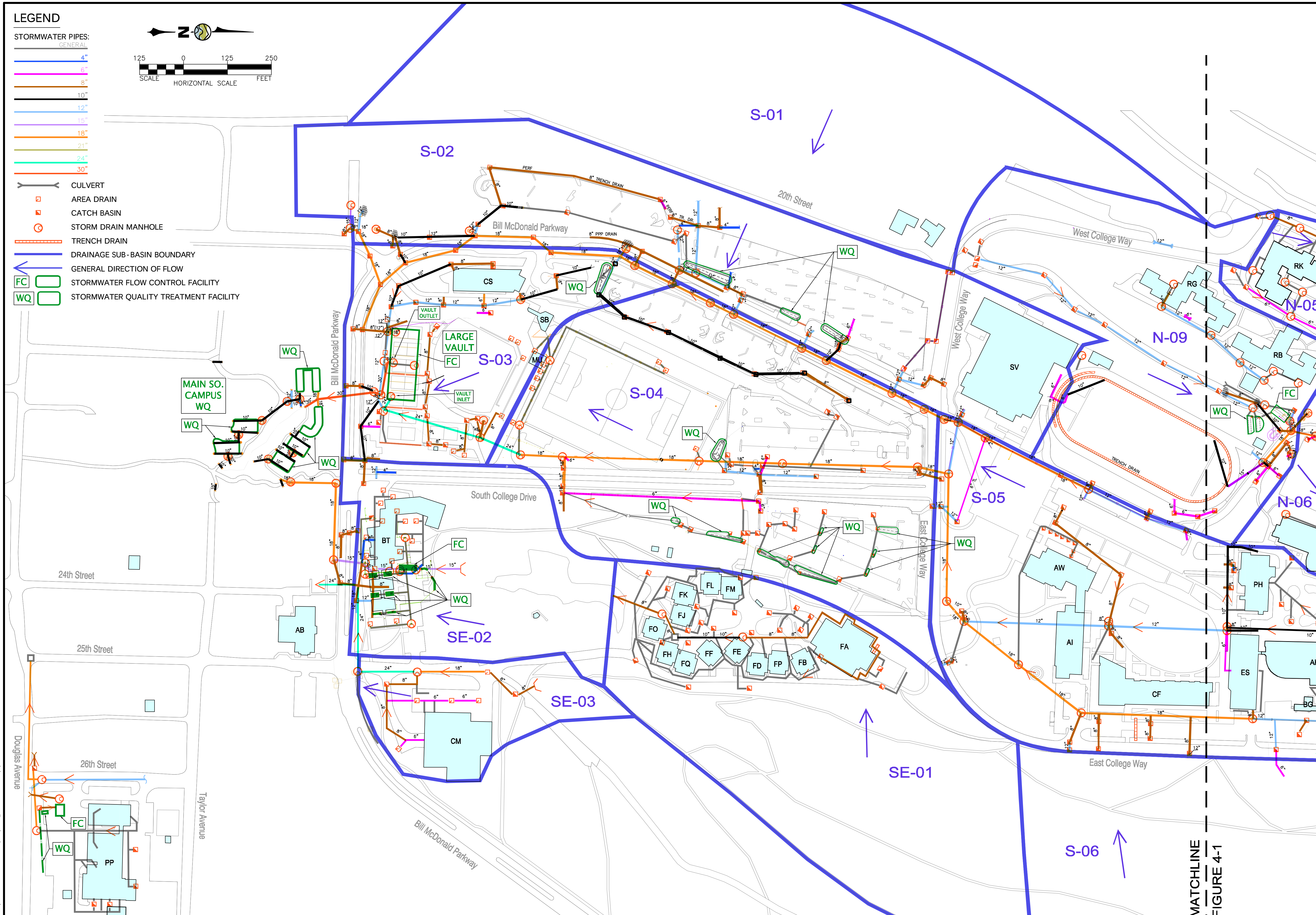

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FIGURE 4-2
SOUTH CAMPUS STORMWATER

DATE JUNE 2017
SCALE AS SHOWN
JOB NUMBER 2016-039
SHEET 1 OF 1

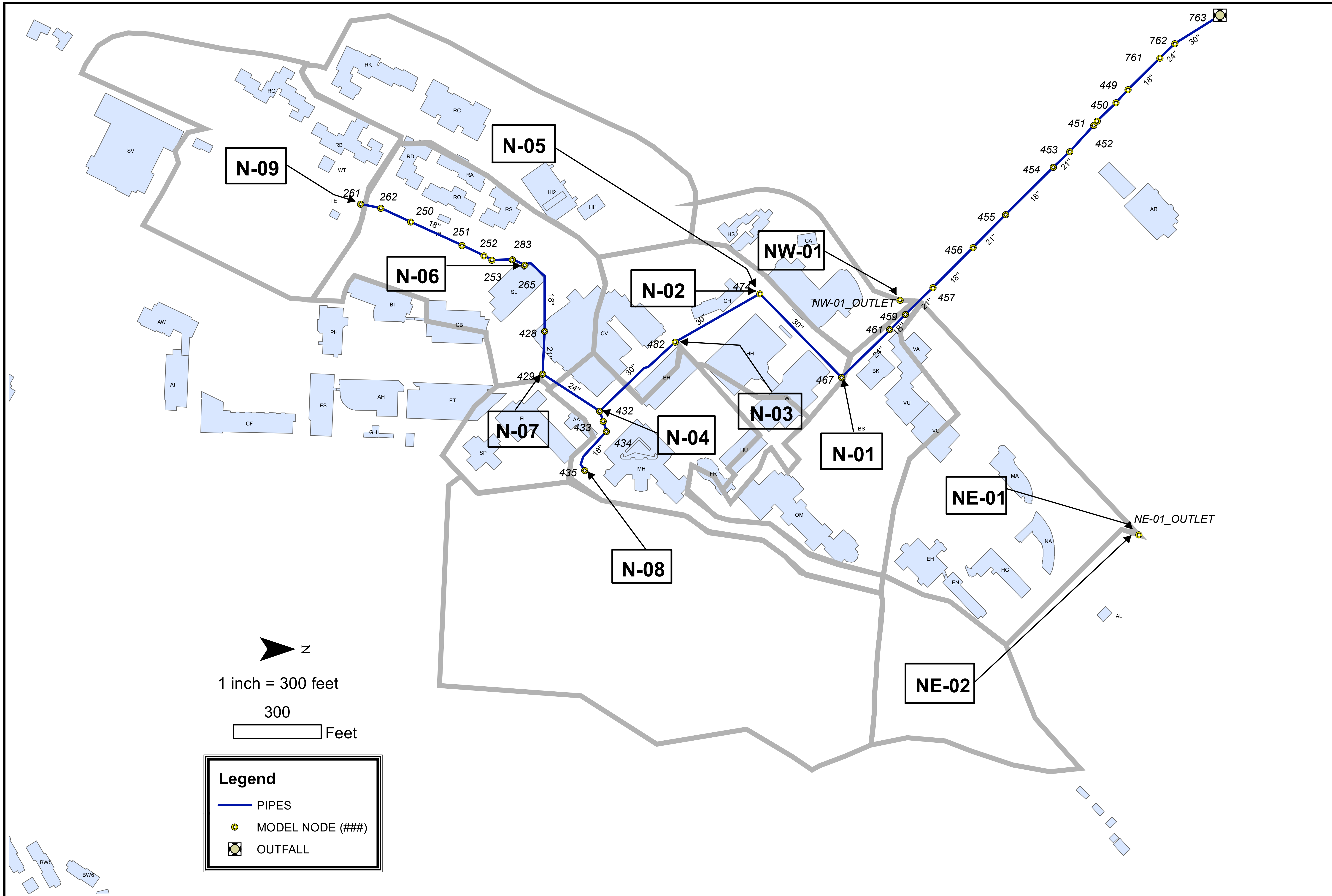

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FIGURE 4-3
SWMM MODEL SCHEMATIC

DATE JUNE 2017

SCALE AS SHOWN

PROJECT 2016-139

SHEET 1 OF 1

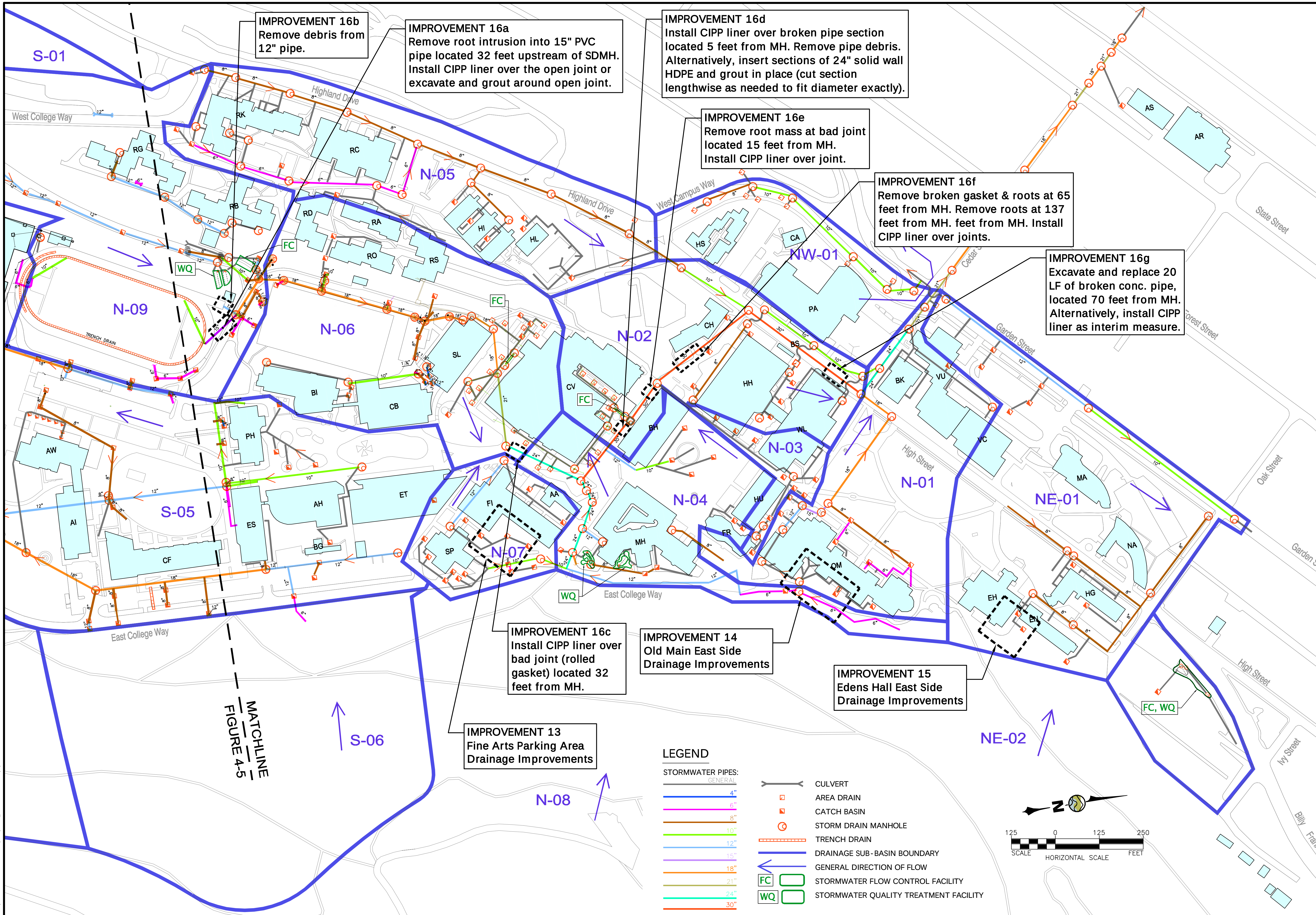

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FIGURE 4-4
RECOMMENDED IMPROVEMENTS NORTH

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JOB NUMBER 2016-039
SHEET 1 OF 1

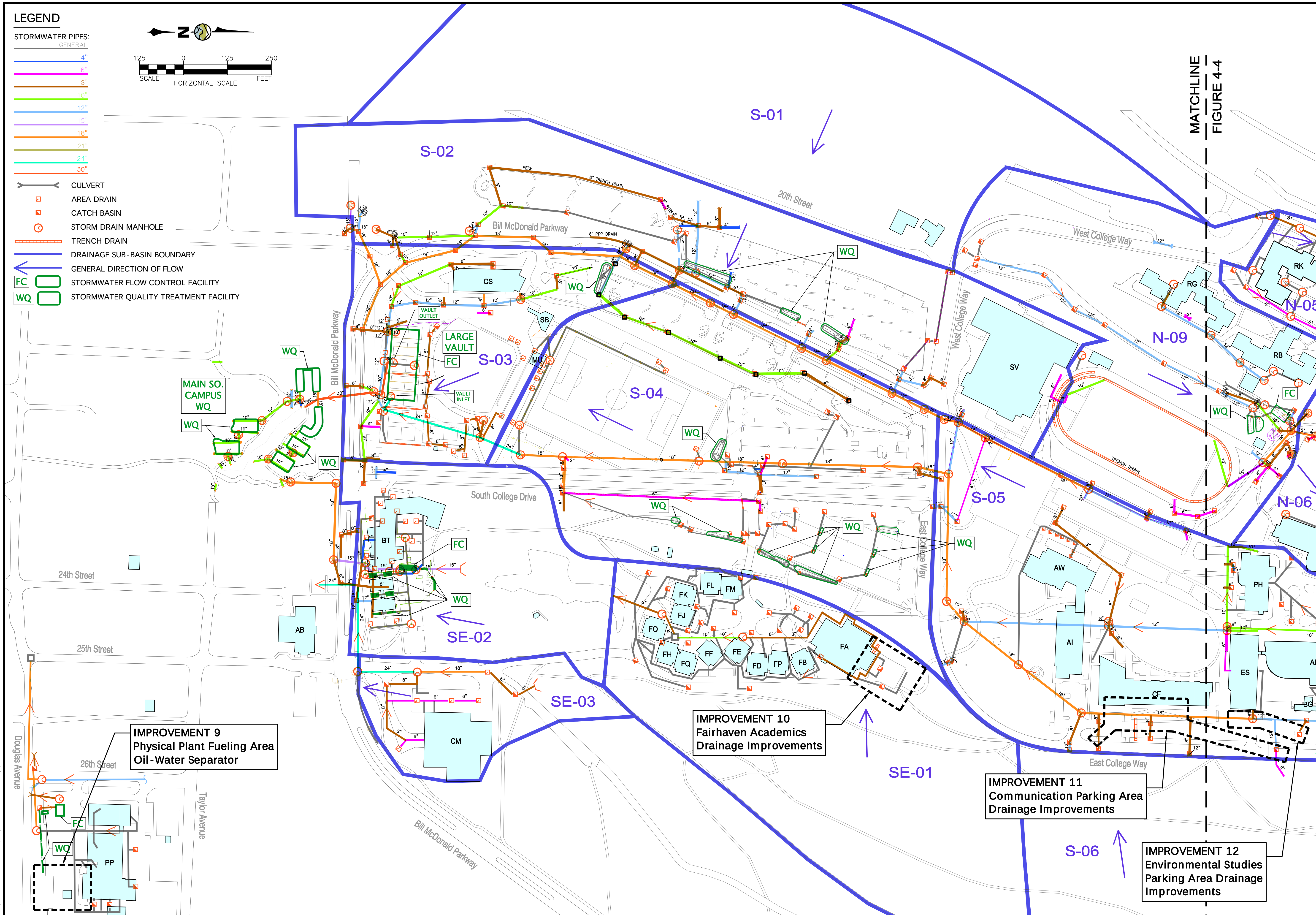

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FIGURE 4-5
RECOMMENDED IMPROVEMENTS SOUTH

DATE JUNE 2017
SCALE AS SHOWN
JOB NUMBER 2016-039
SHEET 1 OF 1

Table 4-1. North Campus Stormwater Model Input Information.

NODES

Name	Invert Elev. (ft)	Rim Elev. (ft)	Max Depth (ft)
261	310.92	318.27	7.35
262	310.62	315.50	4.88
250	310.31	314.70	4.39
251	309.79	314.80	5.01
252	309.57	315.40	5.83
253	309.48	313.99	4.51
283	309.25	316.00	6.75
265	309.06	316.21	7.15
428	307.85	317.83	9.98
429	307.10	318.10	11.00
432	305.39	315.50	10.11
433	305.88	316.80	10.92
434	306.00	316.00	10.00
435	316.34	318.44	2.10
482	304.40	319.30	14.90
474	303.60	319.40	15.80
467	301.90	314.80	12.90
461	287.54	297.10	9.56
459	246.50	260.20	13.70
457	240.70	248.20	7.50
456	211.50	220.60	9.10
455	180.00	190.20	10.20
454	148.00	157.00	9.00
453	142.00	156.70	14.70
452	110.00	127.00	17.00
451	96.00	107.70	11.70
450	75.00	86.40	11.40
449	50.00	65.00	15.00
761	12.50	29.00	16.50
762	11.30	16.80	5.50
763	10.42	OUTFALL	OUTFALL

PIPES

Name	Inlet Node	Outlet Node	Inlet Height (ft)	Outlet Height (ft)	Length (ft)	Slope (%)	Diameter (in)	Material
763c	261	262	0	0	71	0.42	18	CONC
763b	262	250	0	0	112	0.28	18	CONC
763a	250	251	0	0	192	0.27	18	CONC
763	251	252	0	0	82	0.27	18	CONC
574	252	253	0	0	31	0.29	18	CONC
703	253	283	0	0	70	0.33	18	CONC
704	283	265	0	0.04	45	0.33	18	CONC
1007	265	428	0	0.53	279	0.24	18	CONC
1010	428	429	0	0	147	0.51	21	CONC
1031	429	432	0	0.26	234	0.62	24	CONC
1041	435	434	0	0.20	170	5.96	18	CONC
1038	434	433	0	0.05	38	0.18	18	CONC
1037	433	432	0	0	36	1.36	18	CONC
1093-1036	432	482	0.06	0	351	0.30	30	CONC
1096	482	474	0	0.17	333	0.19	30	CONC
1112	474	467	0	0.25	399	0.36	30	CONC
1115	467	461	0.10	2.91	210	5.50	24	CONC
1120	461	459	0	10.65	99	30.70	18	CMP
1119	459	457	0	2.20	120	3.00	21	CONC
1116	457	456	0	1.08	158	17.80	18	CMP
1117	456	455	0	7.25	250	9.70	21	CMP
1118	455	454	0	1.50	210	14.52	18	CMP
1125	454	453	0	3.24	92	3.00	21	CONC
1124	453	452	0	13.98	85	21.20	18	CMP
1123	452	451	1	8.64	30	21.20	18	CMP
1122	451	450	1	4.45	65	27.00	18	CMP
1225	450	449	1	7.25	125	15.00	18	CMP
1121	449	761	1	12.25	105	25.00	18	CMP
1226	761	762	0	0	75	1.60	24	CMP
1227	762	763	0	0	196	0.45	30	CMP

Table 4-2. North Campus 25-Year Design Storm Model Results.

		Model Results for 25-Year Design Storm				
Pipe Name	Inlet Node	Max Flow (Q) (cfs)	Max Velocity (V) (ft/s)	Max Inlet Node Depth (ft)	Manhole Rim Freeboard (ft) *	Depth Over Top of Pipe (ft)
763c	261	3.41	3.05	1.05	6.30	-0.45
763b	262	3.39	2.96	1.24	3.64	-0.26
763a	250	3.36	2.63	1.41	2.98	-0.09
763	251	3.37	2.17	1.72	3.29	0.22
574	252	3.37	2.10	1.82	4.01	0.32
703	253	3.37	1.91	1.84	2.67	0.34
704	283	3.37	1.91	1.96	4.79	0.46
1007	265	7.38	4.61	2.07	5.08	0.57
1010	428	7.38	4.56	1.17	8.81	-0.58
1031	429	8.75	5.18	1.06	9.94	-0.94
1041	435	1.51	5.14	1.32	8.79	-0.18
1038	434	1.51	2.53	0.83	10.09	-0.67
1037	433	1.51	2.27	0.71	9.29	-0.79
1093-1036	432	11.24	3.80	0.25	1.85	-2.25
1096	482	11.76	3.37	1.66	13.24	-0.84
1112	474	20.46	5.51	2.01	13.79	-0.49
1115	467	24.01	15.00	1.19	11.71	-0.81
1120	461	24.01	18.21	1.12	8.44	-0.38
1119	459	24.01	10.88	1.80	11.90	0.05
1116	457	24.00	14.58	1.45	6.05	-0.05
1117	456	24.00	12.06	1.40	7.70	-0.35
1118	455	23.17	13.88	8.49	1.71	6.99
1125	454	23.17	10.65	1.88	7.12	0.13
1124	453	23.17	15.18	1.32	13.38	-0.18
1123	452	23.17	14.25	3.81	13.19	2.31
1122	451	23.66	16.53	2.22	9.48	0.72
1225	450	23.17	13.35	7.14	4.26	5.64
1121	449	23.17	16.65	2.18	12.82	0.68
1226	761	23.15	7.37	5.92	10.58	3.92
1227	762	23.15	5.33	3.60	1.90	1.10

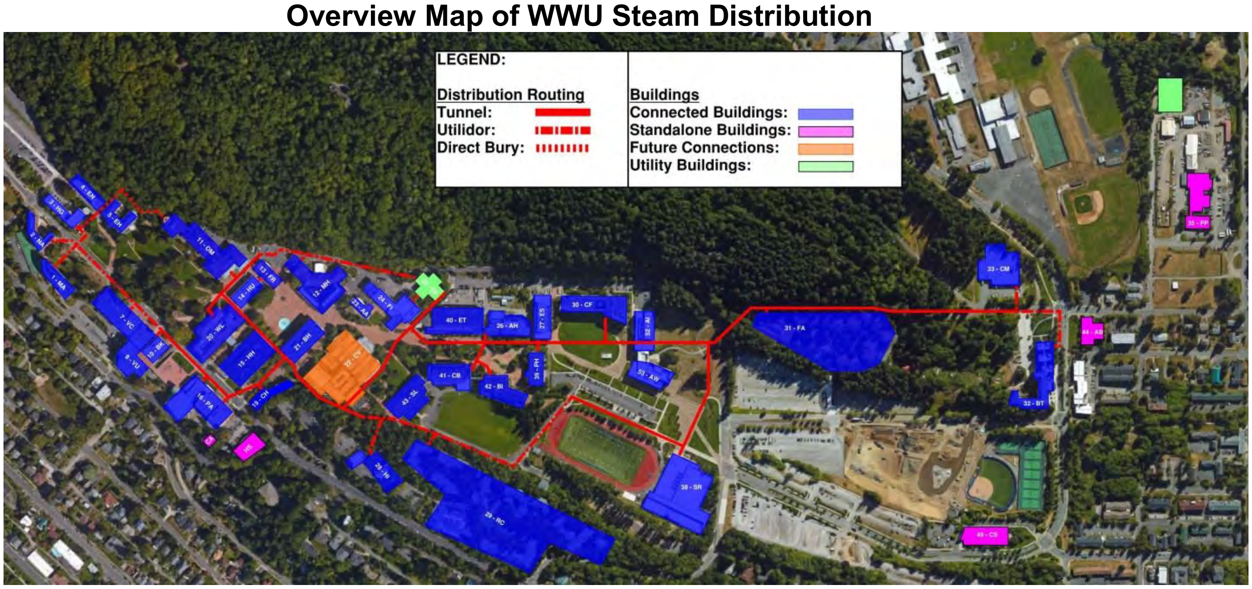
* A manhole rim freeboard depth of 0 would indicate junction flooding.

5. DISTRICT HEATING SYSTEM

5.1. Existing System Overview and Evaluation

The district heating system serving Western Washington University (WWU) is comprised of a central steam production plant and a steam distribution system that serves a majority of the campus facilities through a large utility tunnel system. Steam is provided to 43 of 51 buildings on campus, primarily for heating purposes. Most buildings convert this steam to hot water that is then used for space heating and domestic water needs. Fraser Hall and the Bookstore buildings currently utilize direct steam for all heating needs. There are also a few locations where steam is used for process requirements, primarily in science buildings for lab use, and in buildings for space humidification. The map below provides an overview of the current steam distribution system.

Overview Map of WWU Steam Distribution



Overview of Campus District Energy

The WWU campus benefits from its continued investment in district energy, as it provides an economical and efficient way to heat multiple buildings in a campus setting from a central location. As opposed to distributed generation which requires heating generation equipment at each building, district energy systems use a network of distribution pipes (often underground) to deliver heating/cooling media to multiple buildings in an area such as a downtown district, college, hospital, or other campus setting. This consolidation of thermal loads into a centralized plant provides the ability to reduce energy usage through enhanced production efficiency, reduction in losses, and ability to recover sources of waste heat that would be lost in a distributed generation system. This consolidation also reduces costs associated with renewal and maintenance due to fewer pieces of equipment required as opposed to a distributed system. It also provides the ability to incorporate and transition to renewable sources as they become economically and technically viable in an effective and efficiency manner.

5.1.1. Heating Production Plant Overview

The existing Steam Production Plant was originally constructed in 1946 and is centrally located on the east side of the campus next to the Arboretum Forest. The building is two story and covers 11,000 sq. ft. In 1969 a major building expansion added space for boilers #5, #6, and a chilled water plant with an outdoor cooling tower. The chilled water equipment has since been removed and the space is used for the facility repair shop and district compressed air system. District compressed air is distributed to various buildings throughout campus for controls and process usage.

Existing Plant Equipment

The Steam Production Plant produces steam utilizing five water tube boilers of various sizes. The total installed steam capacity is 260,000 lb/hr. Each boiler has a single stage economizer that utilizes waste heat from the stack exhaust gas to preheat boiler feed water.

Steam Production Plant – Installed Capacity

Name	Year Installed	Nominal Output (lb/hr)	Fuel Type
Boiler #2	1946	15,000	N. Gas/Oil
Boiler #3	1959	25,000	N. Gas/Oil
Boiler #4	1966	40,000	N. Gas/Oil
Boiler #5	1970	100,000	N. Gas/Oil
Boiler #6	1995	75,000	N. Gas

Most of the boilers have duel fuel capability. The primary fuel used for the boilers is natural gas. A 6” natural gas line at 45psig is supplied to the building for use. Fuel oil can also be used in all of the boilers except for #6. Fuel oil is stored outside of the building in four underground tanks: (2) at 44,000 gallons and (2) at 19,000 gallons. The 19,000 gallon tanks were installed in 1946 when the original building was constructed and the 44,000 tanks were installed in 1970 when Boiler #5 was installed.

Boilers #4,5,6 have a fully digital control system. This control system is interfaced into the Campus Apogee control system for monitoring only. Boilers #2,3 currently use pneumatic controls for a majority of the boiler functions.

Boilers #2 and #6 are the only boilers that are currently connected to the emergency generator. As such, these boilers are the only available boilers that can be used during a power outage. The total installed capacity of these boilers is 90,000 lb/hr.

Each boiler has an indirect draft fan located on the cat walk level. Boilers #2,3,4 also have an induced draft fan in addition to the forced draft fan. Boiler #5 has a “MagnaDrive” and Boiler #6 has a variable frequency drive (VFD) on its fan to allow for turndown at part load on the boilers.

Two deaerator tanks are located in the Steam Plant: one sized at 100,000 lb/hr installed in 1946 and 200,000 lb/hr installed in 1970. Each deaerator tank takes steam at 5psig and condensate return at ~180F. The condensate is heated to ~228F to remove a majority of the dissolved air in the water to prevent corrosion in the piping due to carbonic acid formation. Once the water leaves the deaerators it is considered feed water and is pumped to the boilers by five pumps of various sizes at 175 psi. The feed water is pumped through a single stage economizer directly before entering the boiler and has a typical boiler input temperature of ~260F.

When condensate is returned to the Steam Plant it is collected in an approximately 3,500 gallon receiver tank or can directly supply the deaerator if needed. Makeup water can be added either to the condensate receiver or to the deaerator tanks via an emergency bypass. The system appears to be capable of providing 85,000 lb/hr of makeup water if required at the worst assumed condition.

The following table provides an overview of the major Steam Production Plant production equipment aside from the boilers.

Steam Plant Major Equipment list

Equipment Tag	Description
DA-1	100,000 lb/hr Deaerator Tank
DA-2	200,000 lb/hr Deaerator Tank
CR-1	3,500 Gallon Condensate Receiver
P-1,2,3	Boiler Feed Pumps. 178 gpm, 365 TDH
P-4	Boiler Feed Pump. 80 gpm, 355 TDH, 20 HP
P-5	Boiler Feed Pump. 220 gpm, Steam Driven

A schematic diagram showing the current steam production plant layout can be found in the Appendix.

Steam System Operating Parameters

Saturated steam is produced at 100-110 psig for distribution to the campus district steam system. Throughout the distribution system and at the building level, steam is condensed and the condensate is sent back to the Steam Plant to complete the cycle. It has been reported by boiler operation staff that 90-95% of condensate is returned to the Steam Plant with a return temperature ranging between 160F to 180F.

The boilers operate with a variable percent excess air in the exhaust stream.

5.1.2. Heating Production Plant Conditions Evaluation

Overview

The overall appearance of Steam Plant heating system is that it is well maintained. Pipe insulation appears tight with no visible fraying or noticeable missing sections, equipment looks clean with no indication of oil leaks, and there were no indications of water/steam leaks.

Example Photo of Steam Plant Interior

Preventive maintenance is routinely completed and well documented. Detailed logs describing the typical regular maintenance completed for the various equipment of the plant was provided for the past 6 years. The list of regular maintenance items appears to be sufficiently complete to ensure all plant equipment is well taken care of.

Safety Concerns

Plant staff reported no safety issues at the Steam Plant. There are however, noted instances of asbestos insulation that remains in the plant but is still fully contained at this point. Plant staff also reported that there are no regular water hammer concerns with the steam system. There was one anecdotal report of a water hammer incident due to a safety valve closing, but this is not something that is an ongoing issue.

Equipment Conditions

Overall, the boilers appear to be in good shape given the age and typical life expectancy. Conversations with boiler operation staff noted no major issues with the operating condition of the boilers themselves. However, upon the last inspection, boilers #2 and #3 may potentially have a light amount of scale in some tube sections. It must be noted, that with the advanced age of these boilers (with the newest boiler being 22 years old), that a short and long term plan should be put in place to deal with equipment renewal and replacement. For reference, ASHRAE lists that the median service life for steam water tube boilers is 30 years, boiler burners is 21 years, pneumatic controls is 20 years, and condensate pumps is 15 years.

There is some concern over the ongoing ability to cost effectively maintain and operate the aging production equipment. Boilers #2,3,4,5 have obsolete components that will make it difficult to locate and obtain replacement parts in the coming years. Some additional concerns with the future operations and maintenance of the boilers is as follows:

- Boiler #2: Boiler is currently 71 years old and the control system is completely pneumatic. Concern with availability of replacement parts.
- Boiler #3: Boiler is currently 58 years old and the control system is completely pneumatic. Concern with availability of replacement parts.
- Boiler #4: Boiler is currently 51 years old. Concern with availability of replacement parts.
- Boiler #5: Boiler is currently 47 years old. Concern with boiler refractory material and availability of replacement parts. Per boiler operation staff, repairs to the refractory material will be needed within 10 years.

Other Items of Note

Additional concern was noted about the existing diesel storage tanks. Plant personnel expressed apprehension over the lack of full knowledge of the type and condition of the existing tanks. It is currently unknown if the older installed tanks are double wall containment tanks or not. If not, this could indicate a possible future environmental leak hazard. If future concern grows regarding the condition of the tank, it has been noted that a scan of the tank/area by the geology department is a potential option.

5.1.3. Heating Distribution Overview

The majority of buildings are connected to the Steam Plant by way of a walk-able tunnel system. There are also sections of buried trench (referred to as “utilidor” in this document) that are used to protect steam and condensate piping; some of which have since been abandoned. The age of the tunnel and piping vary, however a majority of the existing tunnel system had been established by 1970.

There are entry points to the tunnel at each building and via doorways distributed throughout the tunnel system. The tunnel is ventilated with several intake and exhaust fans located throughout the distribution system.

Steam, condensate, compressed air, and sections of abandoned chilled water piping (installed in 1969) are located throughout the tunnel. Abandoned chilled water piping runs from the Steam Plant to roughly the Performing Arts Building. Power, data, and communication lines are also located throughout the tunnel. There are several sections of the chilled water piping that have been re-appropriated for running data and communication lines.

The typical dimensions of the tunnel vary but are sufficiently large enough to house the existing piping and cabling while providing adequate walk/work space.

The tunnel typically supports pipes using support roller supports spaced roughly every 10 ft. Steam pipe expansion is accommodated by a mix of ball and bellows types expansion joints, located in most node areas.

The high pressure steam (HPS) line has approximately 3” thick insulation with an aluminum jacket on all pipe sizes and the pumped condensate (PC) has approximately 2” thick insulation with an aluminum jacket on all pipe sizes. Asbestos insulation can still be found on sections of piping throughout the tunnel system. Removal of asbestos has been sporadic over the years as repairs have demanded. Following each abatement project, the piping is typically marked with blue bands to indicate it is asbestos free.

Overview of Existing Buildings' Heating Requirements

The following table provides an overview of the buildings on the WWU campus.

General			Heating					Domestic Hot		
Building	Abbrev.	Sq. Ft	Total Steam Req. (Lb/hr)	Bldg. Heating Type	Total Heating (Lb/hr)	Steam Coils (Lb/hr)	HW Converter (Lb/hr)	Domestic Heating Type	Domestic Load (BTU/h)	Domestic Steam (Lb/hr)
ARNTZEN	AH	99,337	9,220	Steam/HW	7,220	620	6,600	Steam	2,000,000	2,000
BIOLOGY BUILDING	BI	81,120	12,791	Steam/HW	12,791	8,591	4,200	Steam/ Electric Booster		
BOND HALL	BH	89,591	4,621	HW Only	4,233	0	4,233	Steam	366,667	388
CARVER GYM	CV	110,700	12,500	Steam/HW	8,500	0	8,500	Steam	3,750,000	4,000
CHEMISTRY BUILDING	CB	72,574	12,152	Steam/HW	11,752	5,152	6,600	Steam		
COLLEGE HALL	CH	32,917	720	Steam/HW	720		720	Steam		
COMMISSARY	CM	37,121	100	Steam/HW	100		100			
COMMUNICATIONS FACILITY	CF	131,365	5,207	HW Only	4,561		4,561	Steam	600,000	646
ENGINEERING TECH	ET	77,592	4,679	Steam/HW	3,779	2,529	1,250	Steam		900
ENVIRONMENTAL STUDIES	ES	111,145	5,468	Steam/HW	4,200	600	3,600	Steam	1,240,000	1,240
ACADEMIC INSTRUCTION CENTER	AI	83,652	5,611	Steam/HW	5,611	1,200	4,411	Electric	848,940	0
ACADEMIC INSTRUCTION WEST	AW	46,997		HW Only						
FAIRHAVEN COLLEGE (ACADEMIC AND DINING)	FA	51,529		Steam/HW				Steam		
FINE ARTS	FI	74,866	2,529	Steam/HW	2,404	2,196	207	Steam	25,000	0
FRASER HALL	FR	13,562	991	Steam Only	991	991	0	Electric - POU	55,277	0
HAGGARD HALL	HH	107,971	4,217	HW Only	3,792	0	3,792	Steam	400,000	425
HUMANITIES BUILDING	HU	33,342	1,170	HW Only	450	0	450	Steam	720,000	720
MILLER HALL	MH	133,117	5,200	HW Only	5,200	0	5,200	Electric	121,131	0
OLD MAIN	OM	145,474	8,654	Steam/HW	6,154		6,154	Steam/Electric	2,684,256	2,500
PARKS HALL	PH	56,109	1,100	HW Only	1,100	0	1,100	Steam		
PERFORMING ARTS CENTER	PA	128,649	4,339	HW Only	3,704	0	3,704	Steam	600,000	635
SMATE (SCI/MATH/TECH EDUCATION)	SL	40,144	4,550	HW Only	4,550	0	4,550	Electric	51,182	0
WILSON LIBRARY	WL	141,027	3,767	Steam/HW	3,767		3,767	Electric	6,824	0

Continued….

General			Heating					Domestic Hot		
Building	Abbrev.	Sq. Ft	Total Steam Req. (Lb/hr)	Bldg. Heating Type	Total Heating (Lb/hr)	Steam Coils (Lb/hr)	HW Converter (Lb/hr)	Domestic Heating Type	Domestic Load (BTU/h)	Domestic Steam (Lb/hr)
BUCHANAN TOWERS COMPLEX	BT	101,095	7,871	HW Only	3,300	0	3,300	Steam	4,320,000	4,571
EDENS NORTH	EN	26,432	950	HW Only	950	0	950	Steam		
EDENS SOUTH	EH	63,662	5,350	HW Only	1,450	0	1,450	Steam	3,640,000	3,900
FAIRHAVEN TOWERS (RESIDENTIAL)	FT	123,231	0	HW Only	0			Steam		
HIGGINSON HALL (RESIDENCE)	HG	47,241	2,960	HW Only	730	0	730	Steam	2,450,000	2,230
HIGHLAND I & II (RESIDENCE)	HI	21,984	2,143	Steam/HW	810		810	Steam	1,260,000	1,333
MATHES HALL (RESIDENCE)	MA	75,381	3,798	Steam/HW	2,496	696	1,800	Steam	1,250,000	1,302
NASH HALL (RESIDENCE)	NA	76,891	3,920	Steam/HW	2,618	504	2,115	Steam	1,250,000	1,302
RDG ALPHA	RA	21,109	2,000	HW Only	2,000	0	2,000	Steam		
RDG BETA	RB	35,857	0	HW Only	0	0		Steam		
RDG DELTA	RD	22,513	3,200	HW Only	700	0	700	Steam	2,000,000	2,500
RDG GAMMA	RG	32,853	0	HW Only	0	0		Steam		
RDG KAPPA	RK	38,529	0	HW Only	0	0		Steam		
RDG OMEGA	RO	48,577	0	HW Only	0	0		Steam		
RDG SIGMA	RS	20,693	0	HW Only	0	0		Steam		
RIDGEWAY COMPLEX (DINING)	RC	20,471	1,087	Steam Only	1,087	1,087	0	Steam		
VIKING COMMONS	VC	30,739	3,560	Steam/HW	2,660	2,209	451	Steam		900
VIKING UNION	VU	65,342	1,100	Steam/HW			8,600	Steam	1,050,000	1,100
BOOKSTORE	BK	17,896	175	HW Only	0		NA	Steam	166,667	175
STUDENT RECREATION	SV	98,300	9,071	Steam/HW	5,470	500	4,970	Steam/Electric (Summer Use)	2,600,000	3,601
Building Totals		**2,888,697**	**156,769**		**119,847**	**26,874**	**101,574**		**33,455,943**	**36,369**

This table was developed by referencing the drawings located on WWU's online drawing vault. Blank cells indicate information that is currently missing and is in need of field verification for completion. In its current state, the table shows that the aggregate building connected load capacity for steam is 156,000 lb/hr consisting of roughly 120,000 for heating and process loads and 36,000 for domestic hot water production. Of this reported 120,000 for heating and process loads, 53,000 is used in buildings that utilize hot water for in-building distribution. It is important to note that this does not represent the expected diversified peak that would be required to be served by the Steam Plant. As a district system, with inherent operating diversity and design safety factors, the actual system coincident peak is often 50% to 75% of the connected load.

5.1.4. Heating Distribution Conditions Evaluation

Overview

The overall appearance of the distribution systems is that it is well maintained. Pipe insulation appears tight with no visible fraying or noticeable missing sections, there is no indication of water/steam leaks, and there is no indication of water infiltration into the tunnel.

Example Photo of Steam Distribution Interior

Tunnel, Piping, and Equipment Conditions

Overall, the tunnel and associated piping/equipment are reported to be in good shape. There is a segment of steam/condensate piping serving the Ridgeway residence halls that is slated for repair and replacement. These segments include the southern half of the complex near the Kappa building and Beta to Gamma buildings.

Life expectancy of steam and condensate pipe varies greatly depending on system conditions. Typical life expectancies are approximately 60 years for steam piping and 30 years for condensate piping. Steam piping typically experiences a longer life than condensate piping because the steam lines are typically at a relatively constant pressure/temperature and has little to no oxygen content. Condensate piping on the other hand sees much more degradation due to carbonic acid formation and potential steam flashing from hot condensate (and it is for this reason why condensate piping is typically schedule 80 as opposed to steam at schedule 40).

With the varying age of the steam and condensate piping a long term plan should be implemented to monitor the condition of the piping system and prepare for renewal and replacement.

Safety Concerns

WWU Staff reported no safety issues with the steam distribution system. There was however, noted instances of asbestos insulation that remains in portions of the distribution system.

Other Items of Note

The tunnel appears to be well ventilated by means of intake/exhaust fans located at most "node" areas in the tunnel system. This intake air is typically introduced to the tunnel from ground level of the main campus. Care should be exercised to ensure vehicles and other equipment are not placed near these intake areas to ensure proper air quality for the tunnel.

It was also noticed that there was a condenser unit located in the tunnel system. While this unit doesn't appear to have a refrigerant charge large enough to be dangerous to the tunnel air quality, care should be exercised if additional refrigerant containing equipment is installed in the tunnel system.

Another item to note is the tunnel ambient temperature. Tunnel temperatures vary from roughly 70F to 100F depending on location. During a site visit tunnel temperatures were measured in excess of 100F in multiple locations near the Steam Plant. The ambient outdoor temperature during these measurements was ~45F in November. This can make the tunnel a potential heat related illness hazard if work is to be performed in the tunnel for extended periods of time.

While these issue appear to be mitigated due to tunnel entry/exit procedures it is still something of which to be aware.

5.1.5. Historic Steam Production and Energy Consumption

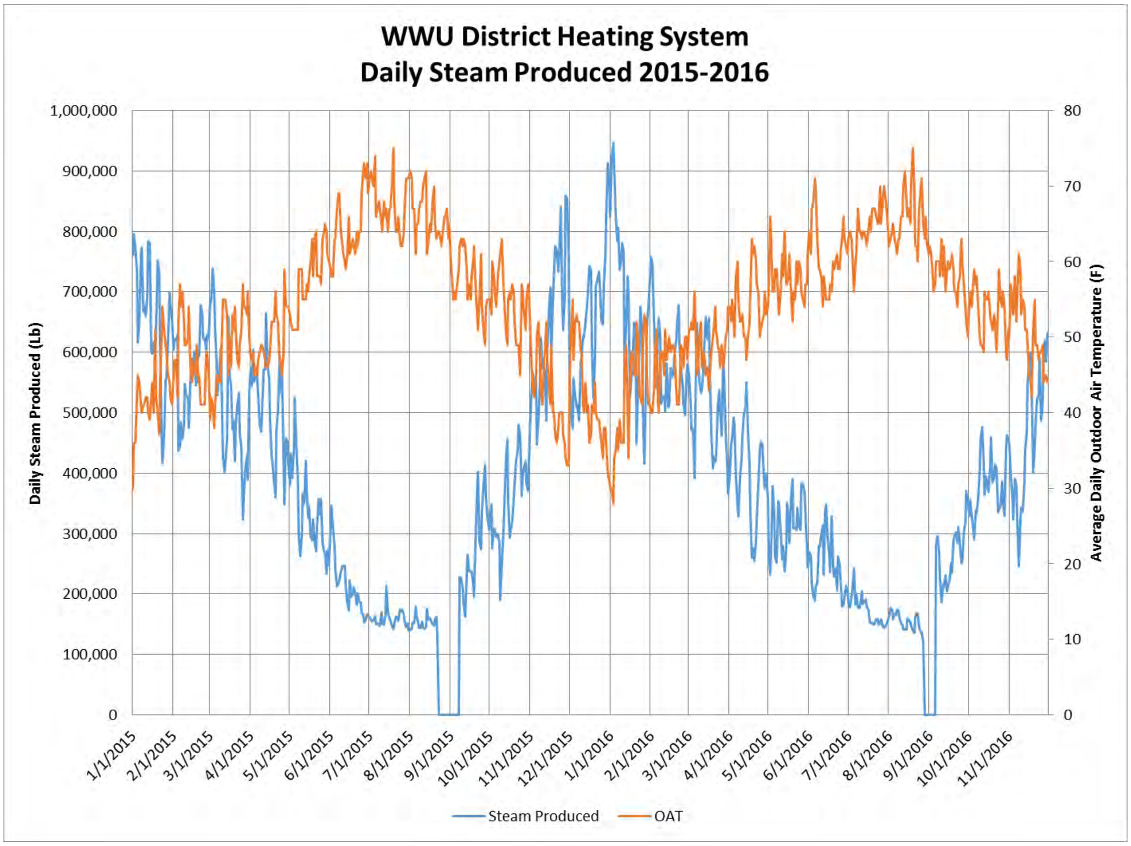
Western Washington University is a large user of energy for both natural gas and electricity. Typical natural gas usage has averaged 2,100,000 therms and electricity usage has averaged 33,000,000 kWh over the last five years for the entire campus.

The last two years of data is shown in the tables below for reference to the magnitude of energy usage and cost for both the steam plant and the WWU main campus.

Year	Month	Steam Plant N. Gas & Electricity Usage					Total Campus N. Gas & Electricity Usage				
		Natural Gas Usage	Natural Gas Cost	Steam Produced	Electricity Usage	Electrical Cost	Total Campus N. Gas Usage	Natural Gas Cost	Total Campus Electricty Usage	Electricity Cost	Total Campus Carbon
		Therms	$	Lb	kWh	$	Therms	$	kWh	$	Mtons
2015	January	255,380	$139,477	20,369,463	66,841	$4,705	261,958	$146,230	2,926,711	$206,028	2,597
	February	199,230	$116,925	15,897,321	60,157	$4,267	204,940	$123,428	2,721,935	$193,054	2,210
	March	198,574	$110,224	16,007,381	64,536	$4,625	204,256	$116,361	2,813,355	$201,619	2,244
	April	186,843	$91,860	15,162,075	62,152	$4,448	191,995	$97,165	2,842,404	$203,416	2,190
	May	128,607	$68,552	10,444,719	59,239	$4,345	133,660	$73,753	2,888,887	$211,905	1,900
	June	79,394	$46,784	6,449,780	50,637	$3,821	82,091	$49,603	2,566,188	$193,645	1,493
	July	63,540	$31,584	4,924,684	49,533	$3,737	64,946	$33,085	2,571,509	$193,989	1,404
	August	43,670	$24,484	3,354,489	46,149	$3,506	44,848	$25,708	2,452,264	$186,274	1,248
	September	83,240	$42,757	6,374,203	50,728	$3,865	85,777	$45,018	2,374,339	$180,924	1,433
	October	142,200	$72,378	10,958,900	64,353	$4,775	145,693	$76,271	2,877,178	$213,504	1,959
	November	239,760	$110,247	19,369,939	66,397	$4,943	245,942	$115,971	2,740,452	$204,012	2,435
	December	245,880	$123,822	20,034,694	63,789	$4,806	253,142	$130,046	2,502,202	$188,512	2,375
	Totals	**1,866,318**	**$979,093**	**149,347,648**	**704,511**	**$51,843**	**1,919,249**	**$1,032,638**	**32,277,424**	**$2,376,882**	**23,487**

Year	Month	Steam Plant N. Gas & Electricity Usage					Total Campus N. Gas & Electricity Usage				
		Natural Gas Usage	Natural Gas Cost	Steam Produced	Electricity Usage	Electrical Cost	Total Campus N. Gas Usage	Natural Gas Cost	Total Campus Electricty Usage	Electricity Cost	Total Campus Carbon
		Therms	$	Lb	kWh	$	Therms	$	kWh	$	Mtons
2016	January	257,360	$126,355	21,066,067	65,059	$4,756	264,565	$132,535	2,870,753	$209,853	2,588
	February	206,625	$102,056	17,018,202	65,328	$4,799	213,105	$107,621	2,736,639	$201,034	2,259
	March	195,721	$86,663	16,060,060	63,031	$4,696	201,375	$91,517	2,704,829	$201,506	2,184
	April	146,440	$67,872	12,028,757	62,824	$4,676	151,266	$72,025	2,722,075	$202,622	1,925
	May	116,866	$53,000	9,644,016	59,668	$4,389	121,242	$56,754	2,829,561	$208,137	1,809
	June	90,321	$42,083	7,395,782	51,425	$3,818	92,630	$44,109	2,380,849	$179,333	1,473
	July	66,550	$32,924	5,327,899	50,064	$3,776	67,713	$33,977	2,360,749	$178,042	1,332
	August	53,758	$28,480	4,166,706	45,532	$3,423	54,488	$29,148	2,410,645	$181,245	1,282
	September	87,089	$46,907	6,656,503	48,636	$3,681	89,618	$48,898	2,304,580	$174,437	1,425
	October	152,310	$77,161	11,823,113	57,413	$4,224	156,980	$80,812	2,820,940	$207,544	1,996
	November	175,390	$94,147	13,863,463	58,458	$4,261	181,504	$98,919	2,714,689	$197,869	2,082
	December						325,670	$164,257	2,535,186	$182,852	2,774
	Totals	**1,548,430**	**$757,648**	**125,050,568**	**627,438**	**$46,499**	**1,920,155**	**$960,572**	**31,391,495**	**$2,324,475**	**23,127**

The last two years of daily steam production and daily average outdoor air temperature is shown on the graph below.



5.1.6. Heating System Efficiency Evaluation

Boiler logs detailing boiler operation, metered data regarding building steam usage, and utility billings from WWU's Energy Center website were provided and analyzed to determine overall system efficiency.

Heating System Efficiency Overview

Year	Heating Degree Day	Total Steam Produced	Total Steam Energy	Natural Gas Usage	Natural Gas Energy	Overall Boiler Energy Loss	Overall Boiler Efficiency	Distribution Energy Loss	Useful Steam Energy	Distribution Efficiency	Total Net System Efficiency
	HDD	Lb	Mbtu	Therms	Mbtu	Mbtu	%	Mbtu	Mbtu	%	%
2012	5,419	179,836,374	187,569,338	2,245,075	224,507,500	36,938,162	83.5%	42,096,925	135,906,377	72.5%	60.5%
2013	5,185	178,687,601	186,371,168	2,196,761	219,676,100	33,304,932	84.8%	51,979,257	124,886,982	67.0%	56.9%
2014	4,628	163,238,183	170,257,425	2,033,226	203,322,600	33,065,175	83.7%	46,435,795	115,138,501	67.6%	56.6%
2015	4,437	149,347,648	155,769,597	1,866,318	186,631,800	30,862,203	83.5%	47,052,556	100,772,792	64.7%	54.0%
2016	3,544	125,050,568	130,427,742	1,548,430	154,843,000	24,415,258	84.2%	41,644,885	82,131,043	63.0%	53.0%
Average	**4,643**	**159,232,075**	**166,079,054**	**1,977,962**	**197,796,200**	**31,717,146**	**84.0%**	**45,841,883**	**111,767,139**	**67.3%**	**56.5%**

The above table details yearly usage for the past five years with the five year average values. The five year average system efficiency is 56.5% defined as the useful steam consumed by the buildings by the energy consumed by the boilers. Please note that the data for 2016 does not include steam production information for the month of December. This affects the total Heating Degree Days, amount of steam produced, and natural gas consumed. The percentage of efficiencies are relatively unaffected by this missing data as it accounts for only one month of the year.

The following definitions were used in calculating the system efficiency:

- ***Heating Degree Day (HDD):*** Is an indicator of the relative amount of heating required in a given year. HDD is defined by the sum of a base temperate minus the daily average outdoor air temperature for all days where outdoor air temperature is less than the base temperature (all positive values). The base temperature is representative of the outdoor air temperature where it is expected a building does not require additional heat input. This value is typically 65F for office/retail buildings and 55F for semi-heated buildings like warehouses.

- ***Overall Boiler Efficiency:*** Is the total efficiency of a boiler including radiation and convection losses of the boiler and energy expelled in the flue gas. This was calculated by determining the total energy inputted to the steam per lb accounting for the energy returned by the condensate (1063 btu/lb for 110 psi steam generated from 180F condensate) and dividing by the natural gas energy consumed by the boilers.

- ***Distribution Efficiency:*** Is the total efficiency of the distribution and buildings systems as defined by useful steam energy delivered to the building divided by the steam energy generated at the Steam Plant.

- ***Useful Steam Energy:*** Is the energy used by the buildings for heating purposes. The amount of non-useful (parasitic) energy lost to the system was determined by completing a regression analysis of steam generated at the plant versus heating degree days. Useful steam was then calculated by subtracting this parasitic energy from the steam energy generated at the plant.

System Losses

Losses in a district steam system are largely static and due to the nature of the system. This can be seen from the above table that as HDD decreases per year, the system efficiency also decreases. This is due to the losses becoming a larger percentage of the total load.

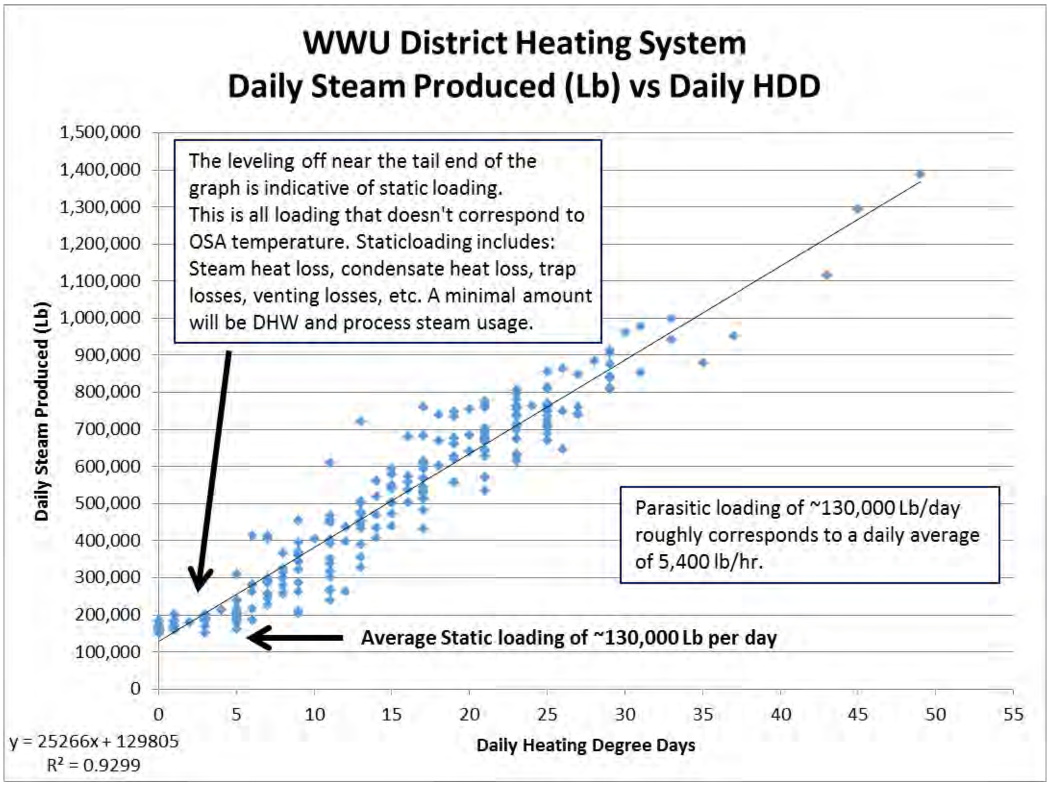
There are multiple categories of loss for a steam system. Steam distribution lines are essentially at constant temperature and pressure throughout the year. Since the lines are located in a tunnel system that is below grade, they are subjected to a nearly constant temperature year round as well. This corresponds to a near continuous level of heat loss from the distribution piping. Also, since steam lines are kept at a consistent pressure, any steam leaks on the steam distribution would also be fairly constant.

Condensate line losses are somewhat similar in nature to steam losses as they are co-located in the same tunnel system and subjected to the same external temperatures. Condensate will experience less loss due to a smaller temperature differential and due to pipes not being completely full as flow is staggered due to condensate receivers.

Steam systems are also subject to physical steam losses due to venting required. Vents are located at deaerator tanks, low pressure flash tanks, and condensate receivers. Venting at deaerators are fairly constant throughout the year while low pressure flash tanks and condensate receivers will vary with the load of the system.

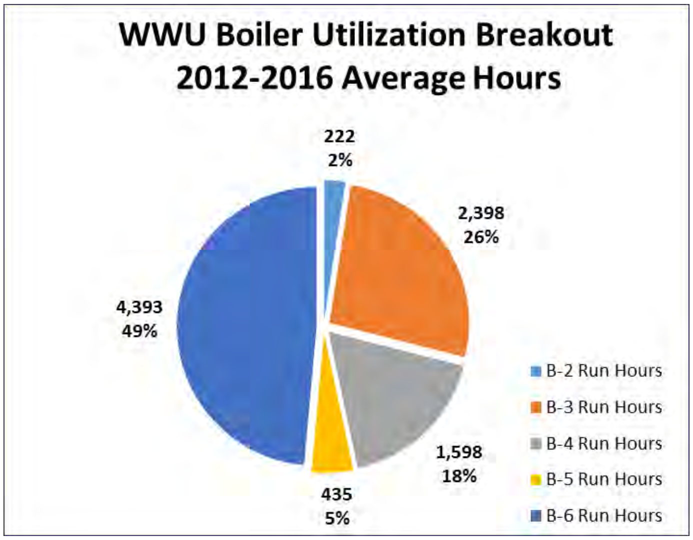
At the building level, buildings that directly use steam are typically older and are likely to have multiple steam control valves that are not operating optimally and thus contributing to the inefficiency of the system.

To determine the amount of distribution energy loss a regression analysis was completed plotting the daily steam production versus heating degree days. The Y-intercept of this regression line represents the average daily energy loss in pounds of steam. For the five year average from 2012-2016 the average daily parasitic loading on the steam system is 130,000 lbs of steam. For a 24-hour period this represents an average boiler loading of 5,400 lb/hr. This calculation reinforces the anecdotal parasitic loading noted by steam plant personnel of 6,000 lb/hr minimum.



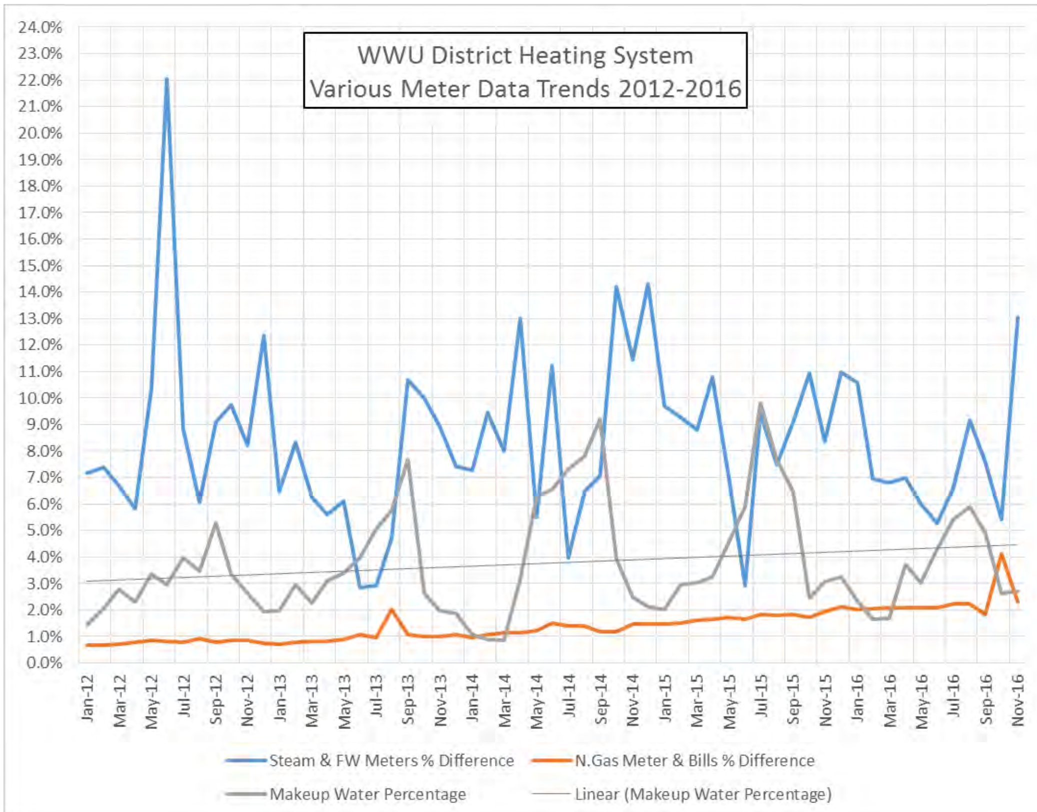
Steam Boiler Utilization

During the efficiency analysis it was noticed that there is a wide range in run hours for each boiler. The graph below breaks out the average run hours for each boiler from 2012-2016. The range of usage for each individual boiler varied from 2%-49% over this time period. The reasons for the variation in usage appear to be due to the age, efficiency, and min/max steam production capability. This wide range of usage means that significantly more work is being performed by B-6 than the rest of the boilers in the Steam Plant. The two least usage boilers, B-2 and B-5, run for approximately 27 days total per year together while B-6 runs for 183 total days on average.



Meter Errors and Drift

During the analysis of the steam system it was noticed that some of the metering was providing values that differed with other meters in the facility or meters owned by the utility. The following graph displays the percent difference in readings between two sets of meters: the two main steam meters (B-2,3,4,5 and B-6) versus the main feed water meter and the “O.S. Gas Meter” versus natural gas billing data. The graph also displays the percentage of makeup water over the same time period.



As shown in the graph above, there is a significant difference in the mass flow reported by the steam and feed water meter. It is currently believed that the feed water meter is reading more accurate numbers than the steam meters as the reported mass flow corresponded to expected boiler efficiencies from the above energy analysis. In general, water flow meters are typically more accurate than steam meters (especially so at lower/part loads) and experience less drift over time. To validate the meter readings a portable ultrasonic flow meter can be attached to the feed water pipe to calibrate the feed water metering. The steam meters could then either be calibrated to the feed water meter or if a manual differential pressure metering station is already installed in the steam distribution the meters can be calibrated to those.

The "O.S. Gas Meter" also shows a difference in reading from the reported utility bills. This difference is relatively small but is drifting wider over time. It is currently believed that the reported utility usage is reading more accurate numbers as it also corresponded to expected boiler efficiencies from the above analysis. It could be assumed that the utility usage is correctly calibrated as utility grade meters are typically very resilient but to ensure complete accuracy the utility can be contacted to test their metering. The internal WWU meter could then be calibrated to the utility.

Also included in this graph is the percentage of makeup water used over time. This usage appears to be quite variable over time with the spikes in usage corresponding to the summer shutdown period. However, looking at a linear trend line over time appears to show an increase in makeup water usage. It is not clear what could be driving the usage increase and currently the loss levels don't appear to be such that it is a major concern. It is also worthwhile to note that for this type of steam system it is impossible to have zero makeup water usage. Water loss will happen at each vent (condensate receivers, low pressure flash tanks, deaerator tanks) where there is direct contact with the atmosphere. In fact, the makeup water usage appears to be sufficiently below average for a steam system of its age and scale.

5.2. Future growth evaluation

5.2.1. Steam Plant Capacity and Requirements for Future Expansion

Steam Generation Capacity

The five boilers housed in the Steam Plant have a total installed capacity of approximately 255,000 lbs/hr of steam. A campus of this type typically requires a certain level of steam production redundancy, meaning that the heat load can still be served even if the largest boiler is off-line for repairs. For the WWU campus to have full (N+1) redundancy, sufficient generation capacity needs to be installed to handle a peak load with the largest unit not operating. Assuming that Boiler #5 (which is the largest boiler) is not operational, the plant will still have the capability of generating 155,000 lb/hr.

Steam Header Capacity

While installed generation capacity is typically the largest concern, pipe sizing in the Steam Plant also needs to be considered when determining maximum distribution capacity. Steam piping is typically sized by limiting maximum velocity in order to control erosion in the pipe and fittings due to entrained water droplets and debris. The higher the velocity the higher the rate of pipe erosion and degradation over time. Recommended limits to velocity vary; ASHRAE 2013 Fundamentals states "steam velocity should be 8,000 to 12,000 fpm, with a maximum of 15,000 fpm." While Spirax

Sarco recommends a maximum velocity of 7,200 fpm. For this report the 7,200 fpm velocity limit is used to remain consistent with the 2007 Master Plan document.

Boilers #2,3,4 directly connect into a common 8” header while Boilers #5,6 directly connect into the 14” main distribution line. An 8” branch line interconnects the 14” distribution and the main header together. There are two additional distribution lines that branch off the 8” common header: a 6” line to the north trench and a 2” line to the Arts Building. Using the pipe sizing limit of 7,200 fpm only 129,200 lb/hr should be sent out for building use (14”: 104,300 lb/hr, 6”: 22,300 lb/hr, and 2”: 2,600 lb/hr) from the Steam Plant with the current header configuration.

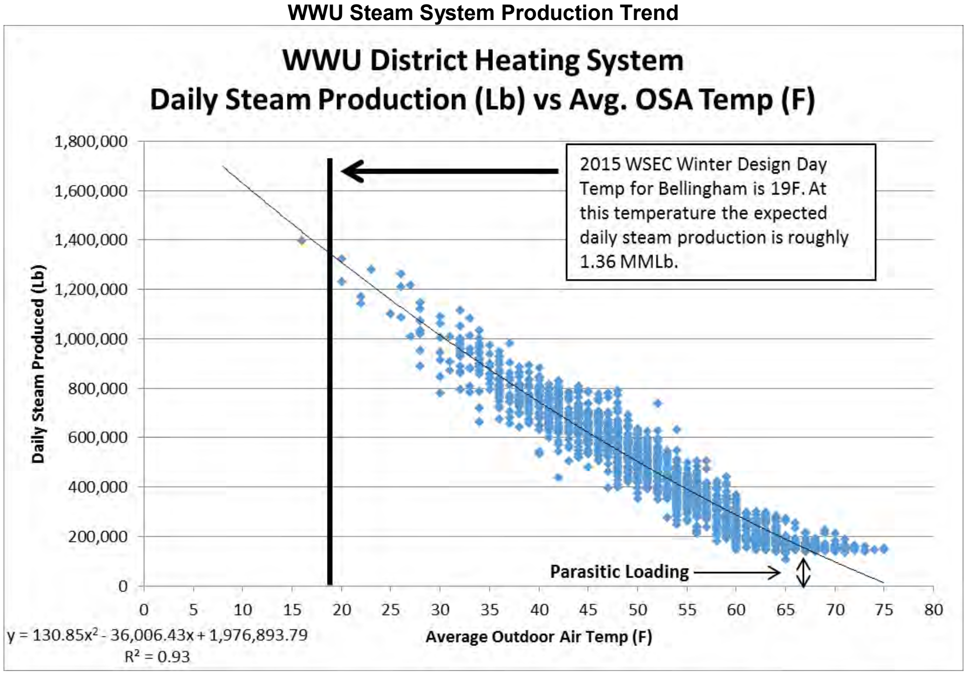
Steam System Load

It has been reported that the record peak steam production of approximately 80,000 lb/hr happened on January 10th, 2006 with an outdoor air temperature that ranged from 12-24F during the day and wind speeds of 4-10 MPH. Instantaneous measurements can be a useful benchmark to correlate steam production requirements to outdoor air temperature but one should exercise caution when using these numbers to determine the exact sizing requirements of a central heating facility. The reasoning for this is that a district heating system’s loading is dependent on multiple buildings that may not all be fully loaded due to building diversity. Building occupation affects room set points, heat load from people/lighting/computers, fresh air load requirements, etc. which all have an impact on the required heating load. A singular day of readings is not typically sufficient enough to truly estimate system peak loading even though it does provide a very good point of reference to compare more empirical data.

In order to determine expected peak system loading an analysis must be completed to understand the system. There are two methods to analyze peak heating requirements of district systems called “white-box” and “black-box” analysis. White-box analysis would be if all the buildings were simulated in energy modeling software where all details of interior requirements can be specified. This method would ensure that the buildings could be specified to have maximum load with solar/weather functions accurately represented; however it is dependent upon the capabilities of the person developing the model and the assumptions contained therein.

Black-box analysis is typically used with historical data to predict heating loads. It is termed black-box because the system is lumped together as a whole and there is no data regarding the individual actions of the buildings of the system. The following graph depicts a black-box analysis approach regarding peak steam loading for WWU.

WWU Steam System Production Trend



The above graph was generated from daily steam records as kept by boiler operation staff. The data provided details daily steam operation parameters for the boilers for the years 2012-2016. As noted on the graph, on a 19F day the approximate daily steam production would be 1.36 MMlb of steam. For a 24 hour period this corresponds to an average loading of 57,000 lb/hr. Peak loading will typically be within 1.5x to 2x this daily average for a total peak loading of approximately 85,000 - 114,000 lb/hr.

While this analysis was completed with daily steam data, the accuracy could be improved with 10 or 15 minute interval data to gain a more precise peak loading estimate.

With the above analysis the maximum expected loading on the steam system is 114,000 lb/hr. This is sufficiently below the current redundant capacity of the Steam Plant of 155,000 lb/hr and the below the maximum steam distribution capacity of 129,200 lb/hr. Assuming a nominal heating intensity of 40 btu/hr/sq.ft for new buildings, approximately 380,000 sq.ft can be added to the district steam system without the need for additional generation capacity or distribution mains.

5.2.2. Future Buildings Heating Requirement

Heating energy usage of new and remodeled buildings will be highly dependent on the type of heating system chosen for the building. A building that uses direct steam for in-building heating typically consumes more energy than a building that uses hot water heating. With the continual improvement to the requirements on new buildings, heating systems will be forced to become smaller and utilize lower grade heating mediums.

The rule of thumb for typical office type buildings is a heating intensity requirement of 40 btu/hr/sq.ft with high performance buildings pushing below 20 btu/hr/sq.ft. For the WWU campus, 40 btu/hr/sq.ft will most likely be more typical for most office type buildings unless specifically designed for high performance.

5.2.3. Tunnel Capacity and Requirements for Future Expansion

Nominal Pipe Capacities

WWU's standard material specification for steam distribution pipe in the tunnel system is schedule 40 A53 black steel pipe with welded connections for pipes 2-1/2" and larger and schedule 80 threaded for all sizes smaller. Standard material specification for condensate distribution pipe is schedule 80 A53 black steel pipe with welded connections for pipes 2-1/2" and larger and threaded for smaller.

For condensate pipe sizing there are two typical design parameters used: pressure drop per 100 ft for 6" pipe and smaller and condensate velocity for 8" pipe and larger. For these two parameters there are two common specifications for allowable pressure drop and water velocity. One school of thought is to limit pressure drop to 2.5' of pressure per 100' of pipe and maintain velocities below 7 fps. The other is to limit pressure drop to 4' of pressure per 100' and maintain velocities below 10 fps. The 2007 Master Plan followed the 2.5' of pressure drop per 100' design velocity and that will be used in this document to remain consistent. It is important to note that if existing pipe sizing was to potentially become a concern with the addition of load on the system, changing the design criteria to 4' drop per 100' of pipe can be a sufficient way to increase capacity of the existing system (at the cost of upgrading pumping head capacity/increased pump energy usage and additional wear of the piping material).

Using a steam pipe sizing criteria of limiting maximum velocities to 7,200 fpm and the condensate piping criteria discussed above, the following table was created detailing maximum flow rates for various pipe sizes.

Pipe Size	Max Flow Rate for HPS at 100 psig	Max Flow Rate for Condensate at 2.5'/100'	Max Flow Rate for Condensate at 4'/100'
Nominal	lb/hr	GPM	GPM
1"	600	5	7
1-1/2"	1,400	15	24
2"	2,300	30	45
2-1/2"	3,700	50	75
3"	5,700	90	130
4"	9,800	185	270
6"	22,300	545	800
8"	38,600	1,000	1,560
10"	60,800	1,570	2,460
12"	86,300	2,220	3,500
14"	104,300	2,680	4,220

Steam Distribution Capacity

A regression analysis was completed using monthly condensate readings from 2011-2016 to determine expected maximum loading at each building based on a 19F design day. The results of that analysis can be seen in the table below. It is important to note that this value differs from the steam system load analysis completed in the preceding section. The reason for this is that this analysis determines the required heat load at each building and excludes all energy losses in the associated distribution piping.

It is also important to note that this table represents individual peak building load capacity, not the overall system diversified peak. Due to building diversity, it would be an extremely unlikely occurrence that all buildings would see peak load at the same time. This method of analysis will provide a conservative estimate for the steam distribution capacity.

Building	Est. Design Consumption Lb	Average Loading Lb/hr	Estimated Peak Load Lb/hr
ACADEMIC INSTRUCTION CTR	920,540	1,237	2,500
ARNTZEN	1,049,726	1,458	3,000
BIOLOGY BUILDING	2,156,786	2,899	5,800
BOND HALL	749,738	1,008	2,100
BOOKSTORE	118,835	160	400
BUCHANAN TOWERS	1,933,516	2,599	5,200
CARVER GYM	1,011,209	1,359	2,800
CHEMISTRY BUILDING	3,495,890	4,699	9,400
COLLEGE HALL	220,113	296	600
COMMISSARY	418,846	563	1,200
COMMUNICATIONS	818,446	1,100	2,300
EDENS NORTH	409,015	550	1,100
EDENS SOUTH	326,613	439	900
ENGINEERING TECH	1,055,211	1,418	2,900
ENVIRONMENTAL CTR.	1,141,382	1,534	3,100
FAIRHAVEN ACADEMIC	271,471	365	800
FAIRHAVEN TOWERS	1,808,565	2,431	4,900
FINE ARTS	1,285,601	1,728	3,500
FRASER HALL	179,339	241	500
HAGGARD	472,484	635	1,300
HIGGINSON	372,118	500	1,100
HIGHLAND I & II	328,746	442	900
HUMANITIES	450,352	605	1,300
MATHES	856,278	1,151	2,400
MILLER HALL	789,833	1,062	2,200
NASH	1,030,210	1,431	2,900
OLD MAIN	1,180,680	1,587	3,200
PARKS HALL	354,735	477	1,000
PERFORMING ARTS	962,885	1,294	2,600
RIDGEWAY COMPLEX	4,035,000	6,004	12,100
RIDGEWAY DINING	1,013,088	1,362	2,800
SMATE (SCI/ED/TECH)	206,662	278	600
STUDENT RECREATION	1,355,075	1,821	3,700
VIKING COMMONS	1,087,149	1,510	3,100
VIKING UNION	1,106,175	1,487	3,000
WILSON LIBRARY	792,874	1,066	2,200
Totals:	**35,765,184**	**48,794**	**99,400**

1. Peak monthly consumption determined by linear regression of data from 2011-2016
2. Peak monthly consumption calculated to 2015 WEC design day of 19F
3. Peak loading is assumed at 2x average loading
4. Ridgeway Complex is sum of individual Ridgeway buildings.
5. Data for Carver is pre-remodel

With the preceding estimate for building full load steam requirements, the distribution system was analyzed for the maximum capacity that could be expected. Three main distribution branches were identified; T-1 with buildings from Carver to Nash, U-1 with buildings from Miller to Higginson, and T-2 with buildings from Chemistry (Morse) to Buchanan.

These distribution branches are interconnected in segments to allow buildings to be fed from multiple directions. Branches T-1 and U-1 are interconnected between Wilson Library/Old Main and Nash/Higginson. Branches T-1 and T-2 are interconnected between Ridgeway and Student Recreation.

The following table was created by adding up building loads along the presumed direction of flow. This assumption, about the presumed direction of flow along the branch lines, essentially ignores the feed potential from the interconnections. Overall, the distribution system appears to have adequate capacity to add significant new loads. The 10” branch line preceding carver gym can support an additional 19,200 lb/hr at the current design velocity. The 6” line to Miller hall can support an additional 13,800 lb/hr and the 10” line to the Chemistry Building (Morse) can support an additional 15,000 lb/hr.

There does appear to be one potential bottleneck in the distribution system that currently exceeds the design limit of 7,200 fpm for steam velocity; the line between Bond Hall and Haggard. The expected maximum flow exceeds the pipe capacity by 100 lb/hr. This is currently not a problem as flow can be provided from the interconnection point to loop U-1 to feed buildings “downstream” (Wilson, Humanities, and Fraser in the current assumed flow direction).

It is also important to note that even in a worst case scenario where a branch line is obstructed or valved off there would not likely be any adverse effects to the piping system. The above numbers are based on a full steam flow scenario which would be quite unlikely due to system diversity. In addition to this, steam velocities could likely be doubled to a maximum of 15,000 for short periods of time indicating that there is an approximate safety factor of 2 in regards to velocity.

The values for condensate are shown for reference only as they reflect what the theoretical maximum flow would be if all the condensate receivers were discharging simultaneously. In reality, all the building's condensate flows would be staggered due to the built in storage the condensate receivers provide.

A visual representation of the current distribution capacity can be found in the appendix.

Branch	Bldg. Initials	Building Name	HPS Line Inches	Required Capacity Lb/hr	Available Capcity Lb/hr	PC Line Inches	Required Capacity GPM	Available Capacity GPM
Fine Arts	FI	Fine Arts	2"	3500	-1,200	1-1/2"	12	3
T-1	CV	CARVER GYM	10"	41,600	19,200	3-1/2"	388	-150
T-1	HI	HIGHLAND I & II	10"	38,800	22,000	3-1/2"	371	-133
T-1	SL	SMATE (SCI/ED/TECH)	10"	37,900	22,900	3-1/2"	365	-127
T-1	RC-ALL	RIDGEWAY COMPLEX	10"	37,300	23,500	3-1/2"	335	-97
T-1	RC	RIDGEWAY DINING	10"	25,200	35,600	3-1/2"	262	-24
T-1	BH	BOND HALL	6"	22,400	-100	3-1/2"	246	-8
T-1	HH	HAGGARD	6"	20,300	2,000	3-1/2"	233	5
T-1	HU + FR	HUMANITIES + FRASER	6"	19,000	3,300	3"	221	-131
T-1	WL	WILSON LIBRARY	6"	17,200	5,100	3-1/2"	199	39
T-1	CH	COLLEGE HALL	6"	15,000	7,300	4"	169	101
T-1	PA	PERFORMING ARTS	6"	14,400	7,900	4"	165	105
T-1	BK	BOOKSTORE	6"	11,800	10,500	4"	135	135
T-1	VU	VIKING UNION	6"	11,400	10,900	4"	120	150
T-1	VC	VIKING COMMONS	6"	8,400	13,900	4"	90	180
T-1	MA	MATHES	4"	5,300	4,500	4"	60	210
T-1	NA	NASH	4"	2,900	6,900	2"	30	0
U-1	MH	MILLER HALL	6"	8500	13,800	2"	129	-99
U-1	OM	OLD MAIN	6"	6300	16,000	4"	99	171
U-1	EH	EDENS SOUTH	4"	3100	6,700	1-1/2"	24	-9
U-1	EN	EDENS NORTH	4"	2200	7,600	2"	19	11
U-1	HG	HIGGINSON	4"	1100	8,700	2"	12	18
T-2	CB	CHEMISTRY BUILDING	10"	45800	15,000	6"	575	-30
T-2	BI	BIOLOGY BUILDING	10"	36400	24,400	6"	418	127
T-2	ET	ENGINEERING TECH	10"	30600	30,200	6"	313	232
T-2	AH	ARNTZEN	10"	27700	33,100	6"	295	250
T-2	PH	PARKS HALL	10"	24700	36,100	6"	277	268
T-2	ES	ENVIRONMENTAL CTR.	10"	23700	37,100	6"	255	290
T-2	CF	COMMUNICATIONS	10"	20600	40,200	6"	225	320
T-2	AI	ACADEMIC INSTRUCTION CTR	10"	18300	42,500	6"	195	350
T-2	SV	STUDENT RECREATION	10"	15800	45,000	4"	164	106
T-2	FA	FAIRHAVEN	8"	12100	26,500	4"	127	143
T-2	CM	COMMISSARY	8"	6400	32,200	4"	90	180
T-2	BT	BUCHANAN TOWERS	8"	5200	33,400	4"	30	240

5.3. System Improvements for Consideration

WWU should begin to make long term renewal and energy efficient investments in the existing district heating system; making sure to do so in a planned, flexible approach that provides short term improvements while setting the stage for long term expansion and conversion to new, more efficient production and distribution systems.

The following items are recommended improvements for consideration:

General:

- **Complete a Life Cycle Cost Analysis:** To best guide the university forward a life cycle cost analysis should be completed detailing different district heating and distribution possibilities. This analysis should be used to determine the most economical and environmentally sound path for the university.
    - At a minimum this analysis should include:
        - A long term analysis horizon of 40-50 years.
        - Comparison of "business as usual" steam production and distribution against a multitude of options encompassing operating and maintenance, renewal, fixed, variable, and capital costs:
            - Steam Production from CHP with Steam Distribution
            - Steam Production from Standard Boilers with Hot Water Distribution
            - Steam Production from CHP with Hot Water Distribution
            - Hot Water from Condensing Boilers with Hot Water Distribution
            - Hot Water from CHP with Hot Water Distribution
            - Hot Water from other technologies with Hot Water Distribution
            - Carbon reduction methods such as Biogas
            - Additional items as deemed worthwhile of study for comparison

In-building systems:

- **Update Heating System Specifications:** To best enable the future buildings to support the implementation of renewables and renewable technology into the district heating system, WWU should consider revising their building heating specifications applicable to remodels and new construction.

  This could include the requirement that all future buildings and future building renovations be connected to the district heating system and that these systems utilized low temperature in-building hot water distribution systems fed from a main heat exchanger. Consideration should be given to designing to the lowest hot water distribution temperature possible with the highest delta in temperature (160F supply temperature for existing buildings and 140F or less for new construction). This will provide a more efficient building and increase the efficiency of the overall district energy plant

  Low temperature building systems provide the most flexibility to the existing district energy system by allowing the condensate return temperature at the plant to be lowered over time. This provides lower losses within the overall distribution system while also allowing for the implementation of condensing stack economizers at the plant. It also provides for an easy transition to an overall heating hot water system for the campus at some point in the future.

  Low temperature hot water systems also enable the efficient implementation of a new heating production source at the district heating plant; such as cogeneration (reciprocating engines, micro-turbines), heat pumps, geo-exchange, and solar thermal.

- **Building Energy Transfer Stations upgrades:** Building energy transfer stations (ETS) are the interface between the district steam network and the in-building heating system. All buildings have some form of ETS that vary from a pressure reducing valve station on buildings that utilize direct steam, to a steam heat exchanger that provides hot water to a building. Various modifications can be made at the ETS and building level to make existing and future buildings more flexible and beneficial to the district heating system. These items include:

  - **Convert to heating hot water:** In buildings that still utilize direct steam from the district network, begin the conversion process to hot water. In-building hot water distribution experiences less thermal energy losses and has higher controllability than existing steam systems. Buildings converted to hot water should attempt to achieve the lowest hot water supply temperature as practical to enable better integration into a future hot water district network.

- o **Reconfigure existing domestic hot water production:** In most buildings, domestic hot water can be reconfigured from taking direct steam (or being an electric standalone unit) to utilizing steam condensate and water storage. This could reduce the steam condensate return temperature low enough to enable condensing boiler operation at the steam plant. A suitably designed system could take advantage of up to 97% of the thermal energy of the steam sent to the building (corresponding to ~70F condensate return temperature – depending on building loading).

- o **Lower building level steam pressure:** On buildings that utilize hot water heating there may be the opportunity to lower the discharge pressure from existing steam PRV's serving the heat exchanger. Typical design for hot water heat exchangers is typically a maximum of 15psig steam input. During a site walk it was noticed that a building heat exchanger was operating at approximately 30 psig (and it should be noted that it was unclear if this pressure was needed for an internal building process). Operating above 15 psig increases losses in the building level flash tank and condensate receiver as the latent energy of steam decreases with increasing pressure. Each building should be checked to ensure it is operating at the minimum steam pressure required.

- o **Install additional building-side metering:** In buildings that utilize hot water for heat, additional meters can be installed to provide a more in-depth picture of building energy usage. Hot water supply/return temperature with flow rate trended on 5 min, 10 min, 15 min, or hourly intervals can give a detailed look into how each building is operating. This level of data collection can be used to identify problems in the building heating system and can track equipment operation/efficiency.

Distribution System

- **Convert from Steam to Hot Water (HW) District Distribution:** This measure could provide WWU an opportunity to greatly improve system efficiency, reduce operating and maintenance costs, and utilize additional automation within the plant. HW production (ideally with a goal of low temperature distribution) would also enable the central plant to incorporate renewable technologies such as low grade waste heat recovery (i.e.: from chillers, process loads, or solar thermal), thermal storage (to allow for load shifting), combined heat and power and/or ground source heat pumps. Rough order of magnitude (ROM) estimated costs and savings potentials can found below.

Conversion could happen in a few ways. The distribution system could be converted after all the campus buildings were converted to hot water, individual hot water distribution legs could be installed in the tunnel with current hot water buildings connected and converted buildings connected over time, or both in-building systems and distribution could be updated in one large project.

The conversion to HW provides the single largest potential for energy efficiency improvements and carbon reduction over the current steam production. For example, a condensing boiler HW production plant could see a thermal efficiency of 88-97% and a distribution efficiency of 90-95% for an overall efficiency of 80-92%.

District Heating Production Plant:

The production plant presents challenges not seen in the in-building/distribution system due to the age of production equipment and the need for renewal. These issues could be eliminated if a large project was implemented to avoid cost expenditures on steam renewal, however, the total cost to implement such a project would most likely be difficult to fund fully using traditional funding means. In any case, improvements made to the Steam Plant should be completed with the conversion to hot water production and distribution (in the future) in mind.

- **Budget for System Renewal and/or Replacement:** The existing district steam system is increasing in age and will be due for significant upgrades in the near future. A majority of the Steam Plant equipment is older and technically past it's useful life (although it has been thus far kept in service due to proper care and due diligence). If the steam system is to be replaced, appropriate costs should be developed depending on the technology considered. If the existing steam system is to be maintained there will be a need for some initial investment to upgrade systems in addition to a need to invest ongoing system renewal dollars annually. In the future it is recommended that following ranges of numbers be budgeted for continual renewal of the system over an assumed 15 year period:
    - Steam Plant Equipment & Piping: $750,000 - $1,100,000 per year
    - District Steam Piping: $700,000 - $1,000,000 per year

- District Condensate Piping: $450,000 - $750,000 per year

- **Install Modular Steam Boilers:** In lieu of purchasing a single large boiler of like size upon replacing existing steam boilers (and contingent upon a determination of whether the campus will at some point be converted to hot water), consideration should be given to purchasing multiple smaller, more modular, steam boilers to cover the same load. Boilers of roughly 15,000-25,000 lb/hr steam output should be able to improve overall production efficiency by providing a higher level of turn down for the low-mid level steam load that the campus currently sees.

  Multiple modular boilers reduce capital costs because smaller boilers can be purchased as replacement is needed. Maintenance and operation expenses are reduced because operation is simplified and similar parts can be kept in stock. Consider the case of five 25,000 lb/hr boilers as opposed to the current mix of boiler sizes contained in the steam plant. The minimum flow rate from the plant is roughly 5,000 lb/hr and any of the boilers can be selected to operate in this condition. As load is increased any of the boilers can be selected allowing any required unit to be down for servicing/inspection. This allows equal run hours to be spread across all boilers. The current expected steam peak could still be served from these five boilers as well: covering the load from its current minimum to maximum. In addition, the boiler equipment/parts are similar between all the boilers allowing for reduced spare parts kept on hand.

  In the existing case with multiple boilers of various sizes, minimum load typically is covered by a single boiler that can operate the most efficiently at this point. Peak loading is typically handled by the larger boilers, meaning that boiler loading is varied across the various boilers throughout the year. Also, since each boiler is a different size that means that each boiler must have its own spare parts.

- **Calibrate Natural Gas and Steam/Feed Water Meters:** Discrepancies were noticed between the supplied trending of natural gas usage and the reported usage from utility billing. There were also discrepancies noticed from the steam and feed water meters. Both sets of metering should be calibrated to ensure they are reading proper values.

- **Utilize Combustion Air Preheating:** Preheating boiler combustion air that is delivered to the boilers with heat from the exiting flue gas is a way to increase system efficiency and potentially enable condensation of the flue gas. To preheat the combustion air, a heat exchanger is installed in the boiler stack exhaust stream. Additional heat exchangers are installed in the combustion air duct work with a pumped water and glycol mixture working fluid to exchange the heat.

Typical efficiency increases range from 2% to 5% of overall boiler efficiency. Combustion air temperature can see a 100F+ rise from ambient and flue gas can see roughly the same temperature reduction.

Potential concern with installing a condensing economizer is exceeding existing fan rated static pressure. Since heat exchangers are installed both on the inlet and outlet of the boiler both forced draft and induced draft fans can be affected. Another concern is that if the existing exhaust stack's temperature is low enough, condensing of the water vapor in the flue gas can occur. This is something that would need to be designed and prepared for (as in ensuring the heat exchanger in the flue gas is made of stainless steel and designed to remove all the moisture without exposing non-stainless steel components).

A final note is that with heating of the combustion air its density will decrease the hotter it becomes. This can mean that existing air/fuel ratios and controls could need to be upgraded if an oxygen trim device does not already automatically control them. Without a full modulation of the air/fuel ratio the less dense air could mean that not enough excess air is being provided to ensure proper efficient combustion.

- **Install Condensing Economizers:** A condensing economizer could provide WWU with additional efficiency gains from the steam production equipment. Condensing economizers condense the water vapor that is produced during the combustion of fuel to extract as much energy from the combustion process as possible. The condensing economizer would be installed in the exhaust stacks of the existing boilers downstream of the current traditional economizers. Makeup water, low temperature steam condensate, or heating hot water (if such a line was created on the campus) could be pumped through the economizer to bring the exiting boiler flue gas down below approximately 130F to extract the latent heat of the flue gas water vapor. Efficiency gains could be on the order of 5% to 7% of overall boiler efficiency – dependent on how low in temperature the working fluid is.

  In order to optimize condensing economizer, a lower temperature fluid is needed to bring the exhaust gas below the condensing point. Existing makeup water flow doesn't appear substantial enough and current steam condensate return temperature is not low enough to provide full optimization of a condensing economizer. However, if this measure were to be implemented in a sequenced, coordinated effort with the implementation of high efficiency energy transfer stations and/or reutilization of waste heat from the condensate lines at select locations (for domestic HW or process loads), the condensate return temperature may be able to be lowered enough to provide substantial efficiency gains from this measure.

Improvement Overview

Below is a table denoting the estimated rough-order-of-magnitude (ROM) cost and ROM lifecycle simple payback ranges for the items listed above. The following cost numbers are the total cost to implement the project (including estimated design, management, contingency, and taxes). While lifecycle simple payback is shown in the table, a more thorough assessment of true cost and benefits would be displayed by completing a long term life cycle cost analysis of the alternatives versus business as usual. The conversion to hot water would likely show improved net present value savings over business as usual when accounting for avoided renewal, operation and maintenance cost, and energy savings over 40-50 years.

Description	ROM Cost Est (+/- 30%)	ROM Yearly Energy Savings (+/- 30%)[1]	ROM Campus Utility Carbon Reduction (+/- 30%)	ROM Lifecycle Simple Payback (+/- 30%)[2]
Combustion Air Preheating	$450,000	$20,000	1%	16
Modular Steam Boilers (25 MMBtu/h) per boiler	$1,250,000	$35,000	1%	24
Condensing Economizers (assuming lowered return water temperature)	$750,000	$75,000	3%	15
New HW Distribution System (Existing Steam Production Plant)	$22,000,000	$350,000	15%	16
New Hot Water Production & Distribution System	$38,000,000	$450,000	17%	16
CHP with Existing Steam Production and Distribution System	$16,000,000	$500,000	7%	20
New Hot Water Production & Distribution System (Recip CHP & TES)	$49,000,000	$1,200,000	25%	17

Notes:
1. ROM Energy Savings accounts for utility savings only.
2. Anticipated Simple payback when accounting for the expected required expenditure to renew, operate, and maintain the existing steam production and distribution system (business as usual; BAU). This reflects the incremental payback by implementing the proposed measure.

It should be noted that there are a few funding options when it comes to completing projects for a University. In addition to state allocations and loans there has been an increase in public-private-partnerships (PPP or P3) as an alternate funding mechanism. If there was a desire to attempt to fund the conversion to hot water in a single large project this could be attractive alternative. In a PPP a joint initiative is taken from WWU and an outside party. The outside party brings funds to construct, own, and operate a new district energy plant that then becomes a thermal utility serving WWU on a long term contract. The PPP benefits both parties by providing the University with an opportunity to fund a complete turnkey project, reduce labor requirements, reduce liability, reduce operating complexity, and the private party benefits from a long term reliable customer.

5.4. Heating System Conclusions

Western Washington University owns and maintains a significant district heating system that provides heat to the majority of the buildings on the WWU campus. This district heating system comprises of a steam generation and distribution system with the campus buildings either taking direct steam or converting the heat to hot water for in-building distribution. The following items are highlights from the main document, meant to give a brief overview of important aspects of the district heating system:

- Most of the existing steam boilers are past their useful life which will make operating and maintain them more of a challenge in the years to come. The current age span of the boilers is 22-71 years with an average age of 50 years across all five boilers.

- The overall efficiency of the district heating system is 56.5% over the last five years. This low efficiency is due to the inherit nature of steam distribution being a high temperature and near constant pressure system.

- Given the current boiler capacity, piping configuration, and distribution pipe capacity, it is expected the existing district heating system can accommodate up to 380,000 additional sq.ft. of new building space assuming a nominal heating intensity of 40 btu/hr/sq.ft.

- There are a significant number of heating technologies that can be used to supplement, augment, and/or replace the existing steam production and distribution system. These options mainly depend on if the system stays with a steam distribution system or converts to a hot water distribution system. Sticking with a steam distribution system has the advantages of utilizing existing distribution piping and equipment but typically comes at reduced benefit as compared to a hot water distribution system. Hot water distribution would see significant efficiency gains, have the ability to accommodate renewables and renewable technology, and most likely provide the highest economic benefit. All these benefits come at the cost of a much more involved and complicated project that would affect every connected building on campus.

The following is a list of recommended measures for Western to consider:

General:

- **Complete a Life Cycle Cost Analysis:** A life cycle cost analysis should be completed detailing different district heating and distribution options as compared to “business as usual” steam production and distribution. This analysis should include a long term horizon of 40-50 years and encompass all costs such as operating and maintenance, renewal, fixed, variable, and capital costs.

In-Building Systems:

- **Update Specifications:** Building mechanical specifications for remodels and new construction can be updated to promote usage of renewables and increased flexibility for the district heating system. Building specifications could be updated to require buildings to use low temperature hot water systems with high differential temperatures. This requirement would like correspond to the least building level heating usage and enable the district heating system to incorporate renewable technologies.

- **Energy Transfer Station Upgrades:** Building level energy transfer stations can be modified in a wide range of ways to enable increased efficiency gains (in the case that buildings are converted from steam to hot water), the ability to enable condensing at the steam plant (by dropping condensate return temperature with suitable design configurations), provide better data/information about building performance (by monitoring instantaneous heating usage or sub-metering specific equipment), and to provide a flexible way to decouple the building from the distribution system in the event that the distribution system is converted to hot water.

Distribution System:

- **Steam to hot water production:** Converting from steam to hot water distribution could provide significant efficiency gains both in the Steam Plant and the distribution system. Thermal efficiency would be increased in the steam plant by enabling the use of a condensing economizer with sufficient hot water return temperature. For the distribution system, overall efficiency would improve significantly due to the much lower temperatures and pressures that a hot water system operates on. Hot water production also enables for additional low temperature heat recovery opportunities as well as the integration of renewables such as solar thermal.

Heating Production Plant:

The production plant presents challenges not seen in the in-building/distribution system due to the age of production equipment and the need for renewal. Improvements made to the Steam Plant should be completed with the conversion to hot water production and distribution (in the future) in mind.

- **Budget for System Renewal or Replacement:** The existing district steam system is increasing in age and many pieces of equipment are technically past their useful life. Although system life has been extended due to proper maintenance and care, the system will need major upgrades in the near future. If the steam system is to be replaced, appropriate costs should be developed depending on the technology considered. In the future it is recommended that following ranges of numbers be budgeted for continual renewal of the system over an assumed 15 year period:
    - Steam Plant Equipment & Piping: $750,000 - $1,100,000 per year
    - District Steam Piping: $700,000 - $1,000,000 per year
    - District Condensate Piping: $450,000 - $750,000 per year

- **Modular Steam Boilers:** If the district heating system is to stay in steam production and distribution, modular steam boilers could be a sufficient way to improve operation and efficiency of the boiler system. In lieu of purchasing like for like sizes for replacement of existing boilers, smaller boilers of consistent size can be purchased instead.

- **Calibrate Natural Gas and Steam/Feed Water Meters:** Discrepancies were noticed between the supplied trending of natural gas usage and the reported usage from utility billing. There were also discrepancies noticed from the steam and feed water meters. Both sets of metering should be calibrated to ensure they are reading proper values.

- **Combustion air preheating:** This measure could be a way to increase the overall thermal efficiency from the Steam Plant and potentially enable the condensing of the water vapor in the flue gas stream.

- **Install condensing economizers:** to increase overall thermal efficiency from the Steam Plant. This measure would be dependent on a low temperature heat sink to enable condensing of the water vapor in the flue gas stream.

Improvement Overview

Below is a table denoting the estimated rough-order-of-magnitude (ROM) cost and ROM lifecycle simple payback ranges for the items listed above. The following cost numbers are the total cost to implement the project (including estimated design, management, contingency, and taxes). While lifecycle simple payback is shown in the table, a more thorough assessment of true cost and benefits would be displayed by completing a long term life cycle cost analysis of the alternatives versus business as usual. The conversion to hot water would likely show improved net present value savings over business as usual when accounting for avoided renewal, operational and maintenance cost, and energy savings over 40-50 years.

Description	ROM Cost Est (+/- 30%)	ROM Yearly Energy Savings (+/- 30%)[1]	ROM Campus Utility Carbon Reduction (+/- 30%)	ROM Lifecycle Simple Payback (+/- 30%)[2]
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CHP with Existing Steam Production and Distribution System	$16,000,000	$500,000	7%	20
New Hot Water Production & Distribution System (Recip CHP & TES)	$49,000,000	$1,200,000	25%	17

Notes:
1. ROM Energy Savings accounts for utility savings only.
2. Anticipated Simple payback when accounting for the expected required expenditure to renew, operate, and maintain the existing steam production and distribution system (business as usual; BAU). This reflects the incremental payback by implementing the proposed measure.

It should be noted that there are a few funding options when it comes to completing projects for a University. In addition to state allocations and loans there has been an increase in public-private-partnerships (PPP or P3) as an alternate funding mechanism.

5.5. Appendices

5.5.1 Reference Material

5.5.2 Review of Heating Technologies

5.5.3 Existing Heating System Piping and Instrumentation Diagram

5.5.4 Steam Plant Layout

5.5.5 Steam/Condensate Distribution Map

5.5.1. Reference Material

Notable District Steam to Hot Water Conversion Projects:

- University of British Columbia: http://energy.ubc.ca/ubcs-story/stats-metrics/
- Stanford University: http://sustainable.stanford.edu/campus-action/stanford-energy-system-innovations-sesi
- District Energy St. Paul: http://www.ever-greenenergy.com/project/district-energy-st-paul/
- Ball State University: http://cms.bsu.edu/about/geothermal
- Eastern Illinois University: http://www.eiu.edu/sustainability/eiu_renewable.php

Notable University Steam District Energy Systems:

- Princeton University: https://facilities.princeton.edu/news/the-princeton-energy-plant
- Texas A&M University: https://utilities.tamu.edu/combined-heat-power/
- Cornell University: https://energyandsustainability.fs.cornell.edu/util/districtenergy.cfm

Notable District Energy Case / Analysis Studies:

- US ACE CRREL Report 95-18, *Efficiency of Steam and Hot Water Heat Distribution Systems*
- United Nations Environment Programme, *District Energy in Cities*
- ASHRAE Journal, May 2010, *Water & Energy Use in Steam-Heated Buildings*

5.5.2. Review of Heating Technologies for Consideration

The goal of this section is to discuss potential technologies that can supplement, augment, and/or replace the existing steam boilers that currently serve the WWU campus. Each item provides a potential pathway to a more economic and sustainable heating system for the campus.

The following information provides only a cursory overview of each technology. A thorough discussion and analysis to what technology/technologies provides the most benefit to the campus is outside the scope of this document. At a minimum, such an analysis should conduct a total cost of ownership analysis, comparing all alternatives against current operation, for an extended time horizon of 40/50 years by a qualified engineering company.

Condensing Boilers

Modular condensing boilers utilize low temperature hot water to enable condensing of the water vapor contained in flue gas due to combustion. These boilers offer substantial efficiency gains over existing non-condensing boilers. Condensing boilers can see thermal efficiencies from 92% to 98% as compared to the theoretical maximum of 86% of a non-condensing boiler.

Condensing boilers are typically made of stainless steel to handle the corrosive nature of the condensed flue gas water. The condensed water is typically collected and neutralized before being sent to drain.

The drawbacks to condensing boilers are that they are limited to producing hot water and are typically smaller in size. An equivalent means of provide stack condensing in a steam system requires the implementation of an additional condensing stack economizer and a strategy to provide the available stack heat to a reliable heating need on campus.

- **Preliminary Analysis Steam to Hot Water Conversion with Condensing Boilers**

  A preliminary analysis of the potential of applying condensing boilers in a new hot water distribution system was completed. This analysis compared the proposed hot water system to the existing steam system. In the existing steam system, the average heat load is approximately 170,000 MMBTU/year, electrical usage is 33,000 MWh/year, and carbon emissions of 24,000 Mtons/year for a total energy cost of $3,500,000/year.

In a new hot water distribution system, the expected yearly heat load on the campus is on the order of 120,000 MMBTU due to reduction in distribution losses. Electrical usage would remain relatively unchanged as the power requirements for a hot water boiler system are not noticeably different than that of a steam boiler system. The condensing boiler system could generate annual energy costs savings in the range of $300,000 - $500,000/year with carbon reductions ranging from 10%-18%.

High Temperature Heat Pumps

High temperature heat pumps (HTHP) are similar to conventional heat pumps in that they move heat from a lower grade source to a higher source. Most HTHP utilize carbon dioxide as the refrigerant and operate in a trans-critical cycle at very high pressures. Output conditions are typically 180-190F hot water and 42-45F chilled water. Typical COP's will be 3-4 for heating and max out near 7.0 for simultaneous heating/cooling operation.

In order to make use of a HTHP the WWU campus would need to convert to a heating hot water (HHW) distribution system as the production temperatures are much too low for steam generation. If WWU did convert to a HHW distribution system, a HTHP could be a compelling option for WWU once enough chilled water load was aggregated on the campus.

Heat recovery chillers are similar to high temperature heat pumps but typically operate with a more traditional refrigerant (R134A) and output lower grade heat (~150F or less). Typical COP's are similar to HTHP's.

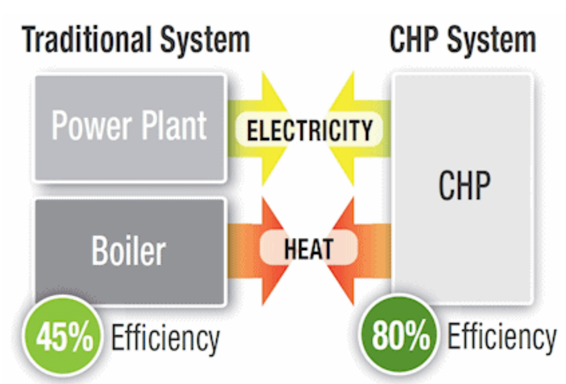
Heat recovery chillers would also need a HHW distribution system in order to be integrated into the WWU campus. The tradeoff between a heat recovery chiller and HTHP is that the heat recovery chillers operate on a more traditional refrigerant and have more industry presence.

Another item of note for both high temperature heat pumps and heat recovery chillers is that the current utility structure would put a design requirement on the system in order for it to be more economical than condensing boilers/CHP in a hot water application. Current gas and electricity rates are $5.00/MMBtu and $21.79/MMBtu respectively. Assuming efficiency near the lower end for condensing boilers/CHP (90% and 80%) the required design COP would be 3.9/3.47 to equal the cost of the same sized gas burning unit. At these COPs it would most likely be a requirement to harvest the cooling provided from the unit for productive use. Another item to note is that as heating COP requirement is pushed higher it typically comes at the exchange for a lower output temperature the unit can provide.

Combined Heat and Power

Also known as cogeneration, combined heat and power (CHP) is a way to increase the efficiency of power plants. Interestingly enough, most conventional power plants produce waste heat as a by-product of generating electricity and then discharge this valuable heat resource to the atmosphere. Standard power plants effectively use just 40 percent of the fuel they burn to produce electricity. Sixty percent of the fuel used in the electric production process ends up being rejected or "wasted" up the smokestack as heat. One of the biggest uses of fossil fuel globally is for generating this same heat resource. CHP offers the opportunity to generate electricity locally and capture the waste heat for use in heating buildings and neighborhoods.

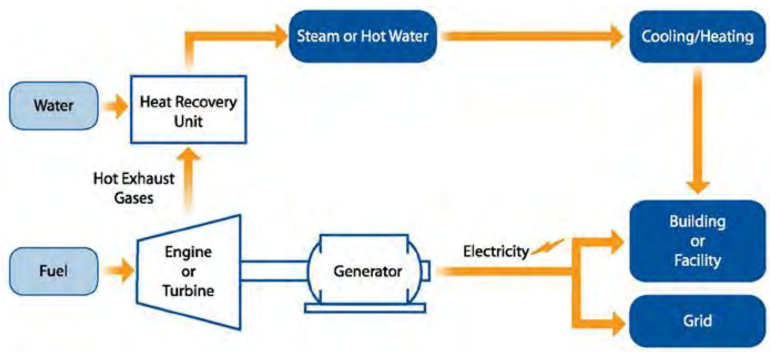
CHP along with thermal storage creates a “smart grid” compatible facility capable of working cooperatively with the local utility in modes of operation that benefit both the Campus and the utility. Examples include afternoon CHP operation in the late summer and fall when hydroelectric resources can be limited. This type of operation would help the local utility especially as Washington eliminates coal generated power.



The heat generated by the CHP can be stored in the thermal storage tanks for utilization during morning warm up and for reheat in buildings with Variable Air Volume (VAV) systems, a very common building HVAC system.

CHP with thermal storage also makes a campus and utility more resilient against utility source power interruptions from transmission lines and central power production facilities outages (wild fires, flooding, earthquake, terrorist, etc.). Also, thermal storage allows for the unit to be maintained without additional production equipment operating (in lieu of backup boilers or additional CHP units to provide heat).

CHP Technologies



Today's market conditions increasingly favor distributed generation fueled by natural gas and renewable fuels. The addition of heat recovery from the power generating source and thermal storage makes the economics all the more attractive. When developing a distributed generation system, there are two primary power sources: reciprocating engines and turbines. Both systems have been proven throughout the US and the world in many thousands of cogeneration installations.

Over the years, both of these technologies have continued to improve in overall operating efficiency, reliability, operating costs and emissions performance. Neither technology is necessarily superior to the other. Instead, each has attributes that make it the most suitable for a specific application due to conditions of fuel type availability and quality, thermal and electric load profile, physical space, local conditions, or other factors. There are also applications where reciprocating engines and turbines work together and provide the ideal levels of electrical reliability, efficiency and economic benefits.

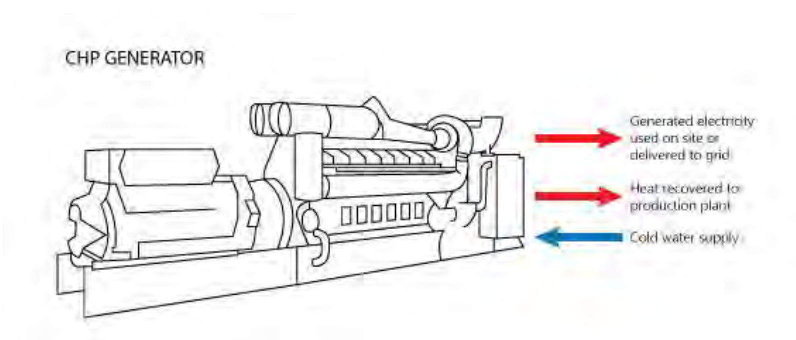
In addition to the economic benefits, CHP can help organizations live up to their sustainability, carbon-reduction, and energy-conservations goals.

As distributed generation resources, both reciprocating engines and turbine are fairly easy to install. In addition, up-front costs per kW are relatively low. The reliability is high, often up to 98 percent annually when properly maintained and operated. Both can also operate efficiently on a variety of fuels and systems are able to accommodate available space through various, flexible configurations.

Reciprocating Engine

Reciprocating engines generally are more fuel-efficient than turbines in pure electric power applications. They have lower initial cost per kW in smaller projects (less than 5 MW) and are more tolerant of high altitude and higher ambient temperatures. They operate on low to medium pressure fuel which can eliminate or reduce the costs to install and operate a gas compressor system.

While the utilization of utility provided natural gas is the most common application, engines readily accept many alternative fuels, such as biogas, digester gas, and landfill gas, as well as specialized fuels like coke gas and coal mine methane.



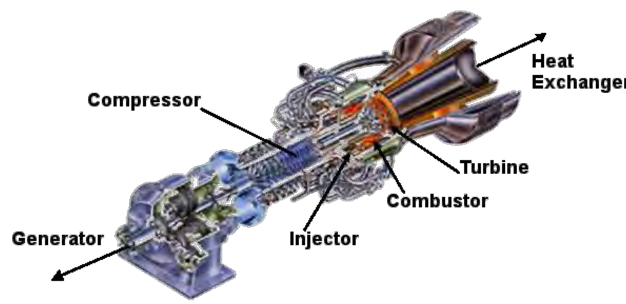
Utilized in a CHP application, engines have multiple recoverable heat sources. These include heat streams linked to exhaust, jacket water, aftercooler, and oil cooler. These recovered heat resources can be used to produce warm water, hot water, and even low quantities of medium-pressure steam (from exhaust).

One of the most obvious points of differentiation is an engine's ability to follow variable loads and to come online quickly (in most cases within 30 seconds). These attributes makes them good candidates for distributed generation in support of electric utility grids. Often, utilities need more capacity to fulfill high-cost peak demands that may occur only during a few weeks each year. This ongoing need can sometimes be filled with, fast-online resources located near the point of end use. Fuel oil powered generators have typically been used for this purpose. With stricter air-quality regulations coming into effect in recent years, coupled with an increase in fuel oil prices, gas-engines are becoming better suited to provide this resource.

With small amounts of steam that can be generated by a reciprocating engine, this technology would truly only viable if Western were to switch to a HHW system.

Gas Turbine

When utilized in a CHP application, the best asset of a gas turbine is their high heat-to-power ratio. Turbines can produce large volumes of exhaust gas at very high temperatures (often up to 1100°F). This low pressure, high volume exhaust is capable of generating high-quality, high-pressure steam, as well as high temperature hot water.



Turbine emissions are also lower than that of a reciprocating engine. They are ideally suited for loads of 5 MW and up; although continued improvements and modifications to technologies are opening the door to turbine utilization in much smaller applications. They can operate on low-energy fuels (biogas/syngas, etc.) and perform extremely well with high-Btu fuels, such as propane.

With a high uptime, turbines offer full-load operation for extended annual hours with very little downtime required for maintenance. Turbines are also relatively lightweight with a compact footprint when compared to a reciprocating engine. Today's turbines have a simple design (i.e.: no liquid cooling system and no spark plugs). Major overhauls require only combustor replacement after about 60,000 hours of duty.

For the WWU campus gas turbines could be an attractive alternative to meet the existing steam loads while producing electricity for consumption on campus. If Western decided to switch to a HHW distribution system, the turbine could also be used to produce hot water instead of steam.

Steam Turbine

Steam turbines are a tried and tested CHP technology that use steam energy to turn a generator that produces electricity. Steam turbines are typically one of the cheapest CHP technologies to install (excluding the steam generating equipment). In order to operate a steam turbine effectively, the inlet steam conditions have to be of high pressure and temperature (~600psi/700F or greater).

Steam turbines can also be used to augment gas turbines to increase the amount of electrical generation from a steam producing system. When a steam turbine is used with a gas turbine it is referred to as a “combined cycle” system.

An appealing use for steam turbines occurs when there is already an existing steam load that needs to be fulfilled by a central generating plant. Steam can be produced at high temperature and pressure, ran through the turbine, and sent out to the distribution at the desired lower pressure. Steam turbines can also be used in an “energy storage” scheme where steam flow can be diverted to/from a turbine depending on current steam demand from the distribution system, effectively acting like a buffer to baseload production.

In order for Western to integrate steam turbines into their existing steam plant effectively, new higher pressure class boilers and piping would be needed to allow for operation of the turbines.

Preliminary CHP Analysis

A preliminary analysis of the potential of applying combined heat and power was completed. This analysis compared the proposed CHP system to the existing steam system. In the existing steam system, the average heat load is approximately 170,000 MMBTU/year, electrical usage is 33,000 MWh/year, and carbon emissions of 24,000 Mtons/year for a total energy cost of $3,500,000/year.

An initial high level analysis of the potential financial benefits of CHP on campus indicates a range of energy cost savings of $700,000 - $1,400,000 per year; as well as an overall campus utility carbon reduction of 15-25%. This preliminary analysis was based on the application of a thermal base loaded system serving a heating hot water distribution system; and would include the implementation of thermal storage.

Thermal Energy Storage

Hot Water Thermal Energy Storage

Hot water thermal energy storage (TES) is a means to collect and productively use waste heat supplied from a cogeneration system or other intermittent waste heat source. It also extends the availability of cogeneration alternatives to serve the campus load and displace natural gas boilers when the daily heat load profile varies above and below the output capacity of the system installed. By doing this, it serves to shave the peak load and distribution system requirements, which help to reduce the installed capital cost of the production equipment. Lastly, it enables the cogeneration to run intermittently (daily cycle) during the lowest load periods during the summer. This will address minimum equipment turndown capability and facilitate scheduled maintenance.

High Temperature Thermal Energy Storage

High temperature thermal energy storage has made significant advances in recent years. Most notable is the current development of heat storing concrete that can store temperatures of up to 800F, enabling the creation of steam from a hot oil loop. These concrete storage systems are of comparable costs to current hot water TES, designed to be modular, and can be cast to conform to existing site shape conditions/requirements.

The development of this technology is still ongoing and therefore not currently recommended for implementation. It is, however, recommended to be aware of this technology as it could provide Western with an alternative to purchasing new generation equipment, provide flexibility in operation, and expanding the capability for other technologies such as CHP to be integrated into the existing steam system.

Augmenting System with Solar PV

Photovoltaic (PV) panels convert energy from the Sun to electricity. A PV system consists of the PV panels, an inverter to convert DC power produced by the panels to AC, electrical conditioning equipment, and electrical metering equipment. Additional equipment is needed to enable Sun tracking which allows the panels to be optimally positioned throughout the day.

A 1000 kW system consisting of fixed 300-watt nominal solar panels would require an area of roughly 75,000 sq. ft. of roof space. Using a tool developed by the National Renewable Energy Laboratory called PVWatts a system sized at 1000 kW with fixed PV panels would produce an average of 1,110,000 kWh per year which would be valued at roughly $83,000/year at the campus' current yearly blended electrical rate of $0.075/kWh. This electrical production is roughly 3.5% of what the campus consumes per year (in 2016 31,391,495 kWh was consumed by the campus).

A ROM cost to implement a 1000 kW PV system would be in the order of $4.5-6.2 million for fixed angle, average efficiency PV panels.

There are significant concerns and design considerations that would need to be resolved in implementing PV panels on the campus. The first hurdle would be working on/in older buildings. PV panels would require a support structure to be installed on each roof and structural evaluation of the roof supports. The panels would also add additional maintenance personnel time to inspect the system and keep the panels clean, requiring time spent working on the roof.

Augmenting System with Solar Thermal

Following the study of PV panels, implementation of Solar Thermal was evaluated. Two common types of solar thermal collectors are flat plates and evacuated tubes. Flat plates consist of a dark sun absorbing flat plate and transfers heat to water. Flat plates typically have a lower maximum operating temperature at roughly 160F or less. Evacuated tubes typically use a heat pipe surrounded by a dark sun absorbing evacuated glass tube. Evacuated tubes can produce high temperatures at roughly 350F or less. Solar thermal would also need to be implemented into a HHW distribution system as the operating temperatures are generally too low for steam production.

Using the same are allotment of 75,000 sq. ft. as the PV analysis above, approximately 1000 solar thermal collectors can be installed. This amount of panels could provide 3,000 – 6,500 MMBtu/year of heating depending on system hot water temperatures.

A ROM cost to implement a 1000 panel solar thermal system would be in the order of $2.5-$3.5 million for standard evacuated tube collectors.

Concerns and design considerations with solar thermal are similar to PV panels due to the roof mounted installations. Additional concerns include the additional piping required to interconnect each solar thermal system to the district heating network. Additional pipe runs would need to be made at each building spanning from the roof to the mechanical room. Solar thermal would also require significant storage capacity to enable its operation due to the intermittent availability of the Sun and the non-concurrent nature of heating load and solar radiation.

Additional Technologies for Future Consideration

Geo-exchange

Geo-exchange dissipates or gains energy with the earth through a series of drilled “wells”. Each well contains a loop of pipe which connects back to a main header to serve a heat pump or a series of heat pumps. This type of heat pump configuration is typically called a ground source heat pump (GSHP). GSHPs benefit from a near constant ambient temperature to extract or dissipate heat from/to which greatly improves COPs during harsher weather periods. A GSHP system would need to be coupled with a HHW distribution system as the output temperatures are too low to generate steam.

There are significant concerns and design considerations that would need to be resolved in implementing a main GSHP on the campus. The first would be the very large well field and associated piping. Each well would need to be interconnected and piped back to the main Central Plant building. This piping would take up considerable underground real estate meaning any future projects requiring pipe routing through the identified areas would need to be well planned and coordinated. Another area of concern would be the pumping energy required to circulate fluid through the piping network. Even if the piping network was designed with pumping efficiency in mind, the sheer amount of piping would still correspond to significant pumping requirements. A final concern is with the degradation over time with the well fields. If heating and cooling loads are not balanced the ground surrounding the well fields will rise/fall in temperature over time reducing the capacity of the well field. For a single building heating system this may be fine since the well field can be oversized to accommodate for any potential degradation. This may be a problem for a district energy system on the campus due to the longevity of the campus and the planned growth of the system.

GSHP systems also have to overcome the design requirement imposed by the utility rate structure. For WWU with their existing low natural gas cost it would likely be difficult to compete against technologies such as condensing boilers or CHP.

Overall, GSHP system are typically better suited for single building applications as the well fields can be done in the building profile or parking area. For the WWU Campus, remote buildings could be a viable candidate for GSHP systems. Any buildings that are near of the district heating system would likely see a better life cycle cost by directly connecting to the district heating system and serving hot water or using the district heating/cooling lines to provide tempering required for a building level water to water heat pump system.

Fuel Cells

Market tested industrial Fuel cells (carbonic type) produce power by reacting a hydrogen rich fuel (such as natural gas) with oxygen from ambient air to produce electricity, heat, and water. Fuel cells offer some of the highest electrical generation efficiencies of CHP units with a typical range of 40% - 60%.

Due to the use of natural gas as the hydrogen fuel source, the fuel cell emits essentially the same amount of CO2 as a combustion device. However, since there is no actual combustion in a fuel cell the unit does produce lower amounts of nitrogen oxide(s) and other pollutants.

A typical fuel cell installation appears to require roughly twice the same area as an equivalent sized reciprocating engine.

Given the limited amount of U.S. installations, size of plant required, and equivalent CO2 emissions as compared to more traditional technology such as reciprocating engines and combustion turbines, fuel cells are not currently a viable alternative for WWU.

Biomass/Biogas/Syngas

A biomass system consumes suitable wood fuel to produce heat. The wood fuel used in a biomass system is considered carbon neutral as burning the wood fuel releases as much carbon as the tree absorbs over its lifetime. Biomass systems require additional emission control devices to reduce the particulate matter created as a result of combustion. Biomass systems also require significant fuel transportation and storage equipment consisting of staging area for shipments of raw fuel, storage bin, and fuel augers to move fuel from storage areas to the boiler.

Biomass systems can be used to produce either steam or hot water depending on the type of boiler used.

In addition to being a net zero alternative, biomass systems also benefit from typically lower fuel costs.

A biogas system uses gas produced from the breakdown of organic matter as a fuel source. Biogas can be produced from multiple sources such as landfills and waste water treatment plants. Syngas is similar to biogas but differs in how the term is defined. Syngas is typically reserved for synthetic gases created from a specific process with a fuel. Either biogas/syngas could be integrated into the existing central plant as it can typically use the existing natural gas pipeline infrastructure. The modifications that would be required at the plant would be boiler upgrades and potential fuel conditioning.

Biogas could be generated on the WWU campus by means of anaerobic digestion (AD) depending on the waste streams available on campus. If there is sufficient food waste from the kitchens on campus and/or landscape waste, AD could be a viable option to reduce waste and produce carbon-neutral gas.

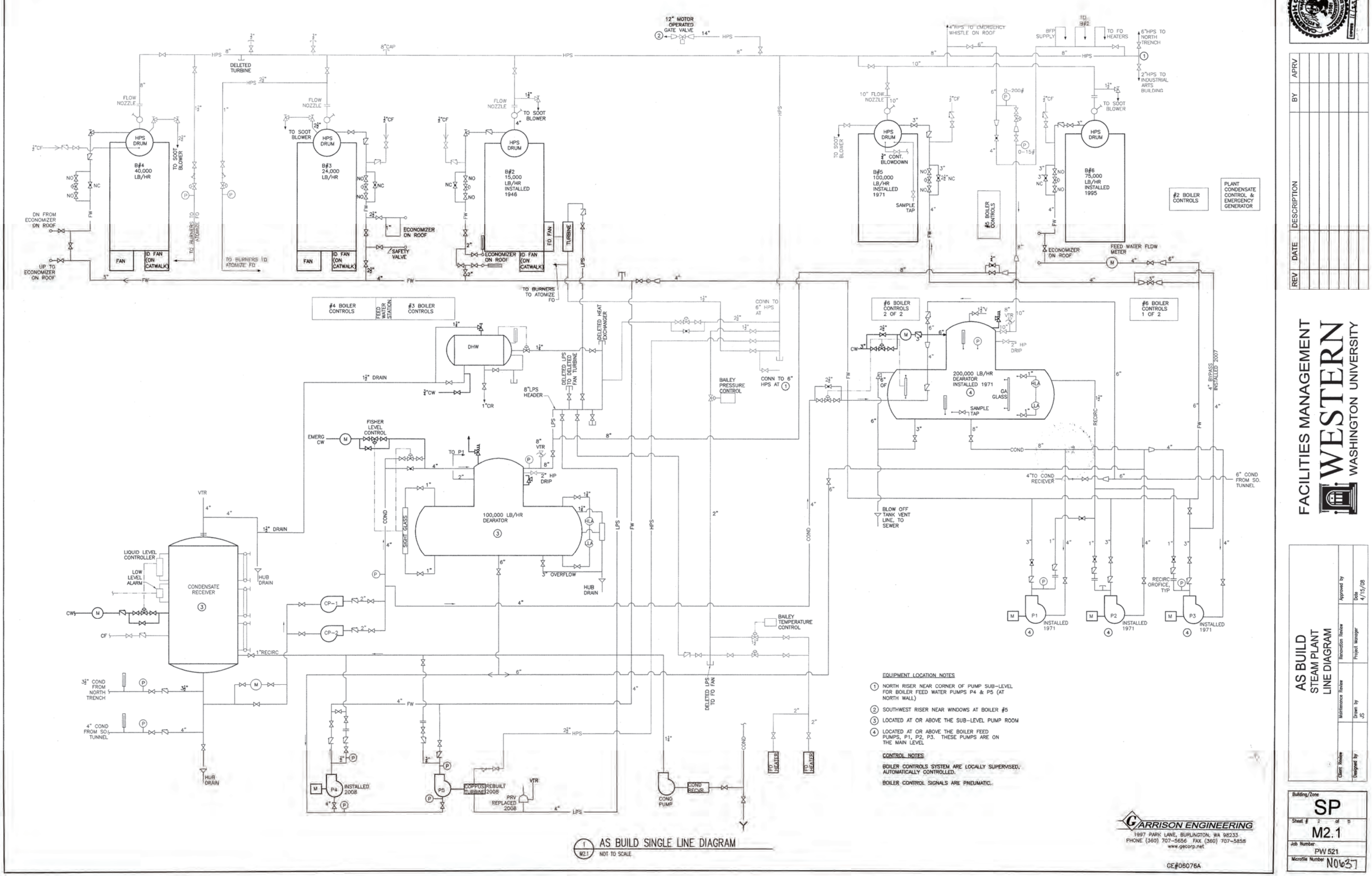
A previous study about the potential application of Biomass/Biogas has already been completed for Western Washington University. For a more detailed discussion on the topic, please review the previously completed study.

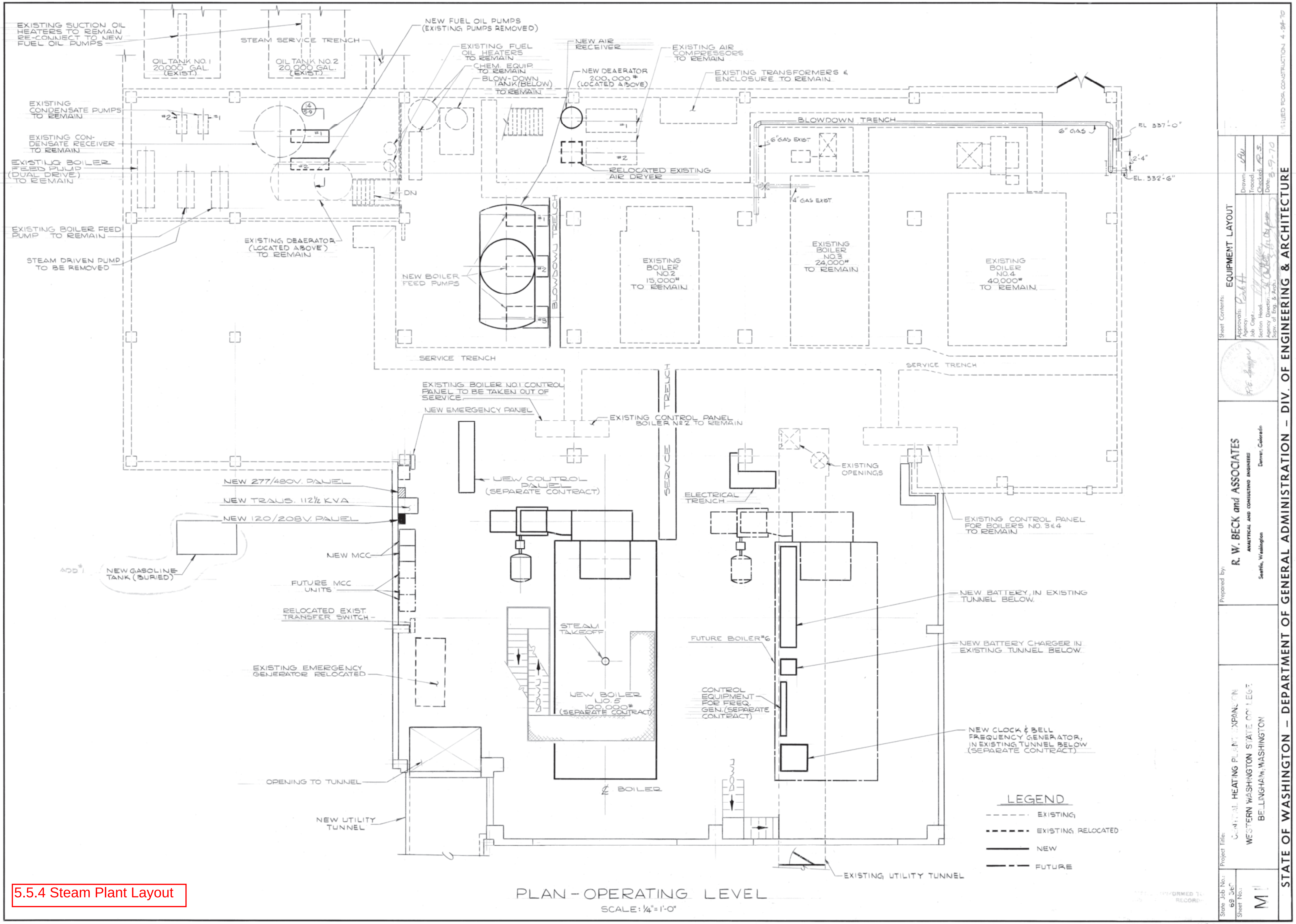
Waste Heat Recovery

A waste heat recovery system captures heat that would otherwise be wasted to the atmosphere for useful heating purposes. On the WWU campus there may only be limited waste heat available for recovery. Waste heat from the boiler exhaust streams can only be captured if there are additional technologies implemented to lower condensate temperature or if a new hot water distribution system is implemented. Heat could be recovered from the few chilled water systems located on campus if there was sufficient year round loading.

There is the potential for waste heat recovery from sources not located on the WWU campus. A previous study indicated a potential waste heat source at the nearby PSE Encogen Power Plant located on the waterfront. For a more detailed discussion on the topic, please review the previously completed study.

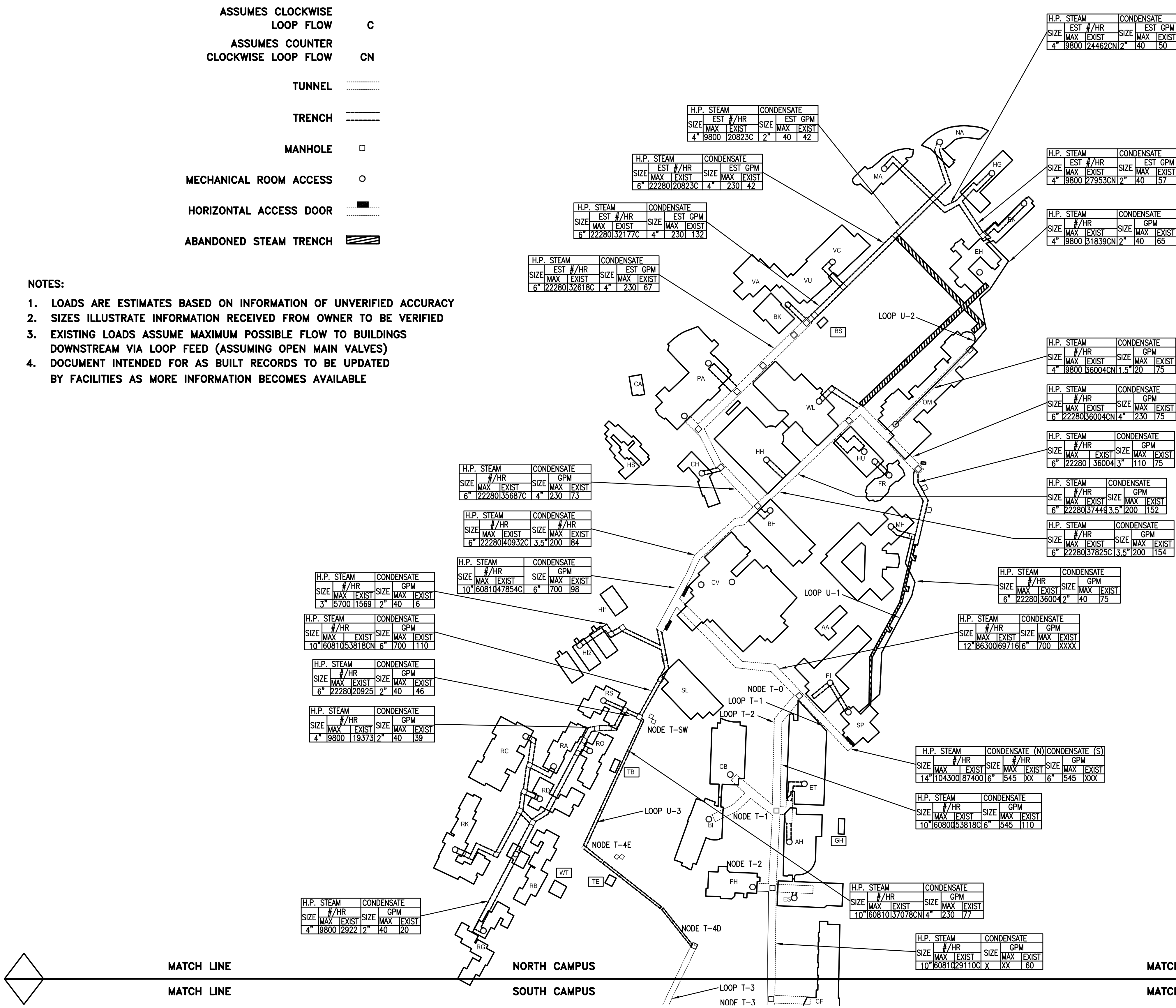
5.5.3 Heating System Piping and Instrumentation Diagram





5.5.4 Steam Plant Layout

5.5.5 Steam/Condensate Distribution Map



NOTES:

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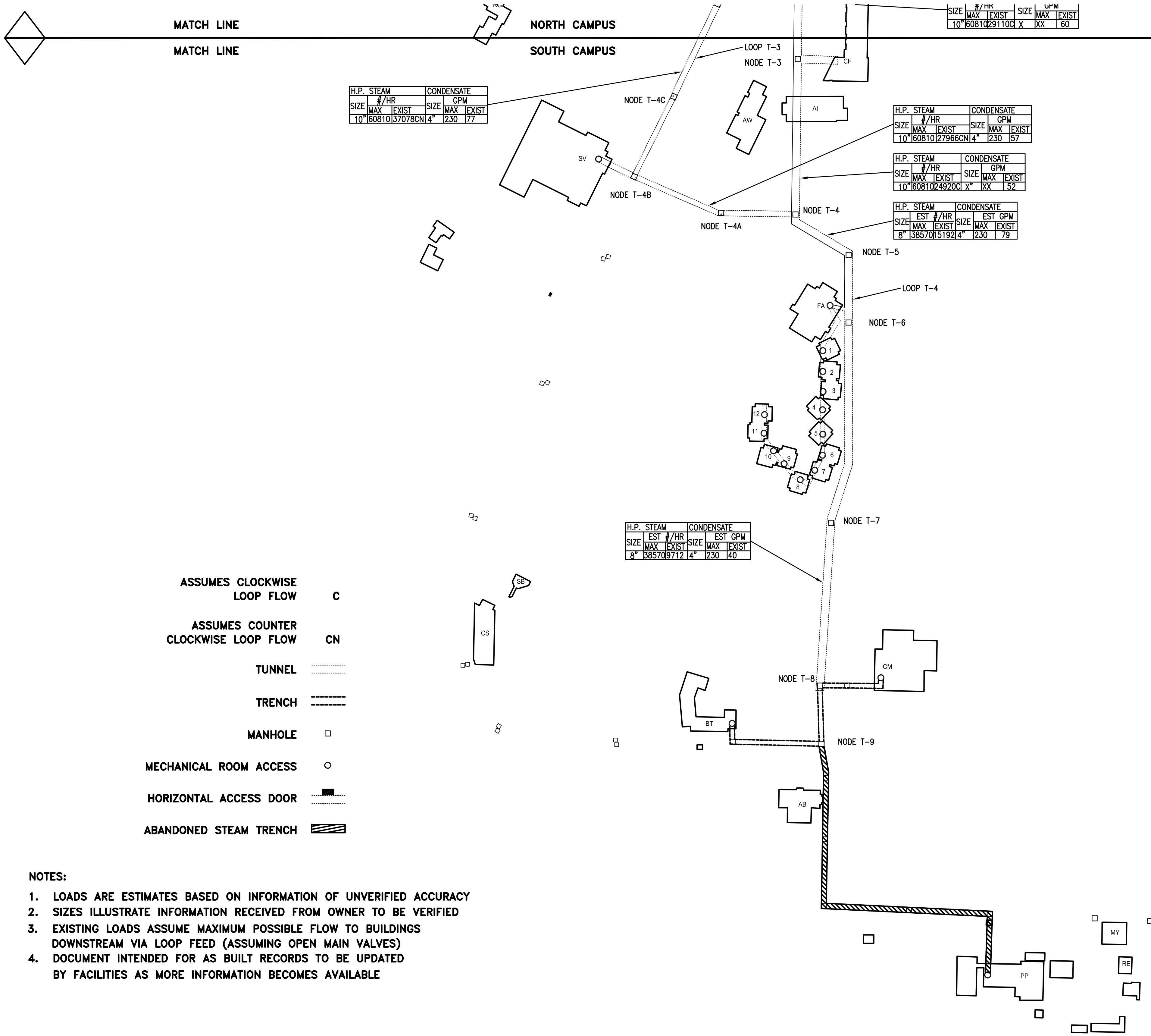
2. SIZES ILLUSTRATE INFORMATION RECEIVED FROM OWNER TO BE VERIFIED
3. EXISTING LOADS ASSUME MAXIMUM POSSIBLE FLOW TO BUILDINGS DOWNSTREAM VIA LOOP FEED (ASSUMING OPEN MAIN VALVES)
4. DOCUMENT INTENDED FOR AS BUILT RECORDS TO BE UPDATED BY FACILITIES AS MORE INFORMATION BECOMES AVAILABLE

BRANCH STEAM AND CONDENSATE TO BUILDINGS

Mark	Description	H.P. Steam			Condensate		
		Exist	Exist	Max	Exist	Exist	Max
			Peak	Recmnd		Peak	Recmnd
		Branch	Branch	Branch	Branch	Branch	Branch
		Size	lb/Hr	lb/Hr	Size	GPM	GPM
AI	ACADEMIC INSTRUCTION CENTER	6"	2,500	22,300	2-1/2"	31	50
AH	ARNTZEN	4"	3,000	9,800	4"	18	270
BI	BIOLOGY BUILDING	6"	5,800	22,300	3"	105	90
BH	BOND HALL	4"	2,100	9,800	2"	13	30
BK	BOOKSTORE	2"	400	2,300	1-1/4"	15	11
BT	BUCHANAN TOWERS	4"	5,200	9,800	2"	30	30
CV	CARVER GYM		2,800			17	
CB	CHEMISTRY BUILDING	6"	9,400	22,300	3"	158	90
CH	COLLEGE HALL	3"	600	5,700	1-1/2"	4	15
CM	COMMISSARY	4"	1,200	9,800	2"	60	30
CF	COMMUNICATIONS		2,300			30	
EN	EDENS NORTH	4"	1,100	9,800	2"	7	30
EH	EDENS SOUTH	3"	900	5,700	1-1/4"	5	11
ET	ENGINEERING TECH	3"	2,900	5,700	2"	17	30
ES	ENVIRONMENTAL CTR.	3"	3,100	5,700	1"	30	5
F?	FAIRHAVEN ADMIN		800			5	
	FAIRHAVEN TOWERS		4,900			30	
FI	FINE ARTS	2"	3,500	2,300	1-1/2"	12	15
FR	FRASER LECTURE HALL		500		1"	9	5
HH	HAGGARD	4"	1,300	9,800	2"	12	30
HG	HIGGINSON	3"	1,100	5,700	1"	12	5
HI	HIGHLAND II	4"	900	9,800	2"	5	30
HU	HUMANITIES	1-1/2"	1,300	1,400	1"	8	5
MA	MATHES	4"	2,400	9,800	3"	30	90
MH	MILLER HALL	4"	2,200	9,800	2"	30	30
NA	NASH	4"	2,900	9,800	3"	30	90
OM	OLD MAIN	6"	3,200	22,300	2-1/2"	75	50
PH	PARKS HALL		1,000		1-1/4"	23	11
PA	PERFORMING ARTS	3"	2,600	5,700	2"	30	30
	RIDGEWAY COMPLEX	6"	12,100	22,300	2"	73	30
RA	RDG ALPHA	2"	1,300	2,300	1-1/2"	10	15
RB	RDG BETA		2,100			17	
RD	RDG DELTA	2"	1,300	2,300	1-1/4"	10	11
RG	RDG GAMMA		2,300			18	
RK	RDG KAPPA		2,800			23	
RO	RDG OMEGA		1,200			10	
RS	RDG SIGMA		1,200			10	
RC	RIDGEWAY DINING	2-1/2"	2,800	3,700	1-1/2"	17	15
SL	SMATE (SCI/ED/TECH)	4"	600	9,800	2"	30	30
SV	STUDENT RECREATION	4"	3,700	9,800	3"	37	90
VC	VIKING COMMONS	3"	3,100	5,700	2"	30	30
VU	VIKING UNION	4"	3,000	9,800	2"	30	30
WL	WILSON LIBRARY	3"	2,000	5,700	2-1/2"	30	50

5.5.5 Steam/Condensate Distribution Map



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		Branch	Branch	Branch	Branch	Branch	Branch
		Size	lb/Hr	lb/Hr	Size	GPM	GPM
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ET	ENGINEERING TECH	3"	2,900	5,700	2"	17	30
ES	ENVIRONMENTAL CTR.	3"	3,100	5,700	1"	30	5
F?	FAIRHAVEN ADMIN		800			5	
	FAIRHAVEN TOWERS		4,900			30	
FI	FINE ARTS	2"	3,500	2,300	1-1/2"	12	15
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MA	MATHES	4"	2,400	9,800	3"	30	90
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NA	NASH	4"	2,900	9,800	3"	30	90
OM	OLD MAIN	6"	3,200	22,300	2-1/2"	75	50
PH	PARKS HALL		1,000		1-1/4"	23	11
PA	PERFORMING ARTS	3"	2,600	5,700	2"	30	30
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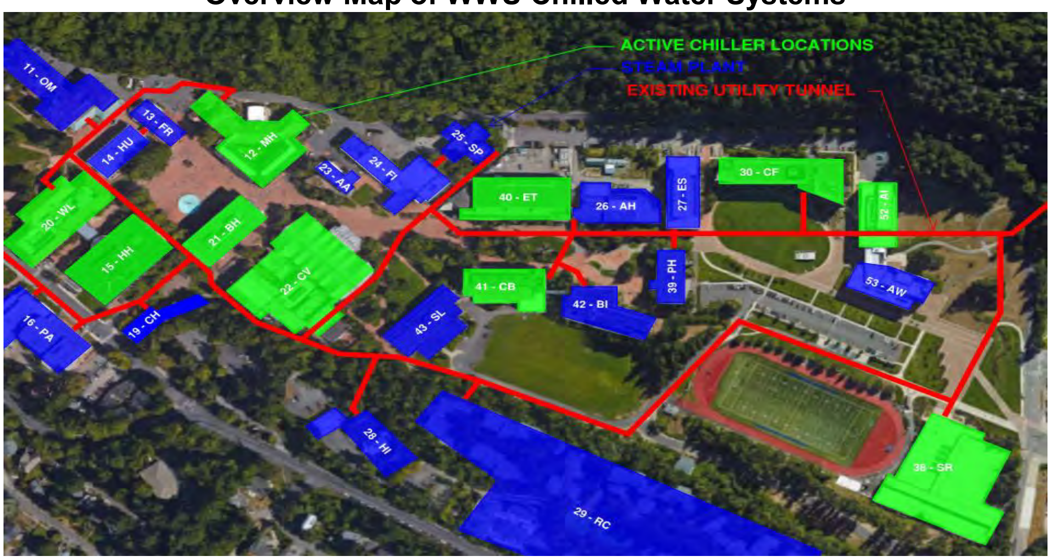
RB	RDG BETA		2,100			17	
RD	RDG DELTA	2"	1,300	2,300	1-1/4"	10	11
RG	RDG GAMMA		2,300			18	
RK	RDG KAPPA		2,800			23	
RO	RDG OMEGA		1,200			10	
RS	RDG SIGMA		1,200			10	
RC	RIDGEWAY DINING	2-1/2"	2,800	3,700	1-1/2"	17	15
SL	SMATE (SCI/ED/TECH)	4"	600	9,800	2"	30	30
SV	STUDENT RECREATION	4"	3,700	9,800	3"	37	90
VC	VIKING COMMONS	3"	3,100	5,700	2"	30	30
VU	VIKING UNION	4"	3,000	9,800	2"	30	30
WL	WILSON LIBRARY	3"	2,000	5,700	2-1/2"	30	50

6. CHILLED WATER SYSTEMS

6.1. Existing System Overview and Evaluation

Western Washington University (WWU) has over 3-million square-feet of campus buildings spread across (51) building locations used for academic, administrative support, mixed use, residential, and student activities. In the late 1960's early 1970's Western Washington University had a 1,000 ton central chilled water plant located at the current steam plant. Central plant pumps (primary pumps) distributed water through the piping system installed in the tunnel to each building. The building pumps (secondary pumps) pulled chilled water from the primary loop and distributed water to their respective coils. Secondary distribution pumps were constant volume flow with a 3-way bypass valve at the coil. Shortly after the central chilled water system was installed it was decommissioned because the campus did not have a large enough cooling load to support the large chillers. The chiller, cooling tower and pumps were removed and majority of the chilled water pipe was decommissioned and remains in place today.

Overview Map of WWU Chilled Water Systems



There are (9) separate chilled water plants presently operational on campus with one under construction currently (Carver Gymnasium). At least four buildings contain decommissioned cooling coils and secondary pumps that were previously tied to the 1970's Campus District Chilled Water system. There are also numerous air cooled direct expansion (DX) unitary systems throughout the Campus. The map above provides an overview indicating location of all the active chiller plants.

6.1.1. Chilled Water Systems Overview

The largest existing chilled water plant on the WWU campus is a 310-ton rooftop air cooled chiller built in 2007 located at AIC and the smallest chilled water plant is a 20-ton rooftop air cooled chiller built in 1987 located at Bond Hall. The following table is a summary of the existing chilled water systems at the WWU campus arranged by year the system was built for each building that has or had a chilled water coil.

Chilled Water Systems Summary

BUILDING NAME	YEAR SYSTEM BUILT	BUILDING AREA (SQ-FT	COOLING CAPACITY (TONS)	AVG CAPACITY USED (TONS)	CHILLER TYPE	REFRIGERANT	PUMP LOGIC
BOND HALL	1987	89,591	30	22.5	TRANE	R-22	--
BOND HALL	1987		30	22.5	LIEBERT	FREE COOLER	--
BOND HALL	1987 (TBD)		20	15	CARRIER	R-22	--
ROSS ENGINEERING TECH	1987	77,592	45	40.5	CARRIER AIR COOLED RECIPRICATING	--	PRIMARY - CV
MORSE HALL (CHEMISTRY)	1991	72,574	54	48.6	CARRIER #30gb-060-6	R-22	PRIMARY - CV
HAGGARD HALL	1999	107,971	277	138.5	TRANE CVHE320 CENTRIFUGAL	R-123	PRIMARY - CV
RECREATION CENTER	2001	98,300	45.5	31.85	AIRCOOLED SCROLL	R-22	PRIMARY - CV
COMMUNICATIONS (CHILLER 1)	2004	131,365	150	75	TRANE RTHC B1B1B1	R-22	PRIMARY - CV SECONDARY - VFD
COMMUNICATIONS (CHILLER 2)	2004		60	0	TRANE CGWD-1	R-22	PRIMARY - CV SECONDARY - VFD
ACADEMIC INSTRUCTIONAL CENTER (CHILLER 1)	2007	--	260	221	PETRA AIRCOOLED SCREW	R-134A	PRIMARY - VV
ACADEMIC INSTRUCTIONAL CENTER (CHILLER 2)	2007		50	50	PETRA AIRCOOLED SCREW	R-134A	PRIMARY - VV
WILSON LIBRARY	2010	141,027	26	7.8	TRANE CGAM026 SCROLL	R-410A	PRIMARY - CV
MILLER HALL	2011	133,117	80	40	AIRCOOLED SCREW	R-410A	PRIMARY - VV
MILLER HALL	2011		24	--	AIRCOOLED	FREE COOLER	
CARVER GYMNASIUM	2016	167,304	50	--	MULTISTACK AIRSTACK AIRCOOLED SCROLL	R-410A	PRIMARY - VV
ARNTZEN HALL (BLDG)	1972	99,337	REMOVED	--	CENTRAL PLANT	--	PRIMARY- PLANT SECONDARY - BLDG
ARNTZEN HALL (AUDITORIUM)	1972		REMOVED	--	CENTRAL PLANT	--	PRIMARY- PLANT SECONDARY - BLDG
PERFORMING ARTS REHERSAL HALL	1972	128,649	REMOVED	--	CENTRAL PLANT	--	PRIMARY- PLANT SECONDARY - BLDG
PERFORMING ARTS RECITAL HALL	1972		REMOVED	--	CENTRAL PLANT	--	PRIMARY- PLANT SECONDARY - BLDG
ENVIRONMENTAL STUDIES	1971	111,145	REMOVED	--	CENTRAL PLANT	--	PRIMARY- PLANT SECONDARY - BLDG

BUILDING NAME	CHWR (°F)	CHWS (°F)	PRIMARY PUMP FLOW RATE (GPM)	SECONDARY PUMP FLOW RATE (GPM)	COIL FLOW RATE (GPM)	COIL VALVES	CHILLER WATER PRESSURE DROP (FT)
BOND HALL	--	--	--	--	--	--	--
BOND HALL	--	--	--	--	--	--	--
BOND HALL	--	--	--	--	--	--	--
ROSS ENGINEERING TECH	--	--	140	--	138.5	3-WAY BYPASS	--
MORSE HALL (CHEMISTRY)	55	45	(2) @ 65	--	130	3-WAY BYPASS	20
HAGGARD HALL	58	44	475	--	453	3-WAY BYPASS	15 (MAX)
RECREATION CENTER	55	45	120	--	75 @ 12°ΔT 120 @ 10°ΔT	3-WAY BYPASS	10
COMMUNICATIONS (CHILLER 1)	58	44	326	215	491	--	10
COMMUNICATIONS (CHILLER 2)	58	44	103	215		--	12
ACADEMIC INSTRUCTIONAL CENTER (CHILLER 1)	54	44	624	--	692	3-WAY BYPASS	17
ACADEMIC INSTRUCTIONAL CENTER (CHILLER 2)	54	44	120	--		3-WAY BYPASS	6
WILSON LIBRARY	51	37	40	--	36.7	3-WAY BYPASS	6.2
MILLER HALL	57	45	150	--	167.6	--	10
MILLER HALL	57	50	66	--		--	28
CARVER GYMNASIUM	56	44	115	--	148.3	--	10
ARNTZEN HALL (BLDG)	56	46	--	375	375	3-WAY BYPASS	--
ARNTZEN HALL (AUDITORIUM)	56	46	--	75	75	--	--
PERFORMING ARTS REHERSAL HALL	55	45	--	80	40	3-WAY BYPASS	--
PERFORMING ARTS RECITAL HALL	55	45	--	151	155	3-WAY BYPASS	--
ENVIRONMENTAL STUDIES	--	--	--	450	350	--	--

According to the mechanical schedules and interviews with facility engineers, the total capacity of all chilled water systems on campus is approximately 1,120 tons with around 60%-65% of the total capacity being utilized on a peak cooling day. The majority of the chilled water systems were not designed with extra cooling or pump capacity, however, most of the systems have excess pipe volume capacity. Haggard Hall and the Communications Facility are exceptions and have been observed by WWU facilities to have additional capacity. Both systems operate at approximately 50% of the rated capacity on peak load days. These two systems may have potential to serve additional cooling loads in their respective buildings or other buildings on campus.

Per discussion with facilities, candidates for additional cooling above and beyond what is already provided are Bond Hall, Parks Hall, Wilson Library, Morse Hall, and potentially select buildings that were designed with chilled water coils and connected to the original

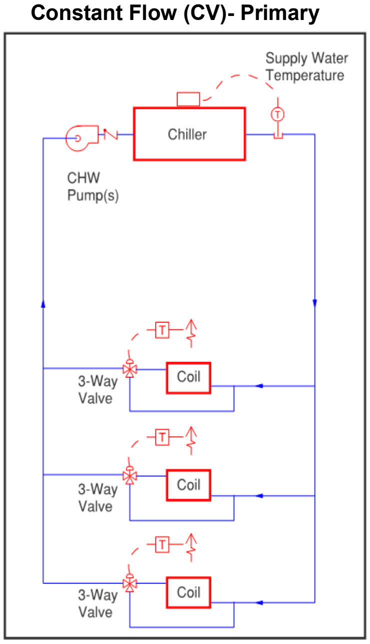
1970's central campus chilled water system; Arntzen Hall, Performing Arts and Environmental Studies.

Arntzen Hall was designed to have roughly 185 tons of cooling for the auditorium and main building air handler(s), Performing Arts main building and Performing Arts Recital Hall had 33 tons and 63 tons respectively, and Environmental Studies has around 185 tons of cooling capacity. Recently the air handler serving the recital hall (AH-7) was retrofitted with a new 30 ton cooling coil to allow for a rental chiller to be temporarily connected. The original 63 ton cooling coil was removed in the early 2000's to save fan energy. To accommodate the chiller rental, new 2" CHWS/ R pipe where installed in the exterior stair to deliver water up to the AHU in the mechanical room.

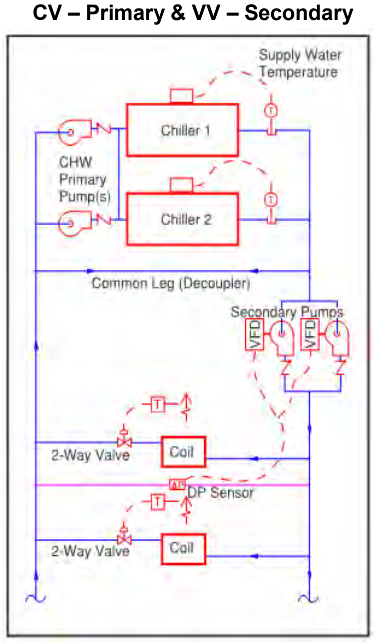
6.1.2. Chilled Water Pumping Overview

The existing chilled water systems on campus vary significantly in capacity, pumping strategy, chiller type, operating temperatures, plant location and age. The five (5) oldest chilled water systems on campus and Wilson Library use a constant flow single loop pumping strategy with 3-way bypass valves at the coil(s). Communications Facility, with two chillers, uses a constant flow primary loop-variable flow secondary loop and the (3) newer buildings use a variable flow single loop pumping strategy. Below are pumping diagrams for each configuration:

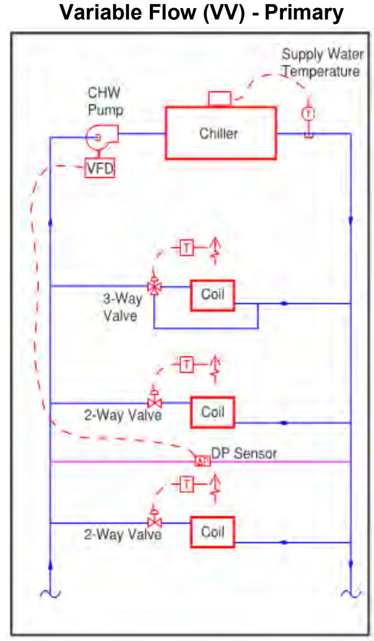
Constant Flow (CV)- Primary



CV – Primary & VV – Secondary



Variable Flow (VV) - Primary



Existing pump strategy depends on the technology available, quantity of chillers, quantity of coils served, size and diversity of the loads served by the coils. Early industry design standards used constant volume pumps with 3-way valves as a result of the available chiller technolgy and requirements to meet minimum chiller water flow rates. Newer construction, like Carver Hall, has access to new chiller technology and can therefore use variable volume chilled water pumps as newer chillers have a much higher compressor turn down rate than older chillers. Turn down and minimum flow rate through the chiller varies by type, size, and manufacturer but is typically 25% to 50% of the design flow for a chiller with a single compressor and closer to 10% turn down for multi-compressor chillers. The Energy Code, economics and chilled water requirements will generally determine the most appropriate chilled water pumping design and coil operating temperatures for each building.

While there is some variance on existing operating temperatures, most systems operate at 10°F temperature difference (ΔT) with 44°F entering coil temperature and 54°F leaving coil temperature. Haggard Hall 14°ΔT, Communications 14°ΔT and Miller Hall 12°ΔT are the exceptions. Similar to the constant volume pumping strategy, early industry design standards used smaller chilled water ΔT (i.e. 10°ΔT) but as the industry has become more energy conscious, chiller water temperatures have become more scrutinized. Research and modeling now show that there are significant benefits to increasing ΔT from a first-cost standpoint as this can reduce the required pipe and pumping size required. This can also correspond to a savings in energy cost as well. The energy cost savings will depend on the relative size of the increase in fan energy usage versus the decrease in pump energy with the increase in ΔT. Fan energy will increase slightly with a larger ΔT because the coil air pressure drop will increase with added rows; however, pump energy will decrease with a larger ΔT because the system does not have to deliver as large a volume of water. Chiller energy use is less affected by an increased ΔT as chiller efficiency is driven by the evaporator temperature that affects leaving chilled water temperature; entering chilled water temperature has just a small impact on efficiency.

Many owners have found an additional advantage of increasing the delta-T on an existing system; primarily where delivery of sufficient cooling capacity has become an issue. By increasing the overall system delta-T, the delivery capacity of the existing infrastructure is increased. This can often be implemented in lieu of replacing existing distribution piping with a larger size; thereby savings implementation cost while also saving energy.

6.1.3. Chilled Water System Evaluation

According to interviews with facility engineering personnel, Bond Hall is considered to be at the end of its useful life and the chiller at Haggard Hall requires frequent monitoring to assure proper operation beyond what is planned as preventative maintenance. Bond Hall has the oldest chiller water system on the WWU campus and has been operating for approximately 30 years. In addition to the chillers reaching their useful life, it was observed the chilled water system may not be functioning as designed. As an example, while on site we observed the Carrier Chiller providing mechanical cooling with the outside air temperature in the low 30's in lieu of using the Liebert Free-Cooler; thus not taking advantage of energy efficiency opportunities.

The Haggard Hall chiller is prone to cycling per facility engineering which is reflected in the number of starts versus run time hours. The chiller has 9,019 total starts in 17,256 run time hours which is 1.9 starts per hour. This can likely be attributed to an apparent low cooling load as the summer time peak load on the system is roughly 80-100 tons for a 320 ton rated system. There are no other reported system defects or equipment requiring maintenance above and beyond what is already being provided as part of the preventative maintenance program. Currently quarterly and annual system checks are being performed by an HVAC technician.

Per ASHRAE, the life expectancy for a Chiller is between 20-25 years, Cooling Tower and pumps at 20 years. Bond Hall, Ross Engineering Tech, and Morse Hall chilled water systems are at or near the end of their projected useful life. Haggard Hall, Recreation Center, and the Communications Facility are due for replacement in 2024-2027.

According to the mechanical schedule and site verification, (7) of the (10) chillers on the WWU campus use R-22 or R-123 refrigerant. These two HCFC refrigerants are in the process of being phased out. January 1, 2020 is the cut-off when no new imported R-22 or HCFC refrigerant will be allowed in the US. It is important to note that although no new R-22 will be manufactured or imported in the US, R-22 will still likely be available for purchase in some capacity (through refrigerant recyclers) at an expected premium price.

New refrigerant equipment selections will largely be unaffected as the current typical refrigerant selection is R-134a, a HFC type refrigerant. It is worthwhile to note that HFC's will also experience a phase out plan similar to HCFC's in the more distant future; although HFC's will not be allowed in "new" equipment after 2024. This is due to regulations shifting toward low ozone depletion and global warming potential. This phase out trend is pushing the industry toward HFO type and natural refrigerants such as CO2 and H20.

6.2. Future Growth Evaluation

As the campus growth plans are developed it will be important to understand what cooling requirements are necessary for existing buildings, future remodels and future development. As older less efficient chillers reach the end of their life, the existing tunnel infrastructure offers an opportunity to replace the older systems with new larger chilled water systems and distribute chilled water to adjacent buildings via the tunnel. This provides opportunities to reduce both installed and operating costs by consolidating cooling production loads. Consolidating these loads could also improve the operating efficiency of the chillers and provide a larger base load, which will also reduce the "cycling" of the chillers.

The WWU campus is reportedly experiencing an increase in need for mechanical cooling. In the past, most of the WWU's cooling needs could be minimized by a combination of tree shading, mild climate, cooling winds from the bay, building mass heating absorption, and convective cooling via operable windows. With the advancement of technology and the expanded use of computers and associated equipment, the occupancy loads and interior heat generation has increased. In addition to larger occupancies, building utilization hours have increased. Professors and students are beginning to expect more comfortable indoor temperatures during evening classes and late office hours. Building mass has also been decreasing as cost for installation has increased. Unfortunately, natural ventilation alone cannot maintain 75°F interior air temperature whenever the outdoor air temperature (OAT) itself is 75°F or greater for newer low mass buildings with increased computer usage, people and equipment interior heat gains. All these factors are putting a higher demand for mechanical cooling in recent years.

WWU campus has a mild climate and receives cool winds from Bellingham Bay. A typical year in Bellingham has 103 hours (1.2%) above 75°F OAT, 842 hours (9.6%) at or above 65°F OAT and 1553 hours (17.7%) above 60°F OAT. The current state energy code requires all new mechanical systems have air economizer configured to modulate the outdoor air and return air dampers to provide up to 100% of the design airflow as outdoor air for cooling. In addition, multi zone HVAC systems are required to have controls for supply air temperature reset. When combined, the effect is an HVAC system that can provide 100% cooling at outdoor air temperatures up to 60°F. Therefore, new code compliance buildings on the WWU campus will need partial mechanical cooling 10% of the year and full mechanical cooling 1.2% of the year; 82% of the year airside economizer will provide adequate comfort cooling in appropriately designed occupied spaces.

It should be noted that the potential for air economizers is inherently dependent upon the original design of the system and the available delivery capacity of the existing ventilation air duct size. This may limit economizer application in existing buildings.

Air Economizer Summary

Outside Air Temperature (OAT, °F)	Economizer Description
< 55°F	Full economizer cooling
55°F - 60°F	Increase in fan airflow, Full economizer cooling
60°F - 75°F	Economizer cooling with supplemental mechanical cooling
> 75°F	Full mechanical cooling; economizer high-limit has been reached

As the expectation for cooling increases it can be assumed that future classrooms, lecture halls, laboratories, and/ or office areas located on the top floor, having west facing exposure and/ or high equipment/ occupant loads will need some mechanical cooling to maintain minimal occupant comfort.

6.2.1. Chilled Water Capacity and Availability for Future Expansion

Utilizing information provided by WWU facility engineers, site walks, and review of the mechanical schedules, the following table was created to show the existing chiller size, location, and percent of chiller capacity used for all campus chilled water systems during peak conditions. Based on the information provided, and knowing that there are large buildings with small chiller sizing, the majority of the chilled water systems installed on campus appear to be designed for larger equipment/ server rooms and/ or high occupant load spaces without substantial excess capacity. Haggard Hall, Communications Facility, and AIC are the exception as these systems appear to be sized and designed to accommodate full building cooling per review of the mechanical plans. With the total connected load at approximately 50%, Haggard Hall and Communications Facility chilled water systems could be candidates to support future expansion as the chilled water plant for each of these buildings is currently being underutilized.

Existing Campus Chillers

BUILDING	***CHILLER SIZE (Tons)***	***BUILDING PEAK LOAD (Estimated Output)***	***BUILDING AREA (sq ft)***
Bond Hall [1]	30	--	89,591
Bond Hall	20	75%	
Ross Eng Tech	45	90%	77,592
Morse Hall	54	90%	72,574
Haggard Hall	280	50%	107,971
Recreational	50	70%	98,300
Communications	150	50%	131,365
Communications	60	0%	
AIC	260	85%	---
AIC	50	100%	
Wilson Library [2]	26	30%	141,027
Miller Hall	80	50%	133,117
Carver Hall [3]	50	--	167,304

Notes:
1. Redundant chiller for Bond Hall (TRANE)
2. Unit is for dehumidification
3. New chiller plant, Capacity at peak output to be verified once in operation

6.2.1.1 Haggard Hall Chilled Water Expansion

Haggard Hall has a 280 ton chilled water plant located in the mechanical room at the roof. The existing chilled water plant was designed to accommodate the cooling requirements of both Haggard Hall and the Wilson Library. However, Wilson Library has not been renovated to take advantage of the available chilled water which explains why the chiller is operating at approximately 50% of its design capacity. Based on the size of

Wilson Library it could be expected that it will need around 135 tons of cooling if only 33% of the building requires cooling. This expansion would effectively take all the existing available capacity of the chiller plant. However, the building was originally designed with space allocated for one additional chiller, cooling tower, and pump package.

In addition, the existing 8" piping system has a tee capped for connection to a new chiller and the pipe size is large enough to accommodate the additional capacity. The additional 280 tons could be used for potential distribution to a north chilled water loop serving Bond Hall (20T), Miller Hall (80T) and Performing Arts with the potential renovation (120T). Depending on how much each building actually needs due to diversity there is also potential to serve surrounding buildings that don't currently have mechanical cooling like College Hall, Fraser Hall and Humanities.

6.2.1.2 Communications Facility Chilled Water Expansion

The Communications Facility has a 210 ton chilled water plant located in the basement mechanical room. The existing system is only operating at approximately 50% (105 tons) of its total design capacity, leaving 105 tons available for potential distribution to a south chilled water loop. With the plant being located in the basement, access to the tunnel is much more direct relative to Haggard Hall. Potential buildings to connect to are the Morse Hall (54T) and Ross Engineering Tech building (45T) since both have chilled water plants are at or reaching their expected life. If there is a desire to maintain Morse Hall and Engineering Tech with independent chilled water systems then the remaining chilled water capacity from the Communications Facility could be used to serve buildings around Haskell Plaza.

6.2.1.3 Chilled Water Expansion Pumping Hydraulic Considerations

There is approximately 140-ft (equivalent to 60 psi of static head) elevation difference between the lowest and highest chilled water plant on the WWU Campus. The system maximum operating pressure is the combination of system component pressure drop (coils, valves, and chiller) and elevation. When considering options for future expansion from existing systems, pressure ratings for each component will need to be closely reviewed to ensure the maximum rated working pressure is not exceeded. Examples of components to review are: piping fittings, coils, expansion tanks, air separators, relief valves, pump impeller housings, etc. If pressure is viewed as a design constraint, a heat exchanger can be provided at each building which will lower the district loop piping system pressure requirements.

Based on the existing chiller locations, pumping hydraulics, temperatures, and utilization a single campus District Chilled Water loop does not appear to be the most effective approach for a WWU cooling system based on the existing conditions and following reasons:

1. **Pumping Configurations:** The existing chilled water systems have a variety of hydraulic pumping combinations that cannot logically be combined without replacing pumps, expansion tanks, relief valves and piping.

2. **Size of Piping:** The existing abandoned pipe layout and sizes are not sufficient to accommodate a single campus chilled water system and there is a significant distance between buildings with chilled water coils. In addition, most of the chilled water systems are on the roof which will require pipe to be routed through existing structure to the tunnel making the campus loop potentially more expensive than providing new building dedicated systems.

3. **Capacity:** Eight of the ten buildings that have chilled water have an existing cooling load of less than 100-tons with only Miller Hall having a load of greater than 55-tons. These are small loads to accommodate for the additional piping cost that will be potentially difficult to economically justify.

4. **Campus Elevation:** The campus has a large difference between lowest and highest chilled water coils. System static pressure would increase significantly if combined. This could result in a requirement for additional equipment like heat exchangers and expansion tanks at each building. Added heat exchanger would require additional building level pumps.

An alternative option to a single campus Chilled Water system would be multiple smaller Chilled Water systems. An example would be a North and South Chilled Water Loop as illustrated below.

Potential Chilled Water Loops

This strategy would require two chilled water systems serving multiple local buildings versus multiple smaller independent systems. Many of the challenges associated with a single campus chilled water loop would still apply but on a much smaller scale which would make two systems more desirable. In addition, such a change could be done at a time when multiple chilled water systems are ready for replacement to more easily justify the economics. For example, the north loop could be comprised of Haggard Hall and Bond Hall which both have chillers near their expected life. Haggard Hall has a mechanical room that could accommodate (2) chillers. These chillers could then serve Haggard Hall, Bond Hall, Wilson Library, Performing Arts, Carver Gymnasium and Miller Hall. Similar logic would be used for defining the South loop.

6.2.2. Future Building Cooling Requirements

Typical mechanical cooling requirements vary by building type, occupancy and use, but can be assumed to be at least 400-sf to 600-sf per ton of cooling. Therefore, if cooling is only provided for spaces with roof exposure, west facing exposure and/ or high people/ equipment load spaces then it can be assumed roughly 33% of the area for all new buildings or renovated buildings will require mechanical cooling. A future 100,000-sf building with good south and west exposure would likely need at least 80 tons of mechanical cooling. Based on Figure 1-1IMP Land Use District Map, the following areas are identified for potential future growth after 2017. The location of these areas relative to each other and the existing campus chilled water plants provides opportunity for a potential central chilled water plant(s); north loop and south loop.

Future Building Expansion

IMP DISTRICT AREA NUMBER	***GROSS SQUARE FOOTAGE***	***EST COOLING LOAD (TONS)***
6	45,000	40
9	101,000	85
11	21,000	20
13	7,000	7
14	309,000	255
TOTAL	483,000	407

IMP District Areas 4, 10, 15 and 16 were not considered as they have a residential component to them that to date have not been considered for chilled water. Performing Arts center which has a predesign for an addition totaling around 56,000 GSF is located in IMP Area 6. Based on the existing building coil requirements and the additional square footage, it can be expected that the total Performing Arts building chilled water load will be over 100 tons. With access to the tunnel, the Performing Arts building is a good candidate for service from Haggard Hall.

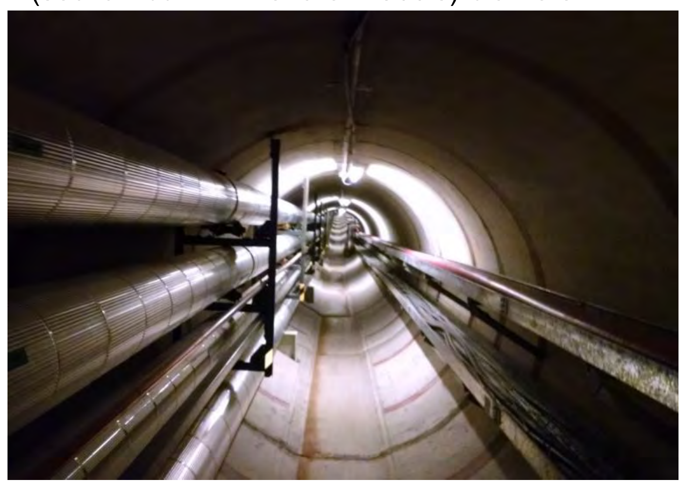
IMP Area 9 contains Carver Gymnasium which is in the process of being renovated. Since Carver Gym is provided with a new 50 ton air cooled chiller, it is most likely not feasible to connect this system to a district loop. However, if a district loop is considered future connections should be provided for expansion.

IMP Area 13 is the Student Recreational center which currently has a 50 ton chiller. Do to the distance from any potential central chilled water system, it is most likely not feasible that the Student Rec Center be connected to a district loop.

IMP Areas 11 and 14 contain the buildings around Haskell Plaza. Development in this area includes potential 161,000 sq-ft addition and renovation for the Science building as well as a potential new building west of Academic Instructional West building. There is not currently enough chilled water capacity available at the Communications Facility or AIC to accommodate the future loads around Haskell Plaza. However, with the proposed new construction in this area and its potential access to the existing tunnel system, a new large chilled water system in a remodeled/new building may be the best alternative for service around Haskell Plaza.

6.2.3. Tunnel Capacity and Requirements for Future Expansion

This existing tunnel system is roughly 7-ft in (section built in the later 1960's) diameter and is used as a pathway for the distribution of steam, condensate, electrical conduit, compressed air, abandoned pipes and other utilities. All systems are racked and organized with power/ communications and piping on opposite sides separated by a walking path down the middle of the tunnel. The existing abandoned chilled water piping leaving the central plant was installed with 14" schedule 40 steel to support approximately 1,000 tons of cooling. However, as determined per site walks, much of the existing chilled water pipe in the tunnel is 8" and has been out of commission for over 45-years. In many cases this piping has been repurposed, cut open, and used as pathway for fiber optic cable. There is sufficient risk and liability in reusing the existing piping system that has been out of commission for over 45-years. Many factors can affect the average life of mechanical systems such as hours in operation, climate, chemical exposure, etc. Useful life can be extended from the average through robust maintenance and likewise decrease from neglect and/ or climate conditions. Industry standards project the service life of schedule 40 steel pipe to be 30-50 years and Victaulic literature indicates 50-year useful life for their 250°F rated gaskets; useful life will increase as temperature decreases. It is recommended that the existing tunnel piping be evaluate further to confirm integrity has not been compromised prior to making any decision on whether it can be reused. Tests/ inspections to be completed:



- Pipe wall thickness verification
- Pressure test for leaks
- Exterior Pitting
- Integrity of bolts, fasteners & gaskets
- Cleanliness inside pipe

To accommodate many of the tests and inspection, it is likely all the existing insulation would need to be removed so pipe thickness can be analyzed and the exterior of the pipes can be inspected for rust deposit and pitting. All Victaulic couplers would likely need to be removed so gaskets can be evaluated and pipe ends can be cleaned of any rust.

The tunnel rack system appears to be in great shape and provides a potential pathway for a future chilled water loop. The current space allocated for an 8" pipe can accommodate between 650 and 900 tons depending on the system temperature difference (10°F to 14°F). While this is not enough capacity to support the entire campus on a single loop, this should be enough cooling capacity if the campus is served by multiple cooling loops. The total cooling (or heating) capacity that can be distributed through a pipe is dependent on the velocity of water and the temperature difference between the supply and return water:

Cooling Capacity (BTUH) = Flow Rate (GPM) x 500 x Temperature Difference (ΔT)

- The 500 value is rule of thumb value based on water in typical operating temperatures. It is defined as follows: Energy Factor (~500 at typical operating temperatures) = (Specific Heat of Water) * (Density of Water) * (60 min/hr) * (0.133 cu ft/gallon water)

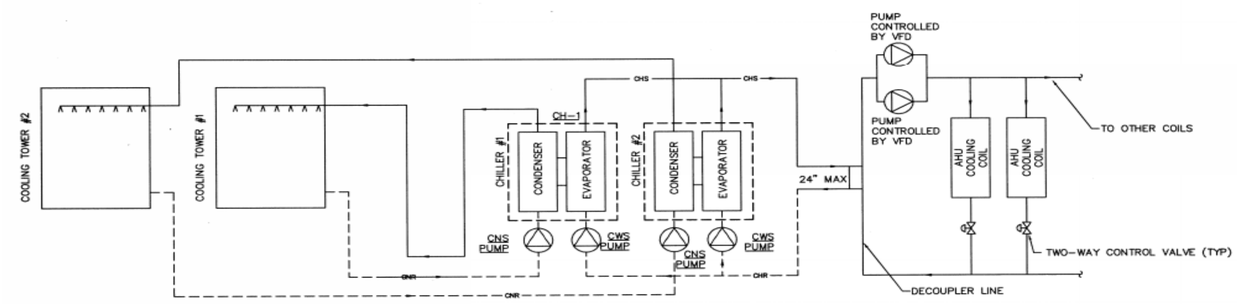
Good engineering practice is to size pipe for 4-ft of pressure drop per 100-ft of pipe or 10 fps (feet per second) whichever is more stringent. Lower pipe pressure drop will result in lower pump energy used and lower pipe velocity with reduce pipe erosion. Based on the linear relationship between flow rate and temperature difference, cooling capacity can be increased by either increasing flow rate with ΔT constant or by increasing ΔT and keeping flow rate constant. Based on the design parameters explained above, the following table was created detailing maximum flow rate for various pipe sizes and cooling capacity through various pipe sizes at different chilled water ΔT's.

Nominal Pipe Size (in)	Max Flow Rate (gpm)	Velocity at Flow Rate (ft/sec)	Friction Loss at Flow Rate (ft/100')	Cooling Capacity 10°ΔT (tons)	Cooling Capacity 16°ΔT (tons)
2	45	4.3	4	19	30
2-1/2	73	4.89	4	30	49
3	130	5.64	4	54	87
4	265	6.68	4	110	177
6	790	8.77	4	329	527
8	1560	10	3.7	650	1040
10	2455	10	2.8	1023	1637
12	3525	10	2.25	1469	2350
14	4295	10	2	1790	2863

6.3. System Improvements for Consideration

- **Centralized Loops (North/ South/ Central):** A central cooling plant on a campus can have several quantifiable advantages over decentralized equipment. Some advantages are improved efficiency, noise reduction, reduced maintenance, ability to cycle easily between alternate energy sources and can accommodate campus diversity. Because cooling loads do not necessarily peak at the same time, the total tonnage of the central cooling plant can often be less than the combined capacity of the individual systems. The following are a couple of central chilled water systems to be considered:

  North Loop - Chilled Water Expansion from Haggard Hall to Wilson Library: The most logical improvement is to use the existing pipes on the bridge, extra chiller capacity, and space available in the penthouse at Haggard Hall to provide cooling to Wilson Library and other nearby buildings. As recommended for the pipe in the tunnel, it is recommended the existing pipe in the bridge be inspected for any defects prior to reusing. The Haggard Hall chilled water system is reportedly operating at 50% of its available chiller capacity and the original design allocated space and interconnecting piping for an additional chiller, pump package, and cooling tower. Two equally sized chillers at Haggard Hall could provide nearly 640 tons of cooling (2 @ 320 tons). This additional space and added chiller could be used to make this building/ plant the north chilled water system for adjacent buildings around Red Square. The system has 8” schedule 40 pipe installed which can accommodate the additional flow to Wilson Library and surrounding buildings. It may be more expensive to expand the existing system and pipe chilled water from the penthouse down into the tunnel to the adjacent buildings than it would be to add chilled water or DX cooling in the adjacent buildings. For



PRIMARY/ SECONDARY SIMPLIFIED CHILLED WATER SCHEMATIC

NTS

NOTE: SCHEMATIC IS FOR GENERAL CONFIGURATION. CHEMICAL FEED, EXPANSION TANKS, AIR SEPARATORS, CONTROLS AND OTHER EQUIPMENT REQUIRED FOR COMPLETE SYSTEM.

this reason any proposed inter-tie should have a separate life cycle cost analysis performed at the time of the expansion to assure validity. If the Haggard Hall cooling plant is expanded to serve the adjacent North Campus buildings then it is recommended that the pumping logic be reviewed with a potential modification required to primary/ secondary with 2-way valves at the cooling coils. Typically if a system is expanded to serve many coils it is cost effective to use a primary/ secondary system with 2-way control valves at the coils and a variable frequency drive (VFD) on the building loop (secondary) pumps per the diagram above.

b. **South Loop - Chilled Water Expansion from Communications** Facility **to South Campus:** Another improvement to consider for chilled water system expansion is at the Communications Facility. This system is reportedly operating at 50% of its available chiller capacity. The cooling tower is on the roof but the chiller(s) and pump(s) are located in the basement with access to the tunnel. The existing chilled water system is already set up as constant volume primary - variable volume secondary with 2-way valves that can maximize the pumped water diversity so no additional pumping revisions should be necessary with the exception of pump controls and the existing secondary pumps should be evaluate to confirm they can accommodate the additional pressure drop through a central piping system. Morse Hall and Ross Engineering Tech are the likely candidates for connection as their current demand of 54-tons and

45-tons respectively fits within the capacity available at the Communications Facility and each are reaching their expected life. If additional future capacity is required at Morse Hall and/or Ross Engineering Tech that pushes the required load over the available capacity from Communications Facility then it may be possible to plan future construction in land use area 14 to utilize the available chiller capacity.

- **Implement Larger System Temperature Differences:** There are many system operating advantages attributed to utilizing a higher ΔT of 16° to 20° as compared to the traditional 10° and 12° ΔT systems that are commonly used. The first cost benefits are smaller pipe, smaller pump(s), smaller pump motor(s) and lower pump energy. The larger temperature difference may require a larger coil but the additional coil cost is often more than offset by the smaller pipe size and coil connection accessories.

  Many owners of older systems have found an additional advantage of increasing the delta-T on an existing system; primarily where delivery of sufficient cooling capacity has become an issue. By increasing the overall system delta-T, the delivery capacity of the existing infrastructure is increased. This can often be implemented in lieu of replacing existing distribution piping with a larger size; thereby savings implementation cost while also saving energy.

- **Update Cooling System Specifications**: To best enable the future buildings to operated efficiently, provide potential to move to larger district cooling systems and support the implementation of renewables and renewable technology into potential district cooling system, WWU should consider revising their building cooling specifications applicable to remodels and new construction. This could include the requirement that all future buildings and future building renovations be connected to the district cooling system; and that these systems utilized a high delta-T coil design of 16° to 20°.

- **Heat Recovery Chillers/ Heat Pumps:** Implementing Heat Recovery is a great way to save additional system energy when designed and operated correctly. HVAC and heating water can consume nearly 50% of the total building energy usage. Heat recovery chillers and heat pumps are an attractive option because they can provide high efficiency cooling (COP 3-4) and heating (COP 3-4). In a combined operation where they provide simultaneous heating and cooling, the coefficient of performance (COP) can be as high as 7. This has substantial benefits over Direct Expansion (DX) cooling which is has a COP of 2.5-3.0 and traditional heating systems that can have a COP of 0.85 for a traditional boiler and 0.95 for a condensing boiler.

During cooling only operation, traditional cooling only chillers produce a controlled source of chilled water leaving the evaporator while dissipating heat through the condenser and ultimately to the environment through an air cooled condenser or cooling tower. When there is a simultaneous need for chilled and hot water, heat recovery chillers have the capability to recover heat and redirect for various applications which saves energy. Depending on which manufacturer is used it is reasonable to expect lift capability around 80°F - 100°F (lift = difference between leaving condenser water and leaving chiller water temperatures). In the event the steam plant transitions to heating water boilers, heat recovery chillers could be utilized as one of the building heating sources.

- **Local Distributed Cooling Systems:** Provide a dedicated cooling system for each new building using a high efficiency cooling system. Dedicate building cooling options could be, but not limited to, Variable Refrigerant Flow (VRF) or chilled water system serving fan coils, chilled beams and/ or an air handler with a cooling coil that will last 20-25 years. These systems offer the following benefits:

    a. Easier to allocate cooling construction and utility costs to the buildings served

    b. Advances in technology have greatly improved turn-down and efficiency of distributed systems.

  Disadvantages include additional equipment to purchase and maintain, lack of ability to share loads and overall system operating efficiency.

- **Plastic pipe:** An alternative to schedule 40 steel pipe in the tunnel would be Schedule 80 PVC or Polypropylene-random (PP-R) pipe. The advantages of plastic pipe over steel are that it's lightweight and easier to handle which can make for a quicker and cheaper installation. PP-R is a specially engineered polypropylene pipe suitable for a wide range of applications and specifically recommended for applications such as heating and cooling. Unlike PVC and or steel in which connections are made by glue, solder or mechanical connections, PP-R systems are joined by heat fusion, which uses electric heat to soften the material and bind it back together at full strength. An added benefit of PP-R over steel is a hot work permit is not required. Some additional benefits of PP-R are that it's engineered for 50 year life cycle, recyclable, has no hazardous waste, has strong structural integrity and among many other things it's resistant to chemical breakdown. Some of the disadvantages to plastic pipe over steel are that more pipe supports are generally required and thermal expansion joints are required as the expansion rate can be up to 10 times larger than steel;

- **Re-Use Existing Chilled Water Piping:** There may be an opportunity to re-use some of the existing CHW piping located in the tunnels. However, there are some concerns about the existing condition; which will have to be analyzed prior to making a final determination. Many factors can affect the average life of mechanical systems and specifically piping such as hours in operation, fluid velocity, climate, exposure to elements, exposure to chemicals, lack of water treatment, etc. Useful life can be extended from the average through robust maintenance and likewise decreased from neglect and/ or climate conditions. Industry standards project the service life of schedule 40 steel pipes to be 30-50 years and Victaulic literature indicates 50-year useful life for their 250°F rated gaskets; useful life will increase as temperature decreases. It is recommended that the existing tunnel piping have further tests done to evaluate integrity prior to making any decision on whether it can be reused. Things to consider for inspection and testing are:

    a. Verify pipe wall thickness – can be accomplish using an ultrasonic thickness gage

    b. Pressure test the system to minimum 150 psi to verify leaks – this should be done with water not air as air is compressible and can be very dangerous if a leak occurs

    c. Inspect exterior of pipe for pitting that would compromise the integrity of the pipe

    d. Inspect bolts, fasteners and gaskets for defects or deficiencies

    e. Inspect cleanliness of inside of pipe. Pipe will need to be free of rust, dirt and debris before it can be used to transfer chilled water through pumps, chillers, AHU coils, etc.

To accommodate a thorough inspection, it is likely all the existing insulation will have to be removed and disposed of so pipe thickness can be analyzed and the exterior of all pipes can be inspected for rust deposit and pitting. All Victaulic couplers should be removed so gaskets can be evaluated and pipe ends can be cleaned of any rust. In addition, existing pipe pathway and sizes need further evaluation to confirm the pipe size is adequate for the required cooling. This evaluation will need to be completed once a location has been identified for a central chilled water plant.

Improvement Overview

Below is a table denoting the estimated rough-order-of-magnitude (ROM) cost and ROM lifecycle simple payback ranges for the items listed above. The following cost numbers are the total cost to implement the project (including estimated design, management, contingency, and taxes). While lifecycle simple payback is shown in the table, a more thorough assessment of true cost and benefits would be displayed by completing a long term life cycle cost analysis of the alternatives versus business as usual.

Description	ROM Cost Est (+/- 30%)	ROM Typical Energy Savings (+/- 30%)[1]	ROM Lifecycle Simple Payback (+/- 30%)[2]
North Loop - Expansion from Haggard Hall to Wilson Library[3]	$75,000	10%	13
Haggard Hall CHW System Renewal and Build Out (640 Ton CHW plant)	$2,000,000	40%	18
South Loop - Expansion from Communications to Engineering Tech and Morse Hall[3]	$350,000	20%	10

Notes:

1. ROM Energy Savings accounts for utility savings only.
2. Anticipated Simple payback when accounting for the expected required expenditure to renew, operate, and maintain the existing chilled water systems (business as usual; BAU). This reflects the incremental payback by implementing the proposed measure.
3. Costs for connecting to existing in-building cooling distribution from the identified district location. This assumes the connected facility has been remodeled with CHW cooling infrastructure and is ready to be connected to a district cooling plant. Also assumes that existing plant has cooling capacity to serve newly connected facility.

6.4. Review Cooling Technologies for Consideration

6.4.1. High Temperature Heat Pumps

High temperature heat pumps (HTHP) are similar to conventional heat pumps in that they move heat from a lower grade source to a higher source. Most HTHP utilize carbon dioxide as the refrigerant and operate in a trans-critical cycle at very high pressures. Output conditions are typically 180-190F hot water and 42-45F chilled water. Typical COP’s will be 3-4 for heating and max out near 7.0 for simultaneous heating/cooling operation.

In order to make use of a HTHP the WWU campus would need to convert to a HHW distribution system as the production temperatures are much too low for steam generation. If WWU did convert to a HHW distribution system, a HTHP could be a compelling option for WWU once enough chilled water load was aggregated on the campus.

Heat recovery chillers are similar to high temperature heat pumps but typically operate with a more traditional refrigerant (R134A) and output lower grade heat (~150F or less). Typical COP's are similar to HTHP's.

Heat recovery chillers would also need a HHW distribution system in order to be integrated into the WWU campus. The tradeoff between a heat recovery chiller and HTHP is that the heat recovery chillers operate on a more traditional refrigerant and have more industry presence.

6.4.2. Magnetic / Oil-less chillers

Water-cooled centrifugal chillers can be the most versatile class of chillers available in capacities greater than 100 tons but they are also the largest consumer of energy in the HVAC system. Oil less chillers with magnetic bearings can provide additional energy efficiency, have better part load efficiency and have higher turn down capabilities than a standard chiller. As opposed to standard chillers where oil in the chiller evaporator creates a decrease in efficiency over time due to oil migration into the refrigerant, these chillers do not suffer this degradation. In addition, no oil in the chiller equates to less maintenance, less startup concerns and eliminates parasitic loads related to oil. They can have a higher first cost so for this reason any proposed upgrade should have a separate life cycle cost analysis performed at the time of the expansion to assure validity.

Chilled water plants with magnetic bearing chillers can operate at very low overall kw/ton (including chilled/condenser water pumps and cooling tower fan energy). Modern high efficiency chilled water plants can see overall operating kw/ton in the range of 0.65-0.45, corresponding to an overall COP of 5.4 -7.8.

6.4.3. Variable Refrigerant Flow (VRF) System

VRF systems with heat recovery capability can operate simultaneously in heating and/or cooling mode, enabling heat to be used rather than rejected to the exterior as would be the case for a traditional heat pump system. Through the use of energy efficient inverter-driven compressor technology, innovative features such as simultaneous cooling and heating and whole building control, VRF systems coupled with a Dedicated Outside Air System (DOAS) with heat recovery delivers energy and operational savings to the user. Inverter-driven compressor technology uses the absolute minimum energy necessary to maintain indoor comfort levels, and can perform at 25 percent higher efficiency than conventional DX systems. The variable speed compressors have 10% to 100% capacity range and can maintain precise temperature control, generally within +/- 1°F. With VRF technology, several indoor units are networked with controls and piping to a heat recovery box and connected to a single condensing unit outdoors.

Each manufacturer has its own design (2-pipe or 3-pipe system). The refrigerant flow to each coil is adjusted precisely, in response to heating and cooling requirements, through an electronic expansion valve in conjunction with the inverter driven compressor. The efficiency is achieved as the outdoor condenser and indoor fan coil units are networked to a heat recovery system that transfers energy from a zone in cooling to a zone requiring heat and vice versa. The controls are also advanced to bypass the condensing unit to save electrical consumption. In addition to energy savings, ceiling space requirements are reduced as VRF uses refrigerant piping to deliver heating and or cooling to a wall cassette, ceiling cassette or low-profile ducted fan coil.

6.4.4. Thermal Energy Storage (TES)

The implementation of TES can provide the ability to load shift chiller operation; utilizing chillers at night during low peak, efficient conditions to charge the tanks. These tanks can then be used during the day to serve the cooling load. Storage can also serve as an additional chiller during peak cooling days requiring less overall chilled capacity. Chilled water thermal energy storage (TES) provides a means to generate and store cooling for later use as required. TES serves to smooth out load variations during a day and allows a large cooling load to be served from smaller pieces of equipment. TES also enables the smaller equipment to run at its most efficient load point at the most convenient time of day. Renewables and renewable technology also benefit from TES as it provides a buffer to use as the resource is available. For instance, if a heat recovery chiller was used on the campus and there was a demand for heating but not for cooling typically the cooling would be rejected to the atmosphere. A chilled water storage tank would allow the operation of the heat recovery chiller when needed in heating mode while sending the cooling for storage in the tank. When the campus needed cooling it could then be provided from the storage tank thereby not wasting energy. A storage tank also allows for renewable technology integration such as night time free cooling. Even during peak heating days in Bellingham it is not uncommon for the nighttime ambient temperature to drop well below 60F. Ambient air could be used to sensibly cool the tank or a cooling tower can be integrated to make use of evaporative cooling.

Given the current lack of large cooling needs on the WWU campus, thermal cooling storage would not currently provide a good financial benefit.

6.4.5. Geo-Exchange

Geo-exchange dissipates or gains energy with the earth through a series of drilled “wells”. Each well contains a loop of pipe which connects back to a main header to serve a heat pump or a series of heat pumps. This type of heat pump configuration is typically called a ground source heat pump (GSHP). GSHPs benefit from a near constant ambient temperature to extract or dissipate heat from/to which greatly improves COPs during harsher weather periods.

There are significant concerns and design considerations that would need to be resolved in implementing a main GSHP on the campus. The first would be the very large well field and associated piping. Each well would need to be interconnected and piped back to the main chilled water plant location. This piping would take up considerable underground real estate meaning any future projects requiring pipe routing through the identified areas would need to be well planned and coordinated. Another area of concern would be the pumping energy required to circulate fluid through the piping network. Even if the piping network was designed with pumping efficiency in mind, the sheer amount of piping would still correspond to significant pumping requirements. A final concern is with the degradation over time with the well fields. If heating and cooling loads are not balanced the ground surrounding the well fields will rise/fall in temperature over time reducing the capacity of the well field. For a single building cooling/ heating system this may be fine since the well field can be oversized to accommodate for any potential degradation. This may be a problem for a district energy system on the campus due to the longevity of the campus and the panned growth of the system.

Overall, GSHP systems are typically better suited for single building applications as the well fields can be done in the building profile or parking area. For the WWU Campus, remote buildings could be a viable candidate for GSHP systems.

6.4.6. Absorption Cooling

In the event that WWU ever determined to implement a cogeneration system, the integration of off-peak heat consuming technologies to extend power generation and minimize summer electrical peak loads could become a topic of consideration. In this case, Absorption / Adsorption cooling technologies utilize heat (or in this case waste heat) to drive a refrigeration cycle that generates chilled water for cooling. This option allows the cogeneration system to provide additional power for the campus while also serving the base cooling load.

Since the lowest campus heating needs correspond with the highest cooling requirements, this option provides an ideal balance to allow additional generation during summer months

Adsorption equipment has seen recent technology improvement that improves operating efficiency, operation simplicity, and practical logistics over absorption equipment. In lieu of a lithium bromide solution in typical absorption machines, adsorption machines typically use a fixed silica gel for refrigerant absorption. This avoids the potential problems of freeze up that an absorption machine can see by having refrigerant (water) being the only moving part. Operation of an adsorption machine is greatly simplified and eliminates the need to handle equipment that carries lithium bromide.

6.5. Cooling System Conclusions

Western Washington University operates and maintains (10) chilled water cooling systems on the WWU campus with each system dedicated to a specific building. The cooling plants range in age, size and usage with some systems providing full building cooling while other systems provide cooling for electrical equipment rooms and/ or high occupancy spaces. The following are highlights from the main document, meant to give a brief overview of important aspects of the chilled water system(s):

- Per ASHRAE HVAC standards, three of the ten chilled water systems have reached their life-expectancy of 25-years in operation; Bond Hall, Morse Hall and Ross Engineering Tech. Bond Hall has the oldest chilled water system on campus and is considered to be at the end of its useful life per interviews with the facility engineers.

- Haggard Hall has been in operation for around 18 years which is approximately 75% of its useful life-expectancy. However, per interviews with the facility engineers the chiller requires frequent monitoring to assure proper operation beyond what is planned as preventative maintenance. Frequent monitoring is likely a result of the relatively large number of starts, 9,019-starts, for 17,256 run time hours and the large number of starts is most likely attributed to the larger chiller size versus low cooling load demand. Ideally, a properly size chiller plant starts and stops once per day. However, it is not uncommon to see a system stop and start 2x to 3x per day. Haggard Hall chiller is stopping and starting nearly once every 2-hours which is putting additional wear on the chiller potentially reducing the useful life as the useful life is proportional to the number of starts. In addition to the large number of starts per run time hours, the efficiency of the chiller is drastically reduced during part load hours when the system is over-sized. Per the mechanical schedules the Haggard Hall chiller was designed to operate at 0.6 KW/Ton. Depending on what maintenance has been performed, it is likely that the chiller is operating closer to 0.7-0.8 KW/ton and during part load conditions could be much closer to 1.0 KW/ton if hot gas bypass is used. In comparison, a new centrifugal water cooled chiller comparable to the one installed at Haggard Hall will operate closer to 0.5 KW/ton. It should also be noted that industry standard recommends a complete rebuild of centrifugal chillers after 8-10 years of operation and/ or 30,000-50,000 hours in operation which could cost around $35k-$70k. This would include new motor, compressor, Eddy current tube analysis, etc. In addition, if the control panel is upgraded ($30k-$35k) and VFD is added ($65k) to the compressor for improved efficiency the cost of upgrading could cost around $170k which is roughly half the cost of a new chiller.

- According to the mechanical schedules and site verification, (7) of the (10) chillers on the WWU campus us R-22 or R-123 refrigerant which is an HCFC refrigerant in the process of being phased out. January 1, 2020 is the cut-off when no new imported R-22 or HCFC refrigerant will be allowed in the US. It is important to note that although no new R-22 will be manufactured or imported in the US, R-22 will still likely be available for purchase in some capacity (refrigerant recyclers) at an expected premium price.
- According to the mechanical schedules and site verification, the majority of chillers on the WWU campus have chilled water systems that appear to be designed for larger equipment/ server rooms and/ or high occupant load spaces without substantial excess capacity. Haggard Hall, Communications Facility, and AIC are the exception as these systems appear to be sized and designed to accommodate full building cooling per review of the mechanical plans. With the total connected load at approximately 50%, Haggard Hall and Communications Facility chilled water systems could be candidates to support future expansion as the chilled water plant for each of these buildings is currently being underutilized.
- This existing tunnel system used as a pathway for the distribution of steam, condensate, electrical conduit, compressed air, abandoned pipes and other utilities is in relatively good condition. All systems are racked and organized with power/ communications and piping on opposite sides separated by a walking path down the middle of the tunnel. The tunnel would serve as an efficient pathway to distribute chilled water if a central chilled water system is considered in the future. It is recommended that the existing abandoned chilled water pipe from the 1970's be tested prior to making and decisions on re-using.

The following is a list of recommended measures for Western Washington University to consider:

- Building Energy Monitoring: Provide BTU meters in the chilled water piping system and electrical metering to provide a resource to monitor mechanical energy usage and to assist in evaluating system efficiency.

- Standardize Campus Design Criteria and Specifications: Per review of the mechanical plans there does not appear to be a standard for design engineers and contractors to follow. It's recommended that a standard be put in place so all buildings are similarly designed with an eye toward the future and a potential transition toward a central chilled water system. Things that can be standardized are:
    - Energy metering at all new buildings
    - Pumping logic
    - System temperature difference (ΔT) and leaving water temperature
    - Equipment manufacturers
    - Office, Kitchen, Lab, Electrical room design requirements, etc.
    - Material types, etc.
- Refrigerant Phase out Plan: It is recommended that WWU create a phase out plan for equipment with R-22 and R-123 HCFC refrigerant as well as for equipment that is approaching its use-full life expectancy. The following is a table indicating each chilled water system, year it was build, replacement time frame and the estimated replacement cost.

CHILLED WATER SYSTEM REPLACEMENT COSTS

BUILDING	YEAR BUILT	REPLACEMENT YEAR	COOLING CAPACITY (TONS)	ESTIMATED TOTAL REPLACEMENT COST	ESTIMATED ANNUAL RENEWAL
BOND HALL	1987	2012-2017	20	$60k - $80k	$60k - $80k
ROSS ENGINEERING TECH	1987	2012-2017	45	$135k - $180k	$135k - $180k
MORSE HALL	1991	2016-2021	54	$162k - $216k	$41k - $54k
HAGGARD HALL	1999	2024-2029	277	$831k – $1,108k	$70k - $93k
RECREATION CENTER	2001	2026-2031	45.5	$138k – $184k	$10k - $13k
COMMUNICATIONS Facility	2004	2029-2034	210	$630k - $840k	$37k – $50k
AIC	2007	2032-2037	310	$930k - $1,240k	$47k - $62k
WILSON LIBRARY	2010	2035-2040	26	$78k - $104k	$3.5k - $4.5k
MILLER HALL	2011	2036-2041	80	$240k - $320k	$10k – $13.5k
CARVER GYMNASIUM	2016	2041-2046	50	$150k - $200k	$5.5k - $7k

The median equipment life expectancy for a reciprocating chiller is 23 years per ASHRAE standards. However, it is not uncommon to see a chiller in operation exceed the expected useful life so a 25-30 year useful life expectancy is being used to project the estimated cost of replacement. The estimated cost for replacement in the table above is based on $3,000 - $4,000 per ton for a high efficiency chilled water system; this would include equipment, accessories and labor within the mechanical room. The Estimated Total Replacement Cost is the approximate cost to replace a system today if it failed while the Estimated Annual Renewal is the approximate cost if the total cost to replace was evenly distributed over the remaining expected life. For example, the total cost to replace Morse Hall would be around $162,000 - $216,000 if WWU waited to allocate funding until the system was replaced. Since the system has 4-years of life remaining, $41,000 - $54,000 could be saved per year to meet the future renewal & replacement cost.

- Bond Hall Chiller Replacement: It is recommended that the chilled water system be upgraded with either a high-efficiency air cooled chiller or connected to a central chilled water system like Haggard Hall (see recommendation below). The 20-ton Carrier chiller has extensive run-time ours, suspect condition and has reached the end of its useful life. In addition, the 30-ton Trane backup chiller is seldom used and considered not very useful because the capacity is much larger than the actual load and the unit lacks staging resulting in a very low operating efficiency. The Liebert unit on the roof is a free cooler without a compressor. It is utilized in the peak winter and parts of the shoulder season when free cooling can be utilized. It should be noted that while on site observing this system the outside air temperature was in the upper 30's and the Carrier chiller was energized, not the free cooler indicating that the controls system needs to be upgraded as well.

- North Chilled Water System: It is recommended that the Haggard Hall building be considered as the source for a north chilled water system that can serve all buildings around Red Square. There are currently (5) buildings around Red Square that have cooling and another building, Performing Arts, that uses cooling via a remote chiller on peak cooling days. Haggard Hall currently has a 280-ton chiller in operation with space allocated for an additional 280-ton, potentially more depending on equipment size versus available space. The total connected load for all chilled water systems around Red Square is approximately 346-tons which is 23% more than what the Haggard Hall system was designed for. When taking into account the chilled water capacity used, envelope diversity and occupant diversity the Haggard Hall system likely has enough capacity to serve all buildings at their current operating conditions. With the addition of a second chilled water system, Wilson Library and Performing Arts could be added to the loop and be fully conditioned as well as other buildings are around Red Square that currently do not have air conditioning. The following table is a summary of the current chilled water capacity for each building around Red Square as well as the cooling tonnage currently being used. In addition, future capacity has been allocated for the Wilson Library and Performing Arts Center to accommodate additional building cooling and the potential renovation and addition at Performing Arts. Future capacity is based on 600 square-feet per ton of cooling and 40% of the building being conditioned. The result is that to be the central plant for the North loop, Haggard Hall will need to accommodate approximately

400-600 tons of cooling depending on each buildings final programming, cooling requirements and building diversity as determined by WWU.

NORTH CHILLED WATER COOLING SYSTEM CAPACITY

BUILDING	***COOLING CAPACITY (Tons)***	***COOLING CAPACITY USED (Tons)***	***FUTURE CAPACITY (Tons)***
Bond Hall	20	15	--
Carver Hall	50	50	--
Haggard Hall	140	140	--
Miller Hall	80	40	--
Wilson Library	26	8	68
Performing Arts	30 (Rental)	30	90
Sub-Total	346	283	158
Combined Total		441-Tons	

- South Chilled Water System: It is recommended that the extra capacity at the Communication Facility be used to cool adjacent buildings around Haskell Plaza. The Communications Facility has a 150-ton and a 60-ton water cooled chiller located in the basement adjacent to the utility tunnel. Of the 210-tons installed, roughly 105-tons is being used. This additional capacity could be distributed to Ross Engineering Tech (45 Tons) and Morse Hall (54 Tons) which have existing chilled water systems at the end of their life expectancy. If additional capacity is required to accommodate future renovation to Arntzen Hall, Biology and/ or Environmental Studies then it is recommended that a future renovated building be the location of the south chiller water cooling plant with capacity and space to accommodate all existing and future cooling loads around Haskell Plaza. The following table is a summary of the current chilled water capacity for each building around Haskell Plaza as well as the cooling tonnage currently being used. In addition, future capacity has been allocated for Arntzen Hall, Biology and Environmental Studies. Future capacity for Biology is based on 600 tons of cooling per square foot and 40% of the building being conditioned. Future capacity for Arntzen Hall and Environmental Studies is based on the buildings original design capacity from the 1970's. This correlated to enough capacity for full building cooling at 600 square-feet per ton of cooling. The result is that the south chilled water system will need to accommodate approximately 700-900 tons of cooling depending on each buildings final programming, cooling requirements and building diversity as determined by WWU.

SOUTH CHILLED WATER COOLING SYSTEM CAPACITY

BUILDING	***COOLING CAPACITY (Tons)***	***COOLING CAPACITY USED (Tons)***	***FUTURE CAPACITY (Tons)***
Communications	210	75	--
Morse Hall	54	49	--
Engineering Tech	45	41	--
AIC	310	271	--
Arntzen Hall	--	--	160
Biology	--	--	55
Environmental	--	--	145
Sub-Total	619	436	360
Total		796-Tons	

- Heat Recovery Chillers: Implementing Heat Recovery is a great way to save additional system energy when designed and operated correctly. HVAC and heating water can consume nearly 50% of the total building energy usage. Heat recovery chillers and heat pumps are an attractive option because they can provide high efficiency cooling (COP 3-4) and heating (COP 3-4). In a combined operation where they provide simultaneous heating and cooling, the coefficient of performance (COP) can be as high as 7. This has substantial benefits over Direct Expansion (DX) cooling which is has a COP of 2.5-3.0 and traditional heating systems that can have a COP of 0.85 for a traditional boiler and 0.95 for a condensing boiler. In the event the steam plant transitions to heating water boilers, heat recovery chillers could be utilized as one of the building heating sources.

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Notes:

1. ROM Energy Savings accounts for utility savings only.
2. Anticipated Simple payback when accounting for the expected required expenditure to renew, operate, and maintain the existing chilled water systems (business as usual; BAU). This reflects the incremental payback by implementing the proposed measure.
3. Costs for connecting to existing in-building cooling distribution from the identified district location. This assumes the connected facility has been remodeled with CHW cooling infrastructure and is ready to be connected to a district cooling plant. Also assumes that existing plant has cooling capacity to serve newly connected facility.

7. ELECTRICAL POWER DISTRIBUTION SYSTEM

7.1. Existing System

7.1.1. Electrical Service

Western Washington's Bellingham Campus is presently supplied power from Puget Sound Energy's Viking Substation with 3 each 12,470 volt, 3 phase, 3 wire circuits. Each circuit is nominally rated 450 amps.

Each circuit from Puget Sound Energy is fed underground to 3 each padmounted style switchgear cabinets located at the Physical Plant yard which provide the service disconnecting means and circuit protection for the primary power distribution system for the campus.

Each of the 3 primary switchgear cabinets are also provided with loop feed tie switches and are wired together in such a manner that, upon a failure of any 1 or 2 of the Puget Sound Energy circuits or the campus distribution circuits, any of the 3 campus distribution circuits can be fed from any 1 or 2 of the Puget Sound Energy circuits.

7.1.2. Existing Campus Primary Power Distribution System

The main campus is fed with 3 each 12,470 volt, 3 phase, 3 wire circuits, each originating from one of the service switchgear cabinets. Each circuit is 500 kcmil, 15 kv shielded copper cables, nominally rated 450 amps.

Existing Circuit A extends from the Physical Plant underground via a conduit duct bank system and through the campus utility tunnels. It is looped through and feeds generally the buildings on the south end and east side of campus. Circuit A ends on an open switch at the existing Steam Plant Substation #4.

Existing Circuit B extends from the Physical Plant underground via a conduit duct bank system and through the campus utility tunnels (generally following the same route as Circuit A). It is looped through and feeds generally the buildings on the north end of campus. It ends at an open switch at the existing Viking Commons (VC) substation.

Existing Circuit C extends from the Physical Plant underground via a conduit duct bank system and through the campus utility tunnels, and is looped through and feeds generally the buildings on the south end and west side of campus. Circuit C extends to the existing Carver Gym Substation #5. From Carver Gym Substation #5, Circuit C also presently feeds some of the buildings at the north end of campus – Bond Hall, Haggard Hall and the Viking Complex.

A 200 amp sub-circuit of circuit C is looped through the Ridgeway Residence Complex of buildings from a padmounted switchgear near the track to the existing Carver Gym Substation #5.

A 200 amp sub-circuit of circuit B is looped through the North Campus Residence buildings from metal enclosed switchgear inside Wilson Library to metal enclosed switchgear inside Old Main.

In general, the existing power distribution system on campus is arranged in a loop so that the failure of a single cable or the like could be bypassed easily and the affected buildings be provided with full power within hours.

7.1.3. Existing Loads

The highest loads on the 3 feeders during the last 13 months, as measured by WWU, are as follows:

- Circuit A 2305 KVA (107 amps)
- Circuit B 1704 KVA (79 amps)
- Circuit C 2689 KVA (124 amps)

All 3 circuits are well below their nominal capacity of 450 amps. Circuit C has the highest load, and it's still only loaded to approximately 30% of nominal capacity.

Each of the circuits also has sufficient capacity so that if any feeder should fail for some reason, any of the other 2 circuits could carry the load of the failed circuit indefinitely. In fact, should any 2 of the feeders fail for some reason, the other feeder would have enough capacity to carry the entire campus load.

7.2. Existing Conditions Deficiencies

7.2.1. Existing Equipment and Cables

As a consequence of the ongoing program to upgrade the existing service and power distribution system, much of the existing equipment and cabling is fairly new and is in good condition.

7.3. Future Conditions Evaluation

7.3.1. Loads

All 3 existing services and circuits are well below their nominal capacity of 450 amps, and certainly have capacity for any planned future expansion of the campus.

The future on-campus growth in building space is expected to be in the 30% - 33% range, with most of the growth in the southern portion of campus. It is expected that the electrical load growth will closely follow the expected growth in building space. The existing service and power distribution system have more than enough capacity for the projected load growth, and will still have capacity to provide power to the entire campus upon the failure of a single service or feeder.

7.3.2. Service and Power Systems Design

The existing primary service and power distribution is a well-designed and functional system allowing most system or equipment failures to be bypassed without significant power outages, and providing spare capacity to handle all loads that are presently planned and more.

7.3.3. System Life

Electrical service and power distribution systems equipment, cables, etc. is expected to have a minimum 20 to 30 year life (or more) if installed properly and not overloaded for any length of time. The major deteriorating factors are heat, moisture and dirt. If the equipment, cables, etc. are loaded, operated and maintained properly in the environment that they were designed for, substantially longer life times are possible.

7.4. Recommended Improvements

7.4.1. Phasing and Priorities

To accomplish the Master Plan, the work does not necessarily have to follow a specific sequence. Recognizing that budgets and priorities do change at times, the work can be done at any time:

Arntzen Hall:	Replace aging medium voltage switchgear.
Buchanan Towers:	Replace aging medium voltage transformer.
Commissary:	Replace aging medium voltage switchgear and transformer.
Engineering Technology:	Replace aging medium voltage switchgear and transformer and provide loop circuit from Arntzen Hall.
Environmental Studies:	Replace aging medium voltage transformer.
Fairhaven Towers Dorm Building Complex:	Convert supply circuit from a radial feed configuration to a loop feed system. This will allow power to be supplied to each building from two directions, allowing any failure point on the system to be isolated and building power restored within hours.

Fairhaven Towers Dorm Building Complex:	The existing exterior padmount transformers are approximately 21 years old. They are nearing the end of their lifecycle. It is anticipated that they will be okay for the next ten years, however, oil testing and monitoring are recommended.
Fairhaven Academic:	Replace aging medium voltage switchgear and transformer. Approximate cost $286,000.
Fine Arts:	Replace aging medium voltage switchgear and transformer, remove supply from tap in the tunnel and resupply with its own circuit from the Steam Plant Switchgear. Re-feed Fine Arts from the Steam Plant switchgear. This will segregate any failures to the building itself and eliminate the possibility that a failure at Fine Arts could disrupt one of the main campus circuits.
Outback Area:	Provide a medium voltage feeder from tunnel Node T7 and provide power service for Outback Area and Amphitheater (this item possibly could be considered a long term improvement that could be achieved beyond the next 10 years).
Parks Hall:	Replace aging medium voltage transformer.
Physical Plant:	Provide a medium voltage feeder and transformer to Physical Plant yard to create a service for battery vehicle charging stations (vans and cars).
Steam Plant:	Replace aging medium voltage transformer supplying the Steam Plant building.

7.4.2. Cost Estimates

Depending on the specifics of the necessary improvements, construction costs for the above described improvement are approximately as follows:

Facility	***Approximate cost***
Arntzen Hall:	$198,000
Buchanan Towers:	$99,000
Commissary:	$286,000
Engineering Technology:	$313,000
Environmental Studies:	$100,000
Fairhaven Towers Dorm Building Complex (Convert to loop system):	$143,000
Fairhaven Towers Dorm Building Complex (Replace transformers):	$138,000
Fairhaven Academic:	$286,000
Fine Arts:	$319,000
Outback Area:	$138,000
Parks Hall:	$55,000
Physical Plant:	$138,000
Steam Plant	$114,000

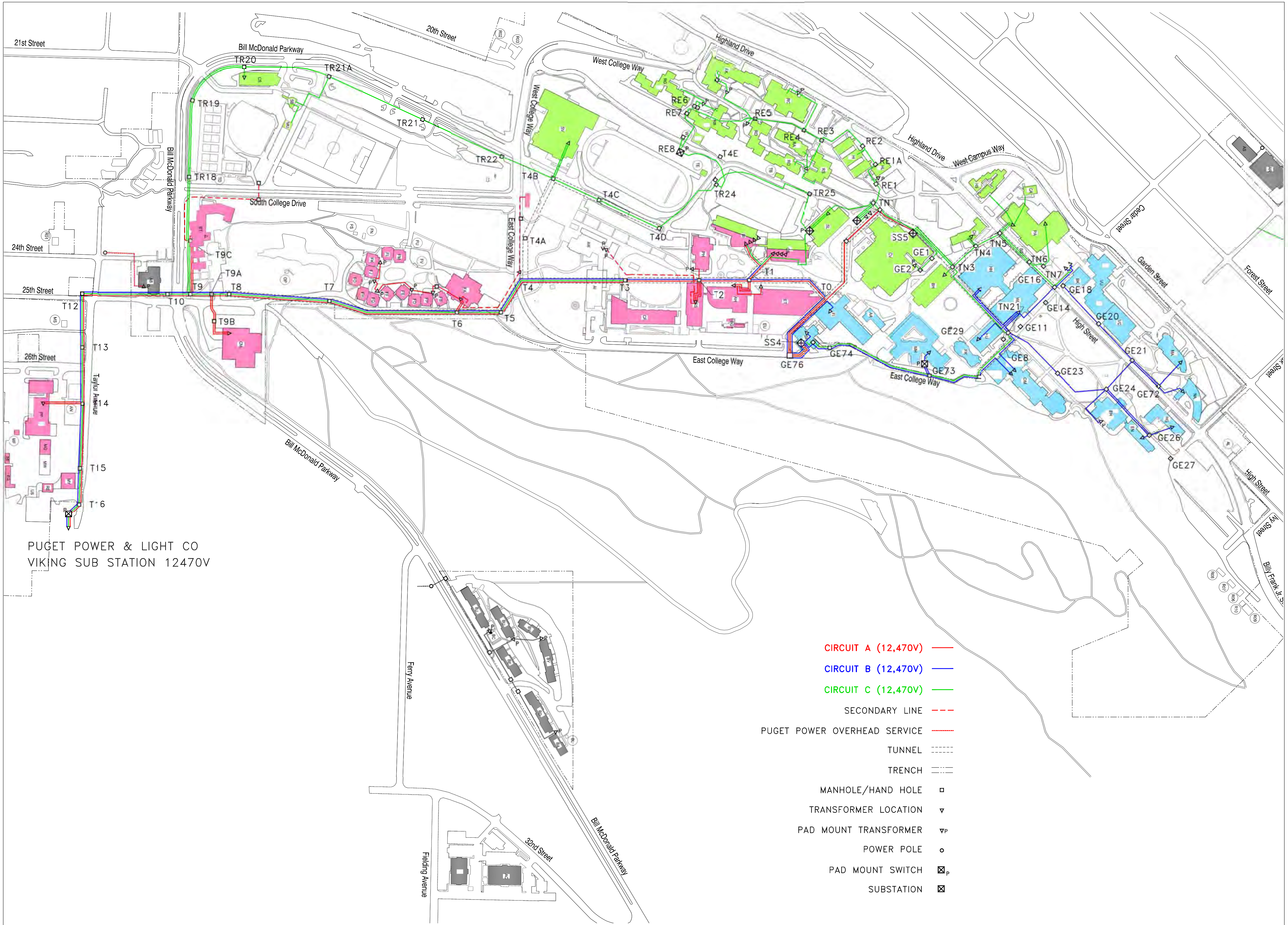
Some of the bigger issues affecting costs are space availability and limitations on when and for how long the power to an existing building can be interrupted. For safety reasons, codes are requiring more exits and more operating and maintenance space around electrical equipment than in the past; therefore, a one-for-one replacement is not always possible without making building modifications and/or relocating the equipment, which increases the costs. Also, because the buildings are existing and have on-going program requirements, the times when power can be interrupted are very limited which, in many cases, can increase the costs significantly.

7.4.3. Conclusions

In the mid-1990's, WWU began a program through various projects to upgrade the existing service and power distribution system on the campus. The primary goals of that program were to replace the old cables, loop the system so a failure could be bypassed easily and power restored within hours instead of days (or even weeks), and to replace the old 4160 volt system which was a serious bottleneck in the system. The upgrade program has been implemented and completed, except for the Fine Arts item listed above.

7.4.4. Appendices

Drawing MP-E1	Campus Electrical System Existing Primary Distribution Location Plan Master Plan (Sheet 1)
Drawing MP-E2	Campus Electrical System Existing Single Line Diagram Master Plan (Sheet 2)
Drawing MP-E3	Campus Electrical System Existing Single Line Diagram Master Plan (Sheet 3)



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REV	DATE	DESCRIPTION	BY	APRV

WESTERN WASHINGTON UNIVERSITY

CAMPUS ELECTRICAL SYSTEM
EXISTING PRIMARY DIST. LOCATION PLAN
MASTER PLAN

Client Review	Maintenance Review	Renovation Review	Approved by
Designed by STV	Drawn by KL	Project Manager JK	Date 6-5-2017

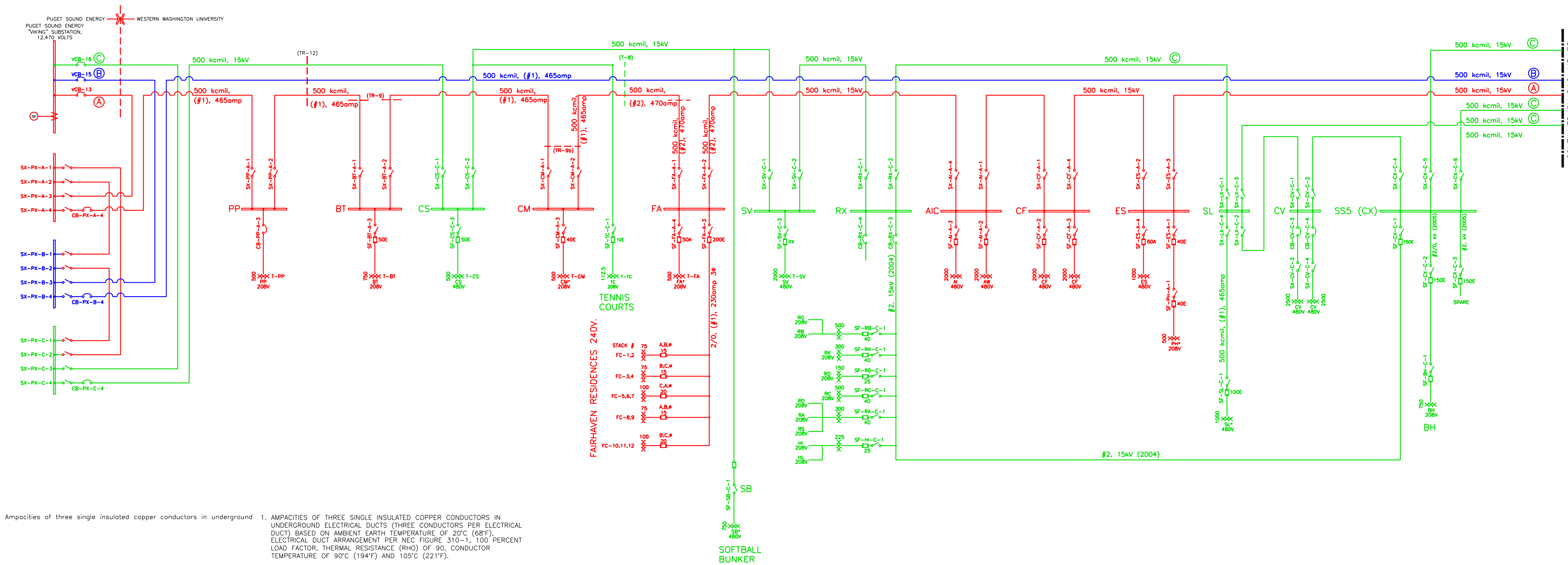
1809

Building/Zone: UT

Sheet #: MP-E1 of

Job Number

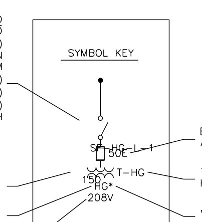
Microfile Number



Ampacities of three single insulated copper conductors in underground

1. AMPACITIES OF THREE SINGLE INSULATED COPPER CONDUCTORS IN UNDERGROUND ELECTRICAL DUCTS (THREE CONDUCTORS PER ELECTRICAL DUCT) BASED ON AMBIENT EARTH TEMPERATURE OF 20°C (68°F), ELECTRICAL DUCT ARRANGEMENT PER NEC FIGURE 310-1, 100 PERCENT LOAD FACTOR, THERMAL RESISTANCE (RHO) OF 90, CONDUCTOR TEMPERATURE OF 90°C (194°F) AND 105°C (221°F).
2. AMPACITIES OF AN INSULATED THREE-CONDUCTOR COPPER CABLE IN ISOLATED CONDUIT IN AIR BASED ON CONDUCTOR TEMPERATURE OF 90°C (194°F), AND 105° C (221°F), AND AMBIENT AIR TEMPERATURE OF 40°C (104°F).
3. AMPACITIES OF AN INSULATED TRIPLEXED OR THREE SINGLE CONDUCTOR COPPER CABLES IN ISOLATED CONDUIT IN AIR BASED ON CONDUCTOR TEMPERATURE OF 90°C (194°F), AND 105°C (221°F), AND AMBIENT AIR TEMPERATURE OF 40°C (104°F)
4. EXISTING AVAILABLE FAULT CURRENT @ PSE VIKING BUS
   32G – 6237.9 @ – 56.5 DEG (A-PHASE) X/R = 16.1
   16G – 5335.5 @ – 58.0 DEG (A-PHASE) X/R = 28.3
   6G – 5402.0 @ – 146.5 DEG (B-PHASE) X/R = 16.1

EQUIPMENT DESIGNATOR LEGEND
SF=SWITCH, FUSED
(SX=SWITCH, NON-FUSED)
HG=BUILDING LOCATION
L=4160 VOLT SYSTEM
(A=12470 VOLT SYSTEM, VCB-13)
(B=12470 VOLT SYSTEM, VCB-15)
(C=12470 VOLT SYSTEM, VCB-16)
1=SEQUENTIAL NUMBER OF SWITCH



TRANSFORMER kVA
BUILDING DESIGNATOR
TRANSFORMER SECONDARY VOLTAGES
E = AIR
A = OIL
T=TRANSFORMER
HG=BUILDING LOCATION
"*" = Existing Demand Meter

NOTE: TRANSFORMER SECONDARY VOLTAGES ARE NOTED UNDER THE TWO LETTER BUILDING DESIGNATOR.
208V DENOTES 120/208V., 3ø, 4W.
240V DENOTES 120/240V., 1ø, 3W.
480V DENOTES 277/480V., 3ø, 4W.

(1) SHUNT TRIP PUSH BUTTON IS LOCATED IN TRANSFORMER ROOM TO ACTIVATE REMOTE SWITCH.

CIRCUIT A (12,470V)
CIRCUIT B (12,470V)
CIRCUIT C (12,470V)

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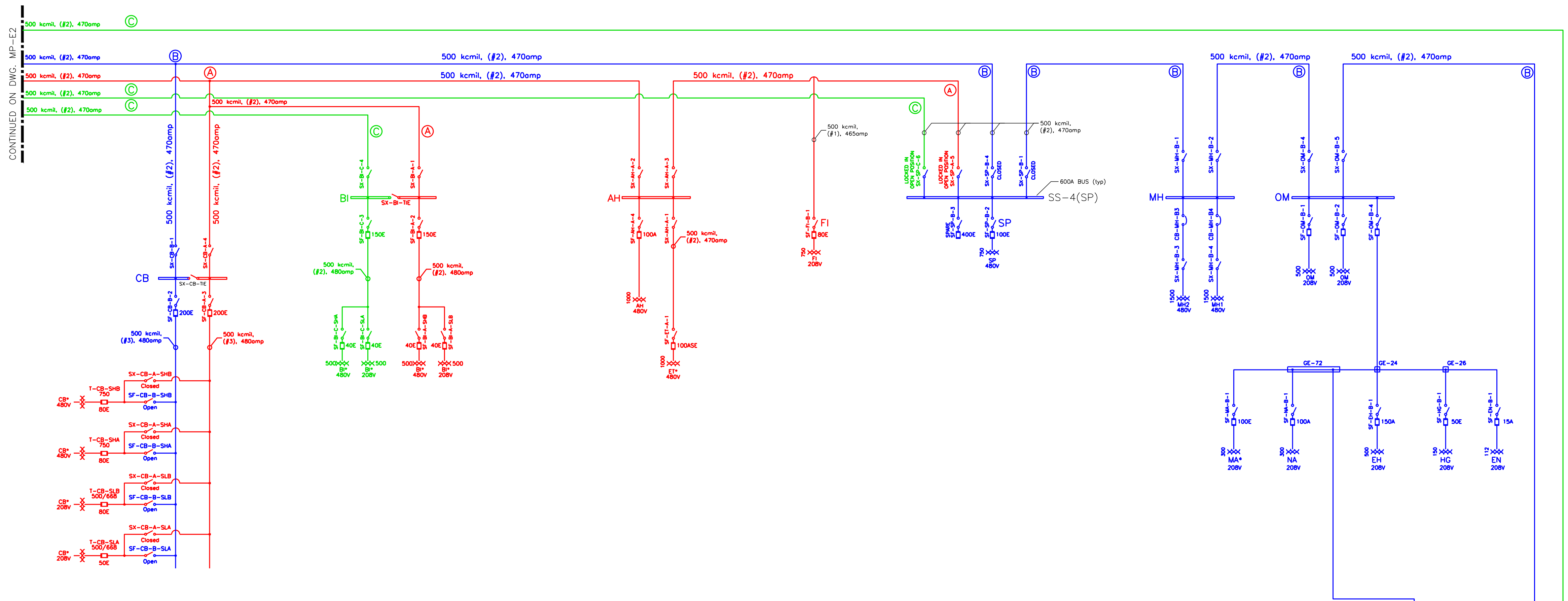
WESTERN WASHINGTON UNIVERSITY

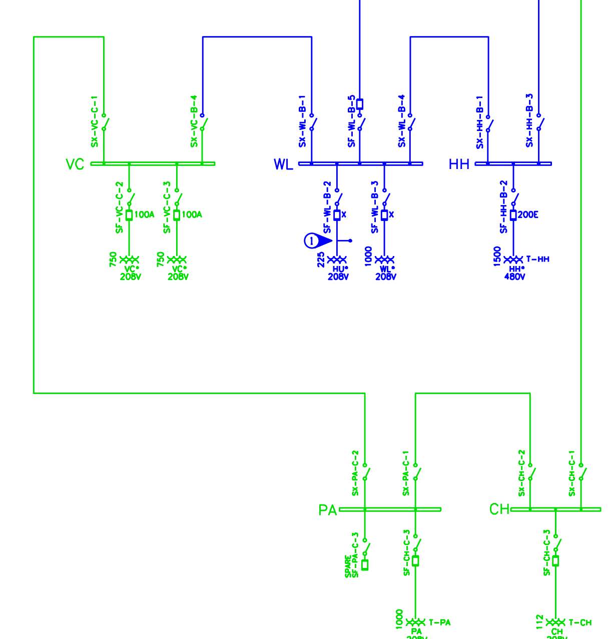
CAMPUS ELECTRICAL SYSTEM
EXISTING SINGLE-LINE DIAGRAM
MASTER PLAN (SHEET 1)

Client Review / Maintenance Review / Renovation Review / Approved by
Designed by STV / Drawn by KL / Project Manager JK / Date 6-5-2017

1809

Building/Zone: UT
Sheet #: MP-E2 of -
Job Number
Microfile Number





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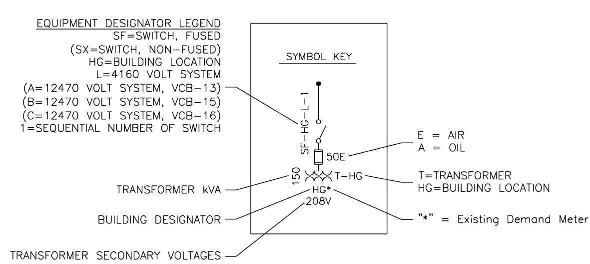

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(1) SHUNT TRIP PUSH BUTTON IS LOCATED IN TRANSFORMER ROOM TO ACTIVATE REMOTE SWITCH.

CIRCUIT A (12.47kV)
CIRCUIT B (12.47kV)
CIRCUIT C (12.47kV)

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REV	DATE	DESCRIPTION	BY	APRV

WESTERN WASHINGTON UNIVERSITY

CAMPUS ELECTRICAL SYSTEM
EXISTING SINGLE-LINE DIAGRAM
MASTER PLAN (SHEET 2)

Client Review | Maintenance Review | Renovation Review | Approved by
Designed by STV | Drawn by KL | Project Manager JK | Date 6-5-2017

1809

Building/Zone: UT

Sheet #: MP-E3 of

Job Number

Microfile Number

8. EMERGENCY & STANDBY POWER SYSTEMS

8.1. Existing Systems

8.1.1. Generators

39 buildings on campus are connected to permanently installed generators as follows:

Administrative Services Building (AC) – 275 KW Kohler diesel fueled generator with 474 gallon fuel tank and weather-proof sound attenuated enclosure. The generator is located outdoors in a concrete enclosure northwest of the building and feeds 2 each telecommunications UPS Units, 1 of the 2 telecommunications room air conditioning units, fire alarm panel, FM200 system, security panel, and miscellaneous lighting in the building via two automatic transfer switches and combination emergency/standby power distribution system.

Arntzen Hall (AH) –50 KW Kohler diesel fueled generator with 200 gallon double wall fuel tank and weather-proof sound attenuated enclosure. The generator is located outdoors east of the building (near the northeast corner of ES) and provides power for both AH and PH via 4 automatic transfer switches. 2 each automatic transfer switches feed AH (1 for emergency power and 1 for standby power) and 2 feed PH (1 for emergency power and 1 for standby power)and their associated power distribution systems.

Academic Instructional Building (AI) – 600 KW Detroit diesel fueled generator with two fuel tanks, one 55 gallon day tank and a second 800 gallon storage tank.

Bond Hall (BH) - 200 KW Cummins diesel fueled generator with 240 gallon double wall fuel tank. The generator is located indoors in Room 101 and feeds 2 each automatic transfer switches (1 for emergency power and 1 for standby power) and associated power distribution systems. For the most part, the emergency and standby type loads are separated into the 2 separate systems. The generator does have sufficient capacity for the addition of up to a 50 HP fire pump in the future.

Biology Building (BI) - 150 KW Aptech diesel fueled generator with 185 gallon fuel tank and weather-proof enclosure. The generator is located outdoors at the Steam Plant Cooling Tower and feeds a single automatic transfer switch and an associated power distribution system with mostly standby type loads.

Buchanan Towers (BT) - 150 KW Kohler diesel fueled generator with 150 gallon fuel tank. The generator is located outdoors north east of the building near the parking lot and feeds two automatic transfer switches powering life safety panel 1LE1 and elevator panel 1LE2.

Chemistry Building (Morse) (CB) - 175 KW Energy Dynamics diesel fueled generator with 150 gallon fuel tank and weather-proof enclosure. The generator is located outdoors at the Steam Plant Cooling Tower. The generator feeder routes through the tunnel system to a power distribution panel in the Chemistry Building then to 2 each automatic transfer switches and associated power distribution systems, 1 for an elevator and the other for both emergency and standby type loads.

Communications Facility (CF) - 130 KW diesel fueled generator with 275 gallon fuel tank. The generator is located indoors in Room 52A and feeds 2 automatic transfer switches and an associated power distribution systems – one for emergency type loads and the other for standby type loads.

College Hall (CH) - 12 KW Generac diesel fueled generator with 30 gallon fuel tank and weather-proof sound attenuated enclosure. The generator is located outdoors north of the building and feeds an automatic transfer switch and an associated power distribution system with mostly emergency type loads.

Commissary (CM) –30 KW Onan diesel fueled generator with 20 gallon double wall fuel tank and weather-proof enclosure. The generator is located outdoors south of the building and feeds 2 each automatic transfer switches (1 for emergency power and 1 for standby power) and associated power distribution systems. For the most part, the emergency and standby type loads are separated into the 2 separate systems.

Campus Services Facility (CS) - 275 KW diesel fueled generator with 540 gallon fuel tank and weather-proof enclosure. The generator is located outdoors northeast of the building and feeds an automatic transfer switch and an associated power distribution system with mostly emergency type loads.

Carver Gym (CV) – A project is underway to replace the existing 12 KW Onan generator with a new 250 KW diesel fueled generator with weather-proof and sound attenuated enclosure. The new generator will be located outdoors (near the south east corner of CV) and feed 2 each automatic transfer switches (1 for emergency power and 1 for standby power) and associated power distribution systems.

Edens Hall (EH) - 15 KW Generac diesel fueled generator with 30 gallon fuel tank. The generator is located indoors in Mechanical Room 123.

Edens North (EN) - 8 KW Onan diesel fueled generator with 30 gallon fuel tank. The generator is located indoors in Mechanical Room MR1 (Room 07).

Environmental Studies (ES) – 200 KW Kohler diesel fueled generator with 500 gallon fuel tank and weather rated sound attenuated enclosure. The generator is located outdoors in the generator bunker on the east side of ES and feeds 3 each automatic transfer switches (1 for fire pumps, 1 for emergency power, and 1 for standby power) and their associated power distribution systems.

Engineering Technologies (ET) - 125 KW Kohler diesel fueled generator with weather rated sound attenuated enclosure. The generator is located outdoors south of the building and feeds 2 automatic transfer switches (1 for emergency power and 1 for standby power) and their associated power distribution systems.

Fairhaven Academic (FA) – 125 KW Kohler diesel fueled generator with 316 gallon fuel tank and weather rated sound attenuated enclosure. The generator is located outdoors at the north east corner of the building and supplies 2 each automatic transfer switches (1 for emergency power and 1 for standby power) and their associated power distribution systems.

Fine Arts (FI) and Arts Annex (AA) – Battery backup type unit equipment. The facilities do not have a generator.

Fraser Hall (FR) – See Humanities Building (HU).

Haggard Hall (HH) - 35 KW Aptech diesel fueled generator with 90 gallon fuel tank. The generator is located indoors in Room 103. The Haggard Hall generator also feeds Wilson Library.

Humanities Building (HU) / Fraser Hall (FR) – 2 automatic transfer switches (1 for emergency power and 1 for standby power) located in the HU basement are fed from the Old Main (OM) generator and provide power to both HU and FR emergency and standby power distribution systems.

Mathes Hall (MA) - 137 KW Kohler diesel fueled generator with a 316 gallon fuel tank and weather rated sound attenuated enclosure. The generator is located outdoors in the generator bunker north west of the building and feeds 2 automatic transfer switches (1 for MA emergency power and 1 for NA emergency power) and their associated power distribution systems.

Higginson Hall (HG) – No generator.

Miller Hall (MH) – 175 KW Caterpillar diesel fueled generator with 750 gallon fuel tank and sound attenuated enclosure. The generator is located indoors on the lower level in the generator room and feeds 3 automatic transfer switches (1 for fire pumps, 1 for emergency power, and 1 for standby power) and their associated power distribution systems.

Nash Hall (NA) – 1 automatic transfer switch (emergency power) located in the NA basement is fed from the Mathes Hall generator.

Old Main (OM) - 125 KW Kohler diesel fueled generator with weather rated sound attenuated enclosure. The generator is located outdoors above the snake pit, south east of OM, and provides power for both OM and HU/FR via 5 automatic transfer switches. 3 each automatic transfer switches feed OM (1 for emergency power, 1 for standby power, and 1 for fire pumps) and 2 feed HU/FR (1 for emergency power and 1 for standby power) and their associated power distribution systems.

Performing Arts Center (PA) – 125 KW Kohler diesel fueled generator with sound attenuated enclosure. The generator is located indoors in the PA basement and feeds 4 automatic transfer switches (2 for emergency power and 2 for standby power) and their associated power distribution systems.

Parks Hall (PH) – 2 automatic transfer switches (1 for emergency power and 1 for standby power) located in the PH basement are fed from the Arntzen Hall (AH) generator.

Physical Plant (PP) - 150 KW Onan diesel fueled generator with 195 gallon fuel tank and weather-proof enclosure. The generator is located outdoors and feeds an automatic transfer switch and associated power distribution system with both emergency and standby type loads. The generator also feeds an auxiliary distribution panel that is kirk-key interlocked and can manually back-feed the entire Physical Plant. Kirk-keys are a physical key similar to any door lock key, however, there is only one key and it operates two breakers. The key has to be inserted in the breaker in order the breaker to be turned on. The key only be removed if the breaker is turned off. Then the key is available to be inserted into the other breaker so that it can be turned on. This ensures that only one breaker is on at one time. This is a manual operation only and is not automatic.

Ridgeway Alpha (RA) - 6 KW Onan diesel fueled generator with 10 gallon fuel tank. The generator is located indoors in Room 01A.

Ridgeway Beta (RB) – No generator.

Ridgeway Commons (RC) - 6 KW Onan diesel fueled generator with 10 gallon fuel tank. The generator is located indoors in Room 01A and feeds an automatic transfer switch in Room 129 and associated power distribution system with mostly emergency type loads.

Ridgeway Delta (RD) - 6 KW Onan diesel fueled generator with 10 gallon fuel tank. The generator is located indoors in Room 220.

Ridgeway Gamma (RG) – No generator.

Ridgeway Kappa (RK) - 18 KW Generac diesel fueled generator with 40 gallon fuel tank and weather-proof enclosure. The generator is located outdoors south of the building and feeds an automatic transfer switch in Electrical Room ER-1 (Room 135) and associated power distribution system with emergency type loads and some standby type loads, including the radio repeater for mobile communications.

Ridgeway Omega (RO) – Supplied with Ridgeway Sigma Generator

Ridgeway Sigma (RS) - 60 KW Cummins diesel fueled generator with 60 gallon fuel tank. The generator is located outdoors.

SMATE (SL) - 15 KW Aptech diesel fueled generator with 55 gallon fuel tank. The generator is located indoors in Room 105A.

Steam Plant (SP) - 150 KW Onan diesel fueled generator with 225 gallon fuel tank and weather-proof enclosure. The generator is located outdoors at the Steam Plant Cooling Tower and feeds an automatic transfer switch and associated power distribution system with mostly standby type loads.

Wade King Recreation Center (SV) - 155 KW Kohler diesel fueled generator with 300 gallon fuel tank and weather-proof enclosure. The generator is located outdoors northwest of the building and feeds 3 each automatic transfer switches (1 for emergency power, 1 for standby power and 1 for the fire pump) and associated power distribution systems.

Viking Complex (VX) - 95 KW Kato Light diesel fueled generator with 110 gallon fuel tank and weather-proof enclosure. The generator is located indoors in Room 598 under the Performing Arts Center overhang and feeds 2 each automatic transfer switches (1 for emergency power and 1 for standby power) and associated power distribution systems.

Wilson Library (WL) – Wilson Library emergency and standby power loads are fed from the Haggard Hall generator.

8.1.2. Portable Generators

In addition to the permanently mounted generators listed above, WWU has 1 each portable generator as follows:

> PP/Whacker Gen Set – 75 KW diesel fueled generator with a 60 gallon fuel tank mounted on a trailer.

The portable generator is normally located at the Physical Plant and is available for relocation to any of the existing buildings in case of the failure of one of the permanently mounted generators or other equipment to provide power to necessary loads during an extended power outage.

Several of the buildings have existing connection boxes on the outside of the buildings so the connection of the portable generators can be accomplished fairly easily and quickly.

8.1.3. Other Emergency & Standby Power Sources

Telecommunications equipment throughout most of campus are also provided with Uninterruptible Power Supplies (UPS) with battery back-up to provide continuous power through a short term power outage or until the generator in that facility can start and provide standby power.

Fire alarm and security panels also are provided with batteries sized as required to operate the entire system, or portions of the system which are powered by the batteries for a minimum of 24 hours.

WWU decided long ago to limit the use individual battery back-up type emergency lighting units and exit signs because of the large quantity that would be required, and their annual maintenance and testing costs.

WWU does have one central battery type inverter systems (similar to a UPS) which was recently installed in Higginson Hall (HG) for emergency egress and exit lights.

8.2. Code Requirements

8.2.1. Emergency Systems

Emergency systems are defined as those essential for safety to human life; therefore emergency lighting, emergency power sources, emergency power supply system equipment and associated emergency power systems are regulated by a seemingly myriad of codes and standards, among them are:

National Electrical Code (NFPA 70) and the associated WAC 296-46B – the entire code applies, but Articles 700 and 701 apply specifically to Emergency and Legally Required Standby Systems, respectively.

Standard for Emergency and Standby Power Systems (NFPA 110)

International Building Code (IBC) and the associated Washington State Amendments

International Fire Code (IFC) and the associated Washington State Amendments

Underwriters Laboratories (UL)

The primary code requirements include the following:

Exit signs and means of egress where 2 or more exits are required (e.g. more than 50 people) shall be illuminated at all times. In the event of a power supply failure, an emergency electrical system shall provide power for a minimum of 90 minutes.

Emergency systems shall also provide power for other functions where power interruptions would produce serious life safety or health hazards such as fire detection and alarm systems, public safety communications systems and similar functions. (Note that there is some conflict between the various codes as to which of these loads are emergency loads and which are legally required standby loads.)

When normal power is lost, emergency power shall be provided automatically within 10 seconds or less.

Emergency power supply (EPS) equipment such as generators, inverter systems, etc. must be located within the building unless approved by the University Architect to be located outside a building. When located within a building, emergency power supply (EPS) equipment shall be located in a separate room with a minimum 2 hour fire rating. The room shall include adequate cooling, heating, ventilation, etc. for the proper operation of the equipment and shall not include other equipment, including architectural appurtenances. Ventilation and discharge air shall be through an exterior wall opening or from a source outside the building by a 2-hour fire rated air transfer system.

Emergency power supply system (EPSS) equipment such as transfer switches, panels, etc. shall be connected to the electrical system as close to the load as possible in order to protect against failure of the building service, equipment failures within the building, fault conditions, open circuits, etc. Emergency power supply system (EPSS) equipment shall not be installed in the same room with the normal service equipment where the service equipment is rated over 150 volts to ground and equal to or greater than 1000 amps.

Emergency power supply (EPS) equipment such as generators, inverter systems, etc. may provide power to both emergency and standby loads; however, emergency power supply system (EPSS) equipment such as transfer switches, circuits, panels, wiring, etc. shall be kept completely separate from other equipment, wiring, etc. (including legally required and optional standby systems).

Emergency system overcurrent devices shall be selectively coordinated with all supply side overcurrent devices; except, the State of Washington has exempted existing systems that were installed before the code rules were adopted.

Emergency power supplies and system equipment have extensive maintenance, testing and record keeping requirements, yearly in most cases.

8.2.2. Standby Power Systems

The various codes and standards differentiate between legally required standby power systems and optional standby power systems.

Legally required standby power systems are intended to provide power to such things as elevators in high rise buildings, smoke control systems, public safety communications systems and other items which would aid in firefighting, rescue operations and the like. (Note that there is some conflict between the various codes as to which of these loads are emergency loads and which are legally required standby loads.) Requirements for legally required standby power systems are much the same as those for emergency systems.

Optional standby systems are just that – optional. Code requirements for optional standby power systems are much the same as those for normal systems. When a new or upgraded system is installed on campus, an optional standby system is added if the building does not have one already.

Emergency power supply equipment (e.g. generators, inverter systems, etc.) may provide power to both emergency and standby loads; however, legally required standby power systems and optional standby power system transfer switches, circuits, panels, wiring, etc. shall be kept completely separate from other equipment.

8.2.3. Fire Pumps

Fire pumps have their own set of codes and regulations, namely NEC Article 695 – Fire Pumps and NFPA 20 – Standard for the Installation of Stationary Pumps for Fire Protection. The main code rules are:

> Normal service to the fire pump shall be tapped ahead of and be separated from the building normal service, so any failure of the normal building service and power distribution system will not affect the fire pump power service.
>
> The normal service overcurrent protection shall be over-sized to essentially allow the fire pump to operate until it fails, rather than disconnect the pump to protect it.

The fire pump shall have a separate transfer switch and feeder circuit direct from the emergency system power supply (e.g. generator).

The power sources shall be arranged so that a fire at one source will not cause an interruption at the other source.

8.3. Existing Conditions Evaluation

8.3.1. General

As difficult and expensive as it may be, it is critical that emergency and legally required standby power supplies and system equipment be installed, maintained, tested and records kept in accordance with current codes, regulations and standards. If this is not done, by definition, what was thought to be an emergency system becomes an optional standby system and that facility does not have an emergency system.

8.3.2. Reliability

Emergency systems are essential for safety to human life; therefore the systems and their equipment must be reliable. Many of the generators on campus are more than 20 – 30 years old and their reliability is being questioned by WWU's own maintenance personnel, including:

Biology Building (BI)
Bond Hall (BH) (Evaluate size for possible Telecom consolidation from 32^{nd} street)
Chemistry Building (CB)
College Hall (CH)
Communications Building (CI)
Edens Hall (EH)
Edens North (EN)
Higginson Hall (HG)
Ridgeway Alpha (RA)
Ridgeway Commons (RC)
Ridgeway Delta (RD)
Steam Plant (SP)

Viking Complex (VU)
Wilson Library (WL)
Ridgeway Alpha (RA), Commons (RC), Delta (RC), Kappa (RK)

It is recommended that each of the above units be replaced or, as a minimum, a certified representative of the manufacturer test and re-build as necessary each of the above units to provide confidence in their continued reliability.

8.3.3. Capacity

Emergency egress and exit lighting loads have actually decreased over the last few years due to the increased efficiency of light fixtures, lamps and ballasts; therefore, generators that feed only emergency loads, if they were sized properly at their initial installation, do not have any capacity issues.

Standby loads, on the other hand, have increased considerably; especially for telecommunications equipment (and their associated cooling loads), computer systems and the like. Standby loads for administration and academic research have also seen an increase.

Another indication that standby loads are increasing is that both the Biology (BI) and Chemistry (CB) Buildings, due to the long cable runs from the Steam Plant (where the generators are located) to the respective buildings, have both experienced voltage drops nearing the point where it will start affecting operation of the equipment.

Whenever new loads are added, careful analysis is required to insure the systems and their equipment are not overloaded and compromise the operation of the emergency systems.

8.3.4. Locations

For the emergency systems and their equipment to operate properly and to not be disrupted by a failure in the normal power system, the emergency power supplies (e.g. generators) need to be located either outside of the buildings if approved by the University Architect, or, in a separate 2-hour rated room within the building and be provided with proper ventilation, air flows, fueling access, etc. Many of the existing installations do not meet those criteria, including:

Edens Hall (EH)
Edens North (EN)
Ridgeway Alpha (RA)
Ridgeway Commons (RC)
Ridgeway Delta (RD)
Ridgeway Kappa (RK)
SMATE (SL)

It can be challenging, especially in existing buildings, to find adequate spaces within the buildings without compromising programmatic needs and that can meet code dictated separation requirements and be provided with the proper ventilation, air flows, exhausts, etc. The only solution in a lot of cases will be to locate the generators outside of the buildings, or add a proper generator room onto the building. Other advantages of locating the generators outside are that with the use of sound attenuated enclosures, noise is much less of a problem and exhaust can be dispersed without infiltrating the buildings. Each building needs a case by case analysis.

8.3.5. Segregation of Circuits and Systems

Because failure of a non-emergency circuit could affect an emergency circuit, emergency circuits and systems are to be completely segregated from non-emergency circuits. There are many instances, especially in the older buildings, where over the years non-emergency circuits have been connected to emergency system panels.

It is recommended that WWU survey all the existing emergency systems panels and remove all non-emergency circuits from them. If those circuits do indeed require standby power, a separate standby power system will have to be provided for those circuits.

8.3.6. Summary

Many of the emergency and legally required standby power supplies and system equipment are not in accordance with current codes, regulations and standards. While probably not enforced as rigorously as they are at this time, most of the major tenants of the codes have not changed since well before many of the existing systems were installed. Because of the deficiencies, what was thought to be an emergency system in many of the existing facilities on campus, by definition, has become an optional standby system and that facility does not have an emergency system.

8.4. Alternate Systems

8.4.1. General

Codes and regulations do allow some options for providing emergency power and lighting.

8.4.2. Unit Equipment

Emergency lighting and exit sign illumination can be provided by individual lighting units with built-in emergency transfer switches and battery packs. Also, other emergency type loads (e.g. critical communications) can be provided with individual uninterruptible power supplies.

WWU decided long ago that the maintenance and record keeping cost of using this method of providing emergency lighting, exit sign illumination and power for other loads would be cost prohibitive. While lamps (many of which are LED type) and batteries for these type of units have improved over the years and they can now be provided with self-testing and self-diagnostic circuitry, the quantity required would still make this method a very expensive solution. Also, the batteries within the unit equipment are sized to provide only 90 minutes of backup power; therefore, all lighting will be off after the batteries are discharged until normal power is restored.

8.4.3. Generators

Individual diesel fueled engine-generator sets for each building has been the method of choice for providing emergency, fire pump, legally required and optional standby power. That remains the best choice from initial cost, maintenance costs, and reliability standpoints.

The real problem becomes where to locate the engine-generator sets. The university's preference has been to locate them inside buildings. Every attempt should be made to locate generators within the buildings in new and modernized facilities, especially within the academic core. Any exceptions need to be approved by the university architect, who will review the location for visual/acoustical impacts.

In existing buildings, it's very difficult without compromising programmatic needs to find a suitable location that meets current codes and regulations, especially those regarding separation requirements and also be provided with the proper ventilation, air flows, exhausts, etc. In general, it has to be in a corner on the ground floor in a dedicated 2-hour rated room on an outside wall with direct outside access and a method to extend the exhaust to above the roof; then noise and building vibrations are still an issue.

In limited cases, the only place available to locate engine-generator sets will be outside of the buildings. Engine-generator sets can be ordered with pre-fabricated weather-proof sound attenuated housings to limit the sound. Access for fueling, testing and maintenance is much easier than on the inside of a building. Location is not a huge issue as long as it's reasonably close the building. Conduits and cables can be run underground into the buildings and, with some planning, kept separate from normal power circuits.

The dilemmas in a campus setting like WWU's are space balancing, aesthetics and life cycle costs. Limited locations are available and nobody wants to see the generator (similar to garbage dumpsters); however, with some creative thinking and well-designed screens, solutions can be found in most cases, such as to the architectural enclosure that has been constructed for the Environmental Studies (ES) & Arntzen Hall (AH) engine-generator sets.

8.4.4. Battery Backed-Up Inverter Systems

These are essentially specialized uninterruptible power systems with built-in transfer switches, battery back-up, battery chargers, etc. These are available in sizes up to about 15 KVA so they could be used in buildings with smaller load requirements. Their cost will be more than an equally sized engine-generator set and the battery life will be at most 5 – 10 years; whereas a quality well maintained engine-generator set would be expected to last at least twice that.

Per code, the inverter system will have to be located in a dedicated 2-hour rated room; however, it does not have the ventilation, air flow, exhaust, etc. requirements of an engine-generator set.

This is certainly a viable option in smaller buildings without fire pumps or significant loads where, for one reason or another, there is not a suitable location for a generator. The initial cost for an inverter system could be less than a generator based system (depending on the size and architectural requirements); however, long term maintenance costs will be higher due to expensive battery replacement. Also, similar to unit type equipment, inverter system batteries are sized to provide only 90 minutes of backup power; therefore, all lighting and other loads will be off after the batteries are discharged until normal power is restored.

8.4.5. Centralized Generation

The codes and regulations do not require that the emergency power supply be a dedicated unit for each building, only that power supply system equipment (e.g. transfer switches, panels, etc.) shall be connected to the electrical system as close to the load as possible in order to protect against failure of the building service, equipment failures within the building, fault conditions, open circuits, etc. This means that each building would have separate emergency, fire pump, legally required and optional standby power transfer switches and power systems; however, the campus could potentially have a single centralized generator(s).

The cost to implement such a system would cost many millions of dollars (rough order of magnitude would be over $10,000,000). Per code, the generator would have to be sized for the total load of all the systems combined. A second generator with paralleling switchgear, if not required, would certainly be recommended; otherwise, if one generator is taken out of service for one reason or another, the entire campus would be without emergency and standby power. A complete generator power distribution system at 12,470 volts (because of the length of the system and its voltage drop) would be required, and it would have to be kept completely separate from the normal power distribution system so that a failure of the normal system wouldn't also take down the generator system. Controls from all the transfer switches would also have to routed back to the generator(s) to tell them to start should a failure happen somewhere in one of the buildings. A generator power distribution panel, located separately from the normal power system, would be required in each building to separate the emergency, fire pump, legally required standby power and optional standby power feeders.

Generators also do not work well under lightly loaded conditions – power output can be less than stable, engines could subject to wet-stacking, etc. Automatically controlled load banks would be required to provide sufficient load for the generator(s) to operate properly. A large amount of fuel will be required for the worst case, so there will probably be problems with fuel stability. Fuel use and exhaust emissions will also increase.

8.4.6. Generator Farms or Districts

Similar to the centralized generation described above, a single generator could provide emergency and standby power to 2 or 3 buildings where the size of the generator could be small enough so that if a failure happened in only one of the buildings, the load is enough so that the generator could still operate properly. This would also eliminate the problem of the extensive generator power distribution system because the feeders would be short enough to provide separate feeders for the emergency, fire pump, legally required standby power and optional standby power systems.

Economics is an issue with generator farms or districts because of the length of feeders required from the engine-generator set to the buildings. Another issue is voltage drop, as evidenced by the increasing problems with voltage drop beginning to be experienced at the Biology (BI) and Morse Hall (CB) Buildings with their generators being located in the Steam Plant. As a practical limitation, the generator feeder circuit length shouldn't exceed the 300' to 400' range.

This system has some merit; but, where this could be implemented will have to be looked at on a building-by-building basis.

8.4.7. Generator Summary

Individual diesel fueled engine-generator sets for each building or shared generators with a few nearby buildings is the recommended approach to supply emergency and optional standby power to campus buildings. It remains the best choice from initial cost, maintenance costs, and reliability standpoints.

Implementation of this generation method depends on master planning, project construction phasing, and physical characteristics of the building and site. All of these parameters need to occur on a case by case basis.

8.5. Future Conditions Evaluation

8.5.1. General

Because the systems are dedicated to each building, future considerations will have to be done on a building-by-building basis; depending on the future plans for that specific building.

8.5.2. Generator Sizes

Emergency and standby load requirements are increasing significantly in most of the facilities, especially for telecommunications and computers; but also for research. Codes and regulations are also adding items that are required to be connected to the systems.

It is also important to not over-size engine-generator sets. Most manufacturers recommend that engine-generator sets not operate for significant periods of time at less than 30% of their rating in order to achieve normal temperatures and properly burn the fuel. Potential problems include engine and exhaust system damage, and output voltage stability.

While additives are available to lengthen the life of the fuel, on site fuel storage should also not be too large to allow sufficient fuel turnover based on scheduled exercise and testing.

Engine-generator sets and their associated emergency and standby power systems need to be sized properly for the expected and potential future loads, but not be over-sized to the point of causing potential engine and fuel problems.

8.5.3. Recommended Improvements

The university needs to thoroughly investigate the systems in each building (especially relating to current code and standard requirements), determine the best method of bringing the systems up to current code and standard requirements, and implement the required changes.

8.5.4. Phasing and Priorities

Essentially, each facility has a stand-alone system; therefore, each system upgrade can be done at any time and is not affected by what is being done at any other facility.

Each emergency system that has any deficiency should have the highest priority. WWU maintenance crews have first-hand knowledge and have provided input on the list of emergency systems that have the highest priority.

8.5.5. Cost Estimates

Depending on the specifics of the necessary improvements, based on recent projects with outdoor generators at Old Main (OM), Engineering Technology (ET) and Fairhaven Academic (FA), costs will range from $105,000.00 to $270,000.00. Based on a recent project with an indoor generator at Performing Arts Generator (PA), costs will be much higher for indoor generators and will be in the ballpark of $370,000.000.

All of the examples in the paragraph above were for the same 125KW generator size. Cost can vary, depending on several things, including:

- size of the engine-generator set,
- modifications and upgrades required to the power systems,
- architectural modifications and/or elements required.

8.5.6. Conclusions

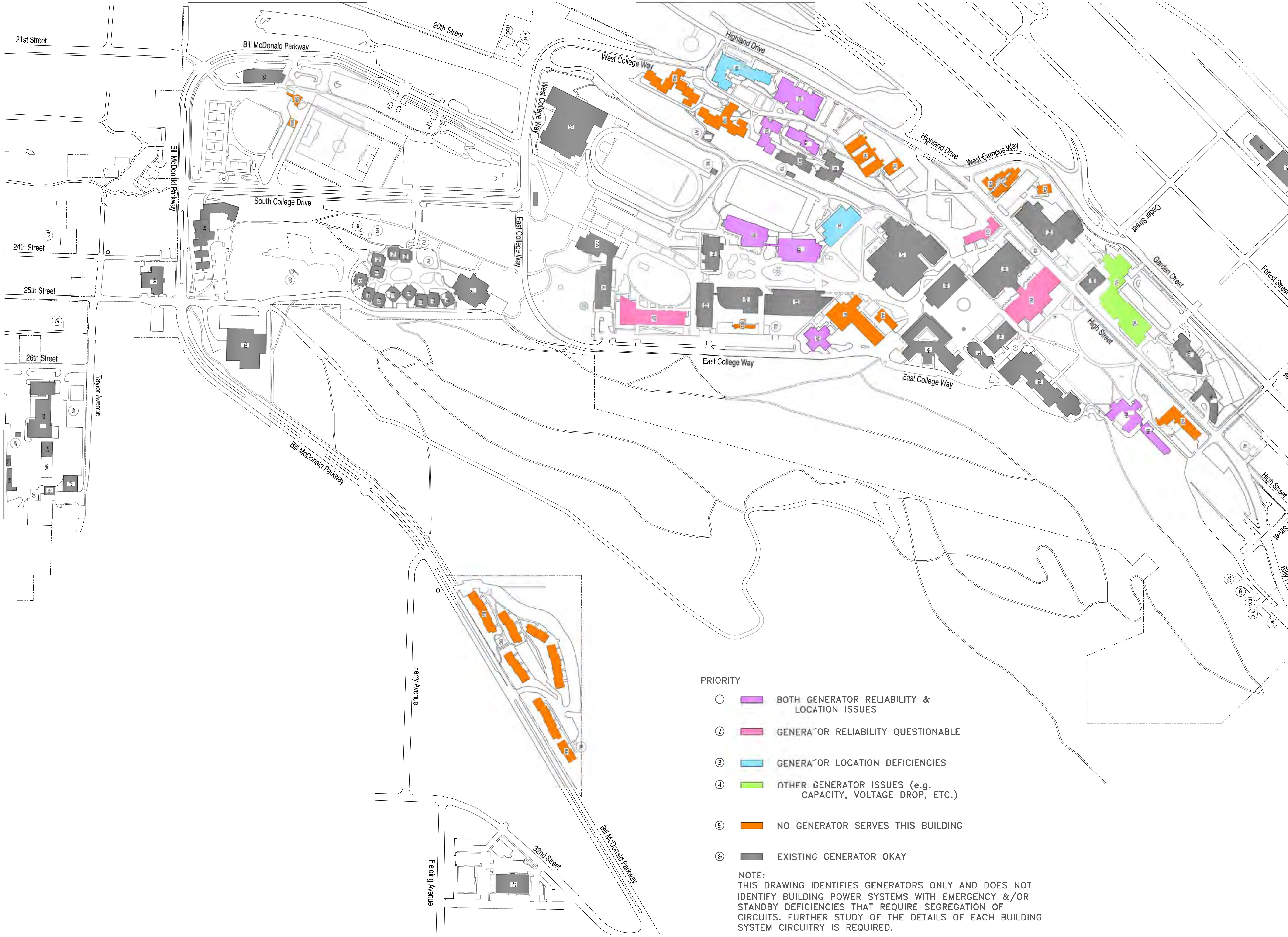
Individual diesel fueled engine-generator sets for each building has been the method of choice for providing emergency, fire pump, legally required and optional standby power. That remains the best choice from initial cost, maintenance costs, and reliability standpoints. The challenge is to find suitable locations either inside or outside of the buildings where the engine-generator sets could be located and meet the various codes, standards, regulations and operational/maintenance/testing requirements.

WWU has begun a program through various projects to upgrade the existing emergency, legally required standby and optional standby power supplies and power systems as evidenced by the new system upgrades presently being constructed for Fairhaven Academic (FA). Also, the systems have been upgraded when a facility goes through a major renovation, such as Miller Hall (MH) and Carver Gym (CV).

The upgrade program needs to be continued. As difficult and expensive as it may be, it is critical that emergency and legally required standby power supplies and system equipment be installed, maintained, tested and records kept in accordance with current codes, regulations and standards. If this is not done, by definition, what was thought to be an emergency system becomes an optional standby system and that facility does not have an emergency system.

8.5.7. Appendices

Drawing MP-E4	Campus Electrical System Generator Deficiencies
Table	Campus Generator Information



PRIORITY

1. BOTH GENERATOR RELIABILITY & LOCATION ISSUES
2. GENERATOR RELIABILITY QUESTIONABLE
3. GENERATOR LOCATION DEFICIENCIES
4. OTHER GENERATOR ISSUES (e.g. CAPACITY, VOLTAGE DROP, ETC.)
5. NO GENERATOR SERVES THIS BUILDING
6. EXISTING GENERATOR OKAY

NOTE:
THIS DRAWING IDENTIFIES GENERATORS ONLY AND DOES NOT IDENTIFY BUILDING POWER SYSTEMS WITH EMERGENCY &/OR STANDBY DEFICIENCIES THAT REQUIRE SEGREGATION OF CIRCUITS. FURTHER STUDY OF THE DETAILS OF EACH BUILDING SYSTEM CIRCUITRY IS REQUIRED.

STEVEN B. TEVEDE, STATE OF WASHINGTON, 41903, REGISTERED PROFESSIONAL ENGINEER, 6/5/2017

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REV	DATE	DESCRIPTION	BY	APRV

WESTERN WASHINGTON UNIVERSITY

CAMPUS ELECTRICAL SYSTEM GENERATOR DEFICIENCIES

Client Review	Maintenance Review	Renovation Review	Approved by
Designed by STV	Drawn by KL	Project Manager JK	Date 6-5-2017

1809

Building/Zone: UT

Sheet # MP-E4 of -

Job Number

Microfile Number

CAMPUS GENERATOR INFORMATION - Updated 6/5/2017 (Steve TeVelde, K Engineers, Inc.)

Legend
Both Generator Reliability & Location Issues
Generator Reliability Questionable
Generator Location Deficiencies
Other Generator Issues (e.g. capacity, voltage drop, etc)
No generator

	BUILDING	BRAND	KW	LOCATION	FUEL TANK (GAL)	RELIABILITY	COMMENTS
AC	ADMINISTRATIVE SERVICES BLG.	Kohler	275	Outside NW	474	Ckay	New set installed 2009/Fuel Consumption per Mfg specs./100% load =19.6gph/75%=15gph/50%=10.4gph/25%=5.9gph(*Actual calculations from filling is 9.29gph*)
AH	ARNTZEN HALL	Kohler	50	Bunker @ ES	200	Ckay	New set installed 2009
AI	ACADEMIC INSTRUCTIONAL CENTER	Dietroit	600	AI Rm183A	55	Ckay	Day Tank
AI	" "			Bunker @ Parking Lot	800	Ckay	Outside Storage Tank
BH	BOND HALL	Onan	200	RM 101	240	Ckay	Evaluate size if Telecom Dept. Consolodates from 32nd Street.
BI	BIOLOGY BUILDING	Aptech	150	SP/Cooling Tower	185	Low	Remove from SP, Condition and location not reliable
	BIRNAM WOOD COMPLEX						No generators
BT	BUCHANAN TOWERS	Kohler	150	Parking Lot/Stand Alone	150	Ckay	New set installed 2010
CB	CHEMISTRY BUILDING	Energy Dynamics	175	SP/Cooling Tower	150	Low	Remove from SP, Condition and location not reliable
CF	COMMUNICATION BUILDING	Generac	130	Rm 52A	275	Low	Replace in next 10 years, potential of leaking, move out of building, possible supply with AI.
CH	COLLEGE HALL	Generac	12	Outside N	30	Low	Replace or tie into Carver Gym.
CM	COMMISARY	Onan	30	Outside S	20	Ckay	Gen set from SPMC installed here 8/07
CS	CAMPUS SERVICES	Kohler	275	Outside NE	540	Ckay	
CV	CARVER GYMNASIUM		250	Outside SE		Ckay	New in 2016
EH	EDENS HALL SOUTH	Generac	15	MR 1(Rm 123)	30	Low	Replace and combine with ES
EN	EDENS NORTH	Onan/Marine	8	MR 1(Rm 07)	30	Low	Replace and combine with EN
ES	ENVIRONMENTAL STUDIES	Kohler	200	Bunker @ ES	500	Ckay	New Set installed 2010/Fuel consumption @ 100%=15.3gph/75%=11.4gph/50%=8.3gph/25%=5.2gph
ET	ENGINEERING TECHNOLGY	Kohler	125	Outside S		Ckay	New in 2014
FA	FAIRHAVEN ADMIN AND STACKS	Kohler	125	Outside	316	Ckay	New in 2016
FI/AA	FINE ARTS / ARTS ANNEX						no generator, just battery backup, connect to Steam Plant
FR	FRASER HALL						Supplied from Old Main generator via Humanities ATS's from Old Main Generator in 2014
HH	HAGGARD HALL	Aptech	35	Rm 103	90	Ckay	
HI/HL	HIGHLAND HALL/HIGHLAND LOUNGE						No generator
HU	HUMANITIES					Ckay	supplied from Old Main generator in 2014
MA	MATHES	Kohler	137	Bunker @ BB Court	316	Ckay	New on 8/31/2012
MC	SHANNON PT. MARINE CENTER	Kohler	100	Outside N	110	Ckay	
HG	HIGGINSON HALL						No generator, Priority to add one to replace failing inverter system.
MH	MILLER HALL	Cat	175	046A	750	Ckay	New with Phase 2 Renovation 9/2011
NA	NASH HALL					Ckay	Supplied from Mathes Hall generator
OM	OLD MAIN	Kohler	125	Above Snake Pit		Ckay	New in 2014
PA	PERFORMING ARTS	Kohler	125	Basement N.		Ckay	New in 2015
PH	PARKS HALL					Ckay	New connection to Arntzen generator in 2016
PP	PHYSICAL PLANT	Onan	150	Outside S	195	Ckay	
RA	RIDGEWAY ALPHA	Onan	6	Rm 01A	10	Low	Needs replacement
RB	RIDGEWAY BETA					Low	No generator
RC	RIDGEWAY COMMONS	Onan	6	Rm 107	10	Low	Needs replacement
RD	RIDGEWAY DELTA	Onan	6	Rm 220	10	Low	Needs replacement
RG	RIDGEWAY GAMMA						No generator
RK	RIDGEWAY KAPPA	Generac	18	Outside S	40	Low	Exhaust fumes and dorm windows, limits time to exercise.
RO	RIDGEWAY OMEGA					Ckay	New Set installed 8/2010, combined with RS
RS	RIDGEWAY SIGMA	Cummins	60	Outside	60	Ckay	New Set installed 8/2010, combined with RO
SL	SCIENCE MATH & TECHNOLGY	Aptech	15	Rm 105A	55	Ckay	Difficult to fuel.
SP	STEAM PLANT	Onan	150	SP/Cooling Tower	225	Low	Remove from SP tower roof. Combine with FI.
SV	STUDENT RECREATION	Kohler	155	Outside NE	300	Ckay	
VU	VIKING COMPLEX	Kato Light Power Systems	95	VU 548/Attached to PA on North end	110	Low	
WL	WILSON LIBRARY					Low	Fed from Haggard Hall generator, add its own ATS
	MOBILE GENERATOR		300	PP Yard	480		No longer exists, was sent to surplus
	MOBILE WHACKER GENERATOR		75	PP Yard	60		Fuel usage calculated from 9/2010 power outage at SP = approx. 2.3 gals/hour
			4503	**Total Fuel**	**6816**		

9. GLOSSARY

Pipe Abbreviations

CI	Cast iron pipe
CMP	Corrugated metal pipe
CONC	Concrete pipe
DI	Ductile iron pipe
HDPE	High density polyethylene (plastic) pipe
PVC	Polyvinyl chloride (plastic) pipe

Other Abbreviations

ac-ft	Acre-feet. A volume equal to 1 foot of water over 1 acre (~325,000 gallons)
ADD	Average Daily Demand for water system
BACS	Building automation control system
BTU	British thermal units (standard measure of the energy content of natural gas)
cfs	Cubic feet per second (usually stormwater flow rate)
CHP	Combined heat and power
CHWS	Chilled water system
CID	Campus Infrastructure Design study (2004 study, PW395)
CIPP	Cured-in-place-pipe (rehabilitation pipe liner material, insert and heat cured)
COP	Coefficient of performance (cooling)
CV	Constant volume
DOH	Washington State Department of Health (Division of Drinking Water)
EPA	Environmental Protection Agency
EPS	Emergency power supply
EPSS	Emergency power supply system
ETS	Energy transfer stations (facilities to transfer district heating to building heating)
FACS	Fire Alarm Control System
GPD	gallons per day
GPM	Gallons per minute
GSF	Gross square feet (combined area in square feet of all building floors)
GSHP	Ground source heat pump
HCFC	Hydrochlorofluorocarbon refrigerant
HDD	Heating degree day (relative quantity of heat needed in a given year)

HHW	Heating hot water
HP	Horse power
HPS	High pressure steam
HTHP	High temperature heat pumps
HVAC	Heating, ventilation and air conditioning
HW	Hot water
IBC	International Building Code
IFC	International Fire Code
IMP	Institutional Master Plan
KW	Kilowatt (measure of electricity flow; equals 1000 Watts)
KWh	Kilowatt-hours (standard measure of electricity consumption)
LEED	Leadership in Energy and Environmental Design
MBC	Modular building controller
MDD	Maximum Day Demand for water system
MDF	Maximum Day Flow for sewer system
NEC	National Electrical Code
NFPA	National Fire Protection Association
PC	Pumped condensate
PHD	Peak Hour Demand for water system
POU	Point of use
PSE	Puget Sound Energy (electric utility)
PSI	pounds per square inch, pressure
PSIG	pounds per square inch, gauge pressure
PV	Photovoltaic (solar to electricity conversion cells)
sf	Square feet (area)
TDH	Total dynamic head (pressure – static head plus other head)
TES	Thermal energy storage
UBC	Uniform Building Code
UL	Underwriters Laboratory
UPC	Uniform Plumbing Code
UPS	Uninterruptible power supply
VFD	Variable frequency drive
VRF	Variable refrigerant flow
VV	Variable volume

10. APPENDICES

Appendix A – NATURAL GAS

Appendix B – CENTRAL COMPRESSED AIR

Appendix C – BUILDING AUTOMATION CONTROL

Appendix D – SITE SECURITY AND ALARMS

Appendix E – MASTER CLOCKS

Appendix F – TELECOMMUNICATIONS

APPENDIX A - NATURAL GAS

A.1. Existing System

A.1.1 Description

Natural Gas service is provided by Cascade Natural Gas with main distribution lines extending into campus from Garden Street on the north side and Bill McDonald way on the south side. Gas is the predominate energy source for fueling the Steam Plant central system boilers. In the past, the boilers have been on a interruptible gas supply with fuel oil backup. Current pricing structures do not make interruptible gas supply advantageous, and oil burning is harder on the equipment, less efficient, and more polluting.

Stand-alone gas service is the fuel source for space heating and domestic water heating at several buildings at the edge or off the main campus where the central steam system is not cost effective to extend. These facilities include:

Alumni House (AH)
Archives Building (AB)
Campus Services (CS)
Canada House (CA)
Fairhaven Commons (FA) – Cooking only
High Street Hall (HS) – partial gas fired heat
Marshalling Storage (MS)
Ridgeway Commons (RC) – cooking only
Viking Commons (VC) – cooking only
Viking Union (VU) – cooking only

Cascade Natural Gas owns the piping up to the meters serving the facilities above, as well as the piping up to “Master Meter Systems” in the central part of campus that become a point of distribution to other facilities. A Master Meter is a gas meter that services more than one facility. Ownership and management of master meter systems are equal to a utility service provider such as Cascade Natural Gas. Currently WWU contracts with Cascade Natural Gas for preventative maintenance and required public awareness/education on our Master Meter systems. Western Washington University owns the master meter systems and is responsible for compliance with all applicable regulations. A breakdown of Master Meters / Sub Meters systems follows:

Master - Arts / Technology (AA)

Arts Annex (AA)
Fine Arts (FI)
Miller Hall (MH)
Bond Hall (BH)

Master - Birnam Woods (BW)

Buildings 1-7 including Commons and Laundry

Master – Environmental Studies (ES)

Biology Building (BI)
Biology Greenhouse (BG)
Chemistry Building (CB) (Morse Hall)
Environmental Studies (ES)

Master – Marshalling Yard (MY)

Marshalling Yard (MY)
Upholstery Shop (US)

Master – Physical Plant (PP)

Physical Plant (PP)
Maintenance Garage (MG)

A.2 Existing Conditions Evaluation

Existing piping, meters and distribution is well maintained and in good condition. Contracting mechanism with Cascade for preventive maintenance of master meter distribution network is meeting the University's day to day needs.

A.3 Future Conditions Evaluation

Natural gas fuel distribution is not a limiting factor to facility expansion on campus. Gas lines are relatively small, and don't have slope-to-drain requirements. Any expansion of to the current distribution system is assumed to be easily achieved.

A.4 Recommendations

The current distribution network with Master Meters exposes WWU to changing State regulations for fuel distribution piping. It is proposed by Facilities Management

Operations to add point of use meters as required to the system, and then transfer ownership and maintenance responsibilities to Cascade Natural Gas for the whole distribution network. The merit of making this change hinges on the Operational cost balance negotiated with Cascade Natural Gas.

In addition, easements and all of their protections should be established. A search should be performed of what easements exist. Facilities Management Operations in not aware of any existing easement for the natural gas lines at WWU that are owned by others.

A.5 Conclusions

Existing Natural Gas infrastructure is in good condition. Initiate preliminary negotiations with Cascade Natural Gas to determine if the ownership transfer of Master Meter network is in Western's best interest. Easements should be obtained.

APPENDIX B –
CENTRAL COMPRESSED AIR

B.1 Existing System

B.1.1 Description

Compressed air is required on campus for a number of purposes. The primary need is to drive pneumatic heating ventilation and air conditioning (HVAC) controls in older buildings and the steam plant. Compressed air is also used for experiments, shop tools, and select equipment.

The central air compressors are located at the Steam Plant. The system includes filters and dryers such that industrial quality process air is distributed. If "medical" quality air is required for specific experiments or research, it is produced at the building. The piping distribution network runs through the utility tunnels and utilidors.

Even though the backbone of the Building Automation Control System (BACS) is now electronic, digital controls, pneumatic control devices on campus are common due to the age of the facilities. It is impractical to convert to digital controls unless a major modernization is underway. Consequently, if compressed air is lost, the ability to heat and condition many buildings will be lost.

Furthermore, the central system is not connected to emergency generation. A Facilities Management construction/maintenance diesel driven compressor trailer is stored at the Steam Plant for minimal operational backup.

B.2 Existing Conditions Evaluation

The majority of the piping in the walk through tunnels has been replaced with copper as of 1995. Some segments of compressed air piping are steel, which are badly rusted and other sections are flexible hose which have become very brittle due to age and steam heat exposure. Pipe ruptures have occurred, and due to lack of funds, at times other piping in the vicinity such as abandoned steam/condensate lines, have been cannibalized for compressed air service. The current system has pin hole and other minor leaks that force the compressors to run unnecessarily to maintain pressure. See attached table for condition and age of piping and hose.

B.3 Future Conditions Evaluation

The HVAC controls standard for all new buildings is to use digital systems compatible with the backbone network. As additional older buildings get modernized the criticality of centralized compressed air will diminish. Centralized distribution of compressed air for experiments, tools, shops it still appropriate for reduced operating costs and points of maintenance.

B.4 Recommendations

Systematically complete replacement of existing steel pipe and hose segments with copper piping which has a much longer service life. Prioritize piping in the worst condition first. In addition, add the central compressors at the steam plant to the Stand-By emergency generator circuits at the Steam Plant. This will enable steam plant controls, and building controls to still operate if there is a power outage.

B.5 Conclusions

The compressed air distribution network is an often overlooked critical system. The current network is leaking and not reliable. Failure of the network loses HVAC control in numerous buildings. Utility investment is required to keep this system running for the foreseeable future.

APPENDIX C –
BUILDING AUTOMATION CONTROL (BACS)

C.1 Existing System

C.1.1 Description

The backbone for the WWU Building Automated Control System (BACS) is a Siemens System 600 Insight Apogee host based computerized system integrating central monitoring and building Heating Ventilation and Air Conditioning (HVAC) control, most exterior lighting control, minimal interior lighting and energy management for Academic Buildings and University Residences. This includes the main campus, and Shannon Point near Anacortes. Programmable Controller Modular (PXC-M's) and point databases along with their network system are centrally monitored and maintained by the Building Automation Control Center at the Physical Plant. From this central control center the temperature in any room and status of any monitored equipment can be queried and adjusted if needed within minutes.

The University has an on-going contract with Siemens Building Technologies, Inc. for the system head end at the Building Automation Control Center including network database management, software/firmware troubleshooting, and operator training. Most of the BAC system has been migrated from a hardwired copper backbone to dedicated fiber optics. In process is converting to an Ethernet based backbone, which will add more speed and capacity to the system and the opportunity for decentralized monitoring of equipment at satellite work stations.

In addition to its core mission of HVAC control and energy management, the BACS system synchronizes other systems and provides a central reporting network. Systems utilizing this aspect of BACS include the synchronizing of the Central Clock System and monitoring of the leak detection system for the direct buried "Perma Pipe" - Steam Line. This system monitors the sealed and insulated portion of the outer jacket of the buried steam and condensate lines that run from Steam Plant to Miller Hall and from Old Main to Edens North residence hall, for internal and external leaks.

The BAC system within each building has no backup power. The head end at the Building Automation Control Center has UPS/generator backup. The loss of power to any controlled facility risks the loss of heat and ventilation control to the affected building with the exception of the Physical Plant and Campus Services where standby generators power the heating systems.

C.2 Existing Conditions Evaluation

The Siemens Apogee system is a state of the art building control system. WWU is fortunate to have enforced consistency of a single integrated system across campus. This allows the highest level of functionality among BACS networks since there are no converters or translators required and lower operating/maintenance costs. All components utilize the exact same communication protocol so the full power of the system can be realized. During the 13-15 biennium a portion of the network was migrated to an Ethernet backbone and a consistent platform of PXC-M's at the major buildings. To achieve the full functionality of the BACS network investment over the years it is important to complete the migration of updating MBC's to PXC-M platform at all buildings and the Ethernet backbone

C.3 Future *Conditions Evaluation*

The Siemens based BACS has the sophistication to accommodate all future growth envisioned on campus. The modular nature of the building control panels facilitates the incremental expansion of the network as new buildings come on line or get renovated.

The advent of state LEED energy efficiency guidelines will require more performance monitoring of buildings and central utilities. The existing BACS system has the backbone capacity to expand to meet these needs.

C.4 Recommendations

Complete the MBC to PXC-M upgrade and Ethernet backbone initiated in the 13-15 biennium to 17-19 so that a uniform platform is provided throughout campus, and access to controllers is decentralized so that Control Technicians working in individual buildings can work more efficiently. The following buildings remain to be completed: AI, AH, BH, CF, CH, CS, FA, HU, ME, PA, PP and SP.

Improve power outage reliability of the system by installing UPS filters at building controllers or backup by standby emergency generation at critical functions.

Expand the monitoring and recording capabilities of the BACS network so that performance benchmarks for energy and resource savings can be measured and realistic conservation goals set. This should include expansion of interior lighting control and monitoring, integrate facilities not connected, and upgrade interconnectivity with electrical power meters. These additional upgrades would allow for a complete energy management approach including load shedding during campus electrical power feeder disruptions. Network updates for efficient communication of buildings, equipment and the building automation control center will remain “air-gapped” from the standard campus network via physical and logical separation. Network will have a highly secure single direction bridge for exportation of records and data. The new optical fiber network will be comingled with Fire Alarm, Access Control, Security and CCTV to leverage resources and maintain building and life safety systems independent of general network traffic.

Continue the sole-source relationship with Siemens Building Technologies, Inc. so the full power and functionality of the investments made to date can be carried into the future.

C.5 Conclusions

Western has a state of the art BACS system. It is fortunate to have enforced consistency over the years resulting in the current system which is fully integrated down to the component level. Continue upgrades and expansions at required to keep pace with future growth on campus and changes in building automation technology.

APPENDIX D – SITE SECURITY AND ALARMS

D.1 Existing System

D.1.1 Description

The campus fire alarm and security system is manufactured by Edwards System Technology (EST). It is an integrated proprietary network that serves as an emergency communication backbone with the Fireworks central monitoring station at the campus police station located in the Campus Services building. The system provides two basic functions:

a. Fire Alarm
b. Security and Burglary Alarm

In addition there remains a fire alarm system independent from FireWorks which is a McCullough Loop. This monitoring meets all building and fire code requirements, but does not provide the benefit of a campus wide addressable system. The buildings that remain on the McCullough Loop are as follows:

Edens North (EN)
Highland Lounge

Fire Alarm and Security components are integrated and share the same central dedicated multi-mode fiber optic reporting network, building and floor level control panels, and programming hierarchy. The majority of components are addressable, as a result, the display at the central reporting station will indicate exactly where on campus the security or alarm event is occurring. The remaining non-addressable components provide general zone information of where the alarm event is located. Exact location is field verified at the building Fire Alarm Control System (FACS).

Each building system includes a 24-hour backup system to assure life safety and security systems stay functional during power outages. In addition, each building is equipped with a phone modem programmed for redundant dial out to the campus dispatcher if for any reason the Fireworks network is down.

A significant advantage of WWU's integrated system is that the fire resistive dedicated conduit network, fiber, wires, control panels, and emergency backup systems are shared by each of the major functions achieving cost efficiency of systems by avoiding redundancy. All components are U.L. listed for their specific service.

FireWorks Fire Central Monitoring

- Most campus buildings provide automatic smoke detection
- Flow monitoring of automatic fire sprinkler systems where they occur
- Tamper switch monitoring for critical fire sprinkler isolation valves
- Building level voice annunciation in most academic buildings
- Building level tone annunciation in some residence halls
- Building level voice annunciation in some residence halls

FireWorks Security Central Monitoring

- Provides burglary alarming appropriate to the risk
- Zone / beam detection
- Breaking glass detectors
- Vibration detectors
- Door Contacts
- Duress buttons
- Computer and electronics protection with PC Tab cabling.

Access Control

- Currently is Edwards ACDB to be replaced with Lenel as it was discontinued by the manufacture on August 1, 2013.
- Access Control has its own dedicated server and clients
- The current Edwards ASDB operates on the closed network as Fire, Security and CCTV. A new optical fiber network to support BAC, Fire, Security, CCTV and Access control air-gapped from the common network is required.
- Key pad or smart card options
- Ability to integrate across campus
- Registry maintained of who entered the building and time
- Secure database

CCTV

- Has its own dedicated recorders and also operates on the same closed network
- Pelco DX8100 DVR's (imbedded XP) need to be replaced with Pelco NVR's in MH, CS, PA, OM, LCTC and PP

Network

- The existing 10/100 network equipment supporting the Life Safety systems is at capacity and will need to be replaced with a new 10/100/1000 optical fiber network. This includes the physical optical fiber cable, network switches and associated pathway
- It is anticipated to combine building systems onto a single network to leverage cost savings including Building Automation, Fire, CCTV and Access Control
- Bridges will need to be implemented between the WWU campus network and the Life safety system network to accommodate access control programming. CCTV viewing and building automation data feed.

D.2 Existing Conditions Evaluation

The existing system serves campus well. The primary avenue for improvement is to migrate the remaining residence halls on the old McCullough Loop to the FireWorks system. This upgrade is dependent on campus Residence Living securing the capital financing to make the change. The current configuration of the McCullough Loop monitoring system is marginally functional and of an age that parts are no longer available. This system only stays active due to the efforts of maintenance personnel. The existing access control system will need to be removed from the Edwards system and connected to the new access control system.

D.3 Future Conditions Evaluation

The FireWorks system is designed with the ability to expand as campus grows or security needs increase. The existing utility infrastructure and Ethernet backbone approach feeding the buildings is at capacity and requires replacement/updating for additional building growth and modernization. The desire on campus for widespread use of access control and CCTV monitoring necessitates the handling of tremendous volumes of data which requires increases in network memory storage and the need for building level system improvements. In addition the pathways and cabling within the buildings to the doors and camera locations doesn't exist in current buildings and will require significant investment.

D.4 Recommendations

Expand FireWorks system as required to accommodate campus growth. The police department should continue to carefully evaluate the risk profile of various locations on campus and the related operating costs of improvements before increasing security monitoring. As Residence Halls are renovated, work to phase out the McCullough Loop and make all facilities FireWorks based. This conversion is required if the security, access control and CCTV systems are needed at a particular residence hall. The McCullough Loop only provides fire alarm reporting. At the institutional level fund building level system improvements for CCTV and Access Control to facilitate future cost effective expansion within the facilities.

The life cycle of a fire alarm system is 10 years per the manufacturer's UL listing, therefore it is anticipated to continue to update existing electronic safety systems in buildings annually. As the systems are updated the expansion of mass notification and improving auditability and intelligibility is required.

D.5 Conclusions

WWU is unique among college campuses nationally with a single, integrated, campus wide Life Safety Alarm system integrating all forms of security alarm and mass notification. The benefits to this approach are consistent addressability, reduced maintenance and training for a single vs. multiple systems.

APPENDIX E – MASTER CLOCKS

E.1 Existing System

E.1.1 Description

All academic buildings require synchronized clocks so class schedules stay coordinated. The campus clocks are analog with either a "3-wire" or "2-wire" type by description. They all operate using 120 volts (2 wires). The clocks are corrected twice per day, morning and evening, to read 5:59 in response to a signal from a central computer carried over the Building Automation Control System (BACS). Correction within the clocks is actually a mechanism of gears that move the hands to this 5:59 position.

This correction activity is triggered in one of two ways. A "3-wire" clock is equipped with an extra wire (3rd wire) to trigger the correction mechanism. The newer buildings and/or remodeled sections have this extra wire installed for the 3-wire clocks. Most of the older buildings do not have this extra 3rd wire and only have the standard 2 wires to the clocks. A "2-wire" clock type uses a small circuit board within the clock that requires a special frequency signal transmitted over the 120vac lines before it will trigger the correction mechanism. This signal is provided by special equipment connected to the building's electrical system called a Frequency Generator and is transmitted throughout the building. If any one of these components doesn't function properly, the clock will not display a correct time.

Frequency generators occur in individual buildings or are centralized for a group of buildings in the utility tunnel. All frequency generators get their synchronized timing from the Siemens Building Automation Control System (BACS).

There are numerous wall clocks throughout campus that are not connected to the central system that are driven by AC power or batteries. There is no central documentation for these clocks.

E.2 Existing Conditions Evaluation

Due to limitations of existing wiring, it is not practical to convert all clocks to a 3-wire standard. As of July 2007 all major frequency generators were replaced with BACS compatible equipment and the central clock system is now a stable platform. Clocks not connected to the system are typically departmental owned and not always reset timely.

E.3 Future Conditions Evaluation

The current clock system does not limit campus growth patterns in any way.

E.4 Recommendations

As new buildings are constructed or existing buildings are modernized, migrate clocks to a 3-wire standard for consistency of operation and maintenance. Replace stand-alone clocks with system clocks.

E.5 Conclusions

Synchronized campus clocks are critical to a smooth running academic class schedule. The current central clock system is a stable platform synchronized by the Building Automation Control System (BACS).

APPENDIX F – TELECOMMUNICATIONS

F.1 Existing System

F.1.1 Description

Data, telephony, and CATV communications are delivered on campus via fiber optic and copper cable plants both within and between buildings. Bond Hall is the primary demarcation point for all internet, telephone, and CATV service to campus from outside providers. Fiber optic cabling between buildings on campus is both single-mode and multi-mode (62.5 micron) fiber. The majority of buildings on campus are wired with a mix of Cat5e and Cat6 copper cabling, though some buildings still contain Cat5 or Cat3 wiring.

Data network service is delivered to all users by Cisco routing, switching, wireless, and security systems. Analog telephone service is delivered to approximately 4000 users (including elevators, emergency phones, fax machines, and other services/facilities) via a Nortel PBX located in Bond Hall, and three fiber remotes in AC, CF, and the Commissary. IP telephony is delivered to approximately 400 users over the data network infrastructure using Microsoft Skype4Business; it interfaces with analog gateways in Bond Hall and AC to connect to both the PBX and the wider PSTN. CATV services are delivered to campus from a Comcast head-end in Bond Hall via a series of transmitters, fiber nodes, and amplifiers across campus. The CATV network includes a return path to Comcast to allow campus to broadcast programming on a community channel in greater Whatcom County.

The wired and wireless data network is divided into academic and residential sections. The academic data network is architected in an active-passive redundant core design with multiple failover points between the two legs. The data network is logically arrayed in three tiers—the redundant core provides routing between the different nodes in the distribution layer (routers and switches that service individual buildings or groups of buildings on campus), and the distribution layer distributes traffic to the access layer devices (switches that service the endpoints—computers, servers, printers, wireless, etc.). The residential network also uses a three-tiered logical design, with a single core router attached to the redundant core routers of the academic network.

Western maintains telecommunications services to several remote sites, such as Shannon Point Marine Center, Lakewood Watersports Facility, the Technology Development Center, the Small Business Development Center, and Alumni/Foundation offices in downtown Seattle and the Bellingham Herald Building. We also maintain co-location services with Portland State University, site-to-site Virtual Private Network connections to Microsoft Azure and St. Joseph's Hospital, and direct fiber connectivity to the Whatcom County Courthouse.

All services and remote site connections pass through Bond Hall—no endpoint on campus can access CATV, internet, or the PSTN without going through Bond Hall to do so. In addition to being the demarcation point for internet, PSTN, and CATV service, Bond Hall serves as the primary datacenter for the campus. The secondary datacenter is located on the second floor of AC, with fiber optic cable on above-ground utility poles connecting AC to the campus network. Internet service is provided via a 10Gbs circuit from the primary provider, and a 1Gbs circuit from the secondary/backup provider. From Bond Hall, Comcast and CenturyLink also maintain their own network demarcations to provide services directly to endpoints on our campus, such as contractors or vendors.

F.2 Existing Conditions Evaluation

- Overall Concerns
    - Lack of direct fiber paths from each building to each core – several buildings have to be patched one or more times through another building to reach a core, which introduces potential points of failure.
    - Multiple instances of chokepoints in our copper cable pathways: daisy-chained connections over multiple 110 blocks, CAT5 jumpers on cross-connects between Cat5e or Cat6 cables, Cat5 or Cat5e hydra cables connected to Cat6 station cables, etc.
    - Most of the network equipment is end-of-life or end-of-support, or will be by 2020. No operating dollars are allocated for upgrading network infrastructure. Most of the hardware and cabling was funded as part of two capital projects (in 2000 and 2010), or as part of other construction projects (Buchanan Towers East, Miller Hall, Carver, etc.), rather than operationalized for regular replacement.
    - The primary and secondary internet connections for campus share a

demarcation point in Bond Hall. In the event of a facilities emergency in Bond Hall, there is no second path to the internet for campus.

  - Lack of insight and input into the design of other networks (building automation and control, fire and life safety, etc.) from our engineers can result in both security and performance issues for those networks, as well and technical issues for the academic network in places where the networks are bridged (i.e. Shannon Point Marine Center)
  - High risk of failure for existing PBX
  - Aging CATV system, lack of training and support for maintenance, lack of funding for equipment replacement, and lack of clear roadmap for the future of CATV (converged with data network vs maintained as a separate physical network).
  - Current wireless network is deployed “ad-hoc”, rather than designed strategically to ensure appropriate coverage and density across campus. As a result, the current wireless network infrastructure is inadequate to meet student needs and operational demands.
- Datacenter and Distributor Room Concerns
  - Lighting in all MDF/IDFs may not meet spec (BICSI TIA-569 Spec.)
  - Temp and Humidity in MDF/IDFs may not meet spec (ASHRAE Class 3 Spec.)
  - Several MDF/IDFs have become “shared spaces” over time, where our equipment competes for space with other departments’ equipment (ladders, custodial supplies, etc.). Lack of strong access controls in these spaces (brass key access only) leaves critical equipment at risk, and the confined space makes it difficult for people to work. Storage of some equipment (such as fluorescent lamps) is precarious, which is a safety concern for people working in the space.
  - MDF/IDF are becoming overcrowded with equipment from BAC, Fire and Life Safety equipment, CCTV hardware, etc. Rack and wall space are become tight, and work space becomes limited. Additional equipment also pushes up the temperature, requiring additional cooling systems to meet spec.
  - The second network core location (Arntzen Hall basement) is a high-traffic corridor for FM personnel to access fire control, electrical equipment, and other equipment. For a network core, this space is inadequately secured and puts south campus network connectivity at risk.

The space allocated for the network core doesn't have room for expansion.

- Lack of clarity around electrical codes—can network equipment be operated on the same circuits as emergency lighting systems? If not, how do we provide a separate emergency power circuit for these systems to stay up during power failures (especially if they are supporting VOIP telephones over POE)?
- High risk / low utilization of AC datacenter facility—the AC datacenter is vulnerable to service breaks due to above-ground utility service. Growth of services in the AC datacenter is constrained by diminished fiber capacity between the facility and campus, which is prohibitively expensive to expand. The facility itself is massively overbuilt in terms of both its physical space and power/cooling systems, relative to the shrinking physical footprint of modern datacenters (due to virtualization and migration to SaaS platforms).
- Access to some MDFs/IDFs (for example, Rec Center and Old Main) are frequently limited because they are only accessible from within another occupied room (training room, group counseling room, cash-counting room, etc.).

- Capacity Concerns
  - Overall fiber capacity between buildings is insufficient in places.
  - Fiber capacity to AC from campus is insufficient and cost-prohibitive to expand.
  - Single-mode fiber capacity for direct connections between cores (AH and BH) does not meet future growth needs
  - Copper pathway capacity in some buildings is insufficient—cable trays are over-packed in places, and the changing specifications around Power-over-Ethernet will require fewer cables to be packed together in order to meet spec.
  - Switch port capacity at the access layer of select buildings is insufficient.
  - Available bandwidth of secondary ISP circuit is insufficient to accommodate normal campus bandwidth consumption during business hours—in the event of a primary ISP failure during a weekday, we will not have sufficient bandwidth on the backup connection to provide internet service to campus.

F.3 Future Conditions Evaluation

- Increased adoption of SaaS solutions, virtualization of servers, increases in storage density, and the shift from a large PBX to a small PBX+VOIP services will further decrease the size of the datacenter footprint required to support services on campus.
- Shifts to hosted solutions and the convergence of services onto the data network will push demand beyond what our network infrastructure can currently support.
- Resilience and flexibility of Azure computation and storage resources will eliminate the need for maintaining two datacenters on campus as a business continuity/disaster recovery solution—one datacenter plus “cloud” backups and a small secondary on-campus site for business-critical services will suffice.
- Movement toward the adoption of IPTV as a delivery mechanism for CATV service would allow us to converge data and CATV services on the data network, reducing or eliminating the need to maintain separate CATV hardware and cable plant.
- Increased use of wireless devices by both students and staff, including the adoption of mobile network devices in university operations (i.e. Asset Works) and instruction (i.e. audience response systems) will drive the need for increased coverage and density of wireless networks, which will in turn drive an increased need for access layer capacity, more Cat6 cable, more fiber, more Power-over-Ethernet switches, and upgrades to 208v power in more closets. These increased needs will also be driven by the proliferation of IP-enabled devices on the wired/wireless network (the “Internet of Things”).
- Not all MDF/IDFs have the physical space to house the additional hardware needed to support the need for more access-layer port capacity.
- Rapidly evolving cable specification standards and accelerating hardware performance options may require the copper cable plant to be upgraded more frequently than in decades past. In lieu of adequate funding to upgrade entire buildings at once, the problem of ad-hoc upgrades and connections patched with mismatched cables could proliferate, making the MDF/IDFs more difficult to physically manage and diminishing overall network performance.

F.4 Recommendations

- Operationalize the costs of network equipment maintenance and replacement, and establish a fully-funded strategic plan for the cyclical replacement and expansion of core-, distribution-, and access-layer network devices, including a continued expansion of the wireless network and accompanying access-layer port capacity.

- Expand fiber capacity between buildings, including upgrading fiber to recommended latest spec.
- Run new fiber optic cables to ensure direct fiber paths exist from each building to each of the two cores, plus additional capacity directly connecting the cores to each other.
- Evaluate more secure/resilient locations on south campus for the second network core, such as Campus Services or Commissary, and relocate the core infrastructure there.
- Bring additional fiber to a new campus location (such as a new network core) to serve as a secondary ISP circuit, physically separating the two ISP connections into separate facilities.
- Consolidate datacenter services in Bond Hall, with a smaller redundant location on campus for business continuity of critical services only. Use cost savings from vacating the AC datacenter to move disaster recovery functions to cloud-hosted platforms.
- Devote time and resources to further investigating Passive Optical Networks (PON) as an alternative to copper cabling in new/remodeled buildings.
- Incorporate central networking/telecommunications team in the planning, configuration, security, and maintenance of data networks other than just academic and residential (i.e. BAC, lighting control, etc.).
- Fully fund the migration of PBX telephone users to IP telephony services, and replace the existing PBX with a smaller PBX to provide telephony to non-IP telephony compatible services only (elevators, fax machines, etc.).
- Fund and strategically plan for the upgrade of all MDF/IDFs on campus to 208v power. Bring humidity/temperature and lighting up to industry specifications. Upgrade and standardize all 110-block termination fields to new campus standard (current standard is Commscope Visipatch system), and upgrade all hydra cables to current communication cable specifications, subject to the study and analysis of PON systems.
- Fund and strategically plan for the upgrade of all horizontal cable systems to latest specification, subject to the study and analysis of PON systems.

F.5 Conclusions

Campus telecommunications is at a critical point in its lifecycle. The data network is resilient, but nearing the end of its supported life with no active plan for upgrade. The analog telephone network is at critical risk, with transition to newer services stymied by lack of funding and lack of clear institutional prioritization and direction. The CATV network is in a state of transition, where institutional leadership has sent mixed signals by investing in both an IP-based distribution for the residence halls and in production/broadcast facilities that rely on non-IP based distribution for academic programs.

The challenges and opportunities facing Western's telecommunications services and infrastructure are not unique; others have weathered these storms before, and we can do so as well with adequate funding, coordination, and commitment from the university to a strategic vision for the future.

11. ELECTRONIC FILES

General

AutoCAD files:

Basemap_2017_WilsonUnscreened.dwg   Base map of non-utility infrastructure

ArcGIS files:

GIS (folder)

- *Data (sub-folder)* contains shapefiles, orthophoto, or other relevant data files used in the ArcGIS map files located in the Projects folder
- *Maps (sub-folder)* contains .pdf files of maps presented in Plan
- *Projects (sub-folder)* contains ArcGIS .mxd map files, which are linked to data files located in the Data folder

Excel spreadsheet files:

Table 1.1 IMP Data.xlsx

Table 1.2 Facility Abbreviations.xlsx

Table 1.3 Residence hall capacities.xlsx

Water Distribution System

ArcGIS map files (and any related *InfoWater* hydraulic model files):

WWU_WATER_MODEL_2017.mxd

FIGURE2-1.mxd

FIGURE2-2.mxd

FIGURE2-2_FULL.mxd (24x36 full detail water system map)

WATER-FIGURE2-3.mxd

WATER-FIGURE2-4.mxd

WATER-FIGURE2-5.mxd

WATER-FIGURE2-6.mxd

WATER-FIGURE2-7.mxd

Excel spreadsheet files:

Table 2-1 WWU Meter Data 2014 to 2016 and Demands.xls

PHD Domestic Pressures – Existing and Future 3-28-2017.xls

Table 2-2 Required Fire Flows updated 3-13-2017.xls

Table 2-3 Existing Sprinkler Residual Pressures 5-18-2017.xls

Table 2-4 Projected Growth Demand Increases by Land Use District.xlsx

Table 2-5 Future Build-Out Sprinkler Residual Pressures 5-18-2017.xls

Table 2-6 Campus Status and Sprinkler Needs updated 5-22-2017.xlsx

PDF files:

City water meter data graphs Daily meter data for week of March 4-12, 2017

Sanitary Sewer

AutoCAD files:

Sanitary Sewer Figures 3.1-3.4.dwg All sanitary sewer infrastructure

Excel spreadsheet files:

Sewer Calcs.xls Sewer pipe flow capacity calculations

Sewer Flows.xls Sewer flows by building and district

Stormwater

AutoCAD files:

Stormwater Figures 4.1-4.2-4.4-4.5 All stormwater infrastructure

Excel spreadsheet files:

Basin Tabulation.xlsx

Table4-1_4-2_SWMM Model Info.xls

Storm Model and detention data South.xlsx

Detention Vault North.xlsx

ArcGIS map files:

07004_STW-FIGURE4-3.mxd

SWMM files:

SWMM (folder)

EPA SWMM 5.0 (sub-folder) - contains general SWMM 5.0 files and installation files

WWU UMP (sub-folder) – contains the hydraulic model files including input and output, rainfall data files, and background .jpeg files

District Heating System

AutoCAD files:

2017.03.08_STEAMMASTER_UMC EE.dwg

Excel spreadsheet files:

Overview of Existing Buildings Heating Requirements.xlsx

PDF files:

5.5.3 Heating System Piping and Instrumentation Diagram
5.5.4 Steam Plant Layout
5.5.5 Steam/Condensate Distribution Map

Chilled Water

None

Electrical Primary Power System

AutoCAD files:

MP-E1.dwg
MP-E2.dwg
MP-E3.dwg

Electrical Emergency Generators

AutoCAD files:

MP-E4.dwg

Excel spreadsheet files:

Gen Set Info Sheet.xlsx